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Irrigation in Southern and Eastern Asia in figures

AQUASTAT Survey – 2011

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Foreword

With the rapid economic transformations occurring in Southern and Eastern Asia region, the need for reliable and systematic information on water, its quality and its use has never been greater.

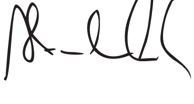
The region represents 15 percent of the global land mass, but houses over half of the world population. While large parts of the region are well endowed with water, the renewable water resources per person in the region are less than half the renewable water resources per persons at a global level. This is an indicator not just of high population growth, it is also a reflection of the intensity of water use across rapidly growing economic sectors – not just agriculture.

Over 60 percent of the global irrigation area is located in this region and more than 80 percent of water withdrawals are used for irrigation, with much of this withdrawal occurring across transboundary river basins. Therefore the joint management of water resources is becoming an imperative and this requires water information to be available and comparable.

In order to understand fully the state, trends and challenges facing water management for agriculture, FAO initiated the AQUASTAT Programme in 1993 to serve as its global information system on water and agriculture. AQUASTAT collects, analyses and disseminates data and information by country to provide users with the most accurate, reliable, consistent and up-to-date information available on water resources and agricultural water management.

This AQUASTAT report presents the most recent information available on water resources and their use in the 22 countries in the Southern and Eastern Asia region. Clearly it has an emphasis on agricultural water use and management. But in addition it contains the relevant tables and maps, and a regional synopsis emphasizing the particular characteristics of this large and diverse region. It also analyses the changes that have occurred since the first survey in 1999. Finally it gives a more detailed description of four transboundary river basins in the region, highlighting the different levels of cooperation and the agreements between countries located in the same river basin: the Ganges–Brahmaputra–Meghna basin, the Indus basin, the Mekong basin and the Salween basin.

We hope that this publication will contribute to a better understanding of irrigation conditions in the Southern and Eastern Asia region and to well-informed decision-making in the field of water management as a whole.



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Units

Lenght

1 km = 1 000 m = 1 x 10^3 m

1 mile = 1.56 km = 1 560 m

1 foot = 30.48 cm = 0.3048 m

1 inch = 2.54 cm = 0.0254 m

Area

1 acre = 4 047 km^2 = 0.4047 ha = 4.047 x 10^{-4} x 1 000 ha

1 are = 100 m^2 = 0.01 ha = 1 x 10^{-5} x 1 000 ha

1 feddan = 4 200 m^2 = 0.42 ha = 4.2 x 10^{-4} x 1 000 ha

1 ha = 0.01 km^2 = 10 000 m^2 = 2.47 acres = 2.38 feddan

1 km^2 = 1 000 000 m^2 = 100 ha = 1 x 10^{-1} x 1 000 ha

1 m^2 = 0.0001 ha = 1 x 10^{-7} x 1 000 ha

Volume

1 dm^3 = 1 litre = 0.001 m^3 = 1 x 10^{-12} km^3

1 hm^3 = 1 million m^3 = 1 000 000 m^3 = 1 x 10^{-3} km^3

1 km^3 = 1 billion m^3 = 1 000 million m^3 = 10^9 m^3 = 10^9 m^3

1 m^3 = 10^{-9} km^3

1 UK gallon = 4.546 litres = 4.546 dm^3 = 0.004546 m^3 = 4.546 x 10^{-12} km^3

1 US gallon = 3.785 litres = 3.785 dm^3 = 0.003785 m^3 = 3.785 x 10^{-12} km^3

Power-energy

1 GW = 1 x 10^3 MW = 1 x 10^6 kW = 1 x 10^9 W

1 GWh = 1 x 10^3 MWh = 1 x 10^6 kMh

1 acre-foot = 1 233.48 m^3

US$1 = 1 United States dollar

1 ºC = 1 degree centigrade

The information presented in this publication is collected from a variety of sources. It reflects FAO's best estimates, based on the most accurate and up-to-date information available at the date of printing.

List of abbreviations

ADB	Asian Development Bank
ARC	American Red Cross
AWDI	Alternative wet and dry irrigation
BCE	Before Common Era
BOD	Biochemical oxygen demand
CA	Conservation agriculture
CIA	Central Intelligence Agency
COD	Chemical oxygen demand
DO	Dissolved oxygen
DTW	Deep tube wells
EPA	Environmental Protection Agency
ESCAP	United Nations Economic and Social Commission for Asia and the Pacific
FAO	Food and Agriculture Organization of the United Nations
FAP	Flood action plan
FCD	Flood control and drainage
FCDI	Flood control, drainage and irrigation
FLIA	Farm land improvement associations
FMTW	Force-mode tubewell
FWUC	Farmer water user communities
GBH	Gravel bed hydroponics
GDD	Growing degree days
GDP	Gross domestic product
GIS	Geographical information systems
HYV	High-yielding variety
IBRD	International Bank for Reconstruction and Development
IA	Irrigators' association
ICARDA	International Center for Agricultural Research in the Dry Areas
ICID	International Commission on Irrigation and Drainage
IDA	International Development Association
IEC	Information education and communication
IFAD	International Fund for Agricultural Development
IAEA	International Atomic Energy Agency
IRBM	Integrated river basin management

IRC	International Water and Sanitation Centre
IRSWR	Internal renewable surface water resources
IRWR	Internal renewable water resources
ISEAS	Institute of Southeast Asian Studies
ISRWR	Internal renewable surface water resources
IWASRI	International Waterlogging and Salinity Research Institute
IWM	Improved irrigation water management
IWMI	International Water Management Institute
JBIC	Japan Bank for International Cooperation
JCWR	Nepal-India Joint Committee on Water Resources
JICA	Japan International Cooperation Agency
LGU	Local government unit
LLP	Low lift pump
MDG	Millennium Development Goals
MOP	Manually operated pumps
MPO	Master Plan Organization
MRC	Mekong River Commission
MSF	Multi-stage flash
MV	Modern variety (seeds)
NGO	Non-governmental organization
O&M	Operation and maintenance
OECD	Organisation for Economic Co-operation and Development
OFWM	On-farm water management
OPEC	Organization for the Petroleum Exporting Countries
PARC	Pakistan Agricultural Research Council
PDR	People’s Democratic Republic (Lao)
PIMD	Participatory Irrigation Management and Development
RAP	Regional Office for Asia and the Pacific (FAO)
R&D	Research and development
RO	Reverse osmosis
RSC	Residual sodium carbonate
SAR	Sodium adsorption ratio
SCARP	Salinity Control and Reclamation Project
SIDA	Swedish International Development Agency
SME	Small and medium enterprises
SMO	SCARP monitoring organization
SMP	Strategic management plan

SOF	Securing Our Future (The Asia Foundation)
SOPAC	Scripps Orbit and Permanent Array Centre
SRI	System of rice intensification
SSWRD	Small-scale water resources development
STW	Shallow tube wells
SWIM	Small water impounding management
TA	Technical assistance
TDS	Total dissolved solids
TRWR	Total renewable water resources
UN	United Nations
UNCCD	United Nations Convention to Combat Desertification
UNDP	United Nations Development Programme
UNEP	United Nations Environment Programme
UNESCAP	United Nations Economic and Social Commission for Asia and the Pacific
UNESCO	United Nations Educational, Scientific and Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USDA	United States Department of Agriculture
USSR	Union of Soviet Socialist Republics
VDSSTW	Very deep-set shallow tubewell
WEPA	Water Environment Partnership in Asia
WFP	World Food Programme
WHO	World Health Organization
WM	Water management
WSI	Water-saving irrigation
WUA	Water user association
WUG	Water user group
WWF	World Wildlife Fund

SECTION I
Presentation of the survey

EXPLANATORY NOTES

This section gives a brief history of AQUASTAT, its main purpose and the methodology used to update country information. It describes the main sources of information, the collection and processing of the information as well as the reliability.

A glossary of all terms used in this report is provided, which also can be found in the AQUASTAT glossary web page (http://www.fao.org/nr/water/aquastat/data/glossary/search.html?lang=en). This web page contains, amongst others, an explanation of all variables and indicators available in the AQUASTAT main country database (http://www.fao.org/nr/water/aquastat/data/query/index.html?lang=en).

Introduction

It is in FAO's mandate, as stated in Article 1 of its constitution "to collect, analyse, interpret and disseminate information related to nutrition, food and agriculture". Within this framework FAO launched in 1993 a programme known as AQUASTAT, its global information system on water and agriculture (http://www.fao.org/nr/aquastat). AQUASTAT collects, analyses and disseminates data and information, by country, on water recourses and water use, with emphasis on agriculture, which is targeted at users in international institutions, national governments and development agencies. Its goal is to support agricultural and rural development through sustainable use of water and land by providing the most accurate information presented in a consistent and standard way and more specifically:

- up-to-date and reliable data by country
- methodologies and definitions for information on the water resources and irrigation sector
- systematic descriptions on the state of agricultural water management by country
- predictions of future agricultural water use and irrigation developments
- in-depth analysis through diverse thematic studies
- contribution to major international publications
- answers to requests from governments, research institutions, universities, non-governmental organizations and individuals

At the time of launch, priority was given to Africa, which initiated the AQUASTAT publication series (FAO, 1995). The survey continued with the Near East (FAO, 1997a), the countries of the former Soviet Union (FAO, 1997b), Southern and Eastern Asia (FAO, 1999), Latin America and the Caribbean (FAO, 2000). In 2005 the African continent was updated (FAO, 2005) and in 2008 the Middle East region (FAO, 2009).

More than a decade after the first publication, it appeared necessary to update the data and information and to identify the main changes in water use and irrigation that had occurred in the countries of Southern and Eastern Asia. The regional division of the world adopted by AQUASTAT is given in Figure 3.

To the two objectives of the previous publication a third has been added in this new survey:

- to provide for every country the most accurate status of rural water resources management, with a special focus on irrigation, by featuring major characteristics, trends, constraints and prospective changes in irrigation and in water resources
- to support regional analyses by providing systematic, up-to-date and reliable information on the status of water resources and of agricultural water management that can serve as a tool for regional planning and predictive studies
- to prepare a series of chronological data in order to highlight the major changes that have occurred in the last decade on national and regional scales

To obtain the most reliable information possible, the survey is organized as follows:

1. Review of literature and existing information at country and sub-country level
2. Collection of information by country using a detailed questionnaire filled in by national experts, international consultants, or the AQUASTAT team at FAO

3. Compilation and critical analysis of the information collected using data-processing software developed for this survey, and selection of the most reliable information
4. Preparation of country profiles and submission to national authorities responsible for water resources or water management for verification, correction and approval
5. Preparation of the final profile, the tables and the figures presenting the information by country
6. Updating of the online database
7. Preparation of the general regional analysis, the figures and the regional tables

Where possible, AQUASTAT has made use of national capacity and competence. While collecting the information by country, preference was given to national experts as they have a better knowledge of their own country and easier access to national or so-called 'grey' documents, which are not available outside the country. The choice of the countries for which a national consultant was recruited depended on several factors, namely: the importance of irrigation in the country; the availability of an expert; the scarcity of data observed during the previous survey; and the funds available. For about half of the countries concerned, a national consultant assisted the AQUASTAT team or direct assistance was provided by government institutions, national research institutions and/or universities.

Country and river basin profiles

COUNTRY PROFILES

Country profiles are prepared in English, which is the FAO official language in most of the countries of the Southern and Eastern Asia region. They describe the state of water resources and water use in the respective countries, as well as the state of agricultural water management. The aims are to describe the particularities of each country and the problems met in the development of the water resources and, in particular, irrigation. They summarize the irrigation trends in the country and the prospects for water management in agriculture as described in the literature. The country profiles have been standardized and organized in the following sections:

- Ø Geography, climate and population
- Ø Economy, agriculture and food security
- Ø Water resources and water use
- Ø Irrigation and drainage development
- Ø Water management, policies and legislation related to water use in agriculture
- Ø Environment and health
- Ø Prospects for agricultural water management
- Ø References and additional information

Standardized tables are used for each country. A hyphen (-) indicates that no information is available. As most information is available only for a limited number of years, the tables present the most recent reliable information and indicate the year to which it refers. In the online AQUASTAT country database, however, all available information is accessible.

The information in the country profiles is much more detailed than that in the previous AQUASTAT survey of the region. In order to establish a more complete picture of the agricultural water sector in each country, it addresses issues related to water and to irrigation that were not previously included. Some issues have been added in response to user demand.

RIVER BASIN PROFILES

In addition to country profiles, profiles have been prepared of four transboundary river basins in the region: the Ganges-Brahmaputra-Meghna, Indus, Mekong and Salween river basins. The major aims are to describe transboundary water issues and to provide a chronology of major events in the basins. The sections are organized as follows:

- Ø Geography, population and climate
- Ø Water resources
- Ø Water quality
- Ø Water-related developments in the basin
- Ø Transboundary water issues

Data collection, processing and reliability

The main sources of information were:

- Ø National policies, and water resources and irrigation master plans
- Ø National reports, yearbooks and statistics
- Ø Reports from FAO and other projects
- Ø International surveys
- Ø Results and publications from national and international research centres and universities
- Ø The Internet

Furthermore, the following sources systematically provide certain data:

- Ø FAOSTAT (http://faostat.fao.org/). This is the only source used for variables of area (total, arable land and permanent crops) and population (total, rural, urban, female, male, and economically active). FAOSTAT data on areas are provided every year by the countries through the FAO representations. As far as population is concerned, it should be noted that the original source for total, urban and rural population data is the United Nations Population Division (http://www.un.org/esa/population/), while the original source for data related to economically active population is the International Labour Organization (http://www.ilo.org/), as indicated on the FAOSTAT website.
- Ø World Development Indicators (http://www.worldbank.org/data/). This is the World Bank's premier annual compilation of data on development. This source provides the data on gross domestic product (GDP) and value added in agriculture.
- Ø Joint Monitoring Programme for Water Supply and Sanitation (JMP) (www.wssinfo.org/). This is a joint programme of the World Health Organization (WHO) and the United Nations Children's Fund (UNICEF), which provides access to data on improved water sources.
- Ø Human Development Index (HDI) (http://hdr.undp.org/statistics/data/). This falls under the responsibility of The United Nations Development Programme (UNDP).

In total, more than 50 variables have been selected and these are presented in the national tables attached to the respective country profiles. They are standardized and ordered in categories corresponding to the various sections of the profile: characteristics of the country and population; water: resources and use; and irrigation and drainage. A detailed description of each variable is given in the glossary below. Additional tables have been added to the country profiles where information is available, especially in order to specify regional or river basin data.

In most cases, a critical analysis of the information is required in order to ensure the general coherence of information collected for a given country. Where several sources result in divergent or contradictory information, preference is given to information collected at national or sub-national level rather than at regional or world level. Moreover, except in the case of evident errors, official sources are privileged. As regards shared water resources, the comparison of information between countries has made it possible to verify and complete the data concerning the flows of transboundary rivers and to ensure coherence at a river basin level. This information has been added more in detail in the country water balance sheets, which are available at: http://www.fao.org/nr/water/aquastat/water_res/index.stm.

In spite of these precautions, the accuracy, reliability and frequency with which information is collected vary considerably according to the region, the country and the category of information. These considerations are discussed in the profiles.

The regional analysis tables show the period 1999–2009 as the period between the two surveys. The AQUASTAT team justifies this choice by virtue of the slow evolution of data for different years for each country. However, should more precision be required, the summary tables and the online database specify the exact year for the items of national data.

Glossary of terms used in this study

The following definitions have been used for the variables presented in the country profiles, the tables and the database.

Access to improved drinking water sources (%)

The proportion of the population (total, urban and rural) with sustainable access to an "improved" water source. It is the percentage of the population who use any of the following types of water supply for drinking: piped water, public tap, borehole or pump, protected well, protected spring or rainwater. Improved water sources do not include vendor-provided water, bottled water, tanker trucks or unprotected wells and springs. Figures are provided by the WHO/UNICEF Joint Monitoring Programme for Water Supply and Sanitation (JMP) website (http://www.wssinfo.org/). To allow for international comparability of estimates, JMP uses a classification to differentiate between "improved" and "unimproved" drinking-water sources as well as sanitation. More details can be found on the website.

Actually irrigated area as % of the total area equipped (%)

Percent of area equipped for irrigation that is actually irrigated in any given year, expressed in percentage. Irrigated land that is cultivated more than once a year is counted only once.

Agricultural drainage water (km^3/year; million m^3/year)

This is water withdrawn for agriculture but not consumed and returned. It does not go through special treatment and therefore should be distinguished from reused wastewater. It can be reused further downstream for irrigation, for example, and is also called secondary water. In some cases direct reuse of agricultural drainage water exists, such as is the case for example when water from rice fields flows from one terrace to the next.

Annual crops (ha)

Area of land under temporary (annual) crops, which are crops with a growing season lasting between several months and about one year and which need to be re-sown or replanted after each harvest, such as cereals and vegetables.

Arable land (ha)

Land under temporary crops (double-cropped areas are counted only once), temporary meadows for mowing or pasture, land under market and kitchen gardens and land temporarily fallow (less than five years). The abandoned land resulting from shifting cultivation is not included. Data for arable land is not meant to indicate the amount of land that is potentially cultivable.

Area of the country (ha)

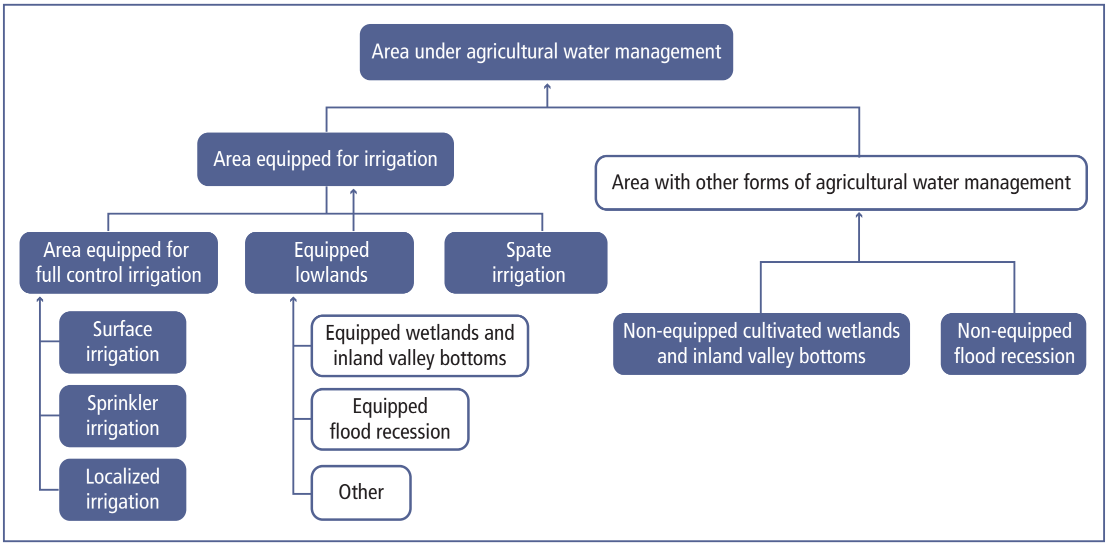
Total area of the country, including area under inland water bodies. Possible variations in the data may be due to updating and revisions of the country data and not necessarily to any change of area.

Area equipped for irrigation: total (ha)

Area equipped to provide water (via irrigation) to crops. It includes areas equipped for full control irrigation, equipped lowland areas, irrigated pastures, and areas equipped for spate irrigation.

Area under agricultural water management (ha)

Sum of total area equipped for irrigation and areas with other forms of agricultural water management (non-equipped flood recession cropping area and non-equipped cultivated wetlands and inland valley bottoms). The classification adopted by AQUASTAT is presented in the following diagram and an explanation of each of the variables is given below. The classes in the non-coloured boxes are not separately mentioned in the AQUASTAT database.



Average annual increase of the area equipped for irrigation (%)

This increase is calculated with the following formula: new area = $(1+i)^n$ x old area, where "n" is the number of years in the period considered between the two AQUASTAT surveys and "i" is the average annual increase. The percentage is equal to (100 x i).

Cropping intensity: irrigated area (%)

The number of times the same area is cropped and irrigated in one year. The area refers to area equipped for full control irrigation. If available, the area actually irrigated is used for the calculation of cropping intensity. If not available, the equipped area is used. The calculation only refers to irrigated crops. This means that in a country with one or two wet seasons only the crops grown under irrigation are taken into consideration. The crops grown on the full control equipped area during the wet season without irrigation (but using the residual soil humidity) are not included in the harvested irrigated crop area when calculating cropping intensity.

Cultivable area (ha)

Area of land potentially fit for cultivation. This term may or may not include part or all of the forests and rangeland. Assumptions made in assessing cultivable land vary from country to country. In this survey, national figures have been used whenever available, despite possible large discrepancies in computation methods.

Cultivated area (ha)

The sum of the arable land area and the area under permanent crops.

Dam capacity (km^3; million m^3)

Total cumulative storage capacity of all large dams. According to ICOLD (International Commission on Large Dams), a large dam is a dam with a height of 15 m or more from the foundation. If dams are 5-15 metres high and have a reservoir volume of more than three million

m^3, they are also classified as large dams. However, each country has its own definition of large dams and if information on other dams in a country is available it is also included. The value indicates the theoretical initial capacity, which does not change with time. The current or actual dam capacity is the state of the dams at a given time that can be decreased by silting. Detailed information dams in the different regions can be found in the AQUASTAT geo-referenced dam databases on http://www.fao.org/nr/water/aquastat/dams/index.stm.

Dependency ratio (%)

Indicator expressing the percent of total renewable water resources originating outside the country. This indicator may theoretically vary between 0 percent and 100 percent. A country with a dependency ratio equal to 0 percent does not receive any water from neighbouring countries. A country with a dependency ratio equal to 100 percent receives all its renewable water from upstream countries, without producing any of its own. This indicator does not consider the possible allocation of water to downstream countries.

Depletion of renewable groundwater resources: rate (km^3/year; million m^3/year)

Annual amount of water withdrawn from renewable aquifers which is not replenished (average overexploitation of aquifers). When the action is continuous, it is a form of overdraft of rechargeable aquifers or mining. Over a long period of time, there is a risk of depleting the aquifer when the abstraction exceeds the recharge.

Desalinated water produced (km^3/year; million m^3/year)

Water produced annually by desalination of brackish or salt water. It is estimated annually on the basis of the total capacity of water desalination installations.

Drained area in area equipped for irrigation (ha)

Irrigated area where drainage is used as an instrument to control salinity, pounding and waterlogging. This refers mainly to the area equipped for surface irrigation and to the equipped wetland and inland valley bottoms (the first part). Areas equipped for sprinkler irrigation and for localized irrigation do not really need a complete drainage system, except perhaps some small structures to evacuate the water in case of heavy rainfall. Flood recession cropping areas (the second part) are not considered as being drained. A distinction can be made between areas drained with surface drains (a system of drainage measures, such as natural or human-made drains meant to divert excess surface water away from an agricultural area in order to prevent inundation) and the area drained with subsurface drains (a human-made system that induces excess water and dissolved substances to flow through the soil to open wells, moles, pipe drains and/or open drains, from where it can be evacuated for final disposal).

Drained area in non-irrigated area (ha)

Area cultivated and not irrigated, where drainage is used to remove excess water from the land surface and/or the upper soil layer to make humid/wet land more productive. A distinction should be made between drainage in humid countries and drainage in semi-arid countries. In humid countries, it refers mainly to the areas which normally are flooded and where flood mitigation has taken place. A distinction could be made between pumped drainage, gravity drainage and tidal drainage. In semi-arid countries, it refers to the area cultivated and not irrigated where drainage is used to remove excess water from the land surface and/or upper soil layer to make humid/wet land more productive.

Drained area: total (ha)

Sum of the drained portions of area equipped for irrigation and non-irrigated land area.

Exploitable water resources regular renewable groundwater (km^3/year; million m^3/year)

Average groundwater flow that is available 90 percent of the time, and economically/environmentally viable to extract.

Exploitable water resources: regular renewable surface water (km^3/year; million m^3/year)

Annual average quantity of surface water that is available 90 percent of the time. In practice, it is equivalent to the low water flow of a river. It is the resource that is offered for withdrawal or diversion with a regular flow.

Exploitable water resources: irregular renewable surface water (km^3/year; million m^3/year)

Irregular surface water resources are equivalent to the variable component of water resources (e.g. floods). It includes the seasonal and inter-annual variations, i.e. seasonal flow or flow during wet years. It is the flow that needs to be regulated.

Exploitable water resources: total (km^3/year; million m^3/year)

Exploitable water resources (also called manageable water resources or water development potential) are considered to be available for development, taking into consideration factors such as: the economic and environmental feasibility of storing floodwater behind dams, extracting groundwater, the physical possibility of storing water that naturally flows out to the sea, and minimum flow requirements (navigation, environmental services, aquatic life, etc). Methods to assess exploitable water resources vary from country to country.

Flood-protected area (ha)

Area of land protected by flood control structures.

Flood recession cropping area: non-equipped but cultivated (ha)

Areas along rivers where cultivation occurs in the areas exposed as floods recede and where nothing is undertaken to retain the receding water. The special case of floating rice is included in this category.

Fossil groundwater: abstraction (km^3/year; million m^3/year; for a given period)

Annual amount abstracted from deep aquifers with a very low rate of renewal (less than one percent per year) so considered to be non-renewable or “fossil”.

Full control irrigation: area equipped for localized irrigation (ha)

Localized irrigation is a system where the water is distributed under low pressure through a piped network, in a pre-determined pattern, and applied as a small discharge to each plant or adjacent to it. There are three main categories: drip irrigation (where drip emitters are used to apply water slowly to the soil surface), spray or micro-sprinkler irrigation (where water is sprayed to the soil near individual plants or trees) and bubbler irrigation (where a small stream is applied to flood small basins or the soil adjacent to individual trees). The following other terms are also sometimes used to refer to localized irrigation: micro-irrigation, trickle irrigation, daily flow irrigation, drop-irrigation, sip irrigation, diurnal irrigation.

Full control irrigation: area equipped for sprinkler irrigation (ha)

A sprinkler irrigation system consists of a pipe network, through which water moves under pressure before being delivered to the crop via sprinkler nozzles. The system basically simulates rainfall in that water is applied through overhead spraying. These systems are also known as overhead irrigation systems.

Full control irrigation: area equipped for surface irrigation (ha)

Surface irrigation systems are based on the principle of moving water over the land by simple gravity in order to moisten the soil. They can be subdivided into furrow, borderstrip and basin irrigation (including submersion irrigation of rice). Manual irrigation using buckets or watering cans is also included. Surface irrigation does NOT refer to the method of transporting the water from the source up to the field, which may be done by gravity or by pumping.

Full control irrigation: total area equipped (ha)

This is the sum of surface irrigation, sprinkler irrigation and localized irrigation. The text uses indifferently the expressions "full control" and "full/partial control".

Full control irrigation: area equipped irrigated from groundwater (ha)

Portion of the full control irrigation area that is irrigated from water from wells (shallow wells and deep tube wells) or springs. The water can be primary freshwater or secondary freshwater (agricultural drainage water and wastewater returned to the system).

Full control irrigation: area equipped irrigated from surface water (ha)

Portion of the full control irrigation area that is irrigated from water from rivers or lakes (reservoirs, pumping or diversion). The water can be primary freshwater or secondary freshwater (agricultural drainage water and wastewater returned to the system).

Full control irrigation: area equipped irrigated from mixed sources of water (ha)

Portion of the full control irrigation area that is irrigated from mixed surface water. The water can be primary freshwater or secondary freshwater (agricultural drainage water and wastewater returned to the system).

Full control irrigation schemes (ha)

Areas of irrigation schemes, usually classified as large, medium, and small schemes. Criteria used in this classification are given in the tables.

Gross Domestic Product (GDP)

GDP at purchaser's prices is the sum of gross value added by all resident producers in the economy plus any product taxes and minus any subsidies not included in the value of the products. It is calculated without making deductions for depreciation of fabricated assets or for depletion and degradation of natural resources. Data are in current United States dollars (US$). Dollar figures for GDP are converted from domestic currencies using single year official exchange rates. For a few countries where the official exchange rate does not reflect the rate effectively applied to actual foreign exchange transactions, an alternative conversion factor is used. Figures provided by the World Development Indicators (WDI), the World Bank's premier annual compilation of data about development (http://data.worldbank.org/).

Harvested irrigated crop area (ha)

Total harvested irrigated crop area. It refers to the crops grown under full control irrigation. Areas under double irrigated cropping (same area cultivated and irrigated twice a year) are counted twice. Therefore the total area may be larger than the full control equipped area, which gives an indication of the cropping intensity. The total is only given if information on all irrigated crops in the country is available.

Households in irrigation

Total number of households living directly on earnings from fully controlled irrigation schemes.

Human Development Index (HDI)

This is a summary measure of human development. It measures the average achievements in a country in three basic dimensions of human development:

1. a long and healthy life, as measured by life expectancy at birth;
2. knowledge, as measured by the adult literacy rate (with two-thirds weight) and the combined primary, secondary and tertiary gross enrolment ratio (with one-third weight);
3. a decent standard of living, as measured by GDP per capita (Purchasing Power Parity US$). Figures provided by UNDP (http://hdrstats.undp.org/en/indicators/default.html).

Irrigated grain production: total (t; tons; metric tons)

The total quantity of cereals harvested annually in the irrigated area. Several harvests per year on the same area are counted several times.

Irrigation: total area (ha)

see *Area equipped for irrigation: total (ha)*

Irrigation potential (ha)

Area of land which is potentially irrigable. Country/regional studies assess this value according to different methods. For example, some consider only land resources, others consider land resources plus water availability, others include economical aspects in their assessments (such as distance and/or difference in elevation between the suitable land and the available water) or environmental aspects, etc. If available, this information is given in the individual country profiles. The figure includes the area already under agricultural water management.

Lowland areas: area equipped for irrigation (ha)

The land equipped for irrigation in lowland areas includes:

- cultivated wetland and inland valley bottoms (IVB) that have been equipped with water control structures for irrigation and drainage (intake, canals, etc.);
- areas along rivers where cultivation occurs making use of structures built to retain receding flood water;
- developed mangroves and equipped delta areas.

Permanent crops (ha)

Crops are divided into temporary and permanent crops. Permanent crops are sown or planted once and then occupy the land for some years and do not need to be replanted after each annual harvest, such as cocoa, coffee and rubber. This category includes flowering shrubs, fruit trees, nut trees and vines, but excludes trees grown for wood or timber.

Precipitation in depth: average (mm/year)

Long-term average (over space and time) of annual endogenous precipitation (produced in the country) in depth.

Precipitation in volume: average (km^3/year; million m^3/year)

Long-term average (over space and time) of annual endogenous precipitation (produced in the country) in volume.

Population: economically active population (inhabitants)

The number of all employed and unemployed persons (including those seeking work for the first time). It covers employers; self-employed workers; salaried employees; wage earners; unpaid workers assisting in a family or farm or business operation; members of producers' cooperatives; and members of the armed forces. The economically active population is also called the labour force.

Population: economically active population in agriculture (inhabitants)

Part of the economically active population engaged in or seeking work in agriculture, hunting, fishing or forestry (agricultural labour force). The economically active population refers to the number of all employed and unemployed persons (including those seeking work for the first time). It covers employers, self-employed workers, salaried employees, wage earners, unpaid workers assisting in a family or farm or business operation, members of producers' cooperatives, and members of the armed forces. The economically active population is also called the labour force.

Population: total (inhabitants)

According to the FAO definition, the total population usually refers to the present-in-area (de facto) population, which includes all persons physically present within the present geographical boundaries of countries at the mid-point of the reference period.

Population: urban, rural (inhabitants)

Usually the urban area is defined and the remainder of the total population is defined as rural. In practice, the criteria adopted for distinguishing between urban and rural areas vary from country to country. However, these criteria can be roughly divided into three major groups: classification of localities of a certain size as urban; classification of administrative centres of minor civil divisions as urban; and classification of centres of minor civil divisions on a chosen criterion which may include type of local government, number of inhabitants or proportion of population engaged in agriculture. Thus, the urban and rural population estimates in this domain are based on the varying national definitions of urban areas.

Population affected by water-related diseases (inhabitants)

Three types of water-related diseases exist:

- water-borne diseases are those diseases that arise from infected water and are transmitted when the water is used for drinking or cooking (for example cholera, typhoid);
- water-based diseases are those in which water provides the habitant for host organisms of parasites ingested (for example shistomasomiasis or bilharzia);
- water-related insect vector diseases are those in which insect vectors rely on water as habitat but transmission is not through direct contact with water (for example malaria, onchocerciasis or river blindness, elephantiasis).

Power irrigated area as percentage of total area equipped for irrigated (%)

Percent of irrigation area where pumps are used for water supply from the source to the scheme, expressed in percentage. It includes also areas where water is drained out with human- or animal-driven water lifting devices.

Renewable water resources: internal (km^3/year; million m^3/year)

Internal Renewable Water Resources (IRWR): long-term average annual flow of rivers and recharge of aquifers generated from endogenous precipitation. Double counting of surface water and groundwater resources is avoided by deducting the overlap from the sum of the surface water and groundwater resources.

Renewable water resources: external (km^3/year; million m^3/year)

External Renewable Water Resources (ERWR) are that part of the country's renewable water resources that are not generated within the country. They include inflows from upstream countries (groundwater and surface water), and part of the water of border lakes or rivers.

Renewable water resources: total natural (km^3/year; million m^3/year)

Total Natural Renewable Water Resources (TRWR_natural or TNRWR): the long-term average sum of internal renewable water resources (IRWR) and external natural renewable water resources (ERWR_natural). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.

Renewable water resources: total actual (km^3/year; million m^3/year)

Total Actual Renewable Water Resources (TRWR_actual or TARWR): the sum of internal renewable water resources (IRWR) and external actual renewable water resources (ERWR_ actual). It corresponds to the maximum theoretical yearly amount of water actually available for a country at a given moment.

Return flow

That part of the water used for agricultural, municipal or industrial purposes which is returned to rivers or aquifers after use.

Safe yield of water systems (km^3/year; million m^3/year)

Amount of water (in general, the long term average amount) which can be withdrawn from the groundwater basin or surface water system without causing undesirable results. This concept concerns mostly groundwater (flow extractable without over exploitation). For the rivers, it is more common to speak of reserved flow (reservation constraint for the environment).

Salinized area by irrigation (ha)

Irrigated area affected by salinization, including formerly irrigated land abandoned because of declining productivity caused by salinization. It does not include naturally saline areas. In general, each country has its own definition of salinized area.

Soil and water conservation

A combination of in-situ water conservation and soil conservation measures. Soil conservation measures comprise any set of measures intended to control or prevent soil erosion or to maintain fertility. Water conservation includes the usage of bunds to slow or stop the migration of surface water.

Spate irrigation: equipped area for irrigation (ha)

Spate irrigation, also sometimes referred to as floodwater harvesting, is a method of informal irrigation using the floodwaters of a normally dry water course or riverbed (wadi). These systems are in general characterized by a very large catchment upstream (200-5000 ha) with a ratio of “catchment area: cultivated area” = between 100:1 and 10 000:1. There are two types of spate irrigation:

1. floodwater harvesting within streambeds, where turbulent channel flow is collected and spread through the wadi where the crops are planted; cross-wadi dams are constructed with stones, earth, or both, often reinforced with gabions;
2. floodwater diversion, where the floods or spates from the seasonal rivers are diverted into adjacent embanked fields for direct application. A stone or concrete structure raises the water level within the wadi to be diverted to the nearby cropping areas.

Temporary crops (ha)

See *Annual crops.*

Wastewater: produced volume (km^3/year; million m^3/year)

Annual quantity of wastewater generated in the country, in other words, the quantity of water that has been polluted by adding waste. The origin can be municipal use (used water from bathing, sanitation, cooking, etc.) or industrial wastewater (excluding cooloing water). In AQUASTAT only municipal wastewater is considered. It does not include agricultural drainage water, which is the water withdrawn for agriculture but not consumed and returned to the system.

Wastewater: treated volume (km^3/year; million m^3/year)

Quantity of generated wastewater that is treated in a given year and discharged from treatment plants (effluent). Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for discharge. In AQUASTAT it refers to treatment of municipal wastewater collected. Three broad phases of traditional treatment can be distinguished: primary, secondary and tertiary treatment. Discharge standards vary significantly from country to country, and therefore so do the phases of treatment. For the purpose of calculating the total amount of treated wastewater, volumes and loads reported should be shown only under the "highest" type of treatment to which it is subjected.

Wastewater: direct use of treated wastewater (km^3/year; million m^3/year)

Quantity of treated wastewater which is directly used in a given year. Wastewater treatment is the process to render wastewater fit to meet applicable environmental standards for recycling or reuse. The use refers to direct use of wastewater and can also be called non-conventional water. If the treated wastewater is returned to the river or lake, then it becomes secondary freshwater.

Water harvesting area (ha)

Areas where rainwater is collected and either directly applied to the cropped area and stored in the soil profile for immediate uptake by the crop (runoff irrigation) or stored in a water reservoir for future productive use (for example used for supplementary irrigation). Rainwater harvesting includes:

- roof water harvesting is mainly used for domestic purposes and sometimes as water supply for family gardens;
- micro-catchment water harvesting is characterized by a relatively small catchment area C (< 1 000 m^2) and cropping area CA (< 100 m^2) with ratio C:CA = 1:1 to 10:1. The farmer usually has control over both the catchment area and the target area. These systems are used for the irrigation of a single tree, fodder shrubs or annual crops. The construction is mainly manual. Examples are pits, semi-circular bunds, Negarim micro-catchment, eyebrow terrace, contour bench terrace, etc.;
- macro-catchment water harvesting collects water that flows over the ground as turbulent runoff and channel flow.

These systems are characterized by a large catchment area C ('external' catchment area of 1 000 m^2-200 ha), located outside the cultivated area CA, with a ratio C:CA = 10:1 to 100:1. The systems are mainly implemented for the production of annual crops. The construction is manual or mechanized. Examples are trapezoidal bunds, large semi-circular bunds, stone bunds, etc.

Water managed area (ha)

See *Area under agricultural water management.*

Water withdrawal for agriculture (km^3/year; million m^3/year)

Annual quantity of water withdrawn for irrigation, livestock and aquaculture purposes. It includes renewable primary freshwater resources as well as over-abstraction of renewable groundwater or withdrawal of fossil groundwater, secondary freshwater (agricultural drainage water and treated wastewater that was returned to the system), and non-conventional water (direct use of agricultural drainage water and treated wastewater, and desalinated water). It includes water withdrawn for irrigation purposes, aquaculture and for livestock watering, although depending on the country this last category sometimes is included in municipal water withdrawal. As far as the water withdrawn for irrigation is concerned, the value far exceeds the consumptive use of irrigation because of water lost in distribution from its source to the crops. The term "water requirement ratio" (sometimes also called "irrigation efficiency") is used to indicate the ratio between the net irrigation water requirements or crop water requirements, which is the volume of water needed to compensate for the deficit between potential evapotranspiration and effective precipitation over the growing period of the crop, and the amount of water withdrawn for irrigation including the losses. In the specific case of paddy rice irrigation, additional water is needed for flooding to facilitate land preparation and for plant protection. In that case, irrigation water requirements are the sum of rainfall deficit and the water needed to flood paddy fields. At scheme level, water requirement ratio values can vary from less than 20 percent to more than 95 percent. As far as livestock watering is concerned, the ratio between net consumptive use and water withdrawn is estimated at between 60 percent and 90 percent. By default, livestock water use is accounted for in agricultural water use. However, some countries include it in municipal water withdrawal.

Water withdrawal for livestock (km^3/year; million m^3/year)

Some countries include this in municipal water withdrawal, others in agricultural water withdrawal.

Water withdrawal for municipal or domestic use (km^3/year; million m^3/year)

Annual quantity of water withdrawn for municipal or domestic purposes. It includes renewable primary freshwater resources as well as over-abstraction of renewable groundwater or withdrawal of fossil groundwater, secondary freshwater (agricultural drainage water and treated wastewater that was returned to the system), and non-conventional water (direct use of agricultural drainage water and treated wastewater, and desalinated water). It is usually computed as the total water withdrawn by the public distribution network. It can include that part of the industries which is connected to the domestic network. The ratio between the net consumption and the water withdrawn can vary from 5 to 15 percent in urban areas and from 10 to 50 percent in rural areas.

Water withdrawal for industry (km^3/year; million m^3/year)

Annual quantity of water withdrawn for industrial uses. It includes renewable primary freshwater resources as well as over-abstraction of renewable groundwater or withdrawal of fossil groundwater, secondary freshwater (agricultural drainage water and treated wastewater that was returned to the system), and non-conventional water (direct use of agricultural drainage water and treated wastewater, and desalinated water). Usually, this sector refers to self-supplied industries not connected to any distribution network. It includes cooling water for energy generation (thermo-electric plants). The ratio between net consumption and withdrawal is estimated at less than 5 percent.

Water withdrawal: total (km^3/year; million m^3/year)

Annual quantity of freshwater withdrawn for agricultural, industrial and municipal purposes. It includes renewable primary freshwater resources as well as over-abstraction of renewable groundwater or withdrawal of fossil groundwater, secondary freshwater (agricultural drainage water and treated wastewater that was returned to the system), and non-conventional water (direct reuse of agricultural drainage water and treated wastewater, and desalinated water). It does not include other categories of water use, such as for mining, recreation, navigation, capture fisheries, etc., which are sectors that are characterized by a very low net consumption rate.

Waterlogged area by irrigation (ha)

Part of the land that is waterlogged because of irrigation. Waterlogging is the state of land in which the water table is located at or near the surface, resulting in a decline in crop yields.

Irrigation can contribute to the raising of the level of the aquifers. The non-saturated area of soils can become too small and the soils are over-saturated with water. If recharge to groundwater is greater than natural drainage, there is a need for additional drainage to avoid waterlogging.

Waterlogged area not irrigated (ha)

Part of the land in non-irrigated cultivated areas that is waterlogged. Waterlogging is the state of land in which the water table is located at or near the surface resulting in a decline of crop yields.

Wetlands and inland valley bottoms

Wetland and inland valley bottoms (IVB) that have not been equipped with water control structures but are used for cropping. They are often found in Africa. They will have limited (mostly traditional) arrangements to regulate water and control drainage.

SECTION II
Regional analysis

EXPLANATORY NOTES

For the regional analysis in this section, the 22 Southern and Eastern Asia countries have been grouped into four subregions, based on geographical and climatic homogeneity: East Asia, South Asia, Mainland Southeast Asia, Maritime Southeast Asia.

This analysis presents distinguishing features arising from the new data collected on a national scale for issues addressed in the 22 country profiles in section 3. The focus is on water resources, water withdrawal, irrigation and water management, trends, legislative and institutional framework of water management, environment and health.

A hyphen (-) in the regional tables indicates that no or not sufficient information is available.

Composition of the Southern and Eastern Asia region

The 22 Southern and Eastern Asia countries have been grouped into four subregions, based on geographical and climatic homogeneity, which has a direct influence on irrigation. These subregions (Figure 4) and the countries they include are:

- **East Asia**: China, Democratic People's Republic of Korea, Mongolia, Republic of Korea.
- **South Asia**: Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan, Sri Lanka.
- **Mainland Southeast Asia**: Cambodia, Lao People's Democratic Republic, Myanmar, Thailand, Viet Nam.
- **Maritime Southeast Asia**: Brunei Darussalam, Indonesia, Malaysia, Papua New Guinea, Philippines, Timor-Leste.

The previous survey (FAO, 1999) distinguished five subregions, including the Far East and Eastern Asia. The Far East was composed of two countries: Japan and the Republic of Korea. The present survey does not include Japan and the Republic of Korea has been included in East Asia, which thus replaces the Far East and Eastern Asia subregions of the previous survey. South Asia is the same as the Indian Subcontinent in the previous survey, but with the addition of Pakistan, which in the previous survey was included in the Near East region (FAO, 1997a). Mainland Southeast Asia is exactly the same as the Southeast subregion in the previous survey. Maritime Southeast Asia is the same as the Islands subregion in the previous survey, but now includes Timor-Leste, which at the time of the preparation of the previous survey was not yet an independent country.

This regional overview presents distinguishing features arising from the new data collected on a national scale for issues addressed in the country profiles and the four transboundary river basins in the region. The interest of this new survey lies in the updating of data and in the trends during the last ten years.

Geography, climate and population

The total area of Southern and Eastern Asia is 20.8 million km², or 15 percent of the world's emerged landmass (Table 1, Table 39). Out of the 22 countries in the region, China represents 46 percent and India 16 percent of the total area, the two countries together occupying almost two-thirds of the total area of the region (Table 29). The smallest six countries - Maldives, Brunei Darussalam, Timor-Leste, Bhutan, Sri Lanka and Republic of Korea - together comprise barely 1 percent of the total area. The cultivated area is estimated at 442 million ha (Table 1). In South Asia almost half of the total area of the subregion is cultivated going down to just over 10 percent in East Asia. Considering the cultivable area, however, in all regions more than three-quarters of the cultivable area is already cultivated. In some countries, the entire cultivable area seems to be already cultivated. However, the definition of cultivable varies from country-to-country, for example one may or may not include the area under permanent pasture in the figure of cultivable.

Average annual precipitation is estimated at 1 136 mm for the region. It varies from less than 100 mm in parts of western China and southern Mongolia to as high as 8 000 mm in the mountain areas of Papua New Guinea and more than 10 000 mm in the Khasi hills in northeast India (Figure 5).

Total population was estimated at 3 605 million inhabitants in 2009, representing about 53 percent of the world's population (Table 2, Table 39). China and India are the most and the second most populous countries in the world respectively, together accounting for about 38 percent of the world's population and 71 percent of the Southern and Eastern Asia region population (Table 30). Population density in the region is 173 inhabitants/km², compared to 51 inhabitants/km² for the world as a whole and 33 inhabitants/km² for Africa, varying from less than two inhabitants/km² in Mongolia to more than 1 000 inhabitants/km² in Bangladesh and Maldives (Figure 6 and Table 30). The annual demographic growth rate in the region was estimated at 0.98 percent for the period 2008-2009, compared to 1.16 percent for the whole world.

The population of Southern and Eastern Asia is predominantly rural: about 61 percent of the total population is rural, similar to Africa, compared to 50 percent for the world as a whole. Though, rural population varies from more than 80 percent in Nepal, Papua New Guinea and

TABLE 1
Regional distribution of total, cultivable and cultivated areas (2009)

Subregion	Total area	Cultivable areas*	Cultivated areas		
			Area	In % of total area	In % of cultivable area
	(ha)	(ha)	(ha)	(%)	(%)
East Asia	1 138 456 000	130 757 000	129 933 000	11	99
South Asia	447 884 000	219 306 000	204 249 000	46	93
Mainland Southeast Asia	193 860 000	61 316 000	46 283 000	24	76
Maritime Southeast Asia	301 885 000	79 963 000	61 828 000	21	77
Total region	**2 082 085 000**	**491 342 000**	**442 293 000**	**21**	**90**

* The cultivable area for Bhutan, China, Democratic People's Republic of Korea, Indonesia, Maldives, Philippines, Republic of Korea, Timor-Leste and Viet Nam was estimated as cultivated area since no data were available. For Sri Lanka it was estimated as being equal to the irrigation potential, since it is larger than cultivated area

TABLE 2
Regional distribution of area and population (2009)

Subregion	Area		Population					
	km²	% of the region	Total population (millions)	% of the region	% living in rural areas	Population density (inhab./ km²)	Economically active population as % of total	% economically active population in agriculture
East Asia	11 384 560	55	1 441	40	52	127	58	60
South Asia	4 478 840	22	1 576	44	70	352	40	53
Mainland SE Asia*	1 938 600	9	223	6	69	115	55	61
Maritime SE Asia*	3 018 850	14	365	10	53	121	45	39
Total region	**20 820 850**	**100**	**3 605**	**100**	**61**	**173**	**49**	**56**

*SE Asia = Southeast Asia

Sri Lanka to less than 30 percent in Brunei Darussalam and Malaysia and even less than 20 percent in the Republic of Korea. Also the percentage of the economically active population engaged in agriculture is, with about 56 percent, high compared to 40 percent for the world.

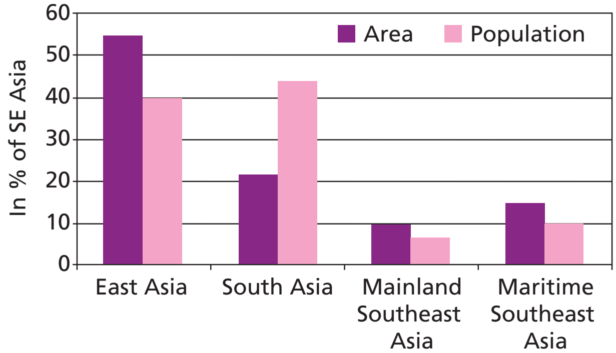
In 2008, around 12 percent of the total population of Southern and Eastern Asia, 17 percent of the rural population and 4 percent of the urban population, had no access to safe drinking water. In 2010, average life expectancy was 69 years.

EAST ASIA

The East Asia subregion includes China, Democratic People's Republic of Korea, Mongolia and the Republic of Korea. It extends over 11.4 million km², which is about 55 percent of the total area covered by this survey and 8.5 percent of the world area (Figure 1 and Table 2). China covers 84 percent of the area of this subregion. The subregion is bordered to the north by Mongolia and the Russian Federation, to the east by the Pacific Ocean, to the south by Viet Nam, Lao People's Democratic Republic, Myanmar, India, Bhutan and Nepal, and to the west by Pakistan, Tajikistan, Kyrgyzstan and Kazakhstan. This region is mainly mountainous with about 80 percent of the landmass lying above the mean altitude of 1 000 m above sea level. In 2009 about 130 million ha was cultivated.

Apart from east and south China, where the climate is determined by the monsoon, the region is generally characterized by long cold winters (September/October to April/May) caused by the north and northwest winds from Siberia with temperatures ranging from -20 °C to -40 °C. Precipitation is more important in the summer months, from May/June to August/September. Large parts of south Mongolia and central China suffer from a very arid climate and are facing severe water scarcity problems.

FIGURE 1
Regional distribution of areas and population



Average annual precipitation in the subregion is 599 mm, varying from less than 25 mm in the Tarim and Qaidam basins in western China to an average of 1 274 mm in the Republic of Korea (Table 31). Among the factors affecting agricultural production in the region are low soil moisture and air humidity in spring and early summer, and frosts in spring and autumn.

Total population was 1 441 million inhabitants in 2009, or 40 percent of the region, with China accounting for almost 95 percent of this total. About 52 percent of the population lives in rural areas, varying from 54 percent in China to 17 percent in the Republic of Korea (Table 2). The average population density of the subregion is 127 inhabitants/km², ranging from less than 2 inhabitants/km² in Mongolia to 480 inhabitants/km² in Republic of Korea. Annual population growth ranges from 0.5 percent in Republic of Korea to 1.3 percent in Mongolia during the period 1999-2009, with a subregional average annual growth of 0.6 percent, while in the previous decade (1989-1999) it was estimated at 1.0 percent.

SOUTH ASIA

The South Asia subregion, comprising Bangladesh, Bhutan, India, Maldives, Nepal, Pakistan and Sri Lanka, covers about 4.5 million km², or 22 percent of the Southern and Eastern Asia region (Table 2). India covers 73 percent of the area of this subregion. The subregion is bordered to the north by China, to the east by Myanmar and the Bay of Bengal, to the south by the Indian Ocean, to the west by the Arabian Sea and the Islamic Republic of Iran, and to the northwest by Afghanistan. The geomorphology of these countries consists of a large portion of floodplains along the Indus and Ganges river basins, some terraces and hilly areas, and the mountainous terrain of the Himalayas, with the world's highest peak, Mount Everest at 8 848 m, located in the Nepal Himalayas. The cultivable area is 219 million ha, 83 percent of which is in India, and in 2009 about 204 million ha was cultivated, or 93 percent of the cultivable area.

The subregion experiences a tropical monsoon climate, with significant seasonal variations in rainfall and temperature. About 80 percent of the total precipitation occurs during the monsoon period. The climatic year includes two monsoon periods: the southwest monsoon (June-September) concentrating most of the rainfall, and the northeast monsoon (November-March), which has relatively light rainfall compared to the southwest monsoon. The highest temperatures are registered during the dry season (generally from March to May) with 43 °C in Bangladesh and 40 °C in the northwest regions of India.

Average annual precipitation in the subregion is about 1 114 mm, varying from less than 150 mm in the northwest desert of Rajasthan in India, to more than 10 000 mm in the Khasi hills in northeast India.

Total population was 1 576 million in 2009, or 44 percent of the region, of which 77 percent lives in India, 11 percent in Pakistan and 9 percent in Bangladesh. About 70 percent of the population lives in rural areas ranging from 82 percent in Nepal to 61 percent in Maldives (Table 2 and Table 30). The average population density in the subregion, 352 inhabitants/km², is more than twice the average density of the region as a whole and more than seven times the population density of the world. National average densities range from 1 040 inhabitants/km² in Maldives and 1 021 inhabitants/km² in Bangladesh, which is amongst the highest density in the world, to 19 inhabitants/km² in Bhutan. Annual population growth ranges from 1.5 percent in Sri Lanka to 2.6 percent in Bhutan during the period 1999-2009, with a subregional average annual growth of 1.6 percent, while in the previous decade (1989-1999) it was estimated at 1.8 percent.

MAINLAND SOUTHEAST ASIA

The Mainland Southeast Asia subregion with an area of 1.9 million km², or 9 percent of the total area of the region, is composed of Myanmar and the four riparian countries of the lower Mekong basin: Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam

(Table 2). Myanmar and Thailand cover 35 percent and 26 percent of the area of this subregion respectively (Table 29). The subregion is bordered to the north by China, to the east by the South China Sea, to the south by the Gulf of Thailand, to the west by the Indian Ocean, the Andaman Sea and the Bay of Bengal, and to the northwest by Bangladesh and India. Mountains and hills are the main physiographical features, covering about two-thirds of the total area, with the highest point situated at 5 800 m above sea level in the extreme north of Myanmar. The extensive plains along the Mekong, Red and Ayeyarwady rivers are frequently subject to flooding. The cultivable area is 61 million ha, 44 percent of which is in Thailand, and in 2009 about 46 million ha was cultivated, or 76 percent of the cultivable area.

The climate is mainly governed by the alternance between the wet season, characterized by the southwest monsoon (May to October) with heavy rainfall, and the dry season, characterized by the northeast monsoon (November to February) which is relatively cool and dry. About 75 percent of the total rainfall occurs during the wet season. This results in a large difference in the water level in rivers between the wet and the dry seasons: the water level in the Mekong river may differ by up to 20 m between the two seasons. The average annual rainfall in the region is 1 825 mm, ranging from 500 mm in the central dry zone in Myanmar and 650 mm in Phan Rang in Viet Nam to more than 4 000 mm in the mountains of Rakhine in Myanmar and Bac Quang in Viet Nam.

In 2009, the total population was 223 million inhabitants, or 6 percent of the region, with Viet Nam and Thailand together accounting for almost 70 percent of this total (Table 30). About 69 percent of the population lives in rural areas, varying from 80 percent in Cambodia to 66 percent in Thailand (Table 2). The average population density of the subregion is 115 inhabitants/km², ranging from 26 inhabitants/km² in Lao People's Democratic Republic to 263 inhabitants/km² in Viet Nam, but going up to more than 1 000 inhabitants/km² in the Red River Delta in Viet Nam. Annual population growth ranges from 0.7 percent in Myanmar to 1.6 percent in Lao People's Democratic Republic during the period 1999-2009, with a subregional average annual growth of 1.0 percent, while in the previous decade (1989-1999) it was estimated at 1.4 percent.

MARITIME SOUTHEAST ASIA

This subregion includes the countries of the Indian and North Pacific oceans, characterized by their insular nature: Brunei Darussalam, Indonesia, Malaysia, Papua New Guinea, Philippines and Timor-Leste. Its land area extends over 3 million km², which is about 14 percent of the total area under this survey (Table 2). Indonesia covers 63 percent of the area of this subregion (Table 29). The relief is dominated by extensive lowland plains and swamps, which contrast sharply with high mountain ranges, with the highest point situated at 5 030 m above sea level in the volcanic mountains of Indonesia. In 2009 about 62 million ha was cultivated.

The climate of this subregion is tropical and monsoonal, characterized by the uniformity of temperature, 27 °C throughout the year, and high humidity, varying from 70 to 80 percent. The region is under the influence of two main air streams: the northeast monsoon, blowing from October to March, and responsible for heavy rainfall, and the southwest monsoon occurring between May and September. Many islands of the region are liable to extensive flooding and typhoon damage during a period extending from June to September. The average rainfall in this region is 2 747 mm, ranging from less than 1 000 mm in Port Moresby in southeast Papua New Guinea to more than 8 000 mm in some mountainous areas in the same country (Table 31).

Total population was 365 million inhabitants in 2009, or 10 percent of the region, with Indonesia accounting for 65 percent of this total (Table 30). The population is unevenly distributed and is mainly concentrated along the coastal areas. About 53 percent of the population lives in rural areas, varying from 25 percent in Brunei Darussalam to 87 percent in Papua New Guinea (Table 2). The average population density of the subregion is 121 inhabitants/km², ranging from 14 inhabitants/km² in Papua New Guinea to 306 inhabitants/km² in the Philippines. Annual population growth ranges from 1.2 percent in Indonesia to 2.9 percent in Timor-Leste during the period 1999-2009, with a subregional average annual growth of 1.5 percent, while in the previous decade (1989-1999) it was estimated at 1.6 percent.

Economy, agriculture and food security

The economy of the Southern and Eastern Asia region is dominated by agriculture, though industry and services are becoming more important. The sum of national GDPs in 2009 amounted to US$8 725 096 million, which is 15 percent of world GDP. It corresponds to a GDP of about US$2 420/inhabitant, ranging from US$426/inhabitant in Nepal to US$29 262/inhabitant in Brunei Darussalam. Based on the Human Development Index (HDI) where 0= lowest and 1 = highest, in 2010 the countries rank between the 89th and the 138th place out of a total of 169 countries, except for Republic of Korea, Brunei Darussalam and Malaysia which hold the 12th, 37th, and 57th place with an HDI of 0.877, 0.805 and 0.744 respectively. The HDI for Bhutan and Democratic People's Republic of Korea is unknown (Table 30).

Although Asia's economy is predominantly agricultural, regions have developed industrially where power facilities, trained labour, modern transport and access to raw materials are available. China, India and the Republic of Korea are making considerable progress. Also petroleum is contributing greatly to the income of some countries such as Malaysia, Thailand and Indonesia, manganese in India and chromites in the Philippines. China produces great amounts of tungsten, antimony, coal, and oil (Columbia University, 2007).

In 2009, the added value of the primary sector (agriculture) contributed 11.6 percent to the GDP of the Southern and Eastern Asia region. It ranged from 0.7 percent in Brunei Darussalam (2006) and 2.6 percent in the Republic of Korea (2009), to 35.9 percent in Papua New Guinea (2009) and 48.4 percent in Myanmar (2004). An average of 56 percent of the economically active population is engaged in the farming sector (Table 2 and Table 30). It ranges from 0.5 percent in Brunei Darussalam, 5.9 percent in Republic of Korea and 13.8 percent in Malaysia to 80 percent in Timor-Leste, 92.8 percent in Bhutan and 93 percent in Nepal. Mainland Southeast Asia is the subregion with most economically active people involved in agriculture, accounting for 61 percent, followed by East Asia with 60 percent, South Asia with 53 percent and Maritime Southeast Asia with 39 percent.

The cultivated area per person economically active in agriculture varies from a low 0.2 ha/person in Nepal, Bangladesh and China to 3.9 ha/person in Mongolia, 4.6 ha/person in Malaysia and 8 ha/person in Brunei Darussalam, giving an average for the region of 0.4 ha/person (Table 29).

Rice, by far the most important food crop, is grown for local consumption in the heavily populated countries (China, India, Indonesia and Bangladesh), while countries with smaller populations (Thailand, Viet Nam and Pakistan) are generally rice exporters. Other important crops are wheat, soybeans, peanuts, sugarcane, cotton, jute, silk, rubber, tea and coconuts.

Water resources

RENEWABLE WATER RESOURCES (PRIMARY FRESHWATER)

Compilation of information on water resources shows large methodological discrepancies between countries. This survey distinguishes between internal renewable water resources (IRWR) and total renewable water resources (TRWR). IRWR is that part of a country's water resources generated from endogenous precipitation. It is computed by summing surface water flow and groundwater recharge and subtracting their common part. The computation of TRWR is made by summing IRWR and external flow. It is a measure of the maximum theoretical amount of water available to a country without any considerations of a technical, economic or environmental nature. The methodology used in the survey also distinguishes between natural and actual external flow: natural flow is the average annual amount of water that would flow at a given point in a river without any human influence, while actual flow takes into account volumes of water reserved by treaties and, depending on the information available, may or may not consider the reduction of flow caused by upstream withdrawal.

The large range of climates encountered in the region generates a variety of hydrological regimes. The region is host to some of the most humid climates (with annual precipitation above 10 000 mm in some places) giving rise to major rivers, while in other parts the climate is very arid with closed hydrologic systems. As a result, the region shows a very uneven distribution of its water resources and of its water-use conditions. In the humid areas, water management concerns have mostly been dominated by considerations related to flood control. This is the case in the Brahmaputra, Ganges, Indus and Mekong basins. In the arid areas, such as in central China, where water is scarce, hydrological studies have been oriented much more towards water resources assessment.

The hydrology of the region is dominated by the typical monsoon climate, which induces large inter-seasonal variations of river flows. In this situation, average annual values of river flows are a poor indicator of the amount of water resources available for use. In the absence of flow regulation, most of the water flows during a short season when it is usually less needed. A fair estimate of water resources available for use to a country should include figures of dry season low flow. However, such information is available only for a few countries: in Bangladesh, the surface flow of the driest month represents only 18 percent of the annual average; in Indonesia, it is 17 percent. In India, the flow distribution of selected rivers in the monsoon period represents 75-95 percent of the total annual flow. In north China, 70-80 percent of the annual runoff is concentrated in the rainy season. Given the seasonal nature of the Himalayan runoff, roughly 85 percent of the annual flow in the Indus in Pakistan is in the summer (*kharif* season). As a first approximation, one could then state that in the absence of storage the amount of water readily available for use is between 10 and 20 percent of the total renewable water resources.

The information collected from the countries of the region does not make it possible to distinguish between actual and natural flow of the major rivers, i.e. the impact of irrigation and other water withdrawal on the runoff. In this survey, figures were systematically considered as natural flow, while also taking into consideration possible treaties. This option of course may lead to an underestimation of natural flow in some cases. At least in one case, the Ganges river, the withdrawals in the upstream country (India), are known to affect significantly the volumes of water available to the downstream country (Bangladesh). This has led to a treaty between the two countries on agreed procedures for the management of the river flow. A treaty also exists between India and Pakistan referring to the rivers in the Indus river basin (see river basin and country profiles). In view of the hydrological regime of the rivers in the region, it can be assumed that runoff in the countries of South Asia and Mainland and Maritime Southeast Asia is not significantly affected by withdrawals, while the difference between natural and actual flow may be much more important in the arid regions in East Asia (mostly China).

Overall, the region is relatively well endowed with water resources: for a total area representing 16 percent of the world's land surface, it receives 22 percent of its precipitation and produces 25 percent of its water resources. However, as the region is home to 53 percent of the world's population, the amount of water resources per inhabitant is 2 970 m^3/year, which is less than half the world's average of 6 236 m^3/year in 2009 (Table 39).

The volume of annual precipitation in Southern and Eastern Asia is estimated at about 23 646 km^3. This volume is equal to a regional average depth of 1 136 mm, compared to a global average of 804 mm, but with significant disparities between countries (Table 3 and Figure 5). Average annual precipitation varies from less than 25 mm in western China to more than 10 000 mm in northeast India. At country-level, the driest country is Mongolia with 241 mm/year on average, followed by Pakistan with 494 mm and China with 645 mm. Papua New Guinea is the rainiest country with, on average, 3 142 mm/year, followed by Malaysia with 2 875 mm, Brunei Darussalam with 2 722 mm and Indonesia with 2 702 mm (Table 31). The driest subregion is East Asia with an annual average of 599 mm, while South Asia receives 1 114 mm, Mainland Southeast Asia 1 825 mm and Maritime Southeast Asia 2 747 mm.

Annual renewable water resources in Southern and Eastern Asia account for 10 707 km^3 (Table 3 and Table 31). In absolute terms China accounts for the largest amount of water resources, 2 812 km^3/year or 26 percent of the region's water resources, but this refers to 46 percent of the region's total area. Indonesia follows with 2 018 km^3, or 19 percent of the water resources of the region, which contrary to China is an important value taking into account that the country represents only 9 percent of the total area of the region. India accounts for 1 446 km^3/year (Table 31 and Figure 7). As for the subregions, Maritime Southeast Asia accounts for 36 percent of the renewable water resources of the region with only 15 percent of the total area of the region. On the other hand, East Asia accounts for 28 percent of the total water resources for an area equivalent to 55 percent of the region. South Asia and Mainland Southeast Asia account both for 18 percent of the total water resources, for an area equivalent to 22 percent and 9 percent respectively (Figure 2).

Population has increased by almost 25 percent since the previous survey, resulting in a decrease in average annual internal renewable water resources (IRWR) per inhabitant from about 3 455 m^3 in 1999 to 2 970 m^3 in 2009. This is less than half of the global average IRWR/habitant

TABLE 3
Regional distribution of the water resources

Subregion	Annual precipitation		Annual internal renewable water resources		
	Height	Volume	Volume	% of the region	Per inhabitant (2009)
	(mm)	(million m^3)	(million m^3)	(%)	(m^3)
East Asia	599	6 823 275	2 979 050	28	2 068
South Asia	1 114	4 991 592	1 935 450	18	1 228
Mainland Southeast Asia	1 825	3 537 620	1 897 767	18	8 499
Maritime Southeast Asia	2 747	8 294 233	3 895 057	36	10 664
Total region	**1 136**	**23 646 719**	**10 707 324**	**100**	**2 970**

of 6 236 m^3, and ranges from 96 m^3 in Maldives, 323 m^3 in Pakistan and 714 m^3 in Bangladesh to 31 155 m^3 in Lao People's Democratic Republic, 109 224 m^3 in Bhutan and 119 499 m^3 in Papua New Guinea (Table 31 and Table 39). The distribution of total actual renewable water resources (TARWR) is different because of transboundary river basins, for example in Cambodia the IRWR are 8 626 m^3/inhabitant while the TARWR are almost four times as high, 34 061 m^3/inhabitant, and in Lao People's Democratic Republic these figures are 31 155 m^3 and 54 573 m^3 respectively. Maritime Southeast Asia is the sub-region with the highest IRWR per inhabitant, 10 644 m^3, followed by Mainland Southeast Asia with 8 499 m^3/inhabitant, East Asia with 2 068 m^3/inhabitant and South Asia with 1 228 m^3/inhabitant.

FIGURE 2
Regional distribution of area and water resources

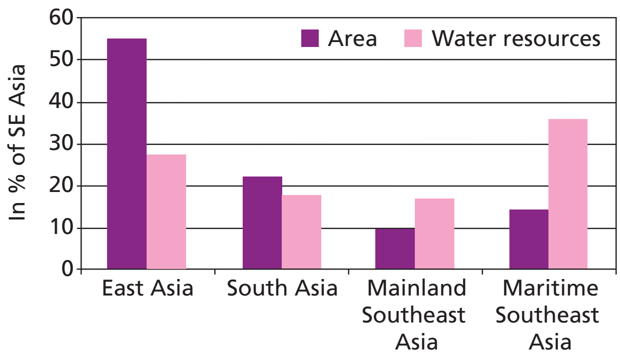


Table 4 presents those countries with IRWR less than 1 700 m^3/inhabitant, which is considered to be a threshold below which there are indications of water stress. Looking at TARWR, all of them except the island Maldives have higher TARWR because they have a relatively large proportion of external renewable water resources. However, except for Bangladesh the situation remains the same, meaning that the TARWR are also less than 1 700 m^3/inhabitant and slowly they are even approaching a situation of chronic water scarcity (threshold 1 000 m^3/inhabitant per year) (Figure 8).

TABLE 4
Countries with Internal Renewable Water Resources (IRWR) of less than 1 700 m^3/inhabitant per year

Country	Internal renewable water resources per inhabitant		Total renewable water resources per inhabitant	
	1999 (m^3)	2009 (m^3)	1999 (m^3)	2009 (m^3)
Bangladesh	825	714	9 645	8 343
India	1 395	1 197	1 844	1 582
Maldives	112	96	112	96
Pakistan	389	323	1 755	1 447
Republic of Korea	1 421	1 352	1 524	1 453

OTHER SOURCES OF WATER

Water scarcity forces national economies to find alternative ways to satisfy the demand for water. Other sources of water might include the following:

- Fossil groundwater
- Overexploitation of renewable groundwater
- Secondary freshwater, which is (treated) wastewater and/or agricultural drainage water returned to the system
- Non-conventional sources of water, which includes desalinated water and direct use of treated wastewater and agricultural drainage water

No information is available on the use of fossil groundwater. Twelve of the 22 countries mention overexploitation of renewable groundwater resources, meaning that the withdrawal is larger than the recharge, which leads to problems such as lowering of the groundwater tables, saltwater intrusion, groundwater pollution, etc. (see the chapter on water withdrawal).

Figures for direct use of treated wastewater are available only for 2 out of 22 countries of the region and are often underestimates. China and Viet Nam report 13 390 million m^3/year and 175 million m^3/year respectively. Even produced and treated wastewater data are available for only 9 countries, of which for 5 countries the latest information is 15-20 years old (Table 5).

Total use of desalinated water in the region is estimated to be 36 million m^3/year. However, only 6 countries report on this source of water. Of these, Indonesia is by far the largest user of desalinated water, accounting for 52 percent of the region's total, followed by China and Malaysia with 30 and 12 percent respectively. In Maldives, being a small country, desalination has a notably importance amounting to 1.2 million m^3, which represents 20 percent of its total water withdrawal. India and the Republic of Korea desalination amounts to only 0.6 and 0.2 million m^3/year (Table 33).

DAMS

Total dam capacity in the Southern and Eastern Asia region is 1 048 km^3, of which 75 percent is located in just two countries: China (54 percent) and India (21 percent) (Table 6). Thirty-nine dams in the Southern and Eastern Asia region have a capacity over 5 km^3, of which seventeen in China, ten in India, five in Thailand, two in Malaysia, two in Pakistan, one in Bangladesh, one in Lao People's Democratic Republic and one in Viet Nam. In total these thirty-nine large dams account for 470 km^3, or 45 percent of the total dam capacity in the Southern and Eastern Asia region. The dam with the largest capacity (39 km^3) is the Three Gorges Dam in China, completed in 2006, which is considered to be the largest hydropower project in the world. The Longtan and Longyangxia dams, both also in China, follow with a capacity of 27 km^3 and 25 km^3 respectively. Outside China, the largest dam is Kaptai Dam in Bangladesh with a total storage capacity of 20 km^3 (Table 7).

TABLE 5
Produced, treated and directly used wastewater

Country		Wastewater (million m^3)		
	Year	Produced	Treated	Direct use
Cambodia	1994		0.16	
China	2004	53 700	22 100	13 390
India	1996	25 410		
Malaysia	1995	2 690	398	
Pakistan	2000	12 330	145	
Philippines	1993		10	
Republic of Korea	1996	7 947	4 180	
Thailand	2007	2 191	523	
Viet Nam	2003	1 100	250	175

TABLE 6
Regional distribution of dams

Subregion	Dam capacity	
	km^3	% of the region
East Asia	589.1	56
South Asia	277.4	26
Mainland Southeast Asia	128.1	12
Maritime Southeast Asia	53.2	5
Total region	**1 047.7**	**100**

TABLE 7

Dams in the Southern and Eastern Asia region with a reservoir capacity larger than 5 km^3

Dam	River	Basin	Completed (year)	Capacity (km^3)	Surface area (km^2)	Main use*	Country
Rengali	Brahmani	-	1985	5.2	378	I, H	India
Baishan (Huadian)	Songhuajiang	-	1986	5.3	85	H, F	China
Rat Cha Prapa	Khlong Saeng	Tapi	1987	5.6	17	I, H, W	Thailand
Liujiaxia	Yellow	Yellow	1974	5.7	130	I, H, F	China
Ertan	Yalong	Yangtze	1999	5.8	101	H	China
Temenggor	Perak	Perak	1972	6.1	-	H	Malaysia
Almatti	Krishna	-	1999	6.4	754	I	India
Nam Ngum	Nam Ngum	Mekong	1985	7.0	-	H	Lao PDR
Gandhi Sagar	Chambal	-	1960	7.3	660	I, H	India
Zhelin	Xiushui	Ganjiang	1972	7.9	202	I, H, F	China
Hirakud	Mahandi	Ganges	1957	8.1	743	I, H, W, F	India
Ukai	Tapi	Tapi	1973	8.5	-	I, F	India
Pong	Beas	Indus	1974	8.6	260	I, H	India
Srisailam	Krishna	Krishna	1984	8.7	616	I	India
Vaijiralongkorn	Quae Noi	Mae Klong	1984	8.9	39	I, H, W, F	Thailand
Fengman	Songhua Jiang		1941	9.2	193	H, F	China
Dongjiang	Laishui	Xiang jiang	1992	9.2	131	H, F	China
Hoa Binh	Da	Red	1994	9.5	-	I, H, W, F	Viet Nam
Sirikit	Nan	Nan	1971	9.5	26	I, H, W, F	Thailand
Bhakra	Sutlej	Indus	1963	9.6	168	I, H	India
Sanmenxia	Huang	Huang	1960	9.6	255	I, H, F	China
Raised Mangla	Jehlum	Indus	1967	10.1	-	I, H	Pakistan
Tianshengqiao No.1	Nanpaniiang	Zhu Jiang	2000	10.3	98	H	China
Rihand	Rihand	Ganges	1962	10.6	46	H	India
Nagarjuna Sagar	Krishna	Krishna	1960	11.6	285	I, H	India
Tarbela	Indus	Indus	1976	12.0	-	I, H	Pakistan
Xiaolangdi	Yellow	Yellow	2000	12.8	-	H	China
Bhumipol	Ping	Ping	1964	13.5	32	I, H, W, F	Thailand
Sanhezha (Hongzehu)	Huaihe	Huaihe	1953	13.5	1 374	I, F	China
Sultan Mahmud	Kenyir	Kenyir	1985	13.6	2 600	H, F	Malaysia
Xinfengjiang	Xinfengjiang	Zhu Jiang	1960	13.9	264	H	China
Shuifeng	Yalujiang	Yalu	1943	14.7	111	H, W, F	China
Srinagarind	Quae Yai	Mae Klong	1980	17.7	42	I, H, W, F	Thailand
Kaptai	Karnafuli	Karnafuli	1962	20.3	749	I, H, F	Bangladesh
Danjiangkou	Hanshui	Han Shui	1973	20.9	286	H, F	China
Xin'anjiang	Xin'anjiang	Qiantang Jiang	1960	21.6	424	H, F	China
Longyangxia	Yellow	Yellow	1989	24.7	383	I, H, F	China
Longtan	Hongshui	Xi	2009	27.3	-	H, F	China
Three Gorges	Yangtze	Yangtze	2006	39.3	1 084	H	China
Total				**470.0**	**-**		

* I = Irrigation; H = Hydropower, W = Water supply; F = Flood protection

TRANSBOUNDARY WATERS

The main transboundary rivers in Southern and Eastern Asia are the Mekong river basin flowing to the South China Sea, the Ganges-Brahmaputra-Meghna river basin flowing to the Bay of Bengal, the Indus river basin flowing to the Arabian Sea and the Salween river basin flowing to the Andaman Sea. These four transboundary river basins cover almost one-fifth of the total area of Southern and Eastern Asia (Table 8 and Figure 9). A more detailed description of these four transboundary basins is given in Section III.

TABLE 8

The four most important transboundary river basins in the Southern and Eastern Asia region

Basin	Area		Countries included	Area of country in basin (km^2)	As percentage of total area of basin %
	km^2	% of the SE Asia			
Mekong	795 000	3.8	China	165 000	21
			Myanmar	24 000	3
			Lao PDR	202 000	25
			Thailand	184 000	23
			Cambodia	155 000	20
			Viet Nam	65 000	8
Ganges-Brahmaputra-Meghna	1 712 700	8.3	India	1 102 000	64
			China	304 400	18
			Nepal	147 500	8
			Bangladesh	120 400	7
			Bhutan	38 400	3
Indus	1 120 000	5.4	Pakistan	520 000	47
			India	440 000	39
			China	88 000	8
			Afghanistan	72 000	6
Salween	320 000	1.5	China	169 600	53
			Myanmar	134 400	42
			Thailand	16 000	5
Total	**3 947 700**	**19.0**			

Water withdrawal

WATER WITHDRAWAL BY SECTOR

Data on water withdrawal by sector refer to the gross quantity of water withdrawn annually for a given use. Table 32 presents the distribution of water withdrawal by country for the three large water-consuming sectors: agriculture (irrigation, livestock watering, aquaculture), municipalities (domestic/municipal) and industry (including water for cooling of thermoelectric plants). Although able to mobilize a significant portion of water, requirements for energy purposes (hydroelectricity), navigation, fishing, environment and leisure activities have a low rate of net water consumption. For this reason, they are not included in the calculation of the regional withdrawals but they do appear in the country profiles where information is available.

For most countries, data on water withdrawal could be obtained from national statistics although large uncertainties remain on computation methods. For five countries (Democratic People's Republic of Korea, Lao People's Democratic Republic, Malaysia, Mongolia and Nepal) data for water withdrawal could not be found in national reports and estimates were done based on modelled data for municipal and industrial water withdrawal using statistical methods and calculated based on irrigation areas, cropping patterns, consumptive water use and efficiency for agricultural withdrawal. It should be noted that these are countries where water resources are not yet a constraint on economic development.

Total annual water withdrawal for the Southern and Eastern Asia region is almost 1 981 km^3, which is around 50 percent of world withdrawals (Table 9 and Table 39). It should be noted here that the total population of the region is more than half the world population. About 82 percent of inventoried withdrawals are by agriculture, which is higher than the value for global agricultural water withdrawal (70 percent). However, this figure varies by country. In 14 out of 22 countries in the region agricultural withdrawal accounts for more than 80 percent of the total water withdrawal, with more than 95 percent in Viet Nam and Nepal, while in Malaysia and Mongolia it represents less than 50 percent, and in the Maldives and Papua New Guinea 0 percent. The Mainland Southeast Asia and South Asia countries use on average 92 and 91 percent respectively of their withdrawal for agriculture while Maritime Southeast Asia countries use 79 percent and East Asia countries use only 65 percent.

TABLE 9
Regional distribution of water withdrawal by sector

Subregion	Annual withdrawal by sector									
	Agriculture		Municipalities			Industry		Total		
	million m^3	% of total	million m^3	% of total	m^3 per capita	million m^3	% of total	million m^3	% of region	m^3 per capita
East Asia	380 657	65	75 175	13	54	132 907	23	588 739	30	417
South Asia	913 113	91	70 225	7	44	20 034	2	1 003 372	51	640
Mainland SE Asia*	165 125	92	7 496	4	34	6 386	4	179 007	9	832
Maritime SE Asia*	165 421	79	23 588	11	71	20 610	10	209 711	11	619
Total region	**1 624 316**	**82**	**176 484**	**9**	**50**	**179 937**	**9**	**1 980 829**	**100**	**561**

*SE Asia = Southeast Asia

Not surprisingly, considering the population, India and China with a water withdrawal of 761 km^3 and 554 km^3 respectively cover the highest withdrawals in the world, accounting for 19 percent and 14 percent of the total respectively, while in the Southern and Eastern Asia region they represent 38 and 28 percent respectively of total withdrawal. Pakistan and Indonesia represent 5 percent and 3 percent respectively of world total withdrawals and 6 and 9 percent of total withdrawals for Southern and Eastern Asia region. Viet Nam has the highest withdrawal in the Mainland Southeast Asia subregion at 4 percent of the total withdrawals in the region (Table 32). Water withdrawal per inhabitant is 560 m^3/year, but this average conceals significant variations between countries. The figure ranges from 10 and 60 m^3/inhabitant in the Maldives and Papua New Guinea respectively to 1 037 m^3/inhabitant in Pakistan and 1 232 m^3/inhabitant in Timor-Leste (Figure 10).

Figures for agricultural water withdrawal expressed in m^3 per hectare of irrigated land show large discrepancies between countries, which cannot be explained solely by differences in climatic conditions. Rather, their difference is to be found in computation methods. Indeed, with a major regional emphasis on flooded rice irrigation, it is particularly difficult to assess agricultural water withdrawal. The gross average for the region is 8 960 m^3/ha/year. Figures for China and India, which together represent 64 percent of the region's agricultural water withdrawal, are: 5 700 and 10 400 m^3/ha of irrigated land respectively. However, other countries show much higher values, as for Viet Nam, Republic of Korea, Sri Lanka, Timor-Leste and the Philippines where agricultural water withdrawal is between 15 000 and 35 000 m^3/ha/year. More research is needed to obtain homogenous information on agricultural water withdrawal among countries.

Municipal water withdrawal is particularly important in the East Asia subregion with 75 km^3 accounting for 13 percent of total withdrawals, while in Maritime Southeast Asia it represents 11 percent, in South Asia 7 percent and in Mainland Southeast Asia 4 percent. Municipal water withdrawal per inhabitant is 50 m^3/year for the Southern and Eastern Asia region as a

whole, with variations between countries from 5 m^3/inhabitant in Nepal to 150 m^3/inhabitant in Malaysia and 141 m^3/inhabitant in the Republic of Korea. Industrial water withdrawal is particularly important in the East Asia subregion with 133 km^3 accounting for 23 percent of total withdrawals, while in Maritime Southeast Asia it represents 10 percent, in Mainland Southeast Asia 4 percent and in South Asia 2 percent. Industrial water withdrawal in China is 129 km^3, which is 71 percent of the region, followed by India with 17 km^3 or 9 percent. Industrial water withdrawal per inhabitant is 51 m^3/year for the Southern and Eastern Asia region on average. However, this figure also varies considerably at country level. In nine countries it amounts to less than 10 m^3/inhabitant per year, especially for the Maldives and Nepal where industrial water withdrawal is 1 m^3/inhabitant per year, whereas in Malaysia and China the figures are 183 and 97 m^3/inhabitant per year respectively.

WATER WITHDRAWAL BY SOURCE

Data on water withdrawal by source refer to the gross quantity of water withdrawn annually from all the possible sources, which are divided into primary and secondary (wastewater and agricultural drainage water returned to the system) freshwater resources, direct use of treated wastewater and agricultural drainage water, and desalinated water produced. Table 10 presents the distribution of water withdrawal by subregion.

For most countries, the methods used for calculation or the measurements for obtaining the values of the withdrawal by source are not specified. For countries for which recent data were not available or were not reliable, estimations have been used that take into account total water withdrawal by sector, given that total water withdrawal by source and total water withdrawal by sector must be equal.

TABLE 10
Regional distribution of water withdrawal by source

Subregion	Annual withdrawal by source									
	Primary and secondary freshwater *				Direct use **					
	Surface water	Ground-water	Surface water and groundwater		Treated waste-water	Agricul-tural drainage water	Direct use as part of total	Desalinated water		Total water withdrawal
	million m^3	million m^3	million m^3	% of total	million m^3	million m^3	% of total	million m^3	% of total	million m^3
East Asia	439 379	101 831	575 338	97.724	13 390		2.274	11	0.002	588 739
South Asia	526 077	341 081	889 900	88.691		113 470	11.309	2	0.000	1 003 372
Mainland SE Asia***	158 168	14 220	178 832	99.902	175		0.098	0	0.000	179 007
Maritime Se Asia***	186 911	21 213	209 688	99.989			0.000	23	0.011	209 711
Total region	**1 310 535**	**478 345**	**1 853 758**	**93.585**	**13 565**	**113 470**	**6.413**	**36**	**0.002**	**1 980 829**

* The distribution between surface water and groundwater withdrawal is unknown for Democratic People´s Republic of Korea and Republic of Korea in East Asia, for Maldives and Sri Lanka in South Asia, for Cambodia and Lao People´s Democratic Republic in Mainland Southeast Asia and for Papua New Guinea and Timor Leste in Maritime Southeast Asia. Thus they are not included in surface water and groundwater withdrawal and therefore their sum is not equal to the total. For these countries total freshwater withdrawal has been estimated taking into account water withdrawal by sector.

** Direct use in East Asia refers to China, in South Asia to India and in Mainland Southeast Asia to Viet Nam.

*** SE Asia = Southeast Asia

Total annual water withdrawal by source is 1 980.829 km^3 for the Southern and Eastern Asia region, which is equal to half of the global water withdrawal (Table 33 and Table 39). Primary and secondary freshwater accounts for 1 853.758 km^3 or 93.585 percent of total water withdrawal, direct use of treated wastewater and agricultural drainage water accounts for 127.035 km^3 or 6.413 percent, and desalinated water accounts for 0.036 km^3 or 0.002 percent. However, while only for India a figure is given for direct reuse of agricultural drainage water, this must the case in many other countries where rice is grown on terraces and irrigated with water flowing from one plot to another lower lying plot (cascades).

Considering the 13 countries out of 22 in the region, for which data on surface water and groundwater withdrawal is available, surface water withdrawal represents 75 percent of the freshwater withdrawal and groundwater 25 percent. Though, there are differences depending on the subregion. In Mainland and in Maritime Southeast Asia, surface water amounts to 92 and 90 percent of the total respectively, while in the East Asia countries surface water accounts for 82 percent and in the South Asia countries surface water accounts for 65 percent. In Bhutan, Brunei Darussalam, Viet Nam, Malaysia and the Philippines surface water withdrawal represents more than 95 percent of the total freshwater withdrawal, whereas in Mongolia and Bangladesh groundwater withdrawal accounts for 82 percent and 79 percent respectively.

From data reported, Maritime Southeast Asia seems the most advanced subregion regarding production of desalinated water accounting for 0.023 km^3, which represents 0.01 percent of the total water withdrawal in the subregion. East Asia follows with 0.011 km3 or only 0.002 percent of the total withdrawal. In the Mainland Southeast Asia countries there is no information on desalinated water available, while in South Asia only 0.002 km^3 are reported. Maldives is the only country in the region where desalinated water represents more than 1 percent of total withdrawals, accounting for 21 percent of the total.

THE WATER INDICATOR OF THE MILLENNIUM DEVELOPMENT GOALS

The Millennium Development Goal (MDG) water indicator, which is the total freshwater withdrawal as a percentage of total renewable freshwater resources, reflects the overall anthropogenic pressure on freshwater resources. In many areas, water use is unsustainable: withdrawal exceeds recharge rates and the water bodies are overexploited. The depletion of water resources can have a negative impact on aquatic ecosystems and, at the same time, undermine the basis for socio-economic development.

When relating the freshwater withdrawal to the renewable water resources in the Southern and Eastern Asia region, 18 out of 22 countries of the region stand out with values lower than 20 percent indicating that the water withdrawn is much lower than the quantity annually renewed on a long-term basis (Table 11 and Table 33). Pakistan has by far the highest water indicator, 74 percent, thoughIndia, Republic of Korea, Sri Lanka and China follow with 40, 37, 25 and 19 percent respectively (Figure 11). However, there can be huge within-country differences, especially in the many large countries in this region, and certain areas in a country are confronted with serious water scarcity issues.

TABLE 11
Millennium Development Goals (MDG) Water Indicator by country

Country	Freshwater withdrawal	Total actual renewable freshwater resources	MDG Water Indicator
	Total	TARWR*	Total freshwater withdrawal as percentage of TARWR
	million m^3	million m^3	%
Bangladesh	35 870	1 226 652	2.9
Bhutan	338	78 000	0.4
Brunei Darussalam	92	8 500	1.1
Cambodia	2 184	476 110	0.5
China	554 089	2 839 719	19.5
DPR Korea**	8 658	77 150	11.2
India	760 999	1 911 370	39.8
Indonesia	113 271	2 018 342	5.6
Lao PDR**	4 260	333 550	1.3
Malaysia	13 206	580 000	2.3
Maldives	5	30	15.6
Mongolia	511	34 800	1.5
Myanmar	33 230	1 167 801	2.8
Nepal	9 787	210 200	4.7
Pakistan	183 421	230 770	79.5
Papua New Guinea	392	801 000	0.0
Philippines	81 555	479 000	17.0
Republic of Korea	25 470	69 700	36.5
Sri Lanka	12 950	52 800	24.5
Thailand	57 302	438 609	13.1
Timor-Leste	1 172	8 215	14.3
Viet Nam	82 031	884 128	9.3

* TARWR = Total Actual Renewable Water Resources
** DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

Considering subregions the percentage of use of renewable water resources is lower in Mainland Southeast Asia and Maritime Southeast Asia, with total freshwater withdrawal amounting to only 5.4 percent of renewable water resources on average. In East Asia and South Asia water withdrawal represents 20 percent and 27 percent respectively of total renewable water resources.

EVAPORATION LOSSES FROM ARTIFICIAL RESERVOIRS

The evaporation from artificial lakes and reservoirs is considered a consumptive water use, since it would not occur if they had not been constructed to retain the water and thus create a surface water body from which water evaporates. This variable does not include evaporation from natural wetlands, natural lakes and rivers.

In theory this amount should be added to the water withdrawal data, but for the moment the information is still too uncertain and a more in-depth study is needed to confirm and complete the information for the whole region. However, a first effort to calculate the evaporation for the Southern and Eastern region, gives a value of 50 km^3/year, representing about 2.5 percent of the total water withdrawal (Table 12). By far the largest values are for India, with 16.95 km^3/year, and China, with 15.46 km^3/year.

TABLE 12
Evaporation losses from artificial reservoirs

Country	Dam capacity (km^3)	Evaporation rate (mm/year)	Evaporation losses from reservoirs (km^3/year)
Bangladesh	20.3	1 200	1.29
Cambodia			5.50
China	562.4	1 020	15.46
Democratic People’s Republic of Korea	10.6	860	0.14
India	224.0	1 560	16.95
Indonesia	22.5	1 650	1.20
Lao People’s Democratic Republic	7.8	1 360	0.65
Malaysia	23.7	1 410	0.86
Myanmar	15.5	1 280	1.30
Nepal	0.1	1 030	0.001
Pakistan	27.0	990	0.67
Papua New Guinea	0.7	1 430	0.07
Philippines	6.3	1 380	0.21
Republic of Korea	16.2	900	0.42
Sri Lanka	5.9	1 570	0.36
Thailand	76.8	1 500	3.58
Viet Nam	28.0	1 300	1.36
Total	**1 047.7**		**50.01**

Irrigation and water management

IRRIGATION POTENTIAL

Methods used by countries to estimate their irrigation potential vary, with significant influence on the results. In computing water available for irrigation, some countries only consider renewable water resources, while others, especially arid countries, include the availability of fossil or non-conventional sources of water. For this reason, comparison between countries should be made with caution. In the case of transboundary rivers, calculation by individual countries of their irrigation potential in the same river basin may lead to double counting of part of the shared water resources. It is therefore not possible to systematically add up country figures to obtain regional estimates of irrigation potential.

The largest irrigation potential is reported by India, 139.5 million ha, followed by China with 70 million ha and Pakistan with 21 million ha (Table 35). While the irrigation potential in Cambodia has never been estimated in terms of physical area, which could be irrigated considering water and land resources, it could be at least 1 million ha. For those countries without data – Bhutan, Brunei Darussalam, Democratic People's Republic of Korea and Timor-Leste – the irrigation potential is estimated as the total area equipped for irrigation, in order to be able to calculate a regional average. The irrigation potential of Southern and Eastern Asia is estimated at, at least, 292.5 million ha, of which 72 percent corresponds to India (48 percent) and China (24 percent). The countries in South Asia (including India) account for 58 percent of the total irrigation potential of Southern and Eastern Asia, followed by East Asia (including China) with 25 percent and Mainland Southeast Asia with 12 percent, whereas Maritime Southeast Asia represent barely 5 percent. It is currently estimated that the total water managed area represents 64 percent of the irrigation potential in the region, ranging from 89 percent in East Asia, and 84 percent in Maritime Southeast Asia to 56 percent in South Asia and 43 percent in Mainland Southeast Asia.

TYPOLOGY OF IRRIGATION AND WATER MANAGEMENT

In most countries of the region irrigation has a long history that is closely linked to the history of rice cultivation. Asia, in general, and the region covered by this survey in particular, represent the bulk of irrigation in the world. The region itself accounts for about 60 percent of the world's irrigation (Table 39). High population density combined with the tradition of irrigated rice cultivation in all the tropical parts of the region are the main factors explaining the importance of irrigation in Asia.

In many countries of the region, irrigation is viewed as an important input to the agricultural production systems. While irrigation development dates back several centuries, the twentieth century, and particularly its second half, saw a rapid increase in what could be called modern irrigation development and a majority of the countries achieved self-sufficiency in cereal crops, mostly rice.

The total area where water other than direct rainfall is used for agricultural production has been named 'area under water management'. The term 'irrigation' refers to areas equipped to supply water to crops. Table 34 and Table 35 present the distribution by country of these areas under water management, making a distinction between areas under irrigation, which is the sum of full control irrigation areas, spate irrigation areas, and equipped lowlands (wetlands, inland valley bottoms and flood recession areas) and areas under other forms of water management, which are non-equipped lowlands (wetlands, inland valley bottoms and flood recession cropping areas). The distinction between irrigation and water management is sometimes difficult. In particular, the demarcation between equipped and non-equipped lowland areas is often vague.

The assessment of land under irrigation in the countries of the region is made particularly difficult by the different approaches used in the countries to compute irrigation. For some countries (for example Bangladesh, Bhutan) paddy fields, cultivated mainly during the wet season, are not considered as irrigated land. For other countries where paddy rice cultivation is practiced, all paddy fields are considered irrigated land. In most cases, schemes are designed primarily to secure rice cultivation in the main cropping season, although the need for intensification has progressively led some countries to design new irrigated schemes for year-round irrigation, for example Thailand, while Viet Nam has three rice crops a year.

The total area equipped for irrigation covers more than 181 million ha in the Southern and Eastern Asia region, but the geographical distribution is very uneven, both from subregion to subregion and from country to country (Table 13, Table 34, Table 35, Figure 12 and Figure 13). About 83 percent of the area equipped for irrigation is concentrated in India (37 percent), China (35 percent) and Pakistan (11 percent). The Maritime Southeast Asia subregion countries account for 5 percent of the area equipped for irrigation, which is a low value taking into account that their total area is 15 percent of the region. Within this sub-region, Indonesia has the largest area equipped for irrigation, accounting for 4 percent of the total area of the Southern and Eastern Asia region, followed by the Philippines, which represents 1 percent. Within the Mainland Southeast Asia subregion, Thailand has the largest area equipped for irrigation, accounting for 4 percent of the total area of the region, followed by Viet Nam, which represents 3 percent (Table 34).

In this survey, figures on spate irrigation have only been provided for Mongolia and Pakistan, amounting to 27 000 ha and 720 000 ha respectively (Table 14 and Table 34). It should be noted that during the previous survey the figure reported for spate irrigation in Pakistan was double the figure reported this time. It is not clear whether the previous figure was wrong or whether, maybe, a large part of the area that was previously reported under spate irrigation, has in the mean time become full control irrigation. Equipped lowlands are frequent in countries with more renewable freshwater resources, such as Malaysia and Myanmar, amounting to 21 970 ha and 27 000 ha respectively.

Full control irrigation, which covers 180 million ha, is by far the most widespread form of irrigation in the Southern and Eastern Asia region. It accounts for 99.6 percent of the area equipped for irrigation.

TABLE 13
Regional distribution of areas under water management

Subregion	Area equipped for irrigation	Non-equipped cultivated lowlands	Non equipped flood recession	Total area under water management	
	ha	ha	ha	ha	% of region
East Asia	65 362 926	-	-	65 362 926	35
South Asia	93 139 770	1 545 000	1 250 000	95 934 770	51
Mainland Southeast Asia	13 773 866	-	599 188	14 373 054	8
Maritime Southeast Asia	8 999 719	3 172 795	63 814	12 236 328	6
Total region	**181 276 281**	**4 717 795**	**1 913 002**	**187 907 078**	**100**

TABLE 14
Regional distribution of areas equipped for irrigation

Subregion	Equipped for full control irrigation	Spate irrigation	Equipped lowlands	Total area equipped for irrigation		
				Area	% of region	% of cultivated area
	(ha)	(ha)	(ha)	(ha)	(%)	(%)
East Asia	65 335 926	27 000	-	65 362 926	36	48
South Asia	92 419 770	720 000	-	93 139 770	51	46
Mainland Southeast Asia	13 746 866	-	27 000	13 773 866	8	31
Maritime Southeast Asia	8 977 749	-	21 970	8 999 719	5	16
Total region	**180 480 311**	**747 000**	**48 970**	**181 276 281**	**100**	**41**
% of area equipped	**99.56**	**0.41**	**0.03**	**100**		

Irrigation is practiced on 41 percent of the total cultivated area of the region compared to 18 percent globally (Table 14, Table 39 and Figure 14). This is the highest level compared to the other major regions of the world. In the East Asia and South Asia subregions it is 48 percent and 46 percent of the cultivated area under irrigation respectively, while in Mainland Southeast Asia and Maritime Southeast Asia the area equipped for irrigation accounts only for 31 and 16 percent (Table 14). At county level, Pakistan has the highest level, with 94 percent of cultivated land under irrigation, followed by Bangladesh with 58 percent and Democratic People's Republic of Korea with 56 percent. Nepal, Republic of Korea, China and Viet Nam have more than 45 percent of cultivated land under irrigation. On the other hand, Malaysia, Cambodia and Mongolia have less than 10 percent of the cultivated area under irrigation (Table 34).

While most wet season rice irrigation is fully gravity irrigation (cascades from plot-to-plot), dry season cropping may require pumping in places. This is the case in Lao People's Democratic Republic where, owing to the pumping costs, dry season rice cropping has not proved economic unless a very bad harvest has been recorded in the previous wet season. In the tropical zone, wet season irrigation is almost only paddy rice. It is usually considered as supplementary irrigation to an already abundant precipitation. During the dry season, a much larger diversity of crops are grown on irrigated fields. In Cambodia, Indonesia, Malaysia and Mongolia, a kind of flood control irrigation is practiced with flood water being used to inundate paddy fields that are then cultivated with rice.

FULL CONTROL IRRIGATION TECHNIQUES

Table 15 presents the subregional distribution of irrigation techniques used on areas under full control irrigation. Data are available for all countries, except Nepal and Timor-Leste. For the purpose of the analysis in Table 15, it was assumed that 100 percent of the area in these two countries used the surface irrigation technique. For India and the Republic of Korea, which have earlier data by technique than for the total full control irrigation area, the percentages for each of the techniques were retained and applied to the areas currently under full control. Therefore, these values are in order of magnitude only and are not an exact reflection of the real situation. However, it seemed worth attempting to complete the data based on the field knowledge of the AQUASTAT team in order to form a more precise picture of the irrigation techniques used in the Southern and Eastern Asia region. Table 36, however, provides the exact data available by country and the year to which they refer, which means that the sum of the different techniques is not equal to the total area equipped for full control irrigation. As shown in Table 15, surface irrigation, accounting for 96.8 percent of the irrigation techniques, greatly exceeds pressurizedirrigation techniques, which are sprinkler irrigation (2.4 percent) and localized irrigation (0.8 percent). Surface irrigation includes all paddy rice cultivation and most of the other crops.

TABLE 15
Regional distribution of full control irrigation techniques

Subregion	Surface irrigation		Sprinkler irrigation		Localized irrigation		Total
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
East Asia	61 692 089	94.4	2 884 352	4.4	759 485	1.2	65 335 926
South Asia	90 320 698	97.7	1 499 422	1.6	599 650	0.6	92 419 770
Mainland SE Asia*	13 745 766	100.0	1 100	0.0	0	0.0	13 746 866
Maritime SE Asia*	8 962 212	99.8	4 500	0.1	11 037	0.1	8 977 749
Total region	**174 720 765**	**96.8**	**4 389 374**	**2.4**	**1 370 172**	**0.8**	**180 480 311**

* SE Asia = Southeast Asia

In most countries, sprinkler or localized irrigation systems are reported to exist only on very small, experimental plots.

In Mainland and Maritime Southeast Asia pressurized irrigation represents less than 0.01 percent and 0.2 percent of the full control irrigation area respectively. In South Asia sprinkler irrigation accounts for 1.6 percent and localized irrigation for 0.6 percent while in East Asia sprinkler irrigation represents 4.4 percent and localized irrigation 1.2 percent. Mongolia is the only country where sprinkler irrigation represents a significant part (75.7 percent) of the area under irrigation as large schemes were systematically equipped with sprinkler irrigation in the 1980s. Besides Mongolia, there is information on pressurized irrigation techniques only for five other countries. In China, sprinkler irrigation and localized irrigation represents 4.5 percent and 1.2 percent respectively of total full control irrigation, while in India they account for 2.3 percent and 0.9 percent respectively. In the Philippines, localized irrigation represents 0.6 percent and sprinkler irrigation 0.2 percent of the irrigation techniques. In Malaysia, 0.03 percent corresponded to localized irrigation in 1994. In Viet Nam, sprinkler irrigation accounts for only 0.02 percent of the area under full control irrigation (Table 36).

ORIGIN OF WATER IN FULL CONTROL IRRIGATION

Table 16 presents available data concerning the origin of irrigation water in the areas under full control irrigation: Primary and secondary surface water, groundwater, and mix of surface water and groundwater. While certainly several countries, especially in the case of rice growing, will directly use agricultural drainage water by irrigating from one plot to the next lower lying plot (cascade), no information on this was available. For the purpose of the analysis in Table 16, it was assumed that for those countries with earlier data on origin of water compared to full control irrigation data, which are Cambodia, Democratic People's Republic of Korea, India, Republic of Korea and Sri Lanka, the percentages for each of the sources were retained and applied to the areas currently under full control. Therefore, these values are in order of magnitude only and are not an exact reflection of the real situation. However, it seemed worth attempting to complete the data based on the field knowledge of the AQUASTAT team in order to form a more precise picture of the sources of water used for irrigation in the Southern and Eastern Asia region. In Table 37, however, the exact information as available is given for all countries, which means that the sum of the different sources is not equal to the total area equipped for full control irrigation.

Regarding 'other sources of water', Pakistan accounts for the highest percentage with 41 percent of mixed surface water and groundwater (Table 37). In the Philippines, 16 percent of the area for irrigation uses a mix of surface water and groundwater, while in Nepal, this area accounts for 1 percent. No information is available in the other countries on other sources of water. Surface water is the major source of irrigation water in the Southern and Eastern Asia region as a whole (56 percent on average), since countries such as China, Indonesia, Thailand and Viet

TABLE 16
Regional distribution of the origin of water used in full control irrigation (primary and secondary water)

Subregion	Surface water		Groundwater		Other sources		Total
	Area	% of total	Area	% of total	Mix of surface water and groundwater		Area
	(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
East Asia	45 680 527	69.9	19 655 399	30.1	0	0.0	65 335 926
South Asia	33 851 116	36.7	50 593 454	54.7	7 975 200	8.6	92 419 770
Mainland SE Asia*	13 017 011	94.7	729 855	5.3	0	0.0	13 746 866
Maritime SE Asia*	8 481 204	94.5	201 905	2.2	294 640	3.3	8 977 749
Total region	**101 029 858**	**60.0**	**71 180 613**	**39.4**	**8 269 840**	**4.6**	**180 480 311**

* SE Asia = Southeast Asia

Nam, which have large areas under irrigation, irrigate mainly with surface water (69, 99, 91 and 99 percent respectively). In Bangladesh, India and Mongolia groundwater represents 79, 64 and 63 percent respectively. Looking at the subregions, in Mainland and Maritime Southeast Asia, surface water accounts on average for 95 percent of the area equipped for irrigation. In the East Asia subregion, surface water accounts for 70 percent of the area equipped for irrigation and groundwater for 30 percent, while in South Asia groundwater accounts for 55 percent, surface water for 36 percent, mixed surface water and groundwater for 9 percent and non conventional sources of water for 0.3 percent (Table 16).

Information on power irrigated area is available only for 12 countries out of 22 of the region. The percentage of power irrigated area over equipped area for irrigation is important in Bangladesh, India, China and Viet Nam with 97, 83, 57 and 47 percent respectively. In Sri Lanka, Republic of Korea, Lao People's Democratic Republic and Philippines it accounts for 30, 20, 15 and 14 percent respectively, while in Malaysia, Thailand, Myanmar and Bhutan the corresponding figures are only 10, 7, 4 and 3 percent respectively.

SCHEME SIZES

The definition of large schemes varies from one country to another. While certain countries, such as Bhutan, Cambodia and Sri Lanka, consider a large scheme to be 100, 400 and 500 ha respectively, other countries, such as India, China and Pakistan classify a large scheme as a minimum of 10 000, 20 000 and 25 000 ha respectively. Viet Nam even considers large schemes to be those over 50 000 ha.

A scheme is often described by its type of management, rather than by its size. In China, the very large, large and medium irrigation schemes are generally administrated by special governmental organizations. The small ones are usually farmer managed. In India, sources for minor irrigation projects generally have both surface water and groundwater, while major and medium projects exploit surface water resources. In Bangladesh, large-scale schemes are represented by major irrigation. In Malaysia there are three types of irrigation schemes: granary schemes, mini-granary schemes and non-granary schemes. The non-granary schemes are scattered throughout the country and their size varies between 50 and 200 ha.

Table 17 shows the scheme sizes in several countries and the criteria used. If no recent information on scheme sizes is available, the information from the previous survey is used, as for Brunei Darussalam, Cambodia, India, Malaysia and Republic of Korea.

TABLE 17
Scheme sizes in some countries (ha)

Country	Year	Criteria	Small	Medium	Large	Total area
Bangladesh	2008	-	4 910 982	-	138 803	5 049 785
Bhutan	1995	100	25 400	-	1 620	27 020
Brunei Darussalam	1995	0.9	1 000	-	-	1 000
Cambodia	1993	100 - 500	17 090	77 820	181 500	276 410
China	2006	667 - 20 000	35 553 278	12 684 402	14 700 546	62 938 226
India	1993	2 000 -10 000	33 017 000	17 084 000		50 101 000
Malaysia	1994	*	100 658	29 507	210 552	340 717
Pakistan	2008	100 - 25 000	4 130 000	440 000	14 700 000	19 270 000
Philippines	2006	100 - 1 000	625 360	548 978	704 746	1 879 084
Republic of Korea	1996	50 - 3 000	362 230	369 630	156 930	888 790
Sri Lanka	2006	80 - 400	200 000	61 000	309 000	570 000
Thailand	2007	**	2 848 240	898 880	2 667 680	6 414 800
Viet Nam	2005	5 000 - 50 000	1 638 297	1 202 390	1 744 813	4 585 500

* Non-granary schemes / mini granary schemes / granary schemes
** < 1 year construction / > 1 year construction and < 12 800 ha / > 12 800 ha

Cultivation in full control schemes

LEVEL OF USE OF AREAS EQUIPPED FOR FULL CONTROL IRRIGATION

It is difficult to calculate the areas actually irrigated in the Southern and Eastern Asia region because information is missing for many countries in both AQUASTAT surveys. Where a country did not have new data, the percentages of the previous survey are used. Given that data about actually irrigated areas are available for only 13 out of the 22 countries, Table 18 only shows these countries.

In Bangladesh, Bhutan, Myanmar, Pakistan and Viet Nam the total area equipped for full control irrigation is said to be actually irrigated. Cambodia and India have a rate exceeding 90 percent and Thailand, Timor-Leste, Sri Lanka, China and Lao People's Democratic Republic have a rate ranging from 79 to 87 percent. Mongolia has a lower use rate accounting for 61 percent. In numerous cases, low rates are explained by deterioration of the infrastructure because of a lack of maintenance (caused by insufficient experience or the use of unadapted techniques) or political and economic reasons. Other causes are: inadequate management of technical means of production under irrigation, soil impoverishment, local instability and insecurity, and the reduction of public funds allocated to irrigation.

CROPPING INTENSITY

Cropping intensity, another indicator of the use of equipped areas, is calculated based on the area actually irrigated in full control irrigation for the eleven countries for which actually irrigated area and harvested irrigated crops area is available. For another seven countries, actually irrigated area is estimated to be equal to the area equipped for full control irrigation. Thus cropping intensity is probably underestimated because the area actually irrigated might be smaller than equipped area in several of these seven countries. In two countries (the Maldives and Papua New Guinea), no irrigation is said to be practiced, while for the remaining two countries (Mongolia and Timor-Leste) no information on harvested irrigated crop area was available. The calculation only refers to irrigated crops. This means that in a country with one or two wet seasons only the crops grown under irrigation are considered. The crops grown on the full control equipped area during the wet season without irrigation (but using the residual soil humidity) are not included in the irrigated crop area when calculating cropping intensity.

Cropping intensity by subregion ranges from 121 percent in South Asia to 159 percent in Mainland Southeast Asia, 169 percent in East Asia and 184 in Maritime Southeast Asia (Table 19).

TABLE 18
Distribution of actually irrigated areas in some countries

Country	Area equipped for full control irrigation	Actually irrigated	
		Area	% of equipped areas
	(ha)	(ha)	(%)
Bangladesh	5 049 785	5 049 785	100
Bhutan	27 685	27 685	100
Cambodia	353 566	317 225	90
China	62 938 226	54 218 976	86
India	66 334 000	61 286 000	94
Lao PDR*	310 000	270 742	87
Mongolia	57 300	35 000	61
Myanmar	2 083 000	2 083 000	100
Pakistan	19 270 000	19 270 000	100
Sri Lanka	570 000	462 500	81
Thailand	6 414 800	5 059 914	79
Timor-Leste	34 649	28 907	83
Viet Nam	4 585 500	4 585 500	100

*Lao PDR = Lao People's Democratic Republic

National cropping intensity ranges from 103 percent in Bhutan to 199 percent in Indonesia (Table 38). Cropping intensity for the Democratic People's Republic of Korea and Malaysia has not been included in Table 38 because data on harvested irrigated area is from 2006 while actually irrigated area refers to 1995 and 1994 respectively, though it is included in Table 19.

Table 20 shows the cropping intensity for those eleven countries where the area actually irrigated is available and, therefore, it is easier to evaluate the real situation. As shown, figures range from 103 percent in Bhutan, meaning that approximately one crop per year is irrigated, to 190 percent in Viet Nam, meaning that almost two crops per year are irrigated on the same area.

The calculation of cropping intensity is straightforward for dry countries because irrigation is indispensable for the growing of crops in all seasons. However, the calculation is more problematic for countries with one or more wet seasons. In this case, for two crop cycles a year, only one is irrigated (during the dry season), the second uses soil moisture provided by precipitation. Therefore, the cropping intensity (irrigated crops only) is 100 percent on the area considered, while the harvested area is double.

IRRIGATED CROPS IN FULL CONTROL SCHEMES

Table 38 shows the national distribution of harvested irrigated crops for those countries that have provided such information. In many countries' statistics no distinction is made between crops that are irrigated and rainfed crops, though in this survey efforts have been made to provide the most accurate data on irrigated crops. Table 21 provides data of the distribution of irrigated crops by subregion.

Cereals represent 70 percent of all harvested irrigated crop areas in the region. Rice alone represents about 39 percent of all harvested irrigated crop areas in the region. However, its regional distribution shows major trends: in the Mainland and Maritime Southeast Asia subregions, rice represents more than 80 percent of harvested irrigated crops, while in the East Asia and South Asia subregions rice represent 34 and 29 percent respectively. Wheat is the second most widespread harvested irrigated crop in the region, accounting for 23 percent on average, mainly cultivated in the South and East Asia subregions where wheat represents 30 and 23 percent of the total harvested irrigated cropped area respectively. Maize represents 6 percent, with special importance in East Asia (10 percent) and Maritime Southeast Asia (8 percent). The group of vegetables, roots and tubers accounts for 5 percent of the total irrigated cropped area of the region, of which 8 percent are potatoes and sweet potatoes. This group of vegetables, roots and tubers represents 10 percent of the total area in the East Asia subregion. In the South Asia

TABLE 19
Cropping intensity over area actually irrigated

Subregion	Area equipped for full control irrigation	Area actually irrigated in full control irrigation	In % of area equipped	Harvested irrigated crop areas	Cropping intensity
	(ha)	(ha)	(%)	(ha)	(%)
	(1)	(2)	(3) = 100 × (2)/(1)	(4)	= 100 × (4)/(2)
East Asia	65 335 926	56 594 376	87	95 761 000	169
South Asia	92 419 770	88 264 270	96	106 946 384	121
Mainland SE Asia*	13 746 866	12 316 381	90	19 593 471	159
Maritime SE Asia*	8 977 749	8 972 007	100	16 467 193	184
Total region	**180 480 311**	**166 083 127**	**92**	**238 768 048**	**144**

* SE Asia = Southeast Asia

TABLE 20
Cropping intensity over area actually irrigated in some countries

Country	Area equipped for full control irrigation	Area actually irrigated in full control irrigation	Harvested irrigated crop areas	Cropping intensity
	(ha)	(ha)	(ha)	(%)
	(1)	(2)	(3)	= 100 × (3)/(2)
Bangladesh	5 049 785	5 049 785	5 976 810	118
Bhutan	27 685	27 685	27 900	103
Cambodia	353 566	317 225	384 531	121
China	62 938 226	54 218 976	93 382 000	172
India	66 334 000	61 286 000	76 820 000	130
Lao PDR*	310 000	270 742	371 676	137
Myanmar	2 083 000	2 083 000	2 722 000	131
Pakistan	19 270 000	19 270 000	21 451 674	111
Sri Lanka	570 000	462 500	744 000	161
Thailand	6 414 800	5 059 914	7 387 072	146
Viet Nam	4 585 500	4 585 500	8 728 192	190

*Lao PDR = Lao People's Democratic Republic

subregion, cotton, sugarcane and pulses account for 5, 5 and 4 percent respectively of the harvested irrigated crops area. Other important crops in the region are soybeans, groundnuts, citrus and tobacco. Permanents crops account for approximately 8 percent.

As shown in Table 38, rice is the main crop in most countries in the region, in many countries representing more than 90 percent of the total harvested irrigated area. By contrast, Pakistan, India, China, Democratic People's Republic of Korea and Nepal have a much more balanced distribution of irrigated crops with rice representing only about one-third or less of the total harvested irrigated crop area. This reflects the cold or arid context of large parts of these countries. In Pakistan, rice represents only 12 percent of the total harvested irrigated crop area, whereas wheat represents 34 percent and fodder 12 percent.

In India, the percentage of harvested area under irrigated wheat is slightly higher than that under irrigated rice (31 percent against 29 percent), the rest being shared between a large variety of crops. In China, rice is the single most important harvested irrigated crop accounting for 34 percent of the total harvested irrigated crop area, followed by wheat with 24 percent, maize with 10 percent and vegetables (including roots and tubers) with 10 percent. However, as reported in the previous survey, done in 1999, in India only 47 percent of the total harvested area for paddy rice was irrigated, while more that 92 percent of the harvested paddy rice in China was irrigated. In Nepal, the percentage of harvested area under irrigated rice is slightly higher than that under irrigated wheat (37 percent against 34 percent).

TABLE 21
Regional distribution of harvested irrigated crop areas under full control irrigation

Sub-region	Wheat	Maize	Rice	Cereals not specified	Vegetables, roots and tubers	Pulses	Soya-beans	Ground-nuts	Sugar-cane	Cotton	Annual crops not specified	Permanent crops not specified	Total
						(1 000 ha)							
East Asia	22 323.00	9 826.00	32 572.00	820.00	10 047.00	86.00	2 741.00	1 900.00	472.00	2 632.00	7 415.00	4 927.00	95 761.00
	(23%)	(10%)	(34%)	(1%)	(10%)	(0%)	(3%)	(2%)	(0%)	(3%)	(8%)	(5%)	(100%)
South Asia	31 774.60	2 863.23	30 721.70	2 811.20	1 059.07	4 489.24	0.00	1 061.01	5 383.70	5 651.80	14 846.46	6 284.37	106 946.38
	(30%)	(3%)	(29%)	(3%)	(1%)	(4%)	(0%)	(1%)	(5%)	(5%)	(14%)	(6%)	(100%)
Mainland SE Asia*	89.000	299.54	15 655.21	0.00	273.95	284.00	97.12	139.30	455.77	107.79	417.48	1 774.30	19 593.47
	(0%)	(2%)	(80%)	(0%)	(1%)	(1%)	(0%)	(1%)	(2%)	(1%)	(2%)	(9%)	(100%)
Maritime SE Asia*	0.00	1 365.70	13 518.88	0.00	531.97	0.00	279.90	337.40	172.45	0.00	222.08	38.18	16 466.56
	(0%)	(8%)	(82%)	(0%)	(3%)	(0%)	(2%)	(2%)	(1%)	(0%)	(1%)	(0%)	(100%)
Total region**	**54 186.60**	**14 354.47**	**92 467.79**	**3 631.20**	**11 912.00**	**4 859.24**	**3 118.02**	**3 437.72**	**6 483.92**	**8 391.59**	**22 901.02**	**13 023.85**	**238 767.41**
	(23%)	**(6%)**	**(39%)**	**(2%)**	**(5%)**	**(2%)**	**(1%)**	**(1%)**	**(3%)**	**(4%)**	**(10%)**	**(5%)**	**(100%)**

* SE Asia = Southeast Asia
** There is no irrigation in Maldives (South Asia) and Papua New Guinea (Maritime Southeast Asia), and no data are available for Mongolia (East Asia) and Timor-Leste (Maritime Southeast Asia). These countries are not included in the table

Trends in the last ten years

Ten years ago the population of the Southern and Eastern Asia region was 3 225 million, or 53 percent of the world's population (1999). Currently it is 3 605 million, still 53 percent of the world's population (2009). Population density has risen from 154 to 173 inhabitants/km^2. The annual rate of population growth over the last ten years is 1.1 percent, a decrease from the 1.6 percent/year for 1989–1999. While ten years ago about 67 percent of the population in the Southern and Eastern Asia region lived in a rural environment, currently it is 61 percent (Table 2 and Table 30). This indicates that there is, even though slow, migration towards cities.

WATER WITHDRAWAL BY SECTOR

On a sectoral basis, the proportions of water withdrawal have changed only slightly: agricultural water withdrawal has increased from 81 percent to 82 percent and municipal withdrawal from 7 percent to 9 percent while industrial withdrawal has decreased from 12 percent to 9 percent. However, total water withdrawal has grown by 4 percent over the last ten years (Table 22).

Between the two survey dates, annual withdrawal per inhabitant has decreased (by 25 m^3). This is because of an increase in total population in the region and a decrease in total water withdrawal in the East Asia and Mainland Southeast Asia subregions from 658 km^3 to 589 km^3 and from 199 km^3 to 179 km^3 respectively. Maritime Southeast Asia is the only subregion in which annual water withdrawal per inhabitant has increased, from 385 m^3 to 634 m^3.

Looking at the municipal sector, water withdrawal per capita has increased from 40 m^3/year, or 110 litres/day, to 50 m^3/year, or 137 litres/day. There is quite some variation between the subregions and between countries. In the East Asia subregion it has increased from 37 to 54 m^3/year, in South Asia from 43 to 44 m^3/ha, while in the maritime Southeast Asia subregion there

TABLE 22
Regional trends in water withdrawal by sector

Subregion	Year	Annual water withdrawal by sector								
		Agriculture		Municipal		Industry		Total		
		km^3	% of total	km^3	% of total	km^3	% of total	km^3	% of Southeast Asia	m^3 per inhabitant
East Asia	1999	441	67	50	8	167	25	658	35	489
	2009	381	65	75	13	133	23	589	30	417
South Asia	1999	820	89	59	6	40	4	918	48	667
	2009	913	91	70	7	20	2	1 003	51	640
Mainland Southeast Asia	1999	171	86	8	4	20	10	199	10	966
	2009	165	92	7	4	6	4	179	9	832
Maritime Southeast Asia	1999	102	85	13	11	5	4	120	6	385
	2009	165	79	24	11	21	10	210	11	619
Total region	**1999**	**1 534**	**81**	**130**	**7**	**232**	**12**	**1 895**	**100**	**585**
	2009	**1 624**	**82**	**176**	**9**	**180**	**9**	**1 981**	**100**	**561**

has been a large increase from 41 to 71 m^3/year. However, in the Mainland Southeast Asia subregion it has decreased from 40 to 34 m^3/year.

In agriculture, the annual water withdrawal per hectare of area equipped for irrigation seems to have decreased from 10 700 m^3 to 9 000 m^3. The reason for this is not fully clear. It could be a result of computation methods, data quality, changed cropping pattern or an improvement in irrigation techniques. In the East Asia subregion it has decreased from 8 000 m^3 to 5 800 m^3, in the South Asia subregion from 11 500 m^3 to 9 800 m^3 and in the Mainland Southeast Asia sub-region from 17 100 m^3 to 12 000 m^3. However, in the Maritime Southeast Asia subregion it has increased from 16 100 m^3 to 18 400 m^3. These data should be used with caution since, as mentioned above, the reason for these changes are not fully clear. It may be that different methods have been used to calculate agricultural withdrawal and irrigation areas.

WATER WITHDRAWAL BY SOURCE

For the Southern and Eastern Asia region as a whole, annual freshwater withdrawal has increased from 1 895.408 km^3 to 1 980.793 km^3, which represents an annual rate of increase of 0.4 percent (Table 23). Desalinated water has increased from 0.024 km^3 to 0.036 km^3, equal to an annual increase of 4.1 percent. Thus, freshwater remains by far the most important source, accounting for 99.998 percent of the total while in the previous survey it accounted for 99.999 percent of the total.

The countries with data on desalinated water, reported figures that are practically the same as for the previous survey. There is no new information for India, Indonesia and Malaysia so the same value is presented as for 1999. Maldives has increased from 0.37 million m^3 to 1.225 million m^3. China and the Republic of Korea report using desalinated water, 11 million m^3 and 0.16 million m^3 respectively, while in 1999 no data were available. Figures on direct use of treated wastewater and agricultural drainage water are available for only three countries. China reported 13 390 million m^3 of direct use of treated wastewater in the previous survey, though no new information was given for the present survey and Viet Nam reports 175 million m^3 in the present survey. Direct use of agricultural drainage water is reported by India accounting for 113.47 km^3 in 2007. This does not mean that it was equal to zero in the previous survey, just

TABLE 23
Regional trends in water withdrawal by source

Subregion		Annual withdrawal by source				
		Total freshwater*		Desalinated water		Total water withdrawal
		million m^3	% of total	million m^3	% of total	million m^3
East Asia	1999	658 340	100.000	0	0.000	658 340
	2009	588 728	99.998	11	0.002	588 739
South Asia	1999	917 848	100.000	1	0.000	917 849
	2009	1 003 370	100.000	2	0.000	1 003 372
Mainland Southeast Asia	1999	198 760	100.000	0	0.000	198 760
	2009	179 007	100.000	0	0.000	179 007
Maritime Southeast Asia	1999	120 460	99.981	23	0.019	120 483
	2009	209 688	99.989	23	0.011	209 711
Total region	**1999**	**1 895 408**	**99.999**	**24**	**0.001**	**1 895 432**
	2009	**1 980 793**	**99.998**	**36**	**0.002**	**1 980 829**

* Refers to primary and secondary freshwater, as well as direct use of treated wastewater and agricultural drainage water

that no data were available at that time. In Table 23 the data on direct use are included in the freshwater data.

AREAS UNDER IRRIGATION

Table 24 presents the trends in the area under irrigation during the last ten years. It should be taken into account that the information for some of the countries is for earlier years as new data were not provided (Table 34).

For the Southern and Eastern Asia region, the increase in the equipped area is 27 percent, which is equal to an annual rate of 1.88 percent using a weighted year index. This is calculated by allocating a weighting coefficient to the year for each country that is proportional to its area equipped for irrigation, therefore giving more importance to countries with the largest areas under irrigation.

The area under full control irrigation has an annual rate of increase of 1.93 percent, which is a little higher than the annual rate for total irrigation. This is explained by the fact that the area of spate irrigation has not increased as much as the area of full control irrigation (in fact, as mentioned earlier the figure for spate irrigation in Pakistan, reported during the present survey, is half of the area reported ten years ago) and because equipped lowlands area have not increased since 1999.

The Maritime Southeast Asia subregion has a relatively high annual rate of increase of 3.7 percent (Table 24). However, this could also be explained by the reclassification of areas previously indicated as non-equipped water managed areas (see glossary for definitions and Table 13), which have been counted as equipped areas this time because of better knowledge of the field situation. Indonesia has the largest annual increase in equipped areas in this subregion, which accounts for 4.3 percent. Malaysia and the Philippines have shown annual rates of increase of 1.5 percent (Table 34).

TABLE 24
Regional trends in the areas under irrigation

Subregion		Irrigation (ha)				
		Full control irrigation	Spate irrigation *	Equipped lowlands	Total irrigation	Annual increase**
		(1)	(2)	(3)	(4) = (1) + (2) + (3)	%
East Asia	1999	55 349 295	27 000	-	55 376 295	1.7
	2009	65 335 926	27 000	-	65 362 926	
South Asia *	1999	70 000 381	1 402 000	-	71 402 381	1.7
	2009	92 419 770	720 000	-	93 139 770	
Mainland Southeast Asia	1999	9 983 995	-	27 000	10 010 995	2.9
	2009	13 746 866	-	27 000	13 773 866	
Maritime Southeast Asia	1999	6 333 639	-	21 970	6 355 609	3.7
	2009	8 977 749	-	21 970	8 999 719	
Total region	**1999**	**141 667 310**	**1 429 000**	**48 970**	**143 145 280**	**1.9**
	2009	**180 480 311**	**747 000**	**48 970**	**181 276 281**	
Change		**+ 38 813 001**	**- 682 000**	**0**	**+ 38 131 001**	

* The total area under irrigation in Pakistan in the South Asia subregion increased, but the area under spate irrigation seemed to be less than reported in the previous survey, which explains the negative value. It is not clear whether the previously reported figure is wrong or whether a large area has been transformed from spate irrigation to full control irrigation.

** Annual increase was calculated using a weighted year index.The weighted year index is calculated by allocating to the year for each country a weighting coefficient proportional to its area equipped for irrigation, therefore giving more importance to countries with the largest areas under irrigation.

The Mainland Southeast Asia subregion has an annual rate of increase of 2.9 percent. The annual rate for Cambodia is 4.5 percent, the largest increase in equipped areas in the Southern and Eastern Asia region. Other countries in the Mainland Southeast Asia subregion, such as Viet Nam and Myanmar, have shown annual rates of increase of 3.9 and 3.5 percent respectively, while the annual increase in Thailand is 2.1 percent and in Lao People's Democratic Republic 1.0 percent.

In the South and East Asia subregions the annual rate of increase is 1.7 percent. Nepal and Bangladesh have an annual rate of increase of 2.9 percent and 2.1 percent respectively. The Republic of Korea has shown a drop in areas equipped for irrigation, at an annual rate of -0.9 percent.

IRRIGATION TECHNIQUES

Table 25 presents the trends in irrigation techniques. For Nepal and Timor-Leste there is no information on irrigation techniques, thus, to facilitate the comparison between 1999 and 2009, we have estimated all the full control area under surface irrigation in both years.

The area under surface irrigation, the most important technique, has increased by 34.5 million ha (25 percent). However, in all subregions except Mainland Southeast Asia, the relative importance of surface irrigation has decreased. Sprinkler irrigation has increased by 3 million ha, which represents a growth rate of 219 percent for this technique. While its relative importance is lower in the Mainland and Maritime Southeast Asia subregions, it has grown especially in East Asia followed by South Asia. Localized irrigation, which is the technique that requires less water, has increased in area by 1.3 million ha, representing a growth rate of 1 827 percent since the previous survey ten years ago. It is developing most in the East and South Asia subregions, where the percentage, compared with the other techniques, has increased from 0 to 1.2 percent and from 0.1 to 0.6 percent respectively. In Maritime Southeast Asia localized irrigation increases in importance only from 0 to 0.1 percent of the total area, while in Mainland Southeast Asia no country has reported the use of this irrigation technique. While growing in importance, the Southern and Eastern Asia region has not yet adopted a large area of sprinkler and localized irrigation. While this maybe explained by its humid weather, or the types of crops (rice), the reasons will have to be studied more in-depth.

ORIGIN OF WATER FOR IRRIGATION

Table 26 presents the trends in the distribution of the origin of water used in full control

TABLE 25

Regional trends in the irrigation techniques in the full control irrigation areas

Subregion		Surface irrigation		Sprinkler irrigation		Localized irrigation		Total
		(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
East Asia	1999	54 671 400	98.8	677 895	1.2	0	0.0	55 349 295
	2009	61 692 089	94.4	2 884 352	4.4	759 485	1.2	65 335 926
South Asia	1999	69 229 381	98.9	700 000	1.0	71 000	0.1	70 000 381
	2009	90 320 698	97.7	1 499 422	1.6	599 650	0.6	92 419 770
Mainland Southeast Asia	1999	9 983 995	100.0	0	0.0	0	0.0	9 983 995
	2009	13 745 766	100.0	1 100	0.01	0	0.0	13 746 866
Maritime Southeast Asia	1999	6 333 522	100.0	0	0.0	117	0.0	6 333 639
	2009	8 962 212	99.8	4 500	0.1	11 037	0.1	8 977 749
Total region	**1999**	**140 218 298**	**99.0**	**1 377 895**	**1.0**	**71 117**	**0.1**	**141 667 310**
	2009	**174 720 765**	**96.8**	**4 389 374**	**2.4**	**1 370 172**	**0.8**	**180 480 311**
Change		**+ 34 502 467**	**+ 25%**	**+ 3 011 479**	**+ 219%**	**+ 1 299 055**	**+1 827%**	**+ 38 813 001**

For China, Timor-Leste and Viet Nam there is no data on the origin of water for irrigation in the previous survey. To facilitate the comparison between 1999 and 2009, we have estimated the same proportion of surface water and groundwater as in the present survey, even though this might not be fully correct.

As shown in Table 26, data on the origin of water used from a mix of surface water and groundwater have been considered in the present survey, while in the previous one only surface water or groundwater were considered. For these reasons the following statistics must be considered with caution. The area irrigated by groundwater has increased from 53 million ha to 71 million ha, which represents a change from 37 percent to 39 percent of the total full control equipped area. In the Mainland Southeast Asia subregion the groundwater proportion has increased from 1 percent to 5 percent, while in the South Asia subregion it has increased from 52 percent to 55 percent. In East Asia, the same proportion of area irrigated by groundwater and surface water is estimated in the previous and present survey. For the whole region, the area irrigated by surface water has increased from 89 million ha to 101 million ha, but its proportion over the entire area under full control irrigation has decreased from 63 to 60 percent. However, another 5 percent of the area has been irrigated by a mix of surface water and groundwater. The area irrigated by groundwater has increased from 53 million ha to 71 million ha, meaning that its proportion in the whole area under full control irrigation has increased from 37 to 39 percent.

IRRIGATED CROPS

There is no irrigation in Maldives and Papua New Guinea and there is no information on harvested irrigated crop area for Mongolia and Timor-Leste, thus they are not included in the totals. Furthermore, in the previous survey there were no data for irrigated crops in Indonesia. To facilitate the comparison between 1999 and 2009, we have estimated the harvested irrigated area by crop proportionally to the increase in full control irrigation area. For these reasons the following statistics must be considered with caution.

The main change in the last ten years has been an increase in rice areas from 68 million ha to 92 million ha and their proportion over the whole area under full control irrigation, from 37 percent to 39 percent. Wheat-growing harvested irrigated areas have increased from 49 million ha to 54 million ha, but their proportion to the whole area under full control

TABLE 26

Regional trends in the origin of water used in full control irrigation

Subregion		Surface water		Groundwater		Other sources		Total
		Area	% of total	Area	% of total	Mix of surface water and groundwater		Area
		(ha)	(%)	(ha)	(%)	(ha)	(%)	(ha)
East Asia	1999	38 771 461	70.0	16 577 834	30.0	-	-	55 349 295
	2009	45 680 527	69.9	19 655 399	30.1	0	0.0	65 335 926
South Asia	1999	33 960 728	48.5	36 039 653	51.5	-	-	70 000 381
	2009	33 851 116	36.7	50 593 454	54.7	7 975 200	8.6	92 419 770
Mainland Southeast Asia	1999	9 886 820	99.0	97 175	1.0	-	-	9 983 985
	2009	13 017 011	94.7	729 855	5.3	0	0.0	13 746 866
Maritime Southeast Asia	1999	6 109 765	96.5	223 874	3.5	-	-	6 333 639
	2009	8 481 204	94.5	201 905	2.2	294 640	3.3	8 977 749
Total region	**1999**	**88 728 774**	**62.6**	**52 938 536**	**37.4**	**-**	**-**	**141 667 310**
	2009	**101 029 858**	**60.0**	**71 180 613**	**39.4**	**8 269 840**	**4.6**	**180 480 311**

irrigation has decreased from 27 to 23 percent. In the previous survey of 1999, however, 4 percent of the total harvested irrigated crop area was under 'other cereals' that could include rice or wheat, while in the present survey only 1 percent is under 'other cereals'. Irrigated cereals as a percentage of total irrigated crops have decreased from 76 percent in 1999 to 69 percent in 2009. The area under vegetables including roots, tubers, potatoes, sweet potatoes and pulses has increased from 7 million ha to 17 million ha and their proportion over the entire area under full control irrigation has increased from 4 percent to 7 percent. The area under permanent crops has also increased from 5 to 8 percent, indicating that a higher percentage of irrigated area is dedicated to these crops. The proportion of other crops has not varied significantly over the whole area under full control irrigation.

USE RATE OF AREAS EQUIPPED FOR IRRIGATION

Amongst the seven countries for which information is available – Bhutan, Cambodia, China, Lao People's Democratic Republic, Myanmar, Thailand and Viet Nam – there has been an improvement in the use rate of equipped areas over the last ten years, in three countries it has decreased, and in three it has remained the same. Areas actually irrigated in Viet Nam, where there has been a large increase in equipped areas, have increased from 70 percent of equipped areas in 1994 to 100 percent in 2005. In China, the area actually irrigated has declined from 88 percent in 1996 to 86 percent in 2006, while equipped areas have notably increased. In Lao People's Democratic Republic, where there has been a large increase in equipped areas, the area actually irrigated has decreased from 89 percent in 1995 to 87 percent in 2005. In Thailand the use rate has fallen from 91 percent to 79 percent between 1988 and 2007, for a large increase in equipped area. In Bhutan, Cambodia and Myanmar the area actually irrigated represented 100, 90 and 100 percent of the equipped areas respectively in both the previous and present surveys.

Legislative and institutional framework of water management

In seven out of the 22 countries of the Southern and Eastern Asia region, for which information is given, water management is based on a water code or on a specific water law or act. A specific Water Law has been enacted in **Indonesia** (2004), **Lao People's Democratic Republic** (1996), **Mongolia** (1995) and **Viet Nam** (1998). **China** and the **Philippines** have a Water Code, signed in 1988 and 1976 respectively. In **Papua New Guinea**, a Water Resources Act was signed in 1982, which is the statutory instrument under which the allocation and management of water resources proceed. In the other countries certain aspects of water management are regulated, but these specific arrangements are not grouped in a water code.

In **Bangladesh**, thus far no policy or act has been formulated related to irrigation or water management, however, in recent years policies such as the National Agriculture Policy, National Water Policy and the National Water Management Plan addressed, to some extent, the minor irrigation and water management issues. **Bhutan** has a Water Policy signed in 2003. In **Cambodia**, laws and policies related to water resources management are many and varied, including the Natural Water Resource Policy (2004) and the Law on Water Resources Management (2007). Agricultural policies of the **Democratic People's Republic of Korea** are directed towards solving the problem of food shortages through the 'four improvements' in agricultural technology: irrigation, farm mechanization, rural electrification, and agricultural chemicals. India adopted a National Water Policy in 1987, which was revised in 2002. In **Malaysia**, although either directly or indirectly much legislation touches on water resources, most of the existing laws are considered outdated. The Water Act of 1920 is inadequate for dealing with the current complex issues related to water abstraction, pollution and river basin management. In the **Maldives**, different water management plans have been presented in the last decades.

In **Myanmar**, even though there is no single law covering all aspects of water resources, the laws deal with the subject in one way or another and many issues still need to be developed. In **Nepal**, an Irrigation Policy and a National Water Plan were signed in 2003 and 2005 respectively. In **Pakistan**, the Draft National Water Policy has been in the process of approval since 2005. The Pakistan Water Strategy was prepared during 2001, which is the basic document for the country's water development and management. In **Sri Lanka**, there are over 50 acts of parliament concerning the water sector and laws are administered by numerous agencies with a wide range of responsibilities, and there are overlaps, gaps and conflicting jurisdictions. In **Thailand**, a draft Water Law has been in the process of approval since 2007. In **Timor-Leste** comprehensive and sophisticated policies are not currently warranted. No information on water legislation is available for **Brunei Darussalam** and the **Republic of Korea**.

For many Southern and Eastern Asia countries, the national institutions responsible for the management and planning of irrigation development are departments or divisions within the Ministry of Agriculture. In **Bangladesh**, minor irrigation schemes are under the jurisdiction of the Ministry of Agriculture and small-scale surface irrigation under the Ministry of Local Government, Rural Development and Cooperatives, while large-scale irrigation schemes are under the Ministry of Water Resources. In **Bhutan**, irrigation management depends on the Irrigation Agency, in **Brunei Darussalam** on the Department of Agriculture of the Ministry of Industry and Primary Resources and in the **Philippines** on the Department of Agriculture of the National Irrigation Administration. In **Nepal** there is a Ministry of Irrigation and in

Thailand, irrigation is managed by the Royal Irrigation Department for public schemes, or by the Department of Water Resources. Some countries, as reported by Bangladesh, Bhutan, China, India, Philippines and Sri Lanka, have different institutions responsible for irrigation at the national, regional and local level.

Overall, the responsibility for water resources management, planning and development is shared by various government agencies and ministries (water resources, environment, natural resources, construction, transport or industry), in some cases there is little coordination between them. In some countries water resources management and development falls mainly under one institution, such as the Ministry of Water Resources in **Bangladesh**, the Ministry of Water Resources in **China**, the Water Resources Coordination Committee in **Lao People's Democratic Republic**, the Ministry of Irrigation in Nepal and the Ministry of Natural Resources and Environment in **Viet Nam**.

In the **Philippines**, the National Water Resources Board is the overall government agency that is responsible for all water resources in the Philippines. In **India**, the federal states are primarily responsible for the planning, implementation, funding and management of water resources development, while the Ministry of Water Resources is responsible for laying down policy guidelines and programmes for the development and regulation of the country's water resources. In **Indonesia**, the Department of Public Works is responsible for surface water resources, while the Department of Mining and Energy is authorized to manage groundwater resources. In **Myanmar**, the Ministry of Agriculture and Irrigation is the main ministry involved in water resources. Municipal water supply, wastewater treatment and water quality depend in some countries on another ministry again (such as health, environment, public works, housing and construction or rural development).

The development of hydropower depends on different ministries, departments and enterprises, such as the Department of Power in **Bhutan**, the Electric Power Enterprise within the Ministry of Electric Power in **Myanmar**, the Ministry of Water and Power in **Pakistan**, the National Power Corporation in the **Philippines**, the Ceylon Electricity Board in **Sri Lanka** and the Ministry of Industry in **Viet Nam**.

The management of the irrigation systems is generally performed jointly by the State, as regards the primary infrastructure or public systems, and by user associations or independent users for the secondary and tertiary infrastructure or private systems. **China, Cambodia, India, Lao People's Democratic Republic, Myanmar, Pakistan, Philippines, Republic of Korea, Sri Lanka, Thailand** and **Viet Nam** have reported the importance of water user associations in the management of water and irrigation.

In most of the countries surface water and groundwater resources are state property. Water tarification is used in most countries of the region, although in different ways. China requires water charges to be collected according to the cost of water delivery. In India there is no uniform set of principles in fixing the water rates. They vary from stateto state, project to project and crop to crop, and are abysmally low and insufficient funds are generated for proper maintenance of irrigation systems, leading to poor quality of service. From the end of the 1960s, Indonesia made large investments into land and water resources development to achieve food self-sufficiency. Since the beginning of the 1990s, however, as Indonesia gained confidence in securing its national food supply, government investments in land and water resources gradually have been decreasing.

In the **Lao People's Democratic Republic** electricity and operating costs are paid directly by farmers who are also responsible for all maintenance matters concerning secondary and tertiary canals. Until 1994, the Irrigation Department was responsible for the operation and maintenance of weirs, dams, pumps and primary canals, after which it was supposed to be handed over to water users associations. In many cases, however, operation and maintenance are still carried out by the Irrigation Department or its provincial services.

In **Malaysia**, it was estimated in 1999 that fees collected from farmers cover only 10-12 percent of the actual operational cost. In the **Maldives**, the domestic tariff is stepped to provide a minimum quantity of water per day at an affordable rate. Wastewater charges are also included in the water charge. The application of charges has made the public aware and willing to conserve and use water judiciously. **Mongolia**'s Law on Water covers pricing policies intended to ensure cost recovery and the equitable allocation of water resources. In 2008, however, only about 65 percent of water costs were recovered through pricing, partly because of the country's present economic conditions. In **Myanmar**, the water tariff covering the Irrigation Department's gravity irrigation systems is very low and does not recover the cost of maintenance work. However, the water tariff in the river pumping systems of the Water Resources Utilization Department is higher. The annual budget for the maintenance and repair of the facilities is mostly paid by the government.

In **Nepal** there is a traditional belief that water is a God-given free commodity and only the water supplied to urban areas for domestic use is charged on a volumetric basis. Irrigation water is levied as a service charge. In **Pakistan**, the difficulties faced in cost recovery (44 percent) have resulted in very poor operation and maintenance. Farmers' organizations are responsible for collecting the water fees. In **Sri Lanka**, the government instituted an irrigation fee for the first time in 1984. In **Viet Nam**, irrigation fees were first established in 1984 in some provinces. Funds are based on water users (farmers), payment (irrigation fees) and the government budget subsidy.

In most countries of the region there has been financial assistance (grants and loans) from international donors and foreign governments, such as the World Bank (WB), International Bank for Reconstruction and Development (IBRD), Japan International Cooperation Agency (JICA), Japan Bank for International Cooperation (JBIC), and Asian Development Bank (ADB), for major construction projects directed at the agricultural and energy sectors.

Environment and health

WATER QUALITY

In the Southern and Eastern Asia region, surface water and groundwater quality is commonly affected by agricultural, industrial and municipal wastewater. This is now being compounded by the mobilization of naturally occurring arsenic in sediments of the Ganges-Brahmaputra system as deeper groundwater circulation is exploited for agriculture and water supply.

Although total water withdrawal, as compared to water resources, remains limited in many countries in the region, the large amounts of water diverted, mostly for agriculture, have an environmental impact that may represent locally significant proportions. In several countries, or regions within countries, competition for water is becoming increasingly important, with direct implications for agriculture.

Upstream river water quality is generally good, but downstream sections of major rivers reveal low water quality. Agriculture, the development of industry and increasing population density is causing river pollution and health risks for people living close to the rivers. Much of the pollution results from inadequate treatment of municipal and industrial wastewater.

In **Bangladesh**, water quality has deteriorated in some locations as a result of pollution from agrochemicals, industrial waste and other sources and arsenic contamination of groundwater has been reported in many documents. In **Cambodia**, groundwater quality is generally satisfactory. However, unpalatably high iron levels are encountered in about 10 percent of the tubewells. In **China**, serious pollution occurs widely throughout every river system, not one single river is clean and more than half of the groundwater resources have been severely contaminated. Municipal wastewater discharges have surpassed industrial discharges since 2000, and have become the most important pollution source. Rural areas have also witnessed an increase in pollution caused by the inappropriate use of chemical pesticides and fertilizers.

In **India**, the upper reaches of most rivers are of good quality, while the lack of wastewater treatment plants in the middle and lower reaches of most rivers cause a major degradation of surface water quality. Groundwater quality is also affected by municipal, industrial and agricultural pollutants and the mobilization of arsenic from the Ganges-Brahmaputra sediments. In **Indonesia**, many rivers are significantly or seriously polluted owing to the high level of municipal and industrial waste and pollution. This is so severe in major cities that industries have been forced to close during dry years because of raw water shortages. In **Malaysia**, the main sources of organic water pollution are municipal and industrial sewage, effluent from palm oil mills, rubber factories and animal husbandry. In the **Maldives**, mostly because of tourism, the quantity of water drawn from Male's aquifer during the 1970s increased tremendously and the increased amount of sewage being disposed ofinto the ground made it more susceptible to groundwater pollution. The increased volumes of groundwater being used to flush toilets were no longer returning to the aquifer but were being discharged to the sea, thus the salinity of the aquifer increased sharply limiting its usefulness as a resource.

Freshwater ecosystems of **Mongolia** are subject to increasing and multiplying threats, including overgrazing, dams and irrigation systems, growing urbanization, mining and gravel extraction, impact of climate change and lack of water management policies and institutional framework. In **Myanmar**, in the lower courses of rivers, sedimentation is one of the major adverse effects of storage dams. In **Pakistan**, indiscriminate and unplanned disposal of effluents (including agricultural drainage water, municipal and industrial wastewater) into rivers, canals and drains is causing deterioration of water quality in the downstream Indus river. The groundwater is marginal to brackish in quality in 60 percent of the aquifer of the Indus Basin Irrigation System (IBIS). In **Thailand**, surface water quality classified as 'good', 'fair' and 'poor' accounted for 48, 32 and 20 percent respectively in 2004. In **Viet Nam**, there is an ever-increasing pollution level of surface water, groundwater and coastal waters. Untreated industrial wastewater discharging into rivers is the main source of the pollution.

Sewage coverage is very low in most countries of the region. In **Cambodia, India, Papua New Guinea** (costal area of Port Moresby) and the **Philippines** it is reported that most of the wastewater flows into the receiving waters without any treatment.

On the other hand, **Lao People's Democratic Republic** reports that the water quality of rivers within the country and the Mekong is considered to be good based on international standards. However, with the pressure of rapid demographic growth, socio-economic development and urbanization the water quality is increasingly exposed to deterioration. In **Sri Lanka**, the quality of the groundwater is generally fairly good and relatively constant throughout the year. However, in some parts of the country (northern and northwestern coastal areas) excessive concentrations of iron and nitrates (from agrochemicals and fertilizers) have been reported. **Timor-Leste** does not suffer from the problems of industrialization and farmers almost never use agrochemicals.

Careful management of surface water and groundwater withdrawal is required in the countries of the Southern and Eastern Asia region to avoid pollution and health problems. Some action plans and measures have been adopted to improve water quality and protect the environment. **Brunei Darussalam**, for example, has excellent facilities for the treatment of its drinking water at six government treatment plants situated throughout the country and two other private plants. There are also bottled water factories using advanced technology to produce purified water. Monitoring of treated water at treatment plants, storage points and end-points is carried out daily. The **Democratic People's Republic of Korea** is applying knowledge on sustainable development of upland water catchments and use of marginal agricultural land to help reduce soil erosion and protect natural resources.

In **India**, the pollution control action plan of the Ganges river basin was formulated in 1984, to oversee pollution control and the consequent cleaning of the Ganges river. Similar programmes for other rivers have also been developed. In **Maldives**, desalination has become one of the few options available for providing sufficient safe water for Male. In **Myanmar**, the government is emphasizing the implementation of the terrace farming system to reduce shifting cultivation. In **Nepal**, the Environmental Action Plan of 1994 provided some guidelines for both Integrated Water Resources Management (IWRM) and maintaining the water quality at the river basin level.

In **Papua New Guinea**, sewerage systems were developed by Australia mainly in Port Moresby and urban cities from the 1960s to the early 1970s, before independence, in the inland area of Port Moresby and were also developed in 1999 and 2000 in the urban cities through a loan from the ADB. Japan financed a new project in 2010, called Port Moresby Sewerage System Upgrading, to develop sewerage facilities in the coastal area of Port Moresby. The **Republic of Korea** decided to implement a 15-year period (1996-2010) environmentally-friendly agriculture promotion plan to minimize pollutants coming from chemical fertilizers, agricultural chemicals, livestock and poultry waste, to maintain and improve agricultural resources including soil and water purity and to support farm households that practice environmentally-friendly agriculture.

SEAWATER INTRUSION

The overexploitation of aquifers (when water withdrawal exceeds water recharge) and the subsequent lowering in their levels is a problem in some countries of the region. This overexploitation is the origin of seawater intrusion and/or the upward diffusion of deeper saline water in at least **Bangladesh, China, India, Sri Lanka** and **Viet Nam**, which leads to a deterioration of groundwater quality. Using saline groundwater for irrigation may increase soil salinity. The use of fossil water, which is water from aquifers with a very low rate of recharge, and which is therefore considered non-renewable, will cause depletion of the aquifers in the long term. In **China**, sea water intrusion has occurred in 72 locations along coastal provinces, covering an area of 142 km^2 (World Bank, 2009). Intrusion of saltwater in deltas is a concern in **Myanmar**, **Viet Nam** and parts of **India**. Overexploitation of groundwater, also causes lowering of water tables, reduction in dry season flows of rivers and streams, groundwater pollution and ecological imbalance.

SALINIZATION

Salinization normally occurs in arid areas because of the low volume of rainwater dissolving the salts generated by the soil. By extracting water from the soil, evaporation and evapotranspiration tend to increase salt concentrations. Direct evaporation from the soil surface causes a rapid accumulation of salt in the top layers. When significant amounts of water are provided by irrigation with no adequate provision for leaching of salts, the soils rapidly become salty and unproductive. Consecutive accumulation of salts year after year degrades the soils and renders them unproductive.

Assessment of salinization at national level is difficult, and very little information on the subject could be found during the survey. Furthermore, no commonly agreed methods exist to assess the degree of irrigation-induced salinization. Figures on area salinized as a result of irrigation are available for eight of the 22 countries of which seven are from the previous survey, since no new information could be obtained (Table 27). In **Bangladesh**, the area salinized by irrigation was estimated at 100 000 ha in 1993. In **Cambodia**, increased salinity is seen in parts of the southernmost (delta) provinces, most likely owing to contamination by salt contained in the original deltaic deposits.

In **China**, the area salinized by irrigation was estimated at 6.7 million ha in 1999, though in recent years the area affected by salinization seems to have somewhat fallen. In **India**, the area salinized by irrigation was 3.3 million ha in 1998. In Indonesia, it is estimated that out of the total irrigated area about 400 000 million ha are affected by salinity. Salinization is also reported in the central dry zones of **Myanmar**, where major groundwater pumping irrigation schemes are located. In **Pakistan**, more than one-third of the irrigation area is reported to be affected by salinization. Soil salinity also constrains farmers and affects agricultural production. In the **Philippines**, the area salinized by irrigation was estimated at 300 000 ha in 1999. In **Thailand**, 10 percent of the irrigated land was affected by salt in the northeast of the country in 1999. Many programmes have been launched to correctly manage cash crops and paddy on saline soils. Salinization is now reported to be affecting large areas in the coastal parts of the central plain. In **Viet Nam**, the area salinized by irrigation was estimated at 300 000 ha in 1999.

TABLE 27
Salinization in irrigation areas in some countries

Country	Salinization		
	Year	ha	% of equipped area
Bangladesh	1993	100 000	3
China	1999	6 700 000	12
India	1998	3 300 000	5
Indonesia	1999	400 000	9
Pakistan	2004	7 003 000	37
Philippines	1999	300 000	18
Thailand	1999	400 000	8
Viet Nam	1999	300 000	8

FLOODING AND WATERLOGGING

A large area of the Southern and Eastern Asia region is subject to flooding and waterlogging as reported for the following countries.

In **Bangladesh**, because of the low-lying topography, about 2.65 million ha or 18 percent of the country is inundated during the monsoon season each year. During severe floods the affected area may exceed 5.3 million ha or 37 percent of the country and, in extreme events such as the 1998 flood, about 66 percent of the country is inundated. Floods are caused by overspills from main rivers and their distributaries, overspills from tributaries and by direct rainfall. Of the total cropped area, about 1.32 million ha are severely flood-prone and 5.05 million ha are moderately flood-prone. In **China**, the area subject to waterlogging was 21.3 million ha in 2005. In northern China in particular waterlogging, salinization and alkalization have been the main constraints to agricultural production.

In **India** the area subject to flooding is estimated at about 40 million ha (about 12 percent of the area of the country). About 80 percent of this area, or 32 million ha, could be provided with reasonable protection. The state that is worst hit by floods is Bihar. With the onset of the monsoon, rivers come down from the Himalayan hills in **Nepal** with enormous force, causing the following rivers Ghagra, Kamla, Kosi, Bagmati, Gandak, Ganges, Falgu, Karmnasa, Mahanadi to rise above the danger level. The total area subject to waterlogging was estimated at 8.5 million ha in 1985, including both rainfed and irrigated areas. In Indonesia, flooding occurs during the rainy season, while drought is frequent in the dry season.

Massive deforestation and environmental degradation have resulted from these extreme conditions. In **Mongolia**, serious flooding of rivers was observed that caused severe property damage and loss of life. About 18 flood events were observed from 1996 to 1999, which resulted in loss of life and much property damage. In **Pakistan**, investments in drainage have been significant during the last two decades, though waterlogging still affects large tracts of land. Waterlogging in the Indus Basin Irrigation System was high in the 1990s as a result of heavy floods while droughts in the 2000–2005 period resulted in lowering of the water table and reduction in the waterlogged area.

In the Philippines, the main area subjected to floods is the central region of Luzon, namely the Pampanga, Zambales and Tarlac provinces. About 1 million ha have been identified as flood-prone areas. In Thailand, Bangkok faces problems of both too much and too little water. Flooding occurs frequently in the wet season owing to low average elevation, high tides and inadequate drainage. The Metropolitan Waterworks Authority is unable to supply water to meet all municipal and industrial demand. As a result, in the outskirts of Bangkok, private and industrial abstraction of groundwater exceeds the safe yield of the aquifer. This accelerates the rate of land subsidence (5-10 cm/year), which in turn aggravates the problem of flooding. Indeed, subsidence has caused some parts of the drainage systems to be below the normal water level and has thus rendered them ineffective. In Timor-Leste, rains can bring with them large-scale flooding, which washes pollution into the waterways. This water quality is often poor. Flooding is an annual event in northern Viet Nam and the cause of enormous losses. With as much as 80 percent of the population living on the coastal plains and deltas, costs incurred from floods and typhoons are colossal. Also there is immense loss of life, homesteads and general suffering of the people.

DRAINAGE AND FLOOD CONTROL

One of the measures needed to prevent irrigation-induced waterlogging and salinization is the installation of drainage facilities. Figures on drained areas are available for ten of the 22 countries of which seven are from the previous survey, since no new information could be obtained (Table 28). Only five countries provide figures on the area equipped for irrigation that has been provided with drainage facilities, varying from 3 percent in **Bangladesh** to 95 percent in the **Philippines**.

In most of Southern and Eastern Asia, drainage is closely linked to irrigation. In traditional terraced paddy cultivation, water flows from one plot to another and no distinction can be made between irrigation and drainage. Bhutan, China, the Philippines and Viet Nam have specifically mentioned this type of drainage but it can apply to most of the areas where paddy rice is cultivated.

In several humid countries of the region, large segments of lowland or wetland are used for paddy cultivation. In such cases, while these areas are generally or usually accounted for as irrigated land, the main purpose of water control is to ensure appropriate control of water level and drainage. Typologies differ from one country to another to indicate very similar situations. **Bangladesh** and **Cambodia** use the terms controlled flooding or inundation, which are typical of paddy cultivation in the major deltas (Brahmaputra, Mekong). **Lao People's Democratic Republic** reports on lowland flooded rice.

In these areas, drainage and flood control are also very much related. **In Bangladesh**, a master plan for water resources development was initiated in 1964, which envisaged the creation of 58 flood protection and drainage projects covering about 5.8 million ha of land. Flood control and drainage projects represent about half of the funds spent on water development projects since 1960. In 1993, the total area of wetlands was 3.14 million ha, of which 1.55 million ha were cultivated and 1.38 million ha were drained by surface drains. The flood protected area in 1990 was estimated at 4.2 million ha. **Brunei Darussalam** is working towards improving the irrigation system and has already introduced dykes and drainage systems to improve the water flow into and out of the fields.

The extreme case of agriculture under flood conditions is floating rice, which is reported in **Cambodia**, but can probably be found in other countries of the subregion. In **Indonesia**, total drained area was estimated at 3.35 million ha in 1990. In **Lao People's Democratic Republic**, drainage and flood protection structures have generally been considered in the design plan of the irrigated schemes but have not been implemented often because of budget restrictions. A specific case of drainage is reported for Malaysia where 940 000 ha were drained in 1994, of which 600 000 ha for oil palm cultivation. In that year, the area equipped for irrigation drained accounted for 340 600 ha and flood protected areas were estimated at 840 000 ha.

TABLE 28
Drainage in some countries

Country	Drainage in some countries				
	Year	Area equipped for irrigation with drainage facilities (1)	(1) as % of area equipped for irrigation	Total area drained (2)	(2) as % of cultivated area
		ha	%	ha	%
Bangladesh	1993	118 400	3	1 501 400	18
China	2006	4 471 950	7	-	-
India	1991	-	-	5 800 000	3
Indonesia	1990	-	-	3 350 000	10
Malaysia	1994	340 600	94	940 600	12
Myanmar	1994	-	-	193 400	2
Pakistan	2008	15 140 000	76	15 140 000	71
Philippines	1993	1 470 691	95	1 470 691	15
Republic of Korea	1996	-	-	1 039 000	53
Viet Nam	2006	-	-	2 538 844	27

In **Myanmar**, in the Ayeyarwady Delta drainage and flood control structures are also linked: in 1995 a total of 193 000 ha were reported to be equipped for surface drainage, which is considered as a form of flood protection. In 2006, the drainage systems covered 2.54 million ha, mostly in the northern and central parts of the country, particularly the Red River Delta. When the Indus Basin Irrigation System was developed in **Pakistan**, the drainage needs were initially minimal. They, however, increased over time as more irrigation water was diverted and the groundwater table rose to harmful levels causing waterlogging and salinity. The drainage systems have mostly been developed over the last 30-40 years. In 2008, the total drained area, all equipped for irrigation, was estimated at 15.14 million ha. In most schemes in the **Philippines**, drainage water from one field goes into another field downstream either through the irrigation canal or directly. In 1993, total drained area was estimated at about 1.47 million ha. Total drained area in the **Republic of Korea** was 1 million ha in 1996. In the wet zone of **Sri Lanka**, flood control and drainage schemes have been incorporated into the irrigation system mainly in the lower reaches of rivers.

Data on drainage infrastructure associated to irrigation in arid and semi-arid areas mostly concern northern China, India and Mongolia. In **China** as a whole (it was not possible to make a distinction between arid and humid areas), in 1996 it was estimated that 24.6 million ha were subject to waterlogging, of which 20.3 million ha were controlled by drainage. In 1995, the power drained area was 4.2 million ha, while in 2006 it was estimated at 4.5 million ha. In 2005, flood protected areas were estimated at 44 million ha. In **India**, drainage works have been undertaken on about 5.8 million ha (12 percent of the irrigated area) in 1991, but investment in drainage works associated with irrigation schemes has been widely neglected and where such investment has been made, poor maintenance has caused many drainage systems to become silted up. In 2010, only some irrigation systems, predominantly in south and western India, have well laid out drainage systems. No data were available for **Mongolia**.

HEALTH AND WATER-RELATED DISEASES

Only 13 out of the 22 countries of the Southern and Eastern Asia region have reported on water-related diseases for this survey, although these diseases are certainly also present in the other countries of the region. The major factors favouring the development and dispersion of these diseases are as follows:

- Ø choice of wastewater to meet water shortage;
- Ø lack of infrastructure, especially related to wastewater treatment and disposal;
- Ø lack of health awareness and proper handling of polluted water; and the
- Ø lack of regulations related to the protection of the environment and public health.

In **Bangladesh** some diseases and health hazards such as arsenicosis, blindness, physical disability, occur as a result of arsenic toxicity to humans (RDA, 2001). Brunei Darussalam has been declared malaria-free by WHO in 1987, though some new cases were reported in 2003, but they were all imported. Water supply- and sanitation-related diseases such as diarrhoeal diseases, hepatitis, cholera and typhoid have also occurred in Brunei Darussalam (WHO, 2004). In Cambodia malaria is a serious problem throughout the country because of the natural ecosystem. In 1999, estimates of about 500 000 cases of malaria per year were common, and approximately 5 000-10 000 people die from malaria each year.

Schistosomiasis (bilharzia) was reported in the Kratie area in 1993. Dengue haemorrhagic fever became a significant cause of child morbidity in the 1990s, about 7 000 cases resulting in 340 deaths were recorded that year. In rural China, the economic cost of disease and premature deaths associated with the excessive incidence of diarrhoea and cancer was estimated at 0.49 percent of the GDP in 2003 (World Bank, 2009). Above the Huang river, for example, abnormally high rates of mental retardation, stunting, and development diseases have been linked to the natural presence of arsenic and lead in the water. In Shanxi province, around the Huang river, high levels of lead and chromium were found in rice and cadmium in cabbages (Burke, 2000).

In **India**, water-related diseases have continued to increase over the years in spite of government efforts to combat them. States such as Punjab, Haryana, Andhra Pradesh and Uttar Pradesh are endemic for malaria because of the high groundwater table, waterlogging and seepage into the canal catchment area. There are also numerous cases of filariasis. In 1998, the population affected by water-related diseases was 44 million inhabitants. In **Maldives**, water-related diseases such as diarrhoea, cholera, shigella and typhoid started spreading as a result of poor sanitary conditions. In **Mongolia**, infections such as dysentery and hepatitis stem from a lack of access to safe water and sanitation infrastructure (UN, 2006).

In **Pakistan**, around 25 percent of all illnesses diagnosed at public hospitals and dispensaries are gastro-enteric and 40 percent of all deaths, 60 percent of infants' deaths are caused by infections and parasitic diseases, most of them are water related. The most common diseases are diarrhoea, dysentery, typhoid, hepatitis, kidney stones, skin disease and malaria. In **Papua New Guinea**, the ratio of water-related diseases in the coastal area is higher than in other areas. Average diarrheal morbidity is 31 percent in the coastal area, while 5 percent in the city. In the **Philippines**, the population affected by water-related diseases in 2000 was more than 850 000. In **Sri Lanka**, large water development projects have increased the malariogenic potential of areas through increased vector propagation, aggregation of labour and resettlement from non-malarious areas of people with no immunity.

In **Thailand**, the main water-related diseases were acute diarrhoea (affecting 1.48 percent of the population) dysentery (0.14 percent) and enteric fever (0.03 percent) in 1999. Malaria, as a water-related disease, affected 0.12 percent of the population. Leptospirosis seems to prevail in flood-prone and irrigation areas, but is under control. There are no clear impacts (positive or negative) of irrigation on health. This is probably because of the complicated interaction among socio-economic factors and land-use changes. People whose rice is in irrigation areas are better off economically than those in rainfed areas and hence can afford better health care.

Changes in land use transform remote irrigation areas into suburban areas with reasonable road access. There is less poverty in areas that are irrigated than in rainfed. In **Viet Nam**, water-related diseases are still a major problem, although improvements are made in providing safe water to the urban and rural populations. Dysentery and diarrhoea are widespread. In four recent years about 6 million cases of six water-related diseases were incurring a direct cost of at least US$27 million for treatment of cholera, typhoid, dysentery and malaria.

CLIMATE CHANGE

Climate change is expected to have significant impacts in the Southern and Eastern Asia region. It may alter the distribution and quality of the region´s water resources. Some of the impacts include the occurrence of more intense rains, changed spatial and temporal distribution of rainfall, higher runoff generation, low groundwater recharge, melting of glaciers, changes in evaporative demands and water use patterns in the agricultural, municipal and industrial sectors, etc. These impacts lead to severe influences on the agricultural production and food security, ecology, biodiversity, river flows, floods, and droughts, water security, human and animal health and sea level rise.

Potential impacts on agriculture include vulnerability of crops to heat stress, possible shifts in spatial boundaries, of crops, changes in productivity potentials, changes in water availability and use, and changes in land use systems. Even a fractional rise in temperature could have serious adverse effects, such as a considerable increase in the growing degree days (GDD, which is a measure of heat accumulation used to predict the date that a flower will bloom or a crop reach maturity). This could not only affect the growth, maturity and productivity of crops, but would also require an additional amount of irrigation water to compensate the heat stress (Afzal, 1997; FAO, 2011c).

It is not the purpose of this survey to deal in detail with climate change issues. Much other research is being done specifically on this issue, which has resulted in many reports, such as FAO's Water Report on "Climate change, water and food security"(FAO, 2011c).

Prospects for agricultural water management

Countries in the Southern and Eastern Asia region consider water and irrigation management a key factor in the use and conservation of their water resources. In the future, agricultural water management in the countries of the Southern and Eastern Asia region, for which information is available, will take into consideration the following: Rehabilitation and modernization of the irrigation and drainage infrastructure, rehabilitation and construction of dams, increase of water use efficiency and recovery of the expenses for water supply service, reuse of water, integrated water resources management, establishment of more river basin organizations, improvement of water awareness and water education, flood and drought contingency plans, water quality management, strengthening of the institutions and policies for integrated water resources management, participatory approach in the decision-making process, innovative technologies, extensive research, water ecosystems protection and coordinated approach of governmental institutions, donors, NGOs and key stakeholder groups at river basin level. Developing water user associations is considered a priority in some countries.

Most countries of the region recognize the failure to develop adequate operation and maintenance mechanisms to ensure the sustainability of the irrigation schemes (mostly large, public schemes). Irrigation management transfer or increased user participation in the management of the schemes is seen by most countries as the solution to this sustainability problem. This is achieved through the development or improvement of water user associations (WUAs). The strengthening of WUAs is also linked to the need expressed in several countries to improve the overall performance and water use efficiency of irrigation schemes.

Water scarcity is another major issue mentioned in several country reports such as for China, Mongolia, the Philippines or India. Increased competition for water between sectors already affects agriculture in China, India, Malaysia, Thailand and the Republic of Korea and the trend is towards an intensification of the problem mainly because of the rapid growth of the municipal and industrial sectors in these countries. In China, the country level data hide massive regional differences in water scarcity behind the average figures. In 2030, the annual deficit at national level would be around 13 km^3, but in the North China Plain it would be as high as 25-46 km^3.

Water scarcity and the interdependency between water use sectors are pushing countries to develop integrated water resources management programmes. In Bangladesh, conflicts among alternative and competing uses of water are becoming sharper as the demand for water has been increasing. Thus it is necessary to formulate a long-term vision for integrated water resources management to address the demands of all water using sectors. In Indonesia, the government has proposed an Integrated Water Resources Management Policy framework to support water resources development and management. In Mongolia, there is an urgent need to consider implementing the Integrated River Basin Management (IRBM) principles for sustainable water management.

Water quality is also a growing concern in several countries, especially where industrial development is important: Republic of Korea, India, Malaysia, the Philippines. The increased importance of water conservation and protection in the national programmes is also mentioned in Indonesia, the Philippines and Bangladesh. In this last country, siltation is the single most important water quality issue.

Changes in rainfall pattern resulting from climate change will significantly disrupt the farmers cropping system particularly in rainfed areas. It will become more difficult and risky for farmers to just rely on rainfall for their planting calendar. Extreme climate events will likely impinge the hydrological system in most of the river basins and will mean that water is becoming either 'too much' or 'too little'. When water becomes too much, the potential effects include flooding from overflowing rivers and excessive runoff from sloping lands damaging water infrastructure, such as dams, irrigation and drainage systems. At the other end, higher temperatures and decreased precipitation mean too little water, resulting in a decreased water supply and an increased water demand, which might cause deterioration in the quality of freshwater bodies.

There will be possible alterations in the distribution of surface water and groundwater resources resulting from changes in recharging and discharging patterns. Stream flows will be significantly reduced and groundwater levels will decline. To be able to deal with water scarcity, the demand and supply side of water management needs to be focussed on through rehabilitation of water sources, water conservation, and augmentation of water supply, including the optimum utilization of wastewater as an alternative water source for irrigation. To be able to deal with flooding and excessive runoff, the drainage facilities that immediately remove excess flood waters need to be improved. In the design of irrigation systems, a review of design methods should include the effects of climate change and incorporate properly designed drainage facilities to protect standing crops. The construction of rainwater harvesting structures (e.g. small water impounding project) to collect and store rainwater in the uplands could contribute to flood mitigations downstream and water availability during the dry season.

As the older public schemes in most countries soon reach 50 years, the issue of rehabilitation and modernization is becoming increasingly important. While for some countries (such as Lao People's Democratic Republic, Myanmar, the Philippines, Viet Nam and parts of India) the extension of irrigated land still represents an important part of their irrigation programmes, in most countries rehabilitation and modernization programmes are gaining increasing importance. The increased land and water scarcity and low expected return of future expansion of irrigation in these countries are often factors explaining the growing importance of modernization in irrigation programmes.

Increasing water-use efficiency and productivity will be made possible if efficient pressurized irrigation techniques and irrigation scheduling is adopted. Increasing the net benefit per unit of land and water could be possible if the cultivation of crops with high water requirements is reduced. In India, to meet the estimate of food grain requirement by 2025, it is assumed that the overall irrigation efficiencies will be around 50 percent for surface water systems and 72 percent for groundwater systems, compared to the present level of 35-40 percent. In Thailand water management in agriculture is said to have to focus on improving water-use efficiency because: i) the trend indicates that Thailand's water shortage is emerging; ii) the agriculture sector consumes the largest proportion of water. In Sri Lanka, increasing irrigation efficiency is one of the feasible options available for meeting future water demand.

According to available information, the current use of non-conventional sources of water (desalination and/or direct use of treated wastewater and agricultural drainage water) only concerns seven out of the 22 countries in the region, representing less than 1 percent of the region's total withdrawals. Non-conventional sources of water, in general, are not included as a priority in the water management plans and policies of the countries of the region. Though, these sources of water are expected to develop in the future, as reported at least by Bhutan and the Maldives. It should also be mentioned that agricultural drainage water is already directly reused in many rice growing areas where water flows on terraces from one plot to another lower lying plot (cascades). Detailed information on quantities is, however, not available.

Financial sustainability requires a revision of measurement, computation and recovery mechanisms related to water fees. In countries such as China, India, Lao People's Democratic Republic, Thailand, the policy is now to adjust water fees so that they cover at least the cost of operation and maintenance. In India the water rates shall be linked directly to the quality of service provided.

Major inter-basin transfer programmes are reported in China and Thailand.

Riparian countries sharing transboundary river basins need to prepare joint water management plans for each basin to ensure clear communication, so as to avoid conflicting approaches, unilateral development, and inefficient water management practices that may cause international crisis in these countries.

While irrigation has been instrumental in achieving self-sufficiency in staple crop production in recent decades in most countries of the region, some countries still indicate self-sufficiency as a major target of their irrigation development programmes; this is mainly to keep pace with rising populations. In Bangladesh, the expansion of irrigation coverage would reach its maximum potential limit by 2025. However, the rate of increase in water demand is expected to register a declining trend in response to demand management practices such as conservation, water-use efficiency, recycling. Cambodia is working to increase investment in irrigation and research to promote agricultural production for poverty reduction and the government has shown a strong commitment to increasing the irrigated area by 20 000 ha per year. In Myanmar irrigation will have to play a major role in the development of the agriculture sector, since the government's objective is to achieve a surplus in rice production, self-sufficiency in edible oil and to set up the production of exportable pulses and industrial crops. In Timor-Leste, it is felt that the production of higher value crops, associated with some form of processing, are the next stage in the development of the agriculture sector.

Information is available for some countries regarding specific water plans for the future. In Lao People's Democratic Republic, the Asian Development Bank and World Bank in 2006 undertook studies to define the scope of an integrated water resources management strengthening programme in the country. Myanmar plans to implement a project on "Strengthening farmers' irrigation management", with technical assistance from the Japanese Government. The objective is to reduce the government's administrative and maintenance costs of new irrigation projects as well as those of existing irrigation systems. In Timor-Leste, the Strategic Development Plan (2010-2020), defines the working plan related to agricultural water management.

Main sources of general information

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Summary tables

EXPLANATORY NOTES

Table 29 - Land use and irrigation potential

- Ø The cultivable area for Bhutan, China, Democratic People's Republic of Korea, Indonesia, Maldives, the Philippines, Republic of Korea, Timor-Leste and Viet Nam was estimated as cultivated area since there was no data available. For Sri Lanka it was estimated as the irrigation potential, since it is larger than cultivated area.
- Ø The irrigation potential area for Bhutan, Brunei Darussalam, Democratic People's Republic of Korea and Timor-Leste was estimated as equipped area, since there was no data available. Irrigation potential in Cambodia has never been estimated, however, it could be at least 1 million ha.
- Ø In the Republic of Korea the irrigation potential was estimated to be equal to the cultivated area and therefore can change from one year to the next.

Table 33 - Water withdrawals by source

- Ø Freshwater withdrawal (surface water and groundwater) for Cambodia, Democratic People's Republic of Korea, Lao People's Democratic Republic, the Maldives, Nepal, Papua New Guinea, Republic of Korea, Sri Lanka and Timor-Leste are unknown. In these cases, total freshwater was estimated taking into account water withdrawal by sector. This also means that the sum of total surface water and groundwater withdrawal is not equal to total freshwater withdrawal.

Table 36 - Full control irrigation techniques

- Ø For India and Republic of Korea the year for the total area under full control irrigation is different from the year for the different techniques.
- Ø For Nepal and Timor-Leste there is no information on irrigation techniques.

Table 37 - Origin of full control irrigation water

- Ø For Bhutan, Cambodia, Democratic People's Republic of Korea, India, Republic of Korea and Sri Lanka the year for the total area under full control irrigation is different from the year for the different origins of water for full control irrigation. This means that the sum of the different techniques is not equal to the total.
- Ø For many countries there must also be direct use of agricultural drainage water in view of the rice cultivation on terraces where water flows from one plot to another lower lying plot (cascades). However, no information was available on quantities and probably countries have included it in the freshwater withdrawal (i.e. considered all as secondary freshwater, which is drainage water and wastewater returned to the system, rather than direct use of non-conventional water).

TABLE 29
Land use and irrigation potential by country

Country	Total area			Cultivable area			Cultivated area (2009)				Irrigation potential			
	area	in % of total area	per inhab	area	in % of total area	per inhab	area	in %of total area	in % of cultivable area	per inhab	per person economically active in agriculture	area	in % of cultivable area	in % of cultivated area
Unit	ha	%	ha/inhab	ha	%	ha/inhab	ha	%	%	ha/inhab	ha/ec. act.pop.	ha	%	%
	(1)	(2)	(3)	(4)	(5)=100x (4)/(1)	(6)	(7)	(8)=100x (7)/(1)	(9)=100x (7)/(4)	(10)		(11)	(12)=100x (11)/(4)	(13)=100x (11)/(7)
Bangladesh	14 400 000		0.10	8 774 000	60.9	0.06	8 549 000	59.4	97.4	0.06	0.24	6 933 000	79.0	81.1
Bhutan	3 839 000	0.18	5.38	100 000	2.6	0.14	100 000	2.6	100.0	0.14	0.35	27 685	27.7	27.7
Brunei Darussalam	577 000	0.03	1.47	13 000	2.3	0.03	8 000	1.4	61.5	0.02	8.00	1 000	7.7	12.5
Cambodia	18 104 000	0.87	1.30	4 626 000	25.6	0.33	4 055 000	22.4	87.7	0.29	0.80	1 000 000	21.6	24.7
China	960 000 000	46.11	0.70	124 320 000	13.0	0.09	124 320 000	13.0	100.0	0.09	0.25	70 000 000	56.3	56.3
DPR Korea*	12 054 000	0.58	0.50	2 855 000	23.7	0.12	2 855 000	23.7	100.0	0.12	0.92	1 460 000	51.1	51.1
India	328 726 000	15.79	0.27	183 000 000	55.7	0.15	169 623 000	51.6	92.7	0.14	0.65	139 500 000	76.2	82.2
Indonesia	190 457 000	9.15	0.80	42 600 000	22.4	0.18	42 600 000	22.4	100.0	0.18	0.89	10 886 000	25.6	25.6
Lao PDR*	23 680 000	1.14	3.87	2 000 000	8.4	0.33	1 468 000	6.2	73.4	0.24	0.63	600 000	30.0	40.9
Malaysia	33 080 000	1.59	1.18	14 175 000	42.9	0.51	7 585 000	22.9	53.5	0.27	4.63	413 700	2.9	5.5
Maldives	30 000	0.00	0.10	7 000	23.3	0.02	7 000	23.3	100.0	0.02	0.30		-	-
Mongolia	156 412 000	7.51	57.67	1 800 000	1.2	0.66	962 000	0.6	53.4	0.35	4.35	518 000	28.8	53.8
Myanmar	67 659 000	3.25	1.42	18 270 000	27.0	0.38	12 135 000	17.9	66.4	0.25	0.63	10 500 000	57.5	86.5
Nepal	14 718 000	0.71	0.50	3 955 000	26.9	0.13	2 520 000	17.1	63.7	0.09	0.22	2 177 800	55.1	86.4
Pakistan	79 610 000	3.82	0.47	21 300 000	26.8	0.12	21 280 000	26.7	99.9	0.12	0.85	21 300 000	100.0	100.1
Papua New Guinea	46 284 000	2.22	6.90	12 500 000	27.0	1.86	960 000	2.1	7.7	0.14	0.47	36 000	0.3	3.8
Philippines	30 000 000	1.44	0.33	10 450 000	34.8	0.11	10 450 000	34.8	100.0	0.11	0.78	3 126 000	29.9	29.9
Republic of Korea	9 990 000	0.48	0.21	1 782 000	17.8	0.04	1 796 000	18.0	100.8	0.04	1.25	1 782 000	100.0	99.2
Sri Lanka	6 561 000	0.32	0.32	2 170 000	33.1	0.10	2 170 000	33.1	100.0	0.10	0.56	570 000	26.3	26.3
Thailand	51 312 000	2.46	0.75	26 790 000	52.2	0.39	18 995 000	37.0	70.9	0.28	0.98	12 245 000	45.7	64.5
Timor-Leste	1 487 000	0.07	1.35	225 000	15.1	0.20	225 000	15.1	100.0	0.20	0.65	34 649	15.4	15.4
Viet Nam	33 105 000	1.59	0.38	9 630 000	29.1	0.11	9 630 000	29.1	100.0	0.11	0.33	9 400 000	97.6	97.6
Total region	**2 082 085 000**	**99.31**	**0.58**	**491 342 000**	**23.6**	**0.14**	**442 293 000**	**21.2**	**90.0**	**0.12**	**0.45**	**292 510 834**	**-**	**-**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 30
Population characteristics by country

Country	Population (2009)				Economically active population (2009)				Gross Domestic Product (2009)			Human Development Index (2010)
	Total	in % of region	% rural	Population density	Total	in % of total population	In agriculture	in % of economically active population	Total	Value added by agriculture	GDP per inhabitant	
Unit	inhabitants	%	%	inhabitants per km^2	inhabitants	%	inhabitants	%	Current million US$	%	Current US$/ inhabitant	(Min 0. Max 1)
Bangladesh	147 030 000	4.08	72	1 021	75 202 000	51	35 562 000	47.3	89 360	18.7	608	0.469
Bhutan	714 000	0.02	66	19	306 000	43	284 000	92.8	1 259	17.6	1 763	-
Brunei Darussalam	392 000	0.01	25	68	187 000	48	1 000	0.5	11 471	0.7	29 262	0.805
Cambodia	13 978 000	0.39	80	77	7 610 000	54	5 074 000	66.7	9 872	35.3	706	0.494
China	1 365 580 000	37.88	54	142	803 851 000	59	498 732 000	62.0	4 985 461	10.4	3 651	0.663
DPR Korea*	24 238 000	0.67	40	201	12 586 000	52	3 092 000	24.6				-
India	1 207 740 000	33.50	70	367	472 440 000	39	261 632 000	55.4	1 310 171	17.1	1 085	0.519
Indonesia	237 414 000	6.58	56	125	111 996 000	47	47 894 000	42.8	540 274	15.8	2 276	0.600
Lao PDR*	6 112 000	0.17	68	26	3 085 000	50	2 323 000	75.3	5 939	34.7	972	0.497
Malaysia	27 949 000	0.78	29	84	11 862 000	42	1 638 000	13.8	193 093	9.5	6 909	0.744
Maldives	312 000	0.01	61	1 040	140 000	45	23 000	16.4	1 473	5.0	4 721	0.602
Mongolia	2 712 000	0.08	38	2	1 159 000	43	221 000	19.1	4 202	23.5	1 550	0.622
Myanmar	47 601 000	1.32	67	70	28 525 000	60	19 331 000	67.8		48.4		0.451
Nepal	29 433 000	0.82	82	200	12 191 000	41	11 340 000	93.0	12 531	33.9	426	0.429
Pakistan	170 494 000	4.73	64	214	62 398 000	37	24 902 000	39.9	161 990	21.6	950	0.490
Papua New Guinea	6 703 000	0.19	87	14	2 873 000	43	2 030 000	70.7	7 893	35.9	1 177	0.431
Philippines	91 703 000	2.54	51	306	38 160 000	42	13 317 000	34.9	161 196	14.8	1 758	0.638
Republic of Korea	47 964 000	1.33	17	480	24 223 000	51	1 441 000	5.9	832 512	2.6	17 357	0.877
Sri Lanka	20 669 000	0.57	86	315	9 058 000	44	3 904 000	43.1	41 979	12.6	2 031	0.658
Thailand	68 706 000	1.91	66	134	38 737 000	56	19 420 000	50.1	263 772	11.6	3 839	0.654
Timor-Leste	1 100 000	0.03	72	74	430 000	39	344 000	80.0	558	25.4	507	0.502
Viet Nam	86 901 000	2.41	70	263	45 819 000	53	29 334 000	64.0	90 091	20.9	1 037	0.572
Total region	**3 605 445 000**	**100.00**	**61**	**173**	**1 762 838 000**	**49**	**981 839 000**	**55.7**	**8 725 096**	**11.6**	**2 420**	**-**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 31
Renewable water resources by country

Country	Average annual precipitation		Annual renewable water resources				
			Internal (IRWR)		Total (TRWR)		Dependency ratio
	height	volume	volume	per inhabitant (2009)	volume	per inhabitant (2009)	
Unit	mm	km^3	km^3	m^3/inhab	km^3	m^3/inhab	%
	(1)	(2)	(3)	(4)	(5)	(6)	(7)
Bangladesh	2 320	334	105	714	1 227	8 343	91.4
Bhutan	2 200	84	78	109 244	78	109 244	0.0
Brunei Darussalam	2 722	16	9	21 684	9	21 684	0.0
Cambodia	1 400	253	121	8 626	476	34 061	74.7
China	645	6 192	2 812	2 059	2 840	2 079	1.0
Democratic People's Republic of Korea	1 054	127	67	2 764	77	3 183	13.2
India	1 170	3 846	1 446	1 198	1 911	1 583	30.5
Indonesia	2 702	5 147	2 018	8 501	2 018	8 501	0.0
Lao People's Democratic Republic	1 834	434	190	31 155	334	54 573	42.9
Malaysia	2 875	951	580	20 752	580	20 752	0.0
Maldives	1 972	1	0.03	96	0.03	96	0.0
Mongolia	241	377	35	12 832	35	12 832	0.0
Myanmar	2 091	1 415	1 003	21 067	1 168	24 533	14.1
Nepal	1 500	221	198	6 734	210	7 142	5.7
Pakistan	494	393	55	323	247	1 447	77.7
Papua New Guinea	3 142	1 454	801	119 499	801	119 499	0.0
Philippines	2 348	704	479	5 223	479	5 223	0.0
Republic of Korea	1 274	127	65	1 352	70	1 453	7.0
Sri Lanka	1 712	112	53	2 555	53	2 555	0.0
Thailand	1 622	832	225	3 268	439	6 384	48.8
Timor-Leste	1 500	22	8	7 468	8	7 468	0.0
Viet Nam	1 821	603	359	4 136	884	10 174	59.3
Total region	**1 136**	**23 647**	**10 707**	**2 970**	-	-	-

TABLE 32
Water withdrawals by sector by country

Country	Year	Annual water withdrawal							
		Agriculture		Municipalities		Industries		Total	
		volume	% of total	volume	% of total	volume	% of total	volume	per inhabitant
	Unit	million m^3	%	million m^3	%	million m^3	%	million m^3	m^3/inhab
		(1)	(2)=100x(1)/(7)	(3)	(4)=100x(3)/(7)	(5)	(6)=100x(5)/(7)	(7)=(1)+(3)+(5)	(10)
Bangladesh	2008	31 500	88	3 600	10	770	2	35 870	247
Bhutan	2008	318	94	17	5	3	1	338	482
Brunei Darussalam	1994							92	326
Cambodia	2006	2 053	94	98	4	33	2	2 184	162
China	2005	358 020	65	67 530	12	128 550	23	554 100	414
Democratic People's Republic of Korea	2005	6 610	76	903	10	1 145	13	8 658	365
India	2010	688 000	90	56 000	7	17 000	2	761 000	630
Indonesia	2000	92 763	82	13 129	12	7 398	7	113 290	531
Lao People's Democratic Republic	2005	3 960	93	130	3	170	4	4 260	741
Malaysia	2005	4 520	34	3 902	30	4 788	36	13 210	506
Maldives	2008	0.0	0	6	95	0.3	5	6	19
Mongolia	2005	227	44	122	24	162	32	511	201
Myanmar	2000	29 575	89	3 323	10	332	1	33 230	739
Nepal	2005	9 610	98	148	2	30	0	9 787	359
Pakistan	2008	172 371	94	9 650	5	1 400	1	183 421	1 096
Papua New Guinea	2005	1	0	224	57	168	43	392	64
Philippines	2009	67 066	82	6 235	8	8 254	10	81 555	889
Republic of Korea	2002	15 800	62	6 620	26	3 050	12	25 470	549
Sri Lanka	2005	11 314	87	805	6	831	6	12 950	653
Thailand	2007	51 786	90	2 739	5	2 777	5	57 302	845
Timor-Leste	2004	1 071	91	99	8	2	0	1 172	1 203
Viet Nam	2005	77 751	95	1 206	1	3 074	4	82 031	986
Total region		**1 624 316**	**82**	**176 484**	**9**	**179 937**	**9**	**1 980 829**	**561**

TABLE 33
Water withdrawals by source by country

Country		Primary and secondary freshwater							Other sources							Total	
		Surface water		Groundwater		Total freshwater				Direct use				Desalinated water			
	Year	Volume	% of total	Volume	% of total	Volume	% of total	MDG Water Indicator	Year	Treated waste-water	Agricultural drainage water	% of total	Year	Volume	% of total	Year	Volume
Unit		million m^3	%	million m^3	%	million m^3	%	%		million m^3	million m^3	%		million m^3	%		million m^3
Bangladesh	2008	7 390	21	28 480	79	35 870	100	2.9								2008	35 870
Bhutan	2008	338	100	0	0	338	100	0.4								2008	338
Brunei Darussalam	1994	92	99	1	1	92	100	1.1								1994	92
Cambodia	2006					2 184	100	0.5								2006	2 184
China	2005	439 287	79	101 412	18	540 699	97.6	19.0	1995	13 390		2.4	2008	11.0	0.002	2005	554 100
DPR Korea*	2005					8 658	100	11.2								2005	8 658
India	2010	396 529	52	251 000	33	647 529	85.1	33.9	2010		113 470	14.9	1996	0.6	0.000	2010	761 000
Indonesia	2000	95 661	84	17 610	16	113 271	99.983	5.6					1990	19.0	0.017	2000	113 290
Lao PDR*	2005					4 260	100	1.3								2005	4 260
Malaysia	2005	12 810	97	396	3	13 206	99.967	2.3					1990	4.3	0.033	2005	13 210
Maldives	2008					5	79.2	15.6					2001	1.2	20.763	2008	6
Mongolia	2005	92	18	419	82	511	100	1.5								2005	511
Myanmar	2000	30 239	91	2 991	9	33 230	100	2.8								2000	33 230
Nepal	2005					9 787	100	4.7								2005	9 787
Pakistan	2008	121 820	66	61 601	34	183 421	100	74.3								2008	183 421
Papua New Guinea	2005					392	100	0.0								2005	392
Philippines	2009	78 349	96	3 206	4	81 555	100	17.0								2009	81 555
Republic of Korea	2002					25 470	99.999	36.5					2000	0.2	0.001	2002	25 470
Sri Lanka	2005					12 950	100	24.5								2005	12 950
Thailand	2007	47 475	83	9 827	17	57 302	100	13.1								2007	57 302
Timor-Leste	2004					1 172	100	14.3								2004	1 172
Viet Nam	2005	80 454	98	1 402	2	81 856	99.8	9.3	2003	175		0.2				2005	82 031
Total region		**1 310 535**	**73**	**478 345**	**27**	**1 853 758**	**93.585**			**13 565**	**113 470**	**6.413**		**36**	**0.002**		**1 980 829**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 34
Area under irrigation by country

Country	Year	Full control irrigation	Spate irrigation	Equipped lowlands	Total equipped for irrigation	% of cultivated area	% of region	Part of equipped area actually irrigated	Annual increase rate over the last 10 years
Unit		ha	ha	ha	ha	%	%	%	%
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)		(6)	(7)
Bangladesh	2008	5 049 785			5 049 785	60	2.786	100	2.3
Bhutan	2007	27 685			27 685	18	0.015	100	0.2
Brunei Darussalam	1995	1 000			1 000	17	0.001	-	0.0
Cambodia	2006	353 566			353 566	9	0.195	90	4.5
China	2006	62 938 226			62 938 226	48	34.720	86	1.7
DPR Korea	1995	1 460 000			1 460 000	56	0.805	-	-
India	2008	66 334 000			66 334 000	39	36.593	94	1.0
Indonesia	2005	6 722 299			6 722 299	18	3.708	-	4.3
Lao PDR	2005	310 000			310 000	27	0.171	87	1.0
Malaysia	1994	340 717		21 970	362 687	5	0.200	-	1.5
Maldives	-						0.000	-	-
Mongolia	1993	57 300	27 000		84 300	6	0.047	75	-
Myanmar	2004	2 083 000		27 000	2 110 000	20	1.164	100	3.5
Nepal	2002	1 168 300			1 168 300	47	0.644	-	2.9
Pakistan	2008	19 270 000	720 000		19 990 000	94	11.027	96	1.7
Papua New Guinea	-						0.000	-	-
Philippines	2006	1 879 084			1 879 084	19	1.037	-	1.5
Republic of Korea	2002	880 400			880 400	47	0.486	-	-0.9
Sri Lanka	2006	570 000			570 000	29	0.314	81	0.0
Thailand	2007	6 414 800			6 414 800	34	3.539	79	2.1
Timor-Leste	2002	34 649			34 649	16	0.019	83	-
Viet Nam	2005	4 585 500			4 585 500	49	2.530	100	3.9
Total region		**180 480 311**	**747 000**	**48 970**	**181 276 281**	**41.1**	**100.000**	**-**	**-**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 35
Water managed area by country

Country	Year	Area equipped for irrigation (table 34)	Non equipped cultivated wetlands and valley bottoms	Non equipped flood recession cropping area	Total water managed area	% of irrigation potential	% of cultivated area
	Unit	ha	ha	ha	ha	%	%
		(1)	(2)	(3)	(4)=(1)+(2)+(3)	(5)	(6)
Bangladesh	2008	5 049 785	1 545 000		6 594 785	95	79
Bhutan	2007	27 685			27 685	-	18
Brunei Darussalam	1995	1 000			1 000	-	17
Cambodia	2006	353 566		367 688	721 254	72	18
China	2006	62 938 226			62 938 226	90	48
DPR Korea*	1995	1 460 000			1 460 000	-	56
India	2008	66 334 000			66 334 000	48	39
Indonesia	2005	6 722 299	3 133 317		9 855 616	91	26
Lao PDR*	2005	310 000		231 500	541 500	90	48
Malaysia	1994	362 687			362 687	88	5
Maldives	-					-	-
Mongolia	1993	84 300			84 300	16	6
Myanmar	2004	2 110 000			2 110 000	20	20
Nepal	2002	1 168 300			1 168 300	54	47
Pakistan	2008	19 990 000		1 250 000	21 240 000	100	100
Papua New Guinea	-					-	-
Philippines	2006	1 879 084	39 478	63 814	1 982 376	63	20
Republic of Korea	2002	880 400			880 400	49	47
Sri Lanka	2006	570 000			570 000	100	29
Thailand	2007	6 414 800			6 414 800	52	34
Timor-Leste	2002	34 649			34 649	-	16
Viet Nam	2005	4 585 500			4 585 500	49	49
Total region		**181 276 281**	**4 717 795**	**1 913 002**	**187 907 078**	**64.2**	**42.5**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 36
Full control irrigation techniques by country

Country	Year	Total full control equipped**	Year	Surface irrigation		Sprinkler irrigation		Localized irrigation	
Unit		ha		ha	%	ha	%	ha	%
Bangladesh	2008	5 049 785	2008	5 049 785	100.0		-		-
Bhutan	2007	27 685	2007	27 685	100.0		-		-
Brunei Darussalam	1995	1 000	1995	1 000	100.0		-		-
Cambodia	2006	353 566	2006	353 566	100.0		-		-
China	2006	62 938 226	2006	59 337 789	94.3	2 840 952	4.5	759 485	1.2
DPR Korea*	1995	1 460 000	1995	1 460 000	100.0		-		-
India	2008	66 334 000	2004	61 937 988	96.8	1 445 805	2.3	578 207	0.9
Indonesia	2005	6 722 299	2005	6 722 299	100.0		-		-
Lao PDR*	2005	310 000	2005	310 000	100.0		-		-
Malaysia	1994	340 717	1994	340 600	99.97		-	117	0.03
Maldives	-	0	-		-		-		-
Mongolia	1993	57 300	1993	13 900	24.3	43 400	75.7		-
Myanmar	2004	2 083 000	2004	2 083 000	100.0		-		-
Nepal	2002	1 168 300	-		-		-		-
Pakistan	2008	19 270 000	2008	19 270 000	100.0		-		-
Papua New Guinea	-	0	-		-		-		-
Philippines	2006	1 879 084	2006	1 863 664	99.2	4 500	0.2	10 920	0.6
Republic of Korea	2002	880 400	1996	888 800	100.0		-		-
Sri Lanka	2006	570 000	2006	570 000	100.0		-		-
Thailand	2007	6 414 800	2007	6 414 800	100.0		-		-
Timor-Leste	2002	34 649	-		-		-		-
Viet Nam	2005	4 585 500	2005	4 584 400	99.98	1 100	0.02		-
Total region		**180 480 311**		**171 229 276**	**96.8**	**4 335 757**	**2.5**	**1 348 729**	**0.8**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic
** The year for total can be different from the year of the irrigation techniques and therefore the total may be different from the sum of the techniques.

TABLE 37
Origin of full control irrigation water by country

Country	Year	Surface water		Groundwater		Mixed surface water and groundwater	
		Area	% of full control area	Area	% of full control area	Area	% of full control area
	Unit	ha	%	ha	%	ha	%
Bangladesh	2008	1 061 714	21.0	3 988 071	79.0		-
Bhutan	2007	27 685	100.0		-		-
Brunei Darussalam	1995	1 000	100.0		-		-
Cambodia	1993	269 500	100.0		-		-
China	2006	43 569 432	69.2	19 368 794	30.8		-
DPR Korea*	1990	1 220 000	85.9	200 000	14.1		-
India	2001	22 481 977	36.3	39 425 869	63.7		-
Indonesia	2005	6 655 076	99.0	67 223	1.0		-
Lao PDR*	2005	309 800	99.9	200	0.1		-
Malaysia	1994	313 460	92.0	27 257	8.0		-
Maldives	-		-		-		-
Mongolia	1993	21 201	37.0	36 099	63.0		-
Myanmar	2004	1 983 000	95.2	100 000	4.8		-
Nepal	2002	929 200	79.5	223 900	19.2	15 200	1.3
Pakistan	2008	7 180 000	37.3	4 130 000	21.4	7 960 000	41.3
Papua New Guinea	-		-		-		-
Philippines	2006	1 477 712	78.6	106 732	5.7	294 640	15.7
Republic of Korea	1996	843 500	94.9	45 300	5.1		-
Sri Lanka	2002	563 172	98.8	6 828	1.2		-
Thailand	2007	5 831 000	90.9	583 800	9.1		-
Timor-Leste	2002	33 956	98.0	693	2.0		-
Viet Nam	2005	4 539 645	99.0	45 855	1.0		-
Total region		**99 312 030**	**56.4**	**68 356 621**	**38.9**	**8 269 840**	**4.9**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 38
Harvested irrigated crops on full control areas by country

Country	Year	Equipped full control irrigation	Year	Full control equipped area actually irrigated	Year	Wheat	Barley	Maize	Rice	Other cereals	Vegetables including roots and tubers	Potatoes and sweet potatoes	Pulses
Unit		ha		ha		ha	ha	ha	ha	ha	ha	ha	ha
Bangladesh	2008	5 049 785	2008	5 049 785	2008	313 000	810	90 000	4 341 000	25 500	236 000	263 000	156 000
Bhutan	2007	27 685	2007	27 685	1994				27 400			500	
Brunei Darussalam	1995	1 000	-		1997				375				
Cambodia	2006	353 566	2006	317 225	2006				373 331				
China	2006	62 938 226	2006	54 218 976	2006	22 250 000		9 500 000	31 347 000	815 000	9 629 000		
DPR Korea*	1995	1 460 000	-		2006	73 000	5 000	323 000	465 000		146 000	104 000	86 000
India	2008	66 334 000	2008	62 286 000	2004	23 498 000	472 000	1 411 000	22 428 000	1 500 000			3 326 000
Indonesia	2005	6 722 299	-		2005			1 269 100	10 733 600		244 388	243 720	
Lao PDR*	2005	310 000	2005	270 742	2005				310 676		33 000		
Malaysia	1994	340 717	-		2006				363 000		6 000		
Maldives	-		-		-								
Mongolia	1993	57 300	1993	35 000	-								
Myanmar	2004	2 083 000	2004	2 083 000	2006	89 000		34 000	1 861 000		47 000	11 000	284 000
Nepal	2002	1 168 300	-		2006	629 000		415 000	710 000		39 000		
Pakistan	2008	19 270 000	2008	19 270 000	2008	7 334 600	81 990	946 530	2 515 400	730 800	352 656	154 317	1 006 441
Papua New Guinea	-		-		-								
Philippines	2006	1 879 084	-		2006			96 600	2 421 900		37 861		
Republic of Korea	2002	880 400	-		2006			3 000	760 000		137 000	31 000	
Sri Lanka	2006	570 000	2006	462 500	2006			700	699 900	100	13 600		800
Thailand	2007	6 414 800	2007	5 059 914	2007				6 268 080		83 421		
Timor-Leste	2002	34 649	2002	28 907	-								
Viet Nam	2005	4 585 500	2005	4 585 500	2005			265 540	6 842 127			99 532	
Total region		**180 480 311**				**54 186 600**	**559 800**	**14 354 470**	**92 467 789**	**3 071 400**	**11 004 926**	**907 069**	**4 859 241**

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 38
Harvested irrigated crops on full control areas by country (continued)

Country	Tobacco	Soya beans	Groundnuts	Fodder	Sugar cane	Cotton	Citrus	Bananas	Other annual crops	Other perennial crops	TOTAL	Cropping intensity (full control equipped area)	Cropping intensity (actually irrigated)
Unit	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	ha	%	%
Bangladesh	18 000				43 000	6 500			444 000	40 000	5 976 810	118%	118%
Bhutan											27 900	103%	103%
Brunei Darussalam									625		1 000	100%	-
Cambodia					9 956		1 244				384 531	109%	121%
China		2 600 000	1 900 000		472 000	2 632 000			7 396 000	4 841 000	93 382 000	148%	172%
DPR Korea*	7 000	93 000								39 000	1 341 000	-	-
India	215 000		1 052 000		4 043 000	2 591 000			10 842 000	5 442 000	76 820 000	120%	130%
Indonesia	198 200	279 900	324 000		95 450						13 388 358	199%	-
Lao PDR*					5 000	8 000	15 000				371 676	120%	137%
Malaysia			1 000		12 000						382 000	-	-
Maldives											-	-	-
Mongolia											-	-	-
Myanmar	1 000				79 000	85 000			200 000	31 000	2 722 000	131%	131%
Nepal					39 000				94 000		1 926 000	165%	-
Pakistan	51 398		9 012	2 459 500	1 241 300	3 054 300	199 369	35 558	718 457	560 046	21 451 674	111%	111%
Papua New Guinea											-	-	-
Philippines	23 884		12 400		65 000		1 970	14 210		22 000	2 695 825	143%	-
Republic of Korea		48 000					8 000		12 000	39 000	1 038 000	118%	-
Sri Lanka					17 400				4 100	7 400	744 000	131%	161%
Thailand					256 016				37 396	742 159	7 387 072	115%	146%
Timor-Leste											-	-	-
Viet Nam	8 600	97 119	139 304		105 800	14 790	46 068	54 626	170 485	884 201	8 728 192	190%	190%
Total region	**523 082**	**3 118 019**	**3 437 716**	**2 459 500**	**6 483 922**	**8 391 590**	**271 651**	**104 394**	**19 919 063**	**12 647 806**	**238 768 038**		

* DPR Korea = Democratic People's Republic of Korea; Lao PDR = Lao People's Democratic Republic

TABLE 39
Southern and Eastern Asia region compared to the world

Variable	Unit	Southern and Eastern Asia	World	SE Asia as % of the world
Total area 2009	1 000 ha	2 082 085	13 459 150	15
Cultivated area	1 000 ha	442 293	1 534 505	29
- in % of total area	%	21	11	-
- per inhabitant	ha	0.12	0.23	-
- per economic active person engaged in agriculture	ha	0.45	1.18	-
Total population 2009	inhabitants	3 605 445 000	6 818 021 000	53
Population growth 2008-2009	%/year	1.0	1.2	-
Population density	inhabitants/km²	173	51	-
Rural population as % of total population	%	61	50	-
Economically active population engaged in agriculture	%	56	40	-
Precipitation	km³/year	23 647	108 231	22
	mm/year	1 136	804	-
Internal renewable water resources	km³/ year	10 707	42 517	25
- per inhabitant	m³/year	2 970	6 236	-
Actual total renewable water resources	km³/ year	13 926	53 727	26
Total water withdrawal by sector	km³/year	1 981	3 944	50
- agricultural	km³/year	1 624	2 745	59
- in % of total water withdrawal	%	82	70	-
- municipal	km³/year	176	467	38
- in % of total water withdrawal	%	9	12	-
- industrial	km³/year	180	732	25
- in % of total water withdrawal	%	9	19	-
Total water withdrawal by source	km³/year	1 981	3 944	50
- total freshwater	km³/year	1853.76	3 938	47
- in % of internal renewable water resources	%	17	9	-
- in % of total actual renewable water resources	%	13	7	-
- desalinated water	km³/year	0.04	6	0.6
Irrigation	ha	181 276 281	304 405 000	60
- in % of cultivated area	%	41	20	-

Regional figures

EXPLANATORY NOTES

Figure 3: Regional division of the world adopted by AQUASTAT

- Ø This is the regional division as given in FAO. 2003. Review of world water resources by country. *Water Report 23.* FAO, Rome. 110 pp.

FIGURE 3
Regional division of the world adopted by AQUASTAT

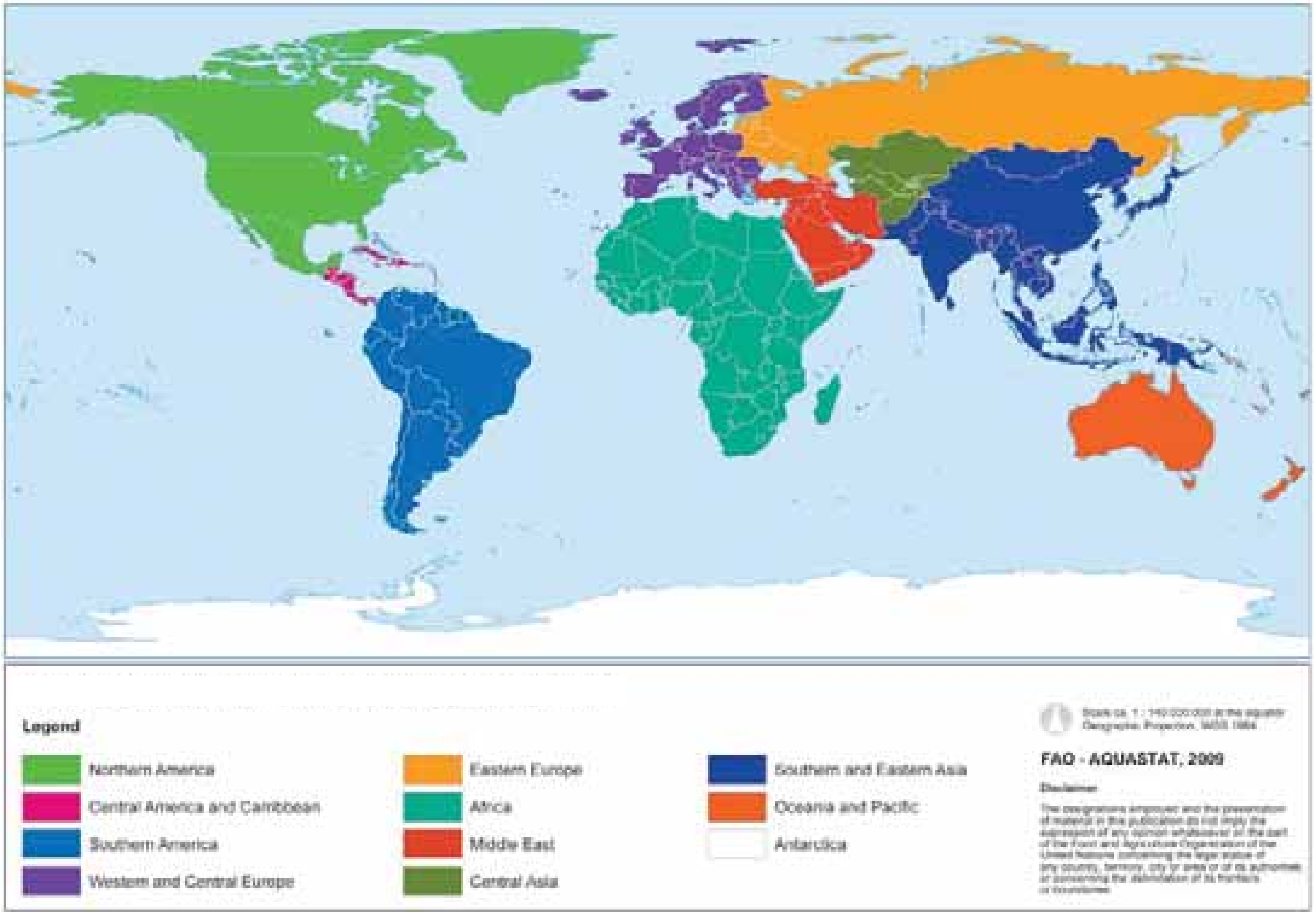


FIGURE 4
Regional Division of Southern and Eastern Asia

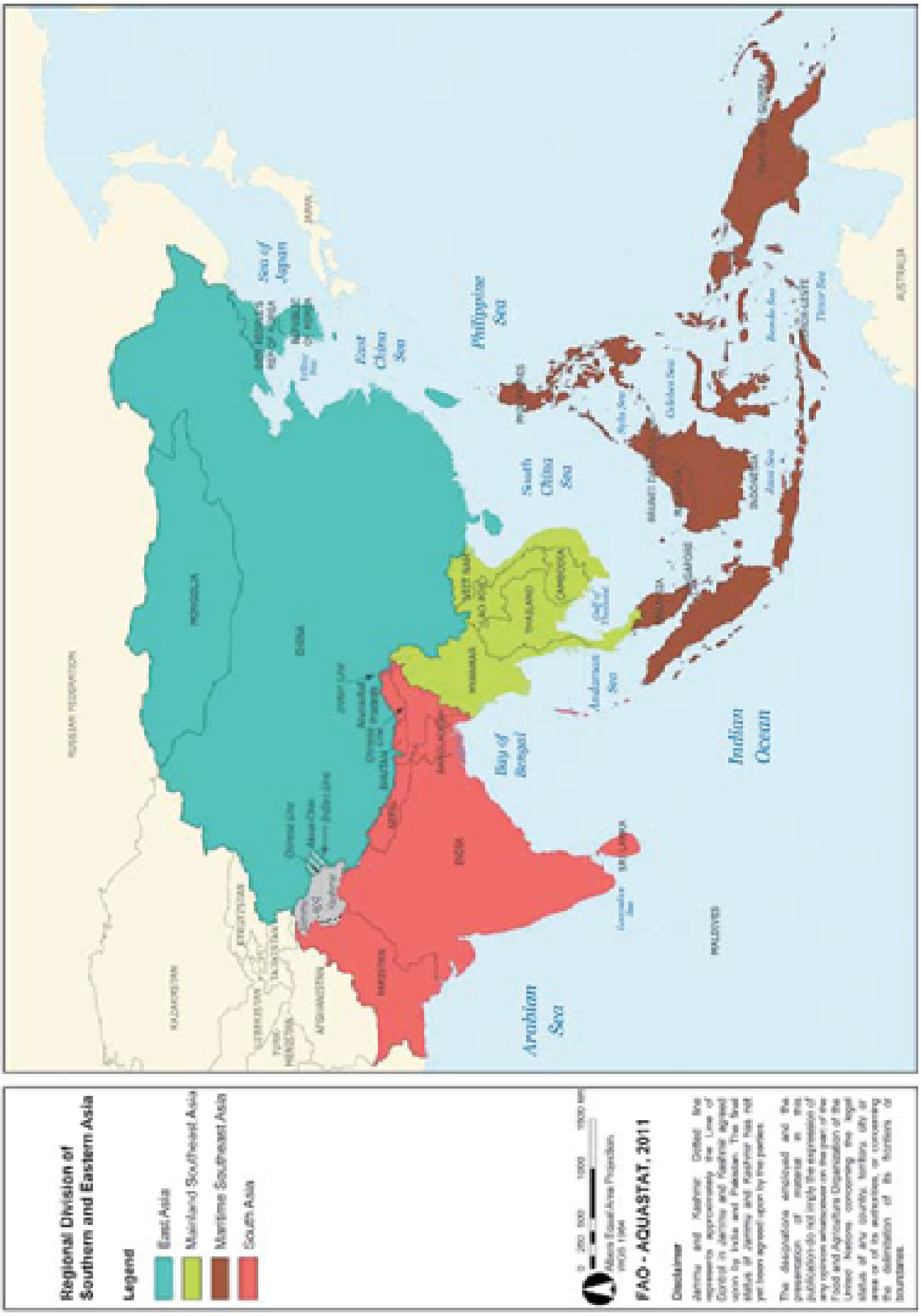


FIGURE 5
Average annual precipitation

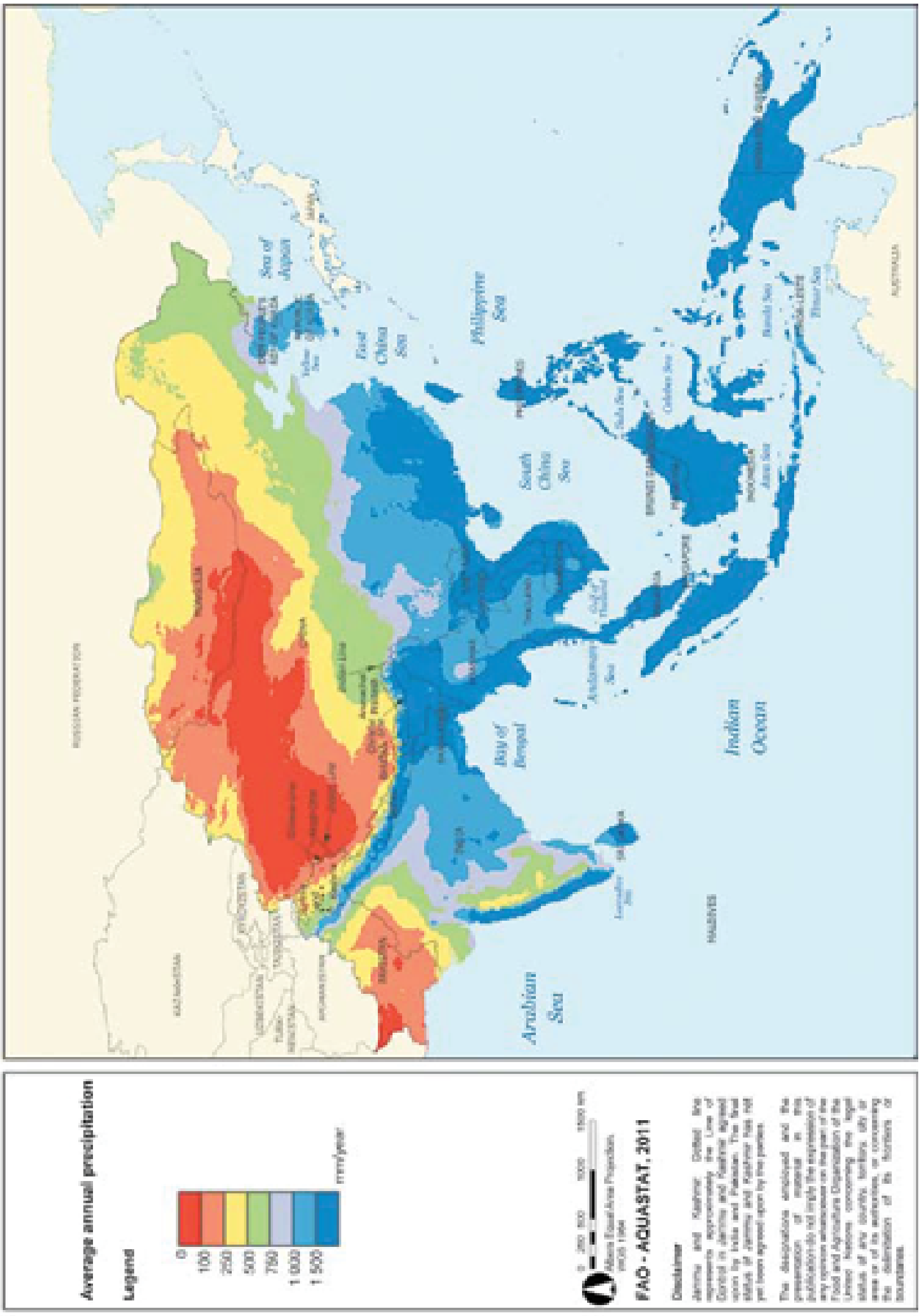


FIGURE 6
Population density

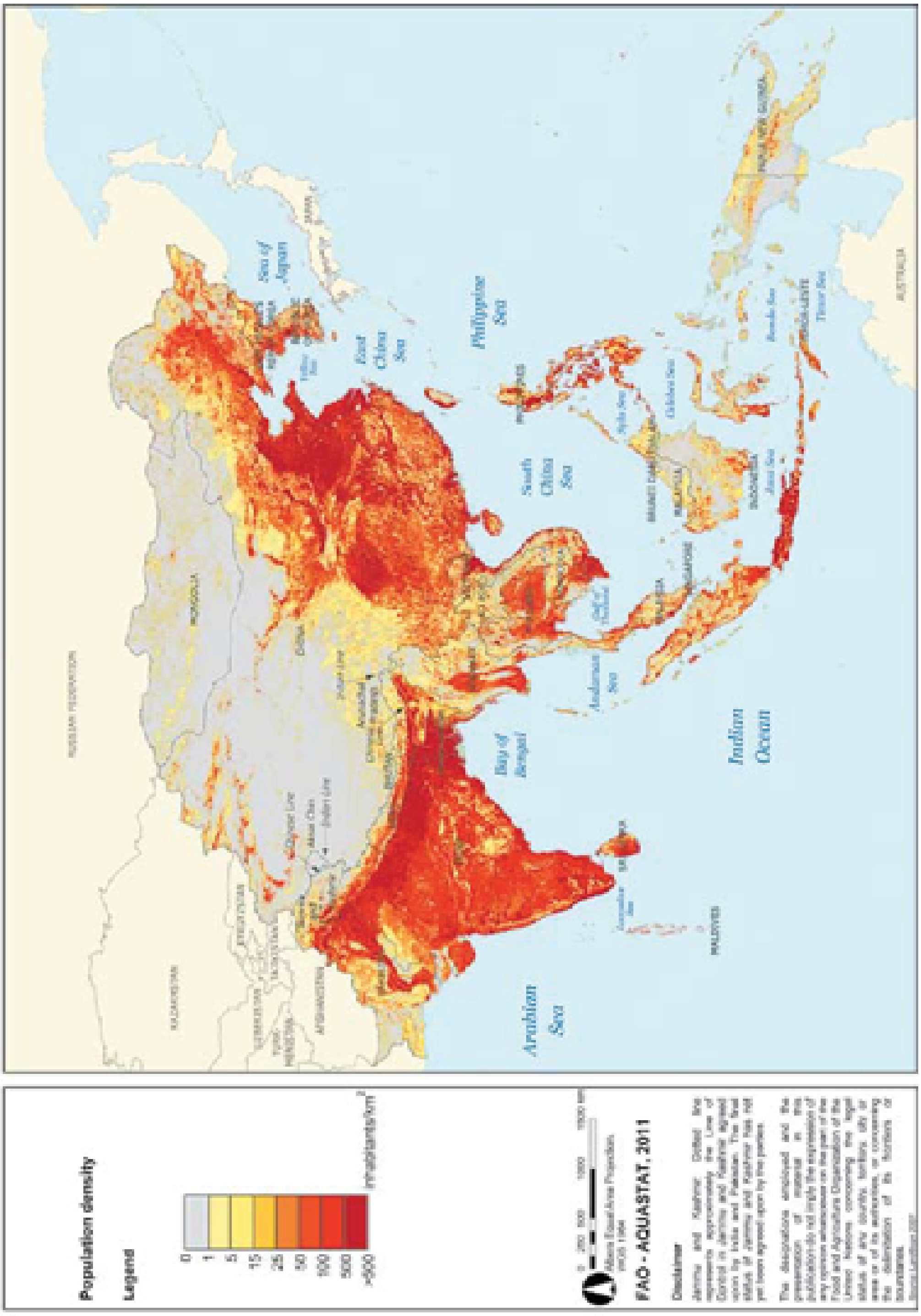


FIGURE 7
Internal renewable water resources

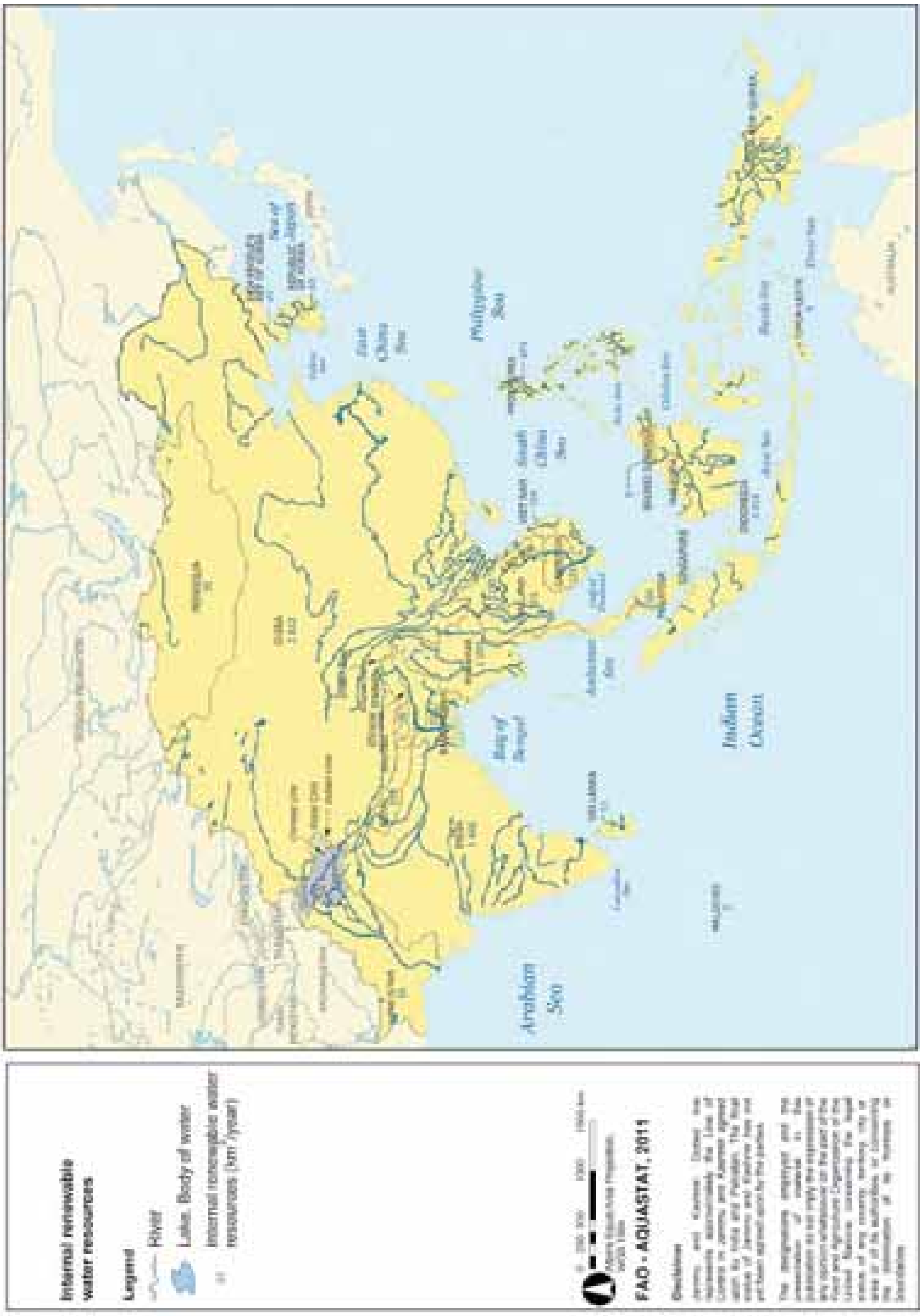


FIGURE 8
Total renewable water resources per inhabitant (2009)

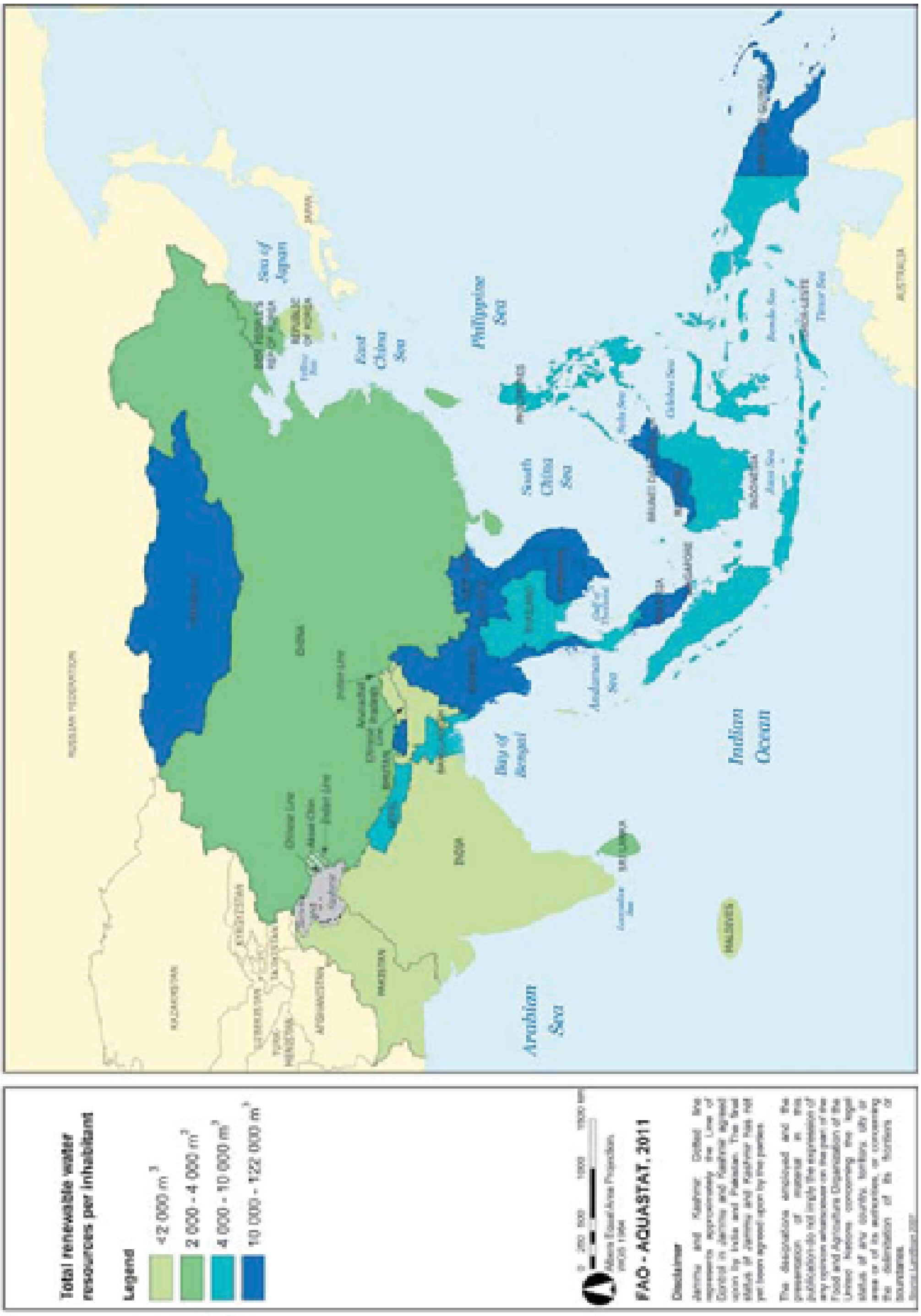


FIGURE 9
Transboundary river basins

FIGURE 10
Annual water withdrawal per inhabitant

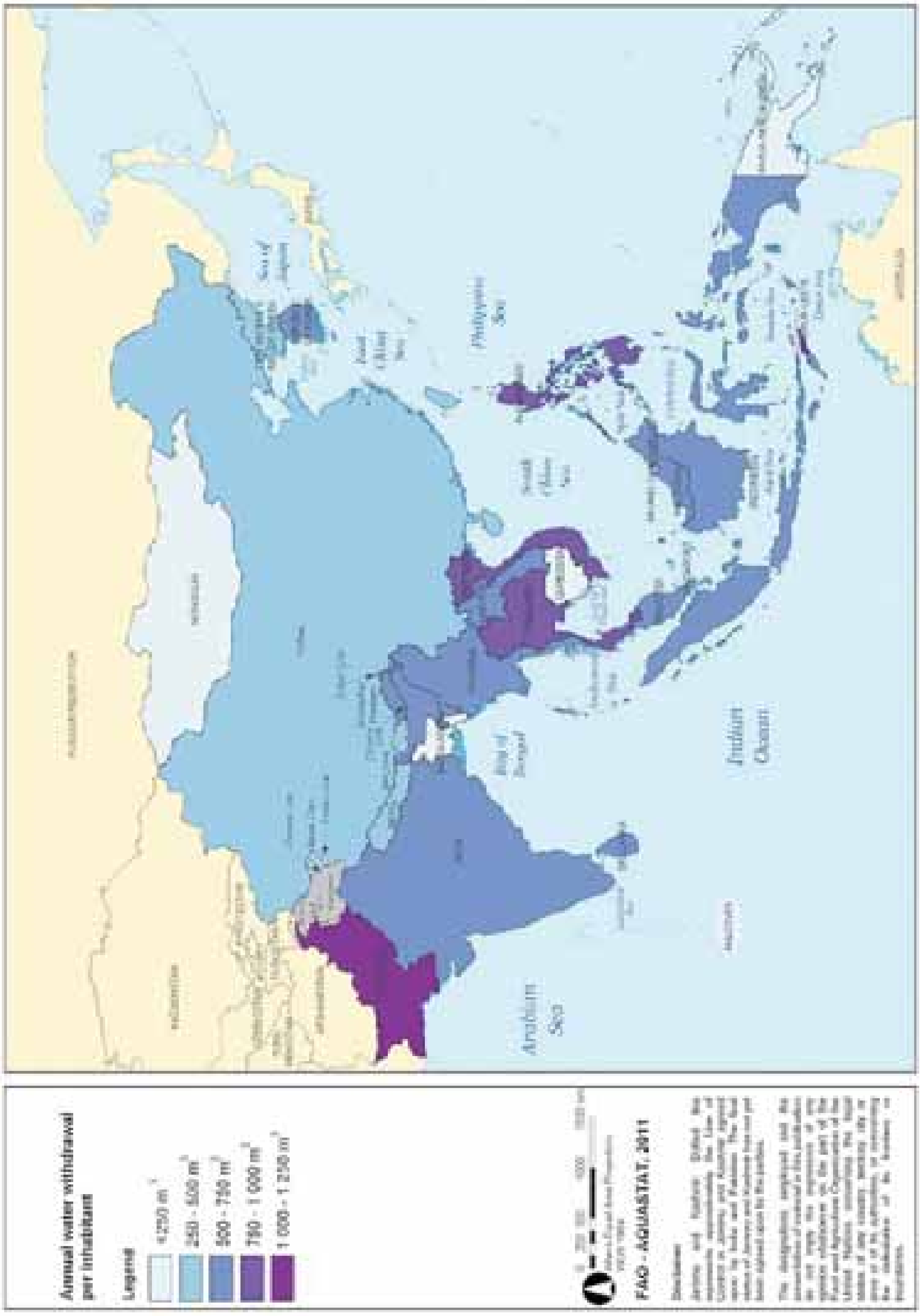


FIGURE 11

Annual fresh water withdrawal as a percentage of total actual renewable water resources: Millennium Development Goal Water Indicator

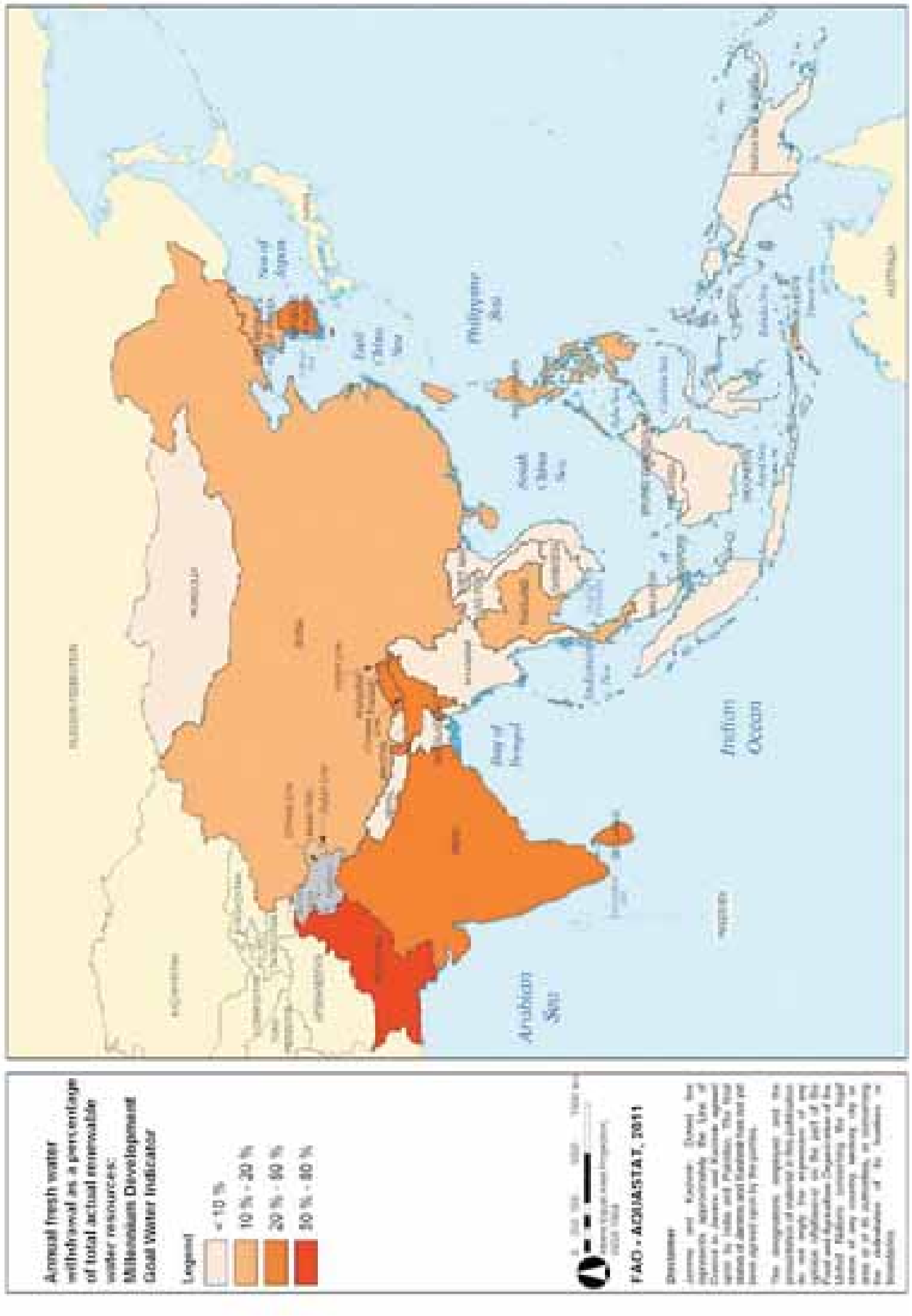


FIGURE 12
Area equipped for irrigation

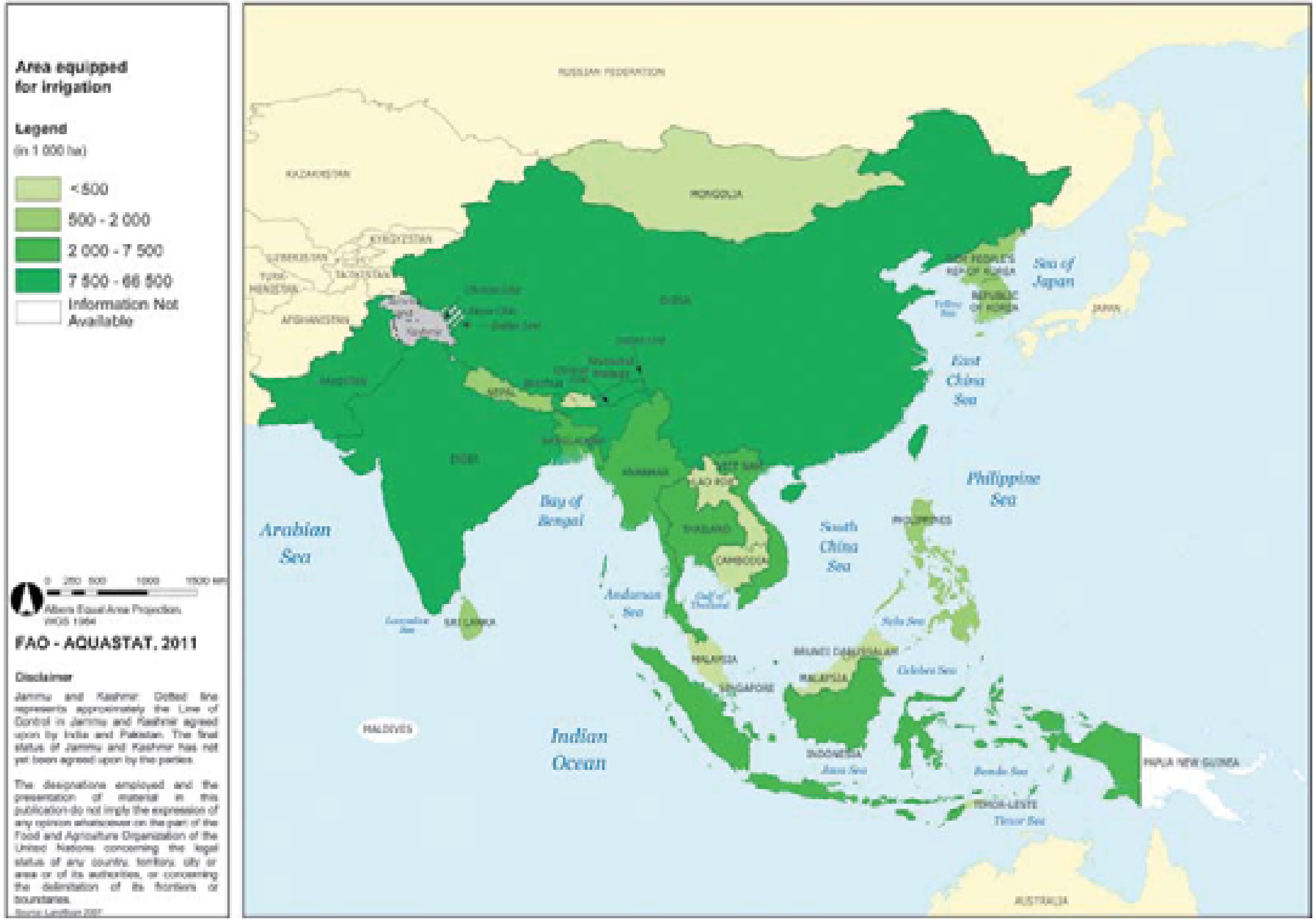


FIGURE 13
Area equipped for irrigation as percentage of country area

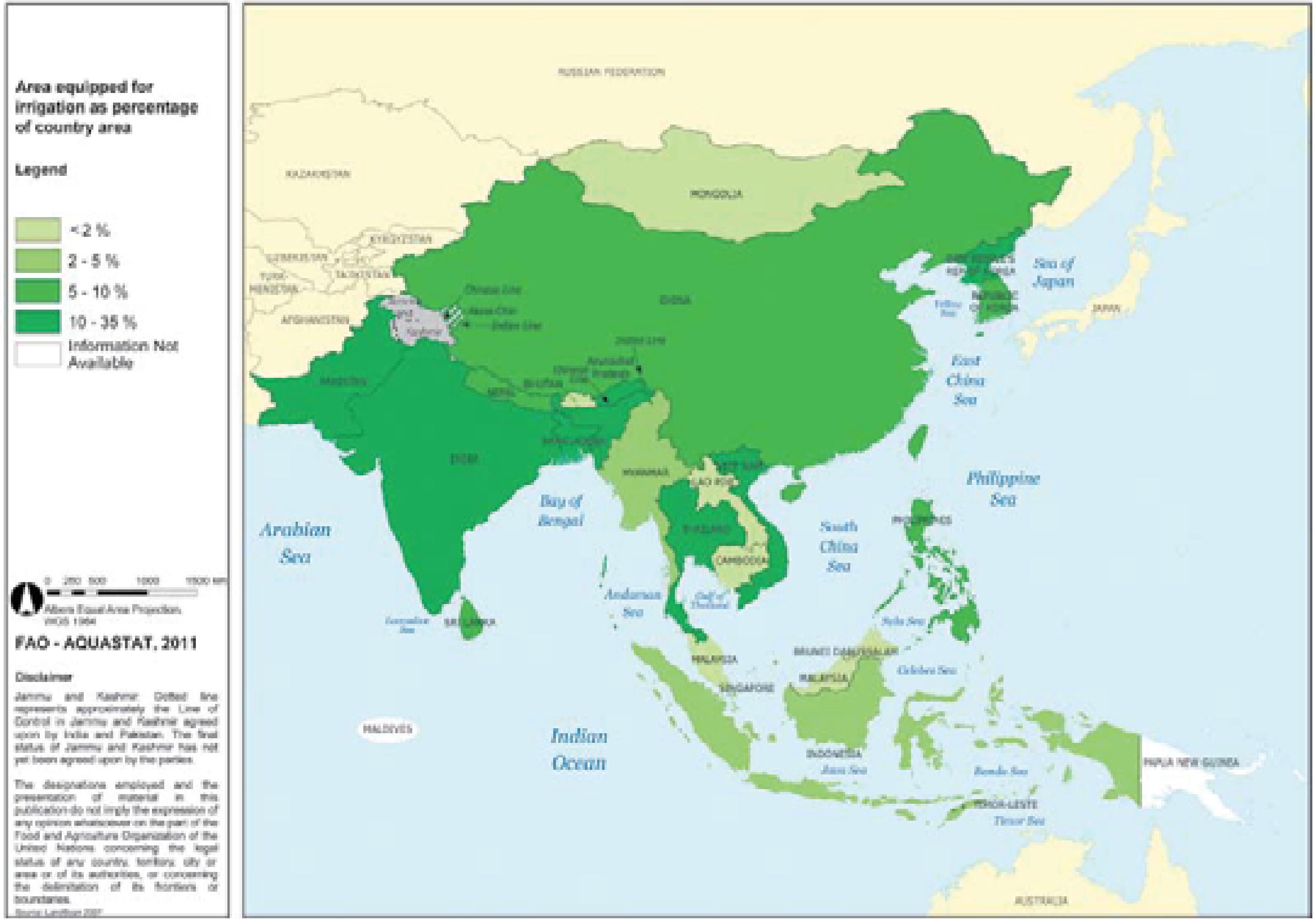
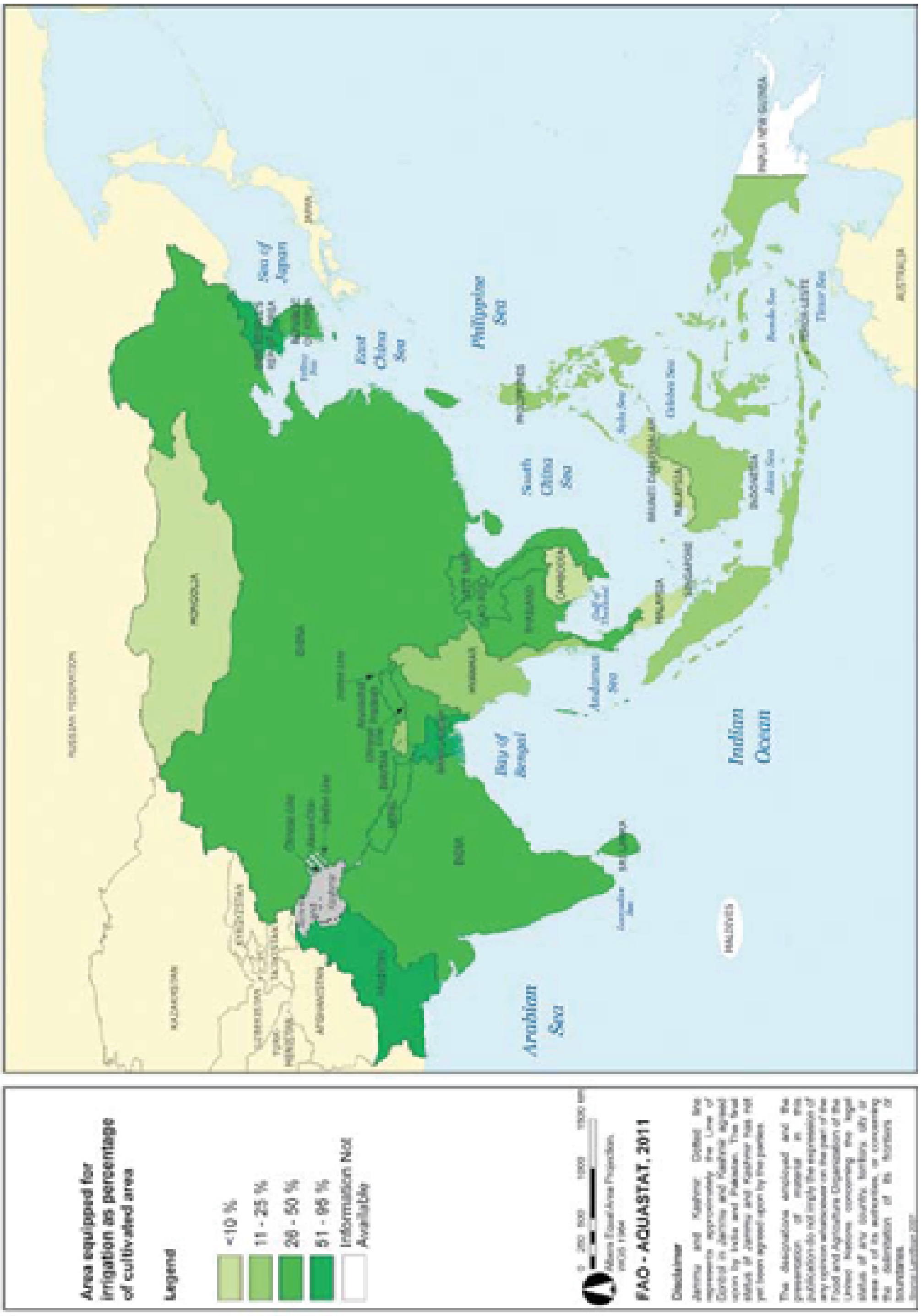


FIGURE 14

Area equipped for irrigation as percentage of cultivated area



SECTION III
Transboundary river basins

EXPLANATORY NOTES

In this section river basin profiles for the Ganges-Brahmaputra-Meghna, Indus, Mekong and Salween river basins have been designated as an extra to the publication with their exclusive assigned numbers to figures and tables, and including a detailed map for each river basin.

The main reason for this is that these profiles have also been included on the AQUASTAT river basin web page *(http://www.fao.org/nr/water/aquastat/countries_regions/index.stm)*, where each river basin profile can be downloaded as a stand-alone profile in PDF format.

A hyphen (-) in the river basin tables indicates that no information is available.

Ganges-Brahmaputra-Meghna river basin

GEOGRAPHY, POPULATION AND CLIMATE

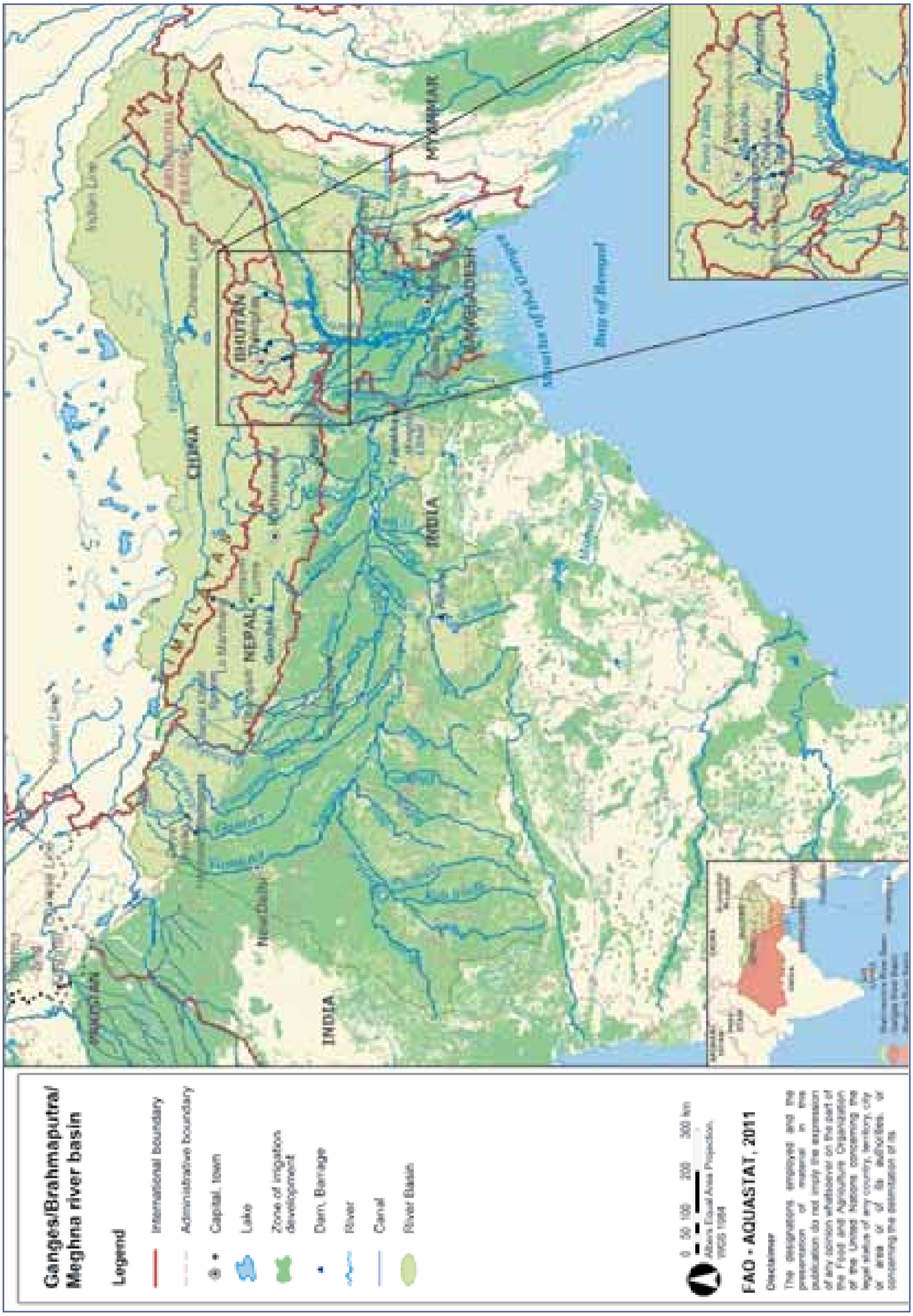
Geography

The Ganges-Brahmaputra-Meghna (GBM) river basin is a transboundary river basin with a total area of just over 1.7 million km^2, distributed between India (64 percent), China (18 percent), Nepal (9 percent), Bangladesh (7 percent) and Bhutan (3 percent) (Table 1). Nepal is located entirely in the Ganges river basin and Bhutan is located entirely in the Brahmaputra river basin. The GBM river system is considered to be one transboundary river basin, even though the three rivers of this system have distinct characteristics and flow through very different regions for most of their lengths. They join only just a few hundred kilometres upstream of the mouth in the Bay of Bengal. Not only is each of these three individual rivers big, each of them also has tributaries that are important by themselves in social, economic and political terms, as well as for water availability and use. Many of these tributaries are also of a transboundary nature (Biswas, after 2006). The GBM river system is the third largest freshwater outlet to the world's oceans, being exceeded only by the Amazon and the Congo river systems (Chowdhury and Ward, 2004).

TABLE 1

Country areas in the Ganges-Brahmaputra-Meghna river basin (Source: JRCB)

Basin	Area		Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total area of the country
	km^2	% of Southeast Asia				
Ganges	1 087 300	52	India	860 000	79	26
			China	33 500	3	0.3
			Nepal	147 500	14	100
			Bangladesh	46 300	4	32
			Bhutan	-	-	-
Brahmaputra	543 400	27	India	195 000	36	6
			China	270 900	50	3
			Nepal	-	-	-
			Bangladesh	39 100	7	27
			Bhutan	38 400	7	100
Meghna	82 000	4	India	47 000	57	1
			China	-	-	-
			Nepal	-	-	-
			Bangladesh	35 000	43	24
			Bhutan	-	-	-
Total	**1 712 700**	**83**	**India**	**1 102 000**	**64**	**33**
			China	**304 400**	**18**	**3**
			Nepal	**147 500**	**8**	**100**
			Bangladesh	**120 400**	**7**	**83**
			Bhutan	**38 400**	**3**	**100**


Ganges/Brahmaputra/
Meghna river basin
Legend
International boundary
Administrative boundary
Capital, town
Lake
Zone of irrigation development
Dam, Barrage
River
Canal
River Basin
FAO - AQUASTAT, 2011
CHINA
NEPAL
BHUTAN
BANGLADESH
INDIA
MYANMAR
PAKISTAN
Bay of Bengal

The headwaters of both the Ganges and the Brahmaputra river originate in the Himalayan mountain range in China. The Ganges river flows southwest into India and then turns southeast, being joined by many tributaries. After flowing into Bangladesh, the Ganges, Brahmaputra and Meghna rivers join and flow into the Bay of Bengal as the Meghna river. The Brahmaputra river (known as Yalung Zangbo in China) flows east through the southern area of China, then flows south into eastern India, turns southwest, then enters Bangladesh (where it is also called Jamuna) before merging with the Ganges and Meghna rivers. The tributaries of the Meghna river originate in the mountains of eastern India (the main one called Barak), flow southwest and join. The Meghna river flows southwest and joins the Ganges and Brahmaputra rivers before flowing into the Bay of Bengal (McEwen, 2008).

Bangladesh has been formed as the greatest deltaic plain at the confluence of the Ganges, Brahmaputra and Meghna rivers and their tributaries. About 80 percent of the country is made up of fertile alluvial lowland that becomes part of the Greater Bengal Plain. The country is flat with some hills in the northeast and southeast. About 7 percent of the total area of Bangladesh is covered with rivers and inland water bodies and the surrounding areas are routinely flooded during the monsoon.

Population

It is estimated that at least 630 million people live in the GBM river basin. This is almost two-thirds of the population of Africa, while the size of Africa is about 18 times the size of the GBM river basin. In 2008, the total population in Bhutan, which is entirely located in the Brahmaputra river basin, was estimated at 687 000 inhabitants, of which 66 percent is rural. About 95 percent of the population lives in the southern subtropical zone or in the central mid-mountainous zone of Bhutan, mainly in the relatively gentle sloping areas of the river valleys. In Nepal, located entirely in the Ganges river basin, the total population was 28.8 million, of which almost 83 percent rural. The total population of Bangladesh is 160 million (73 percent rural) of which 122 million inhabitants live inside the GBM river basin. The total territory of India has a population estimated at 1 181 million inhabitants (71 percent live in rural areas), of which 476 million inhabitants live inside the GBM river basin (World Bank, 2010). In the total territory of China, the population is about 1 345 million, of which 57 percent are living in rural areas. However, only 1.7 million inhabitants are estimated to be living in the GBM river basin (World Bank, 2010). Population density in the basin area ranges from 6 and 18 inhabitants/km^2 in China and Bhutan respectively, to 195, 432 and 1 013 inhabitants/km^2 in Nepal, India and Bangladesh respectively.

In 2008, access of population to improved drinking water sources reached 92, 88 and 80 percent in Bhutan, Nepal and Bangladesh respectively. In the total territory of India, 88 percent of the population had access to improved water sources and in the total territory of China this was 89 percent.

The GBM river basin contains the largest number of the world's poor in any one region. The population is increasing steadily, population density is very high in a large part of the basin, and, unless the current development trends are broken, poverty will become even more pervasive. The region is endowed with considerable natural resources that could be used to foster sustainable economic development. Water could be successfully used as the engine to promote economic development in the region, which has been hindered because the most populous part of the basin is shared by three countries – Bangladesh, India, and Nepal – which have in the past been unable to agree to an integrated development plan (Biswas and Uitto, 2001).

Climate

The GBM river basin is unique in the world in terms of diversified climate. For example, the Ganges river basin is characterized by low precipitation in the northwest of its upper region and high precipitation in the areas along the coast. High precipitation zones and dry rain shadow areas are located in the Brahmaputra river basin, whereas the world's highest precipitation area is situated in the Meghna river basin (Mirza et al., 2011).

Precipitation in the Ganges river basin accompanies the southwest monsoon winds from July to October, but it also comes with tropical cyclones that originate in the Bay of Bengal between June and October. Only a small amount of rainfall occurs in December and January. In the upper Gangetic Plain in Uttar Pradesh (India), annual rainfall averages 760–1 020 mm, in the Middle Ganges Plain of Bihar (India) 1 020–1 520 mm, and in the delta region 1 520–2 540 mm. The delta region experiences strong cyclonic storms, both before the commencement of the monsoon season – from March to May – and at the end of it – from September to October. Some of these storms result in much loss of life and the destruction of homes, crops and livestock (Ahmad and Lodrick).

Nepal, located entirely in the Ganges river basin, experiences tropical, meso-thermal, micro-thermal, taiga and tundra types of climate. Mean annual precipitation is 1 500 mm, with a maximum of 5 581 mm recorded in 1990 at Lumle in Kaski district at an elevation of 1 740 m and a minimum of 116 mm recorded in 1988 at Jomsom in Mustang district. There are two rainy seasons in Nepal: one in the summer from June to September, when the southwest monsoon brings more than 75 percent of the total rainfall, and the other in winter from December to February, accounting for less than 25 percent of the total. With the summer monsoon, rain first falls in the southeast of the country and gradually moves west with diminishing intensity.

During winter, rain first enters Nepal in the west and gradually moves eastward with diminishing intensity. Temperature increases from the high Himalayan region to the lowland terai (northern part of the Ganges plain). Extreme temperatures recorded are –14.6 °C in 1987 in Lo Manthang (Mustang district), located at an elevation of 3 705 m, and 44 °C in 1987 in Dhangadhi (Kailali district), located at an elevation of 170 m. Precipitation falls as snow at elevations above 5 100 m in summer and above 3 000 m in winter. Temperature is a constraint to crop production in the Himalayas and the mountain region where only a single crop per year can be grown. On the other hand, in the lowland terai three crops per year are common where the water supply is adequate. Single rice cropping is possible up to elevations of 2 300 m while double rice cropping is limited to areas below 800 m.

The climate in Bhutan, located entirely in the Brahmaputra river basin, is cold in the north, with year-round snow on the main Himalayan summits, temperate in the inner Himalayan valleys of the southern and central regions, and humid and subtropical in the southern plains and foothills. Bhutan's generally dry spring starts in early March and lasts until mid-April. Summer weather starts in mid-April with occasional showers and continues through the early monsoon rains of late June. Autumn, from late September or early October to late November, follows the rainy season. From late November until March winter sets in, with frost throughout much of the country and snowfall common above elevations of 3 000 m. Temperatures vary according to elevation.

In the capital Thimphu (elevation 2 320 m), temperatures range from approximately 14 °C to 25 °C during the monsoon season of June through September but drop to between about –4 °C and 14 °C in January. Most of the central portion of the country experiences a cool, temperate climate year-round. In the south, a hot, humid climate helps maintain a fairly even temperature range of between 15 °C and 30 °C year-round, although temperatures sometimes reach beyond 35 °C in the valleys during the summer. Average annual precipitation is estimated at 2 200 mm, varying from a low of 477 mm at Gidakhom in Thimpu district to as high as 20 761 mm at Dechenling in Samdrup Jhongkhar district. The climate of the north is severe and cold with only about 40 mm of annual precipitation, primarily snow. In the temperate central regions, a yearly average precipitation of around 1 000 mm is more common and 7 800 mm has been registered at some locations in the humid, subtropical south, giving rise to the thick tropical forest. Western Bhutan is particularly affected by monsoons that bring between 60 and 90 percent of the region's precipitation. The winter northeast monsoon brings gale-force winds down through high mountain passes.

Bangladesh has a tropical monsoon climate with significant variations in rainfall and temperature throughout the country. There are four main seasons: i) the pre-monsoon during March-May, which has the highest temperatures and experiences the maximum intensity of cyclonic storms, especially in May; ii) the monsoon during June-September, when the bulk of rainfall occurs; iii) the post-monsoon during October-November which, like the pre-monsoon season, is marked by tropical cyclones on the coast; iv) the cool and sunny dry season during December-February. Average annual precipitation over the country is 2 320 mm, of which about 80 percent occurs in the monsoon. It varies from 1 110 mm in the extreme northwest to 5 690 mm in the northeast. The country is regularly subjected to drought, floods and cyclones. Mean annual lake evaporation is 1 040 mm, which is about 45 percent of the mean annual rainfall. Mean annual temperature is about 25 °C, with extremes as low as 4 °C and as high as 43 °C. Humidity ranges between 60 percent in the dry season and 98 percent during the monsoon.

WATER RESOURCES

Surface water

The main Ganges river is the flow combination of two rivers, the Alaknanda and the Bhagirathi, which meet at Deva Prayag in Uttarakhand State (India) within the mountain range of the Himalayas. During its middle course in an easterly direction, a number of large and small tributaries join onto the northern side (left bank) from the Himalayan sub-basin, namely, Ramganga, Sarda, Gomti, Ghagra, Gandak and Kosi, the last five originate within the mountain range of the Himalayas in Nepal. Therefore, the contribution of flow of these tributaries is from Nepal within the Himalayan range and from India on the southern side of the Himalayan foothills. Another tributary, Mahananda, joins the river in Bangladesh. On the southern, peninsular side (right bank), the tributaries are Yamuna, Kehtons, Son, Punpun and Kiul. Amongst the Himalayan streams, the Ghagra with its tributaries contributes the maximum annual runoff (about 94.5 km^3) and the Gomti the minimum (about 7.4 km^3). Amongst the peninsular streams, the Son contributes the maximum annual runoff (about 32 km^3) and the Kiul the minimum (about 35 km^3).

The Ganges river enters Bangladesh about 50 km below Farakka (left side falls in Bangladesh) and tributaries such as Mahananda, Punarbhaba, Atrai (Boral) and Karatoya, which originate in India, join the Ganges river on its left side. The river joins the Brahmaputra river another 220 km further downstream, near Goalanda Ghat in Bangladesh as the Padma and further down the combined discharge joins the Meghna river at Chandpur after travelling another 70 km. The combined stream is called the Meghna river, which 90 km further downstream discharges into the Bay of Bengal. The total length of the Ganges-Padma river from Deba Prayag to the sea is about 2 515 km (Parua, after 2001).

The Brahmaputra river originates on the northern slope of the Himalayas in China, where it is called Yalung Zangbo. It flows eastwards for about 1 130 km, then turns southwards and enters Arunachal Pradesh (India) at its northern-most point and flows for about 480 km. Then it turns westwards and flows through Arunachal Pradesh, Assam and Meghalaya for another 650 km and then enters Bangladesh. Then the river curves to the south and continues on this course for about 240 km until its confluence with the Ganges river. Within Bangladesh, the river varies considerably in width ranging from less than 2 km to more than 12 km. The Brahmaputra river is classed as a braided channel, while the Ganges river is basically a meandering channel.

During low flows the river becomes a multiple channel stream with sand bars in between and the channels shift back and forth between the main stream banks, which are 6 to 12 km apart. The discharge of the Brahmaputra river mostly comes from the snowmelt in China on the other side of the Himalayas before it enters Arunachal Pradesh. In Arunachal Pradesh, Assam and Meghalaya of India and Dinajpur and Mymenshingh districts of Bangladesh rainfall is quite heavy and this contributes substantially to the river flow. The river reach between Bahadurabad, where the river leaves India and enters Bangladesh, and Aricha, where the river joins the Ganges river, is popularly known as Jamuna in Bangladesh (Parua, after 2001). The total length of the river from its source to the sea is about 2 840 km.

The Meghna river system flows on the east of the Brahmaputra river through Bangladesh. The Barak river divides into two branches within the Assam state in India. The northern branch is called Surma, which flows southwards through the eastern side of Bangladesh next Sylhet town. The southern branch is called Kushiara, which flows through India and then enters Bangladesh. First the northern branch joins the Meghna river near Kuliar Char and then the southern branch joins the Meghna river near Ajmiriganj. The lower Meghna river is one of the largest rivers in the world, being the mouth of the three great rivers: Ganges-Padma, Brahmaputra and Meghna. The total length of the river is about 930 km. The river is predominantly a meandering channel, but in several reaches, especially where small tributaries contribute sediment, braiding is evident with sand islands bifurcating the river into two or more channels (Parua, after 2001).

The annual flow of the Brahmaputra river basin from China to India is 165.40 km^3 and from Bhutan to India 78 km^3. The annual flow of the Brahmaputra river basin from India to Bangladesh is 537.24 km^3. The annual flow of the Ganges river basin from China to Nepal is 12.0 km^3. All rivers in Nepal drain into the Ganges river with an annual flow of 210.2 km^3 to India. The annual flow of the Ganges river basin from India to Bangladesh is 525.02 km^3. The annual flow of the Meghna river basin from India to Bangladesh is 48.36 km^3. This gives a total annual GBM river basin inflow into Bangladesh from India of 1 110.6 km^3.

Based on observations of the flood cycle in the Ganges river, the flow starts decreasing in October, is minimum between the last week of March and the last week of April and is maximum between the last week of August and the last week of September (Parua, after 2001).

Over 138 700 m^3/s of water flows into the Bay of Bengal during floods through a single outlet of the GBM rivers in Bangladesh. This is the largest in the world for a single outlet to the sea and exceeds even that of the Amazon discharge into the sea by about 1.5 times (Parua, after 2001).

Groundwater

The groundwater potential in the Ganges and Brahmaputra river basins is quite high but it is primarily confined to piedmont areas in India. It has been estimated that the Ganges river basin in India and Nepal has an annual groundwater yield of 108.5 km^3, while the Brahmaputra river basin in Assam (India) has a yield potential of 10.7 km^3. Compared to India, groundwater recharge potential is lower in Bangladesh, estimated at 21 km^3/year. Except for a limited area in the northwest, the top soil in most places in Bangladesh is composed of old alluvium with a large percentage of clay materials. The old alluvium is dissected in old stream beds, which in turn are connected with the existing stream system (Fazal, 1990). The groundwater resources in Bhutan are probably limited and are drained by the surface water network, which means that they are more or less equal to overlap between surface water and groundwater.

Water quality

In all the countries of the GBM river basin, the deterioration of both surface water and groundwater quality is now a matter of serious concern. Water is essential to sustain agricultural growth and productivity. More than half of the morbidity in the GBM basin stems from the use of impure drinking water. Safe water supply and hygienic sanitation are basic minimum needs, which the GBM river basin countries are yet to meet in both rural and urban areas. A holistic approach is required to monitor the water quality in each country together with regional initiatives, both to prevent further deterioration and to bring about improvement in the quality of water. Monitoring of water quality in the GBM rivers is not as extensive as it should be except in the case of the Ganges river in India and the Buriganga river in Bangladesh. Setting up uniform standards, relating to water quality along with establishing an effective water quality monitoring network in all countries is important, as well as a review of their existing water quality/pollution laws. Coordination of their actions in order to deal with transboundary transmission of pollution and evolving a mechanism for real time water quality data exchange could lead to efficient water quality management (Biswas, after 2006).

In Bangladesh, irrigation water quality has deteriorated owing to pollution from agrochemicals, industrial waste and other sources. Arsenic contamination of groundwater has been reported in many government and donor agency documents (GoB, UNICEF, WB, FAO). Arsenic concentration has been found to be at a maximum within the upper 50 m depth of aquifers in most regions of the country (Water Aid, 2000). In many places concentration of iron and arsenic in irrigation water has gone beyond the limit of safe water quality standards of Bangladesh and WHO. Some diseases and health hazards such as arsenicosis, blindness, physical disability, occur as a result of arsenic toxicity to humans (RDA, 2001). Throughout the country, about 1.44 million tubewells have been affected by arsenic contamination and about 30 million people are exposed to arsenic toxicity (Ahmed, 2007). The mitigation of the additional problems of salinity and arsenic in Bangladesh involves special action plans. Saline intrusion in coastal areas could be addressed through dry season flushing of channels by means of methods such as storing monsoon water and resuscitating moribund channels. The Bangladesh Arsenic Mitigation Water Supply Project (BAMWSP) is presently engaged in assessing the extent, dimensions, and causes of the arsenic problem with a view to developing a long-term strategy for supplying arsenic-free water (Biswas, after 2006).

In Bangladesh, during the dry season groundwater has become an increasingly important source of water for irrigation, municipal and industrial purposes. Some environmental hazards have been encountered in many areas and a number of adverse effects have emerged as a result of the over-abstraction of groundwater, such as lowering of water tables, reduction in dry season flows of rivers and streams, groundwater pollution, intrusion of saline water in coastal areas, ecological imbalance and possible land subsidence. There has been evidence of permanent lowering of groundwater levels in some locations, particularly in the Dhaka metropolitan area where the average annual decline in the groundwater level is about 3 m (BADC, 2006) and in the northwest region of the country.

In India, the water quality of rivers in their upper reaches is good, though the importance of water use for cities, agriculture and industries, and the lack of wastewater treatment plants in the middle and lower reaches of most rivers cause a major degradation of surface water quality. Groundwater is also affected by municipal, industrial and agricultural pollutants. The pollution control action plan of the Ganges basin was formulated in 1984 and has been enforced by the Ganges Project Directorate, under the Central Ganges Authority, to oversee pollution control and the consequent cleaning of the Ganges river. The water quality in the middle stretch of the Ganges river, which had deteriorated to class C and D (the worst class is E, the best A), was restored to class B in 1990 after the implementation of the action plan.

Climate change

The GBM rivers create flood problems in their respective basin areas during monsoon months almost every year. Bangladesh, being the lower riparian country, suffers most from such floods which cause enormous loss of life and property (Parua, after 2001).

Climate change may alter the distribution and quality of GBM river basin water resources. Some of the impacts include occurrence of more intense rains, changed spatial and temporal distribution of rainfall, higher runoff generation, low groundwater recharge, melting of glaciers, changes in evaporative demands and water use patterns in agricultural, municipal and industrial sectors, etc. These impacts lead to severe influences on agricultural production and food security, ecology, biodiversity, river flows, floods, and droughts, water security, human and animal health and sea level rise.

Bihar is the worst flood hit state in India. Hardly a year passes without severe flood damage. With the onset of the monsoon, rivers come down from the Himalayan hills in Nepal with enormous force, causing rivers like Ghagra, Kamla, Kosi, Bagmati, Gandak, Ganges, Falgu, Karmanasa, Mahanadi to rise above the danger level. This results in severe floods in North Bihar. The Kosi river, popularly known as "the sorrow of Bihar", has not yet matured enough to settle on a course, and has changed its course 15-16 times the last time being as recent as August 2008. About 2.8 million people were said to have been marooned by these floods in Bihar.

Bangladesh is now widely recognized as one of the countries that is most vulnerable to climate change. Increased variability of temperatures and rainfall and increased occurrence of natural hazards are expected to affect the availability of both surface water and groundwater. Investments are needed to ensure a continuous and sustainable access to water resources.

WATER-RELATED DEVELOPMENTS IN THE BASIN

Use of water of the Ganges river for irrigation, either by flooding or by means of gravity canals, has been common since ancient times. Such irrigation is described in scriptures and mythological books written more than 2 000 years ago. Irrigation was highly developed during the period of Muslim rule from the twelfth century onward, and the Mughal kings later constructed several canals. The canal system was further extended by the British. The cultivated area of the Ganges valley in Uttar Pradesh and Bihar benefits from a system of irrigation canals that has increased the production of cash crops such as sugarcane, cotton and oilseeds. The older canals are mainly in the Ganges-Yamuna Doab (*doab* meaning "land between two rivers"). The Upper Ganga Canal, beginning at Hardiwar, and its branches have a combined length of 9 575 km. The Lower Ganga Canal, extending 8 240 km with its branches, begins at Naraura. The Sarda Canal irrigates land near Ayodhya, in Uttar Pradesh. Higher lands at the northern edge of the plain are difficult to irrigate by canal, and groundwater must be pumped to the surface. Large areas in Uttar Pradesh and Bihar are also irrigated by channels running from hand-dug wells. The Ganges-Kabadak scheme in Bangladesh, largely an irrigation plan, covers parts of the districts of Khulna, Jessore, and Kusthia that lie within the part of the delta where silt and overgrowth choke the slowly flowing rivers. The system of irrigation is based on both gravity canals and electrically powered lifting devices (Ahmad and Lodrick).

Total area equipped for irrigation in the GBM river basin is estimated to be around 35.1 million ha, of which 82.2 percent in India, 14.0 percent in Bangladesh, 3.3 percent in Nepal, 0.4 percent in China and 0.1 percent in Bhutan. Area actually irrigated is estimated at 34.1 million ha. The equipped areas irrigated by groundwater and by surface water account for 67 and 33 percent respectively.

Of the 29 million ha equipped for irrigation in India inside the GBM river basin, 67 percent is irrigated by groundwater and 33 percent by surface water. The development of sprinkler and localized irrigation in recent years has been considerable, mainly the result of the pressing demand for water from other sectors, a fact that has encouraged government and farmers to find water-saving techniques for agriculture. The Government has offered subsidies to adopt drip systems. Drip-irrigated crops are mainly orchards (grapes, bananas, pomegranates and mangoes).

Localized irrigation is also used for sugarcane and coconut. Investment in drainage has been widely neglected in India, and where such investment has been made, poor maintenance has caused many drainage systems to become silted up. On the eastern Ganges plain, investment in surface drainage would probably have a greater productive impact, and at a lower cost, than investment in surface irrigation.

In Nepal, which is entirely located in the Ganges river basin, the area equipped for irrigation was estimated at 1 168 300 ha in 2002, of which 79.5 percent was irrigated by surface water, 19.2 percent by groundwater and 1.3 percent by mixed surface water and groundwater. Seasonal canals accounted for 58 percent of the area irrigated by surface water, permanent canals for 39 percent, and ponds for 3 percent. In 1992, the area equipped for irrigation accounted for 882 400 ha and in 1982 for 583 900 ha. In 1994, 73.9 percent of the area equipped for irrigation was irrigated by surface water, 12.4 percent by groundwater and 13.8 percent by irrigation systems not fully identified. Most irrigation systems use surface irrigation (basin, furrow). Some areas in the hills and mountains use sprinkler irrigation, but no figures are available. In 2005, the harvested irrigated crop area covered around 1 335 000 ha, of which 47 percent consisted of wheat, 36 percent of rice, 4 percent of maize, 3 percent of vegetables, 2 percent oil crops, 4 percent of other annual crops and 3 percent of sugarcane.

China accounts for approximately 138 000 ha of area equipped for irrigation inside the GBM river basin of which 98 percent is irrigated by surface water.

In Bhutan, which is entirely located in the Brahmaputra river basin, most rivers are deeply incised into the landscape and hence the possibilities for run-of-the-river irrigation are limited. The irrigated areas are called wetland in the local classification. This means that they have been terraced for basin irrigation. In 2007, throughout the country these areas were estimated at 27 685 ha, which corresponds to actually irrigated area. In summer, almost all wetland is under rice cultivation. Double cropping of rice is limited to the lowest altitudes where the winter temperatures still allow its cultivation. Where rice cannot be cultivated, wheat, buckwheat, mustard and potatoes are cropped on wetland areas during the winter season. The wetland areas can be cropped during the winter season, though watering of these winter crops is generally limited to one irrigation at the time of land preparation. To a limited extent, farmers have started to irrigate horticultural crops, including orchards, using hose pipes and surface irrigation methods. In 1994, total irrigated cropped area was estimated at 27 900 of which 98 percent is rice and 2 percent potatoes.

In Bangladesh, though the country has abundant surface water resources, particularly in the monsoon season, its flat deltaic topography and the instability of major rivers make large gravity irrigation systems both technically difficult and costly. On the other hand, during the dry season irrigation using surface water has become difficult or practically impossible owing to limited availability. Therefore the use of groundwater for irrigation has become increasingly important. In 2008 the national irrigation coverage was 5.05 million ha, of which approximately 4.93 million ha inside the GBM river basin where groundwater covered 75 percent and surface water covered 25 percent of the total irrigated area. In 1993, the total area of wetlands throughout the country was 3.14 million ha, of which almost 1.55 million ha were cultivated and 1.38 million ha were drained by surface drains. Thus, total water managed area is estimated at 6.59 million ha. Surface irrigation is the only technology used in large irrigation schemes. In 2008, total harvested irrigated cropped area in Bangladesh was estimated at 5.98 million ha, of which the most important crops are rice accounting for 4.34 million ha (73 percent), wheat 0.31 million ha (5 percent), potatoes 0.26 million ha (4 percent) and vegetables 0.24 million ha (4 percent).

Because of the low-lying topography, each year about 18 percent of Bangladesh is inundated during the monsoon season. During severe floods the affected area may exceed 37 percent of the country and in extreme events like the 1998 flood about 66 percent of the country is inundated. Floods are caused by overspills from main rivers and their distributaries, overspills from tributaries and by direct rainfall. Flood control works can reduce floods from the first two, but only drainage can have any effect on the latter two. The basic benefit of drainage is water control – supply as well as removal.

The particular benefits can be:

1. potential increase in cropped area through earlier drainage;
2. higher yields from transplanted Aman rice through early planting;
3. crop diversification in the wet season through better drainage; and
4. more control over crop calendars and patterns through control of the water regime.

In 1964, a master plan was initiated for water resources development. This envisaged the development of 58 flood protection and drainage projects covering about 5.8 million ha of land. Three types of polders were envisaged: gravity drainage, tidal sluice drainage and pump drainage. Flood control and drainage projects have accounted for about half of the funds spent on water development projects since 1960. They include:

- Ø Large-scale projects such as: Coastal Embankment Project (949 000 ha), Manu River Project (22 500 ha), Teesta Right Embankment (39 000 ha), Ganges-Kobadak Project (141 600 ha), Brahmaputra Right Flood Embankment (226 000 ha), Chandpur Irrigation Project (54 000 ha), and Chalan Beel Project (125 000 ha).
- Ø Medium-scale projects such as: Sada-Bagda, Chenchuri Beel and Bamal-Salimpur-Kulabasukhali projects implemented under the Drainage and Flood Control Projects (DFC I to DFC IV) and financed by the World Bank. These projects typically cover areas of 10 000–30 000 ha and involve flood control and drainage with limited irrigation development.
- Ø Small-scale projects such as those implemented under the Early Implemented Project, the Small-scale Irrigation Project and the Small-scale Drainage and Flood Control Project.

Total water withdrawal in the GBM river basin is estimated at 373.928 km^3, of which 68 percent is groundwater and 32 percent surface water. Irrigation withdrawal accounts for 337.728 km^3, or 90 percent of the total withdrawal. India's total withdrawal inside the GBM river basin has been estimated around 328.2 km^3, of which 90.4 percent (296.7 km^3) for agriculture. In Bangladesh, in 2008 total water withdrawal within the GBM river basin was estimated at about 35.0 km^3, of which 88 percent (30.7 km^3) was for agriculture, 10 percent for municipalities and 2 percent for industries. Approximately 79 percent of the total water withdrawal comes from groundwater and 21 percent, from surface water. In Nepal, in 2005 total water withdrawal was estimated at 9.79 km^3, of which 98.2 percent (9.61 km^3) for agriculture, 1.5 percent for municipalities and 0.3 percent for industry. In Bhutan, in 2008 total water withdrawal was estimated at 0.338 km^3, all surface water. This represents a mere 0.43 percent of the annual renewable water resources. About 94 percent of this water withdrawn (0.318 km^3) was used for agriculture, while the municipal and industrial sectors used 5 percent and 1 percent respectively. Total water withdrawal of China inside the GBM river basin has been estimated around 0.6 km3, of which 67 percent (0.4 km^3) for agriculture.

In Nepal, total dam capacity is estimated at 85 million m^3, although potential for at least 138 km^3 exists. Hydroelectricity accounted for more than 96 percent of total electricity generation. Theoretical hydropower potential is estimated at about 83 000 MW. However, the identified economically feasible potentials are about 40 000 MW (Biswas, after 2006). The two main diversion barrages are the ones of Kosi and Gandaki reservoirs.

In Bhutan, several large dams were constructed for hydroelectric power generation. These include the 40 m high Chhukha dam (CHPP) on the Wang river in Chhukha district in the southwest, the 91 m high Tala-Wankha dam further downstream on the Wang (Raidak) river near Phuntsholing town, the 33 m high Kurichhu dam on the Kuri river in Mongar district in the east, the Basochu dam (BHPP) near Wangduephodrang town in the centre-west. The 141 m high Punatsangchu dam on Puna Tsang river downstream of Wangduephodrang town is under construction. Total hydropower generation capacity was 477 MW in 2006, of which 336 MW from the Chhukha hydropower plant, 60 MW from the Kurichu hydropower plant and 24 MW from the Basochu hydropower plant. Hydropower represented 96 percent of the country's electricity generating capacity and 99.9 percent of its electricity generation in 2006. With the commissioning of the first two units of the Chhukha hydroprojects in 1986, and the other two units in 1998, the electricity generation capacity has substantially increased and Bhutan became a significant exporter of electricity to India. With the commissioning of "Tala Hydro Power Project" in 2006, there is a substantial improvement in the energy generation of the country.

The expansion of hydropower production capacity in Bhutan has had an enormous impact as by the end of the Ninth Five-Year Plan (2002-2007), the energy sector contributed to around a quarter of GDP. With a further doubling of capacity envisaged by the end of the Eleventh Five-Year Plan (2014-2019), the energy sector will probably contribute close to half of GDP. The following hydroelectric projects have been identified for future development:

- Ø Mangdue Chu Hydroelectric Project was planned in the Ninth Five-Year Plan (2002-2007) and is expected to be completed in the Tenth Five-Year Plan (2008–2013). The project comprises two dams.
- Ø Sunkosh Multipurpose Project (SMP) is the largest proposed hydroelectricity project in Bhutan.

India controls the flow of the Ganges river with a dam completed in 1974 at Farakka, 18 km from the border with Bangladesh. The Farakka barrage is a not very high diversion structure and is not classified as a large dam. During the dry season it diverts water from the Ganges river to the Hooghly river through the Hooghly Canal. The Bhimgoda dam at Haridwar diverts melted snow from the Himalayas to the Upper Ganges Canal, which was built by the British in 1854. This water is used for irrigation and the flow of the river has been greatly diminished.

India is endowed with rich hydropower potential, ranking fifth in the world. The gross hydropower potential was estimated at 148 700 MW as installed capacity, to which the Brahamaputra, Ganges and Indus river basins contribute about 80 percent. The installed capacity of hydropower generation in India is about 22 000 MW (Biswas, after 2006). The total water storage capacity constructed in the country is estimated at 224 km^3. Out of the seven larger dams with a reservoir capacity exceeding 8 km^3 in India, only the Rihand dam is in the GBM river basin, on the Rihand river (10.6 km^3).

No large dams exist in the GBM river basin in Bangladesh. Three barrages have been constructed across the Teesta, Tangon and Manu rivers, which are used as diversion structures for irrigation purposes only.

Table 2 shows important dams in the GBM river basin

TABLE 2
Large dams in the Ganges-Brahmaputra-Meghna river basin

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m^3)	Main use *
Bhutan	Chhukha	Chhukha	Ti Chu	1988	40	-	H
	Tala-Wankha	Phuntsholing	Wang (Raidak)	2006	91	-	H
	Kurichhu	Gyelposhing	Kuri	2002	33	-	H
	Basochu	Wangduephodrang	Baso stream	2001	-	-	H
	Punatsangchu	-	Puna Tsang	(under constr.)	141	-	H
India	Rihand	Sonbhadra	Rihand	1962	91	10 600	H
	Farakka barrage	-	-	1974	-	-	-
	Bhimgoda	-	-	1854	-	-	I
Nepal	Gandaki	-	-	-	-	-	-
	Kosi	-	-	-	-	-	-
Bangladesh	Manu barrage		Manu				I
	Tangon barrage		Tangon				I
	Teesta barrage		Teesta				I

* I = irrigation; H = Hydropower

TRANSBOUNDARY WATER ISSUES

The problems in the GBM river basin are typical of those related to conflicting interests of upstream and downstream riparians. India has used its position of power in the basin to insist on a series of bilateral treaties rather than engaging in a multilateral negotiation (World Bank, 2010).

In 1875, an agreement between the British Government and the State of Jind was signed to regulate the supply of water for irrigation from the Western Jumna Canal. In 1893, the British Government and the Patiala State signed an agreement regarding the Sirsa branch of the Western Jumna Canal. In 1908, Great Britain and the Panna State signed an agreement respecting the Ken Canal (World Bank, 2010).

In 1905, an agreement between India and Bhutan took place regarding the Chhukha Hydroelectric Project. India financed the project with a 60 percent grant and 40 percent low-interest loan.

A joint commission for the exploitation of the Kosi river was set up between Nepal and India in 1954 and 1966, and another for the exploitation of the Gandak river in 1959. In 1978, Nepal and India signed an agreement on the renovation and extension of the Chandra Canal, Pumped Canal and distribution of the Western Kosi Canal (World Bank, 2010).

The Indo-Bangladesh Joint Rivers Commission (JRC) was established on a permanent basis pursuant to the Joint Declaration of the Prime Ministers of Bangladesh and India in March 1972. The Statute of JRC was accordingly signed in November 1972 to maintain liaison between the participating countries to ensure the most effective joint efforts in maximizing the benefits from common river systems to both the countries. Subsequently, the Government of Bangladesh established the Joint Rivers Commission Bangladesh (JRCB) to address the issues relating to the sharing and managing of the water from transboundary rivers with the co-riparian countries. The main activities of the JRCB are (JRCB, 2011):

- Ø Negotiating with the co-riparian countries on development, management and sharing of water resources of common rivers.

- Ø Holding meetings with India at different levels to discuss issues on sharing of waters of common rivers, transmission of flood-related data from India to Bangladesh, river bank protection works along common/border rivers and other pertinent issues.
- Ø Monitoring and sharing of the Ganges waters at Farakka and monitoring at Hardinge Bridge (Bangladesh) between 1 January and 31 May every year as per provision of the Ganges Water Sharing Treaty of 1996.
- Ø Working jointly with Nepal for harnessing common water resources and mitigating floods and flood damages and conducting research and technical studies.
- Ø Cooperating with China in the field of water resources, enhancing the flood forecasting capability through exchange of flood-related data and information of the Brahmaputra river, using and protecting the water resources of transnational rivers in the region keeping in mind the principles of equality and fairness, conduct training in the relevant technical field, etc

As mentioned earlier, India controls the flow of the Ganges river through a dam completed in 1974 at Farakka, 18 km from the border with Bangladesh. The Farakka barrage was originally conceived by the British imperial government, however not implemented until after India's independence from British rule. This dam was a source of tension between the two countries, with Bangladesh asserting that the dam held back too much water during the dry season and released too much water during monsoon rains.

In 1977, an agreement between Bangladesh and India was signed on sharing of the Ganges waters at Farakka and on augmenting its flows (World Bank, 2010). In 1978, in the JRC, India and Bangladesh had placed separate proposals for augmentation of the Ganges river flow at Farakka. While the Bangladesh proposal concentrated on storage of Ganges water itself during floods by constructing dams and reservoirs to be located mostly in Nepal, the Indian proposal was based on inter-basin transfer of water from the Brahmaputra river basin to the Ganges river basin through a link canal as the Brahmaputra has plenty of water mostly untapped. This would also minimize the flood hazards as the floods in the Brahmaputra come more than two months before those of the Ganges.

However, none of the proposals materialized because of the objections from either side on various grounds. After the disastrous floods in Bangladesh in 1988, the Indian Government expressed concern about the damage and showed interest in regional cooperation for flood mitigation in both the countries through a joint action plan. The Bangladesh Government also came closer to India and had talks on river cooperation (Parua, after 2001). In 1996, India and Bangladesh signed the Ganges Water Sharing Treaty, which regulates the Ganges sharing waters at Farakka. Bangladesh is ensured a fair share of the flow reaching the dam during the dry season.

In planning and management terms, it is simply impossible to consider the GBM river system as one system because of its sheer size, complexities and multinational character. Accordingly, following the Ganges Water Sharing Treaty between India and Bangladesh, the main focus of bilateral negotiations between these two countries has currently been on the Teesta river, an important tributary of the Ganges river. In 1983, a primary agreement between India and Bangladesh was reached on the sharing of the Teesta river waters (World Bank, 2010). These negotiations are ongoing, but no mutually acceptable framework for the management of the Teesta river is in sight (Biswas, after 2006).

Around 1980, Bhutan initiated a plan to develop the hydropower potential of the Wangchu Cascade at Chhukha, in close cooperation with India. Following extensive consultations, India agreed to construct a 336 MW run-of-the-river project at Chhukha, on the basis of a 60 percent grant and 40 percent loan. The project was commissioned in stages from 1988 onwards and was so successful that it had paid by itself by 1993. The generating capacity was later increased to 370 MW. Because of the Indian support to the planning and construction of the project, Bhutan agreed to sell excess electricity to India at a mutually agreed rate. A 220 kV transmission line was constructed, which linked the Bhutanese capital, Thimpu, and the city of Phuntsholing on the Indian border, from where electricity was subsequently supplied to four Indian states.

The agreement between the two countries is that the electricity generated will be first used to satisfy Bhutan's own internal needs. Before the construction of the Chhukha plant, electricity was generated by diesel and mini-hydro plants. Thus, total electricity generated was limited. Since the construction of the Chhukha project proved to be beneficial to both countries, they have agreed to expand their collaborative efforts to other new hydropower projects. Bhutan realized that the revenues from the development, use and export of its hydropower potential can accelerate the economic and social development processes of the country, and can contribute very significantly to poverty alleviation.

The arrangement has also been beneficial to energy-thirsty India, whose electricity requirements have been increasing in recent years at 8-9 percent per year. India and Bhutan have subsequently collaborated with the funding and construction of a 45-MW run-of-the-river hydropower station at Kuri river. Similar collaborative efforts have taken place, or are under active consideration, for Chhukha II (1,020 MW) and Chhukha III (900 MW, with a storage dam). In addition, the two countries signed an agreement in 1993 to study the feasibility of a large storage dam on the Sunkosh river. Considering the fact that its present population is only just over 2 million, this sale of hydropower to India means a very substantial income for this relatively small country (Biswas, after 2006).

In 1996, India and Nepal ratified a treaty on the Mahakali river, located on the border between the two countries. The treaty provides for equal entitlement in the utilization of water from the Mahakali river without prejudice to respective existing consumptive uses.

The Punatsangchu Hydroelectric Power Project (PHPP) is a proposed project between Bhutan and India signed in 2003. It is a run-of-the-river scheme along the course of the Puna Tsang river, downstream from Wangduephodrang town. It will have an installed capacity of 870 MW with an annual average generation of 4 330 GWh.

The Tala Hydroelectric Project Authority (THPA) is the largest Indo-Bhutan joint project, entirely funded by the Government of India by way of grants and loan and fully operational since 2007.

In September 2008, the third meeting of the Nepal-India Joint Committee on Water Resources (JCWR) took place, to resolve pending issues and pave the way both to mitigate the flood problems along the Nepal-India border and to enhance bilateral cooperation in the water sector. The Pancheshwar Multipurpose Project was identified as a priority project and JCWR reviewed the current status of discussions on issues related to location of the regulating dam, unit size and installed capacity of the power plants, assessment of project benefits in terms of irrigation and power to India and Nepal and sharing of the project cost by the two sides. JCWR decided to set up a Pancheshwar Development Authority (PDA) at the earliest in accordance with Article 10 of the Mahakali Treaty for the development, execution and operation of the Pancheshwar Multipurpose Project.

In December 2008, the first meeting of the India-Nepal Joint Standing Technical Committee (JSTC) was held. During the above-mentioned third meeting of JCWR, it was decided to have three tier joint mechanisms to expedite the decision-making process and the implementation of decisions undertaken at the institutional interactions. Whereas a Joint Ministerial Commission on Water Resources would be headed by the Ministers of Water Resources of India and Nepal, a Joint Standing Technical Committee was constituted to rationalize technical committees and subcommittees that exist to cover issues in India and Nepal related to flood management, inundation problems and flood forecasting activities besides project specific committees on hydropower. The JSTC coordinates all technical committees and subcommittees under JCWR.

The fourth meeting of JCWR was held in March 2009 to discuss the issues of water resources development projects in a comprehensive manner, further strengthening the ties between the two countries. India and Nepal hoped that the works on the breach closure of the Kosi barrage would be completed in time with the cooperation of the two governments. Nepal informed of the demands of local people for the maintenance and rehabilitation of Main Gandak Western Canal and flood control structures. To date, no noticeable progress on these demands could be observed. India informed that short-term measures have already been implemented.

Table 3 lists the main historical events in the GBM river basin.

TABLE 3
Chronology of major events in the Ganges-Brahmaputra-Meghna river basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
1875	Agreement on Western Jumna Canal	India and United Kingdom	Agreement between the British Government and The State of Jind for regulating the supply of water for irrigation from the Western Jumna Canal
1893	Agreement on the Sirsa branch of the Western Jumna Canal	India and United Kingdom	Agreement between the British Government and the Patiala State regarding the Sirsa branch of the Western Jumna Canal
1905	Agreement on Chhukha Hydroelectric project	India and Bhutan	India financed the project with a 60 percent grant and 40 percent low interest loan
1908	Agreement on the Ken Canal	India and United Kingdom	Great Britain and the Panna State signed an agreement respecting the Ken Canal
1954-1966	Joint commission for the exploitation of the Kosi river	Nepal and India	
1959	Joint commission for the exploitation of the Gandak river	Nepal and India	
1964	Master plan for water resources development was developed.	Bangladesh	This envisaged the development of 58 flood protection and drainage projects covering about 5.8 million ha of land
1972	Indo-Bangladesh Joint Rivers Commission (JRC) was established	India and Bangladesh	Maintains liaison between the participating countries to ensure the most effective joint efforts in maximising the benefits from common river systems to both the countries.
1974	Farakka dam	India and Bangladesh	Located in India, 18 km from the border with Bangladesh. This dam was a source of tension between the two countries, with Bangladesh asserting that the dam held back too much water during the dry season and released too much water during monsoon rains
1977	Agreement on Ganges waters at Farakka	India and Bangladesh	An agreement was signed on sharing of the Ganges waters at Farakka and on augmenting its flows
1978	Agreement on the Chandra Canal	Nepal and India	Agreement on the renovation and extension of the Chandra Canal, Pumped Canal and distribution of the Western Kosi Canal
1983	Primary agreement on Teesta river waters	India and Bangladesh	A primary agreement was reached on the sharing of the Teesta river waters
1988	Chhukha dam	Bhutan and India	Around 1980, Bhutan initiated a plan to develop the hydropower potential of the Wangchu Cascade at Chhukha, in close cooperation with India. India agreed to construct a 336 MW run-of-the-river project at Chhukha, on the basis of a 60 percent grant and 40 percent loan. The project was commissioned in stages from 1988 onwards and was so successful that it had paid by itself by 1993.
1993	Agreement to study the feasibility of a large storage dam on the Sunkosh river.	Bhutan and India	
1996	Treaty on the Mahakali river	Nepal and India	The treaty makes provision for equal entitlement in the utilization of water from the Mahakali river without prejudice to respective existing consumptive uses.
1996	Ganges Water Sharing Treaty	India and Bangladesh	Regulates the Ganges sharing waters at Farakka
2003	Punatsangchu Hydroelectric Power Project is proposed	Bhutan and India	Proposed and signed project between Bhutan and India
2006	Tala Hydroelectric Project constructed	Bhutan and India	Is the biggest Indo-Bhutan joint project, entirely funded by the Government of India by way of grants and loan and fully operational since 2007.
2008	Third meeting of the Nepal-India Joint Committee on Water Resources	Nepal and India	The Pancheshwar Multipurpose Project was identified as a priority project

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Indus river basin

GEOGRAPHY, POPULATION AND CLIMATE

The transboundary Indus river basin has a total area of 1.12 million km^2 distributed between Pakistan (47 percent), India (39 percent), China (8 percent) and Afghanistan (6 percent) (Table 1). The Indus river basin stretches from the Himalayan mountains in the north to the dry alluvial plains of Sindh province in Pakistan in the south and finally flows out into the Arabian Sea. In Pakistan, the Indus river basin covers around 520 000 km^2, or 65 percent of the territory, comprising the whole of the provinces of Punjab and Khyber Pakhtunkhwa and most of the territory of Sindh province and the eastern part of Balochistan. The drainage area lying in India is approximately 440 000 km^2, nearly 14 percent of the total area of the country, in the States of Jammu and Kashmir, Himachal Pradesh, Punjab, Rajasthan, Haryana and Chandigarh. Only about 14 percent of the total catchment area of the basin lies in China, covering just 1 percent of the area of the country, and Afghanistan, where it accounts for 11 percent of the country's area. Very roughly, at least 300 million people are estimated to live in the Indus basin.

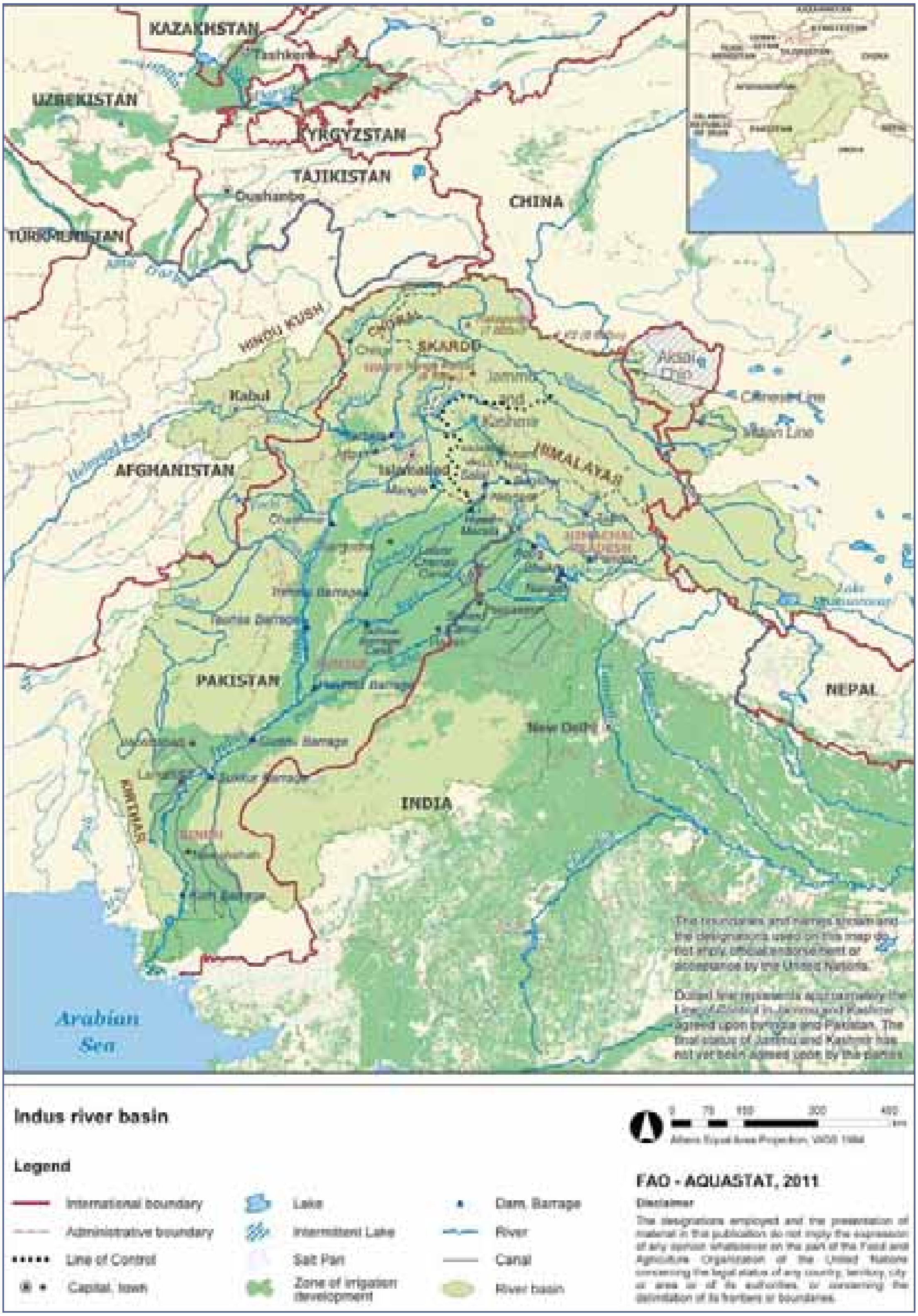
Climate is not uniform over the Indus river basin. It varies from subtropical arid and semi-arid to temperate subhumid on the plains of Sindh and Punjab provinces to alpine in the mountainous highlands of the north. Annual precipitation ranges between 100 and 500 mm in the lowlands to a maximum of 2 000 mm on mountain slopes. Snowfall at higher altitudes (above 2 500 m) accounts for most of the river runoff (Ojeh, 2006).

The Upper Indus river basin is a high mountain region and the mountains limit the intrusion of the monsoon, the influence of which weakens northwestward. Most of the precipitation falls in winter and spring and originates from the west. Monsoonal incursions bring occasional rain to trans-Himalayan areas but, even during summer months, not all precipitation derives from monsoon sources. Climatic variables are strongly influenced by altitude. Northern valley floors are arid with annual precipitation from 100 to 200 mm. Totals increase to 600 mm at 4 400 m, and glaciological studies suggest accumulation rates of 1 500 to 2 000 mm at 5 500 m. Winter precipitation (October to March) is highly spatially correlated across the Upper Indus basin, north and south of the Himalayan divide. From 1961 to 1999 there were significant increases in winter, summer and annual precipitation and significant warming occurred in winter whilst summer showed a cooling trend. These trends will impact upon water resource availability (Fowler and Archer, 2005).

The climate in the Indus plains is arid to semi-arid. In the lower plain December to February is the cold season and mean monthly temperatures vary from 14 to 20 °C. Mean monthly

TABLE 1
Country areas in the Indus river basin

Basin	Area		Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total area of the country
	km^2	% of Southeast Asia				
Indus	1 120 000	54	Pakistan	520 000	47	65
			India	440 000	39	14
			China	88 000	8	1
			Afghanistan	72 000	6	11


KAZAKHSTAN
UZBEKISTAN
KYRGYZSTAN
TAJIKISTAN
Dushanbe
TURKMENISTAN
CHINA
HINDU KUSH
SKARDU
Kabul
AFGHANISTAN
Islamabad
HIMALAYAS
Taunsa Barrage
PAKISTAN
NEPAL
New Delhi
INDIA
Arabian Sea
Indus river basin
Legend
International boundary
Administrative boundary
Line of Control
Capital, town
Lake
Intermittent Lake
Salt Pan
Zone of irrigation development
Dam, Barrage
River
Canal
River basin
FAO - AQUASTAT, 2011
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temperatures during March to June vary from 42 to 44 °C. In the upper plain mean temperature ranges from 23 to 49 °C during summer and from 2 to 23 °C during winter. Average annual rainfall on the Indus plains is about 230 mm. On the lower plain, Larkana and Jacobabad areas, on average receive about 90 mm of rainfall annually. On the upper plain, Multan receives 150 mm and Lahore about 510 mm of rain. Because of the hot climate, the evaporation rate is very high and the mean annual evaporation on the lower plain (Nawabshah) is 204 mm while on the upper plain (Sargodha) it is 1 650 mm (WCD, 2000).

WATER RESOURCES

Surface water

The river flows are comprised of glacier melt, snowmelt, rainfall and runoff. Outside the polar regions, the Upper Indus river basin contains the greatest area of perennial glacial ice in the world (22 000 km^2); the area of winter snow cover is an order of magnitude greater. The glaciers serve as natural storage reservoirs that provide perennial supplies to the Indus river and some of its tributaries (WCD, 2000). The Indus river system forms a link between two large natural reservoirs, the snow and glaciers in the mountains and the groundwater contained by the alluvium in the Indus plains of the Sindh and Punjab Provinces of Pakistan (Ojeh, 2006).

The Indus river has two main tributaries, the Kabul on the right bank and the Panjnad on the left. The Panjnad is the flow resulting from five main rivers (literally Punjab means “five waters”): the Jhelum and Chenab, known as the western rivers with the Indus river, and the Ravi, Beas and Sutlej, known as the eastern rivers. This division came into effect at the time of settlement of a water dispute between India and Pakistan in 1960. Under this Indus Water Treaty, the following rules apply:

- *Western rivers*: Pakistan shall receive for unrestricted use all those waters of the western rivers, i.e. Chenab and Jhelum, which is India under obligation to let flow, except for restricted uses, related to domestic use, non-consumptive use, agricultural use and generation of hydroelectric power of which the amounts are set out in the Treaty. Annual flow from China to India in the Indus basin is 181.62 km^3 and it is estimated that the flow generated within India is 50.86 km^3, resulting in a flow from India to Pakistan in this part of 232.48 km^3, of which 170.27 km^3 are reserved for Pakistan and 62.21 km^3 are available for India.
- *Eastern rivers*: All the waters of the eastern tributaries of the Indus river originating in India, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for unrestricted use by India. Pakistan shall be under an obligation to let flow, and shall not permit any influence with, the waters (while flowing in Pakistan) of any tributary which in its natural course joins the Sutlej Main or Ravi Main before these rivers have finally crossed into Pakistan. The average annual flow in India before crossing the border is estimated at 11.1 km^3. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej Main or Ravi Main after these rivers have crossed into Pakistan shall be available for unrestricted use of Pakistan.

All the rivers of the Indus system are perennial (WCD, 2000). Aided by a number of smaller rivers (Swat, Haro, Kunar [Chitral], Tochi, Shah Alam, Naguman, Adezai, Soan, etc.) and streams/Nullahs, these rivers supply water to the entire Indus Basin Irrigation System (NDMA-UNDP, 2010).

The Indus river is the twelfth largest river in the world (Ojeh, 2006) and originates near lake Manasarovar to the north of the Himalayas range on the Kailash Parbat mountain in China at an elevation of 5 500 m. The Indus catchment area is unique in the sense that it contains seven of the world’s highest peaks after Mount Everest. Among these are K2 (8 600 m), Nanga

Parbat (8 100 m) and Rakaposhi (7 800 m). The river is 3 200 m long out of which 1 114 m are in India. The river has 27 major tributaries above Guddu barrage. The largest tributary is the Shyoke river (640 km long with a catchment area of 20 160 km^2) (NDMA-UNDP, 2010). The flow of the Indus river depends on the season, it decreases during the winter and floods the banks during the monsoons.

The Sutlej river originates in China in Western Tibet in the Kailas mountain range and near the source of the rivers Indus, Ganges and Brahmaputra. The river is 1 536 km long and has a catchment area of 75 369 km^2 (of which 70 percent is in India). It flows into Pakistan (Punjab) near Ferozepur and eventually joins the Chenab river close to Punjnad barrage. The Sutlej river has eight major tributaries (all except Rohi Nullah join Sutlej river in India). The largest tributary is the Beas river, which is 464 km long and with a catchment area of 9 920 km^2 (NDMA-UNDP, 2010).

The Ravi river originates in the lesser Himalayas range in India. The river is 880 km long with acatchment area of 24 960 km^2. It runs almost along the India-Pakistan border. The Ravi river has five major tributaries (Ujh, Bein, Basantar, Deg and Hudiara nullahs [streams]), the upper catchments of which lie in India. The largest tributary is Deg Nullah river, which is 256 km long with a catchment area of 730 km^2 (NDMA-UNDP, 2010).

The Chenab river is formed at the confluence of the Bhaga and Chandra rivers, which join at a place called Tandi. Its uppermost part is snow covered and forms the northeast part of Himachal Pradesh. From Tandi to Akhnoor the river traverses high mountains. The river is 1 232 km long and the catchment area is 41 760 $km^{2.}$ The river enters Pakistan a little over Head Marala with very sharp changes in slope. The river has 12 major tributaries. Doara, Dowara, Halsi, Bhimber, Palku and Budhi join close to Marala. The largest tributary is the 120 km long Palku Nullah, with a catchment area of 1 269 km^2 (NDMA-UNDP, 2010).

The Jhelum river originates in the Kashmir Valley, about 54 km east of Anant Nag, and is 816 km long with a catchment area of 39 200 km^2. The river has ten major tributaries, including Neelum/Kishan Ganga (the largest tributary, is 260 km long with a catchment area of 3 968 km^2), Kunhar, Poonch and Kanshi (NDMA-UNDP, 2010).

The first record of gauge heights was made on the Indus at Attock in 1848. The next was on Chenab at Alexandria Bridge in 1879. The most important river gauging stations, called the rim-stations, have continuous discharge data from the early 1920s when the Indus Discharge Committee was established for this purpose (WCD, 2000).

Total inflow from China to India in the Indus river basin is estimated at 181.62 km^3. Total inflow from Afghanistan to Pakistan in the Indus basin is estimated at 21.5 km^3, 15.5 km^3 from the Kabul river (of which 10 km^3 come from Kunar river, which first enters Afghanistan from Pakistan and then flows back to Pakistan after joining the Kabul river) and 6 km^3 from other tributaries (Pansjir, Gomal, Margo, Shamal, Kuram). The mean annual inflow into Pakistan from India through the western tributaries, the Jhelum and the Chenab, considering the Indus Water Treaty, amounts to 170.27 km^3. The mean annual natural inflow into Pakistan through the eastern rivers (the Ravi, the Beas and the Sutlej) is estimated at 11.1 km^3 but, according to the Treaty, this is reserved for India.

Groundwater

The Indus river basin represents an extensive groundwater aquifer, covering a gross command area of 16.2 million ha. The water table was well below the surface (>30 m) and the aquifer was in a state of hydrological equilibrium before the development of the canal irrigation system. The recharge to aquifer from rivers and rainfall was balanced by outflow and crop evapotranspiration.

When the canal irrigation system was introduced, percolation to the aquifer was increased in irrigated areas of the Indus basin resulting in the twin menace of waterlogging and salinity. Although, there are disadvantages in having a high water table, it was used for irrigation with dug wells and tubewells in the fresh groundwater zone. In 2000, estimated groundwater extraction from the aquifer was almost equal to the recharge in fresh groundwater areas; although the balance between recharge and abstraction is not uniform across the basin (WCD, 2000).

Water quality

Water quality of the Indus river and its tributaries is excellent. Total dissolved solids (TDS) range between 60-374 ppm (parts per million), which is safe for multiple uses (Bhutta, 1999; PWP, 2000). TDS in the upper reaches range between 60 ppm during high-flow to about 200 ppm during low-flow. Water quality deteriorates downstream but remains well within permissible limits, with TDS in the lower reaches of the Indus (at Kotri barrage) ranging from 150 to 374 ppm. TDS of some of the tributaries such as Gomal river at Khajuri, Touchi river at Tangi Post and Zhob river at Sharik Weir range between 400 to 1 250 ppm (IWASRI, 1997).

Indiscriminate and unplanned disposal of effluents (including agricultural drainage water, municipal and industrial wastewater) into rivers, canals and drains is causing deterioration of water quality in the downstream parts. In 1995 around 12.435 km^3/year (40 million m^3/day) of untreated water were being discharged into water bodies (Ahmad, 2008b). It was estimated that 0.484 and 0.345 km^3/year (1.3 and 0.9 million m^3/day) of sewage was produced in Karachi and Lahore metropolitan areas respectively and most of it was discharged untreated into water bodies. The polluted water is also being used for drinking in downstream areas, causing numerous water-borne diseases.

The groundwater is marginal to brackish in quality in 60 percent of the Indus Basin Irrigation System's (IBIS) aquifer (Ahmad, 2008a; 2008b). Groundwater quality varies widely, ranging from < 1 000 ppm to > 3 000 ppm. Besides TDS, there are quality concerns regarding sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) (WAPADA 2006).

Use of pesticides and nitrogenous fertilizers is seriously affecting shallow groundwater and entry of effluents into rivers and canals is deteriorating the quality of freshwater. Almost all shallow freshwater is now polluted with agricultural pollutants and sewage (Ahmad, 2008a; Ahmad, 2008b).

Investments in drainage have been significant during the last two decades, though waterlogging still affects large tracts of land. Soil salinity and sodicity also constrain farmers and affect agricultural production. These problems are further exacerbated by poor quality groundwater (Kijne and Kuper, 1995). In fresh groundwater areas, excessive pumping by tubewells leads to mining and reduction of groundwater quality (WRRI, MONA and IIMI, 1999).

In the 1990s waterlogging in the IBIS area was high in the 1990s because of heavy floods, while droughts in the early years of the current decade (2000-2010) resulted in lowering of the water table and in reduction of the waterlogged area. The overall analysis depicts that there is no change in waterlogging. Currently, in the Pakistani part of the basin, the waterlogged and saline areas are around 7 million ha. During the late 1990s most of the SCARP tubewells were abandoned and farmers were provided support to install shallow tubewells (Zaman and Ahmad, 2009).

WATER-RELATED DEVELOPMENTS IN THE BASIN

The 4 000-year-old Indus civilization has its roots in irrigated agriculture. Canal irrigation development began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur Headworks on Ravi river. Until that time, irrigation was undertaken through a network of inundation canals, which were functional only during periods of high river flow.

These provided water for *kharif* (summer) crops and residual soil moisture for *rabi* (winter) crops. The UBDC was followed by the Sirhind Canal from Rupar Headworks on Sutlej in 1872 and the Sidhnai Canal from Sidhnai barrage on the Ravi river in 1886. The Lower Chenab from Khanki on Chenab in 1892, and Lower Jhelum from Rasul on Jhelum in 1901 followed suit. Lower and Upper Swat, Kabul river and Paharpur Canals in Khyber Pakhtunkhwa (Pakistan) were completed during 1885 to 1914.

In the beginning of the 1900s, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable land. The supply from the Ravi river, serving a large area of Bari Doab, was insufficient while Jhelum had a surplus. An innovative solution, the Triple Canal Project, was constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi river. The Triple Canal Project was a landmark in integrated inter-basin water resources management and provided the key concept for the resolution of the Indus waters dispute between India and Pakistan in 1960 with the Indus Water Treaty (IWT).

The Sutlej Valley Project, comprising four barrages and two canals, was completed in 1933, resulting in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir. During the same period, the Sukkur barrage and its system of seven canals serving 2.95 million ha in the Lower Indus plain were completed and considered as the first modern hydraulic structure on the downstream Indus river. Haveli and Rangpur from Trimmu Headworks on Chenab in 1939 and Thal Canal from Kalabagh Headworks on Indus were completed in 1947. This comprised the system inherited by Pakistan at the time of its creation in 1947. The IBIS, spread over the flat plains of the Indus Valley, is the largest contiguous irrigation system in the world and is the result of large surface irrigation schemes promoted by the British up to 1947 when their Indian colony was divided into India and Pakistan.

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without considering the irrigated boundaries. This resulted in an international water dispute in 1948, which was finally resolved by the enforcement of the Indus Water Treaty in 1960 under the aegis of the World Bank.

After Partition, Kotri, Taunsa and Guddu barrages were completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals. The Taunsa barrage was completed in 1958 to divert water to two large areas on the left and right banks of the river making irrigated agriculture possible for about 1.18 million ha of arid landscape in Punjab province (Pakistan). Currently rehabilitation and modernization of the barrage is in progress. Also, three additional inter-river link canals were built before the initiation of the Indus Basin Project. The last inundation canals were connected to weir-controlled supplies in 1962 with the completion of the Guddu barrage on the Indus river.

The Indus Basin Project (IBP) was developed in pursuance of the Indus Water Treaty, including Mangla dam, five barrages, one syphon and eight inter-river link canals, completed during 1960-1971, and Tarbela dam started partial operation in 1975-1976. The two main components of IBP were the major storage reservoirs on Jhelum (Mangla) and Indus (Tarbela) to mitigate the effect of diverting the three eastern rivers by India and to increase agricultural production in the IBIS (Table 2). As part of the implementation schedule of IBP, the Mangla Dam Project was taken up first and completed by 1968. In the meantime, the decision was also taken to go ahead with the Tarbela dam after its re-evaluation by the World Bank and lining up of the additional funding. Consequently construction started in 1968, was substantially completed by 1974, and started partial operation in 1975-1976 (WCD, 2000).

TABLE 2
Works completed under the Indus Basin Project (Source: WCD, 2000)

Description of work		Completion year	Between rivers	Command
Construction of link canals	Trimmu -Sidhnai		Chenab-Ravi	
	Sidhnai-Mailsi		Ravi-Sutlej	
	Mailsi-Bahawal			
	Rasul-Qadirabad		Jhelum-Chenab	Mangla
	Qadirabad-Balloki		Chenav-Ravi	
	Balloki Suleimanki II		Ravi-Sutlej	
	Chashma-Jhelum		Indus-Jhelum	Tarbela
	Taunsa-Panjnad		Indus-Chenab	
Construction of barrages *	Sidhnai	1965	Ravi	
	Marala	1968	Chenab	Mangla
	Qadirabad	1967	Chenab	
	Rasul	1967	Jhelum	
	Chashma	1971	Indus	Tarbela
	Mailsi (Siphon)	1965	Under Sutlej	
Construction of dams	Mangla	1968	Jhelum	Mangla
	Tarbela	1976	Indus	Tarbela
	Chashma (barrage)	1971	Indus	
Remodelling of existing works	Balloki-Suleimanki Link I		Ravi-Sutlej	
	Marala-Ravi Link		Chenab-Ravi	Mangla
	BRBD Link		Chenab-Ravi	
	Balloki Headworks		Ravi	

* Barrages are constructed to divert river water into canals and the storage capacity is insignificant.

As a result of these extensive developments, Pakistan now possesses the world's largest contiguous irrigation system. It commands a full control equipped area of 14.87 million ha (2008) (36 percent is under Mangla command and 64 percent under Tarbela command (WCD, 2000)) and encompasses the Indus river and its tributaries including three large reservoirs (Tarbela, Mangla, and Chashma), 23 barrages/headworks/siphons, 12 inter-river link canals and 45 canals commands extending for 60 800 km, with communal watercourses, farm channels, and field ditches covering another 1.6 million km to serve over 90 000 farmers' operated watercourses.

River water in the Indus system is diverted by barrages and weirs into main canals and subsequently branch canals, distributaries and minors. The flow to the farm is delivered by over 107 000 watercourses, which are supplied through outlets (*moghas*) from the distributaries and minors. The *mogha* is designed to allow a discharge that self-adjusts to variations in the parent canal. Within the watercourse command (an area ranging from 80 to 280 ha), farmers receive water proportional to their land holding. The entire discharge of the watercourse is given to one farm for a specified period on a seven-day rotation. The rotation schedule, called *warabandi*, is established by the Provincial Irrigation and Power Department, unless the farmers can reach a mutual agreement.

In Pakistan, more than 95 percent of irrigation is located in the Indus river basin. In 2008, the total area equipped for irrigation throughout Pakistan was estimated at 19.99 million ha. The total water managed area in Pakistan is around 21.20 million ha, and can be divided according to the following classification:

Ø Full control irrigation schemes cover a total area of 19.27 million ha, of which 14.87 million ha lie within the IBIS and 4.40 million ha outside. The areas outside the

IBIS cover minor perennial irrigation schemes, groundwater schemes including tubwells, wells, karezes and springs. They are located in Khyber Pakhtunkhwa and Balochistan.

- Spate irrigation covered a total potential area of 2 million ha in 2004. This area refers to potential spate area, but actual area varies based on flood occurrence and frequency and is around 0.72 million ha in an average year. In Pakistan, these areas are known as Rod Kohi in Khyber Pakhtunkhwa and Punjab, or Bandat in Balochistan, and are often called flood irrigation.
- Flood recession cropping areas covered a total area of 1.21 million ha in 2004. In Pakistan these areas are known as Sailaba, and are often called falling flood irrigation areas. Sailaba cultivation is carried out on extensive tracts of land along the rivers and hill streams subject to annual inundation. The moisture retained in the root zone is used after the flood subsides together with subirrigation owing to the capillary rise of groundwater and any rain.

In 1990, the area equipped for irrigation in Pakistan was estimated at 15.73 million ha and total water managed area was estimated at 16.96 million ha.

The total area equipped for irrigation in the entire Indus river basin is estimated to be around 26.3 million ha, of which Pakistan accounts for approximately 19.08 million ha or 72.7 percent, India for 6.71 million ha or 25.6 percent, Afghanistan for 0.44 million ha or 1.7 percent and China for 0.03 million ha or 0.1 percent. Area actually irrigated is estimated at 24.5 million ha. The equipped area irrigated by surface water accounts for 53 percent while groundwater accounts for 47 percent.

The cropped area in the Indus basin in Pakistan expanded with the increased availability of water from the Tarbela dam. Other factors helped to increase the cropped area: increased numbers of tractors, availability of planting machinery and credit support. A rapid rise in population also encouraged the cultivation of additional areas to meet the growing needs of the population. The major *rabi* crops in the Tarbela command are wheat, fodder and horticultural crops. Sugarcane also needs irrigation during the *rabi* season and thus competes for water with *rabi* crops. There was a significant shift in cropping patterns with the increased availability of water from Tarbela dam. There was a net increase in the cropped area of food grains and cash crops such as wheat, rice, cotton and sugarcane. Consequently, there was a decrease in the cropped area of coarse grains and conventional oilseeds.

In the Indus basin, irrigated agriculture saw an increase in area of 36 percent, 44 percent, 39 percent and 52 percent for wheat, cotton, rice and sugarcane, respectively. The overall increase in the cropped area was around 39 percent (Table 3).

TABLE 3
Cropped area of selected crops in the Indus basin irrigated agriculture in Pakistan (Source: Agricultural statistics of Pakistan, Government of Pakistan, in: WCD, 2000)

Crops	Cropped Area (million ha)					Percent increase 1971-1975 to 1991-1995
	1971-1975	1976-1980	1981-1985	1986-1990	1991-1995	
Wheat (rabi)	593	649	724	760	806	36
Cotton (kharif)	192	191	222	253	276	44
Rice (kharif)	151	188	198	201	210	39
Sugarcane (year-round)	61	76	90	82	93	52
Oilseeds (kharif and rabi)	59	53	41	41	61	4
All Fruits (year-round)	20	26	36	44	50	150
Total area	**1 076**	**1 183**	**1 311**	**1 391**	**1 496**	**39**

Wheat is the leading food grain for human consumption, while its straw is used as a source of cheap roughage for livestock feed. The increase in the area under sugarcane, in particular, is the result of the availability of additional irrigation water from the Tarbela reservoir as it is a crop that demands at lot of irrigation. Other factors that contributed towards this increase were the development of the sugarcane industry and the road infrastructure, both of which provided the necessary linkages for growth (WCD, 2000).

In 2008, total harvested irrigated cropped area in Pakistan was estimated at 21.45 million ha, most of it in the IBIS. The major irrigated crops in the country are wheat, rice, sugarcane, cotton and fodder. These crops comprise almost 78 percent of the total harvested area, or 16.6 million ha, with wheat covering 7.3 million ha, rice 2.5 million ha, sugarcane 1.2 million ha, cotton 3.1 million ha and fodder 2.5 million ha (GoP, 2008).

When the IBIS was developed, the drainage needs were initially minimal. Water tables were deep and irrigation water supplies were too low to generate much groundwater recharge and surface water losses. Whatever little drainage was required, could readily be accommodated by the existing natural drainage. The drainage needs, however, increased over time as more irrigation water was diverted and the water table rose to harmful levels causing waterlogging and salinity. The drainage systems mostly have been developed over the last 30-40 years (Bhutta and Smedema, 2005).

Total water withdrawal in the Indus river basin is estimated at 299 km^3, of which Pakistan accounts for approximately 63 percent, India for 36 percent, Afghanistan for 1 percent, and China for barely 0.04 percent. Irrigation withdrawal accounts for 278 km^3, or 93 percent of the total. Surface water and groundwater account for 52 percent and 48 percent of total withdrawals in the Indus river basin respectively.

Most summer rains are not available for crop production or recharge to groundwater because of rapid runoff from torrential showers.

In the Pakistani part of the basin, in 2005, total dam capacity was estimated at 23.36 km^3. Currently, there are three large hydropower dams and 50 smaller dams (more than 15 m high), while 11 smaller dams are under construction. The designed live storage capacity of the three large hydropower dams in the Indus river basin is 22.98 km^3 (Tarbela 11.96 km^3, Raised Mangla 10.15 km^3, which includes recent raising of 3.58 km^3, and Chashma 0.87 km^3). The current live storage capacity of these three large hydropower dams is 17.89 km^3, representing an overall loss of storage of 22 percent (World Bank, 2005).

Pakistan can barely store 30 days of water in the IBIS. Each km^3 of storage capacity lost means one km^3/year less water that can be supplied with a given level of reliability. There is an urgent need for storage just to replace capacity that has been lost because of sedimentation. Given the high silt loads from the young Himalayas, two large reservoirs are silting rapidly. In 2008, because of the raising of the Mangla dam, the loss resulting from sedimentation was recovered (World Bank, 2005). The designed live storage capacity of 50 small dams is 0.383 km^3. Information related to sedimentation and loss of live storage of small dams is not available. Therefore, it was assumed that on average 25 percent of the live storage of these small dams has been lost as a result of sedimentation, leading to a current live storage capacity of these small dams of 0.287 km^3.

There are more than 1 600 mini dams (less than 15 m high), which were constructed for small-scale irrigation purposes, but the capacity of these mini dams is low as a mini dam is normally constructed for an individual farmer. Information on the live storage capacity of mini dams is not available and it is negligible compared to small dams. According to certain estimates, the total designed capacity of these mini dams would be in the order of 0.036 km^3.

The Pakistani part of the Indus river basin has a hydroelectric potential of about 50 000 MW. Its main gorge, between the Skardu and Tarbela, has a potential of almost 30 000 MW. These include Bashan (4 500 MW), Disso (3 700 MW), Banjo (5 200 MW), Thicket (1 043 MW), Paten (1 172 MW), Racicot (670 MW), Yuba (710 MW), Hugo (1 000 MW), Tunas (625), and Sakardu or Kithara (possibly 4 000 to 15 000 MW). Almost 20 000 MW potential is available on various sites on the rivers: Swat, Jhelum, Neelam, Punch and Kumar (Qazilbash, 2005).

In 2010, India had six large dams in the Indus basin, with a total dam capacity of 18.6 km^3. Bhakra and Nangal dams are on the Sutlej river, Pandoh and Pong dams are on the Beas river and Salal and Baglihar are on the Chenab river.

Table 4 shows the large dams in the Indus river basin.

Table 5 shows the barrages in the Indus river basin.

TRANSBOUNDARY WATER ISSUES

In 1948 India unilaterally cut off supplies to Pakistan canals originating from the headworks located on the eastern rivers of Ravi and Sutlej thereby asserting its right to the waters of three eastern rivers (Ravi, Beas and Sutlej). Besides causing a serious setback to the national economy, this would have seriously disrupted Pakistan´s water resources development plans. Therefore, right from its creation, the country had to accord the highest priority to the resolution of water disputes involving India. After protracted negotiations, the dispute was finally resolved and culminated in the signing of the Indus Water Treaty in 1960 (WCD, 2000).

Details of the flows under this Treaty are given in the section: Water resources. This Treaty helped to resolve the issues between the two countries and allowed Pakistan to investment extensively in the Indus Basin Project (IBP) during the 1960s to construct a network of canals and barrages to divert waters from the western rivers to the command of the eastern rivers as replacement works. However, in the last few years Pakistan has objected to India's development of hydropower projects on the western rivers, Chenab and Jhelum.

Baglihar dam, constructed in the Chenab in Jammu and Kashmir and completed in 2008, has been the source of continuing disputes between India and Pakistan. After construction began in 1999, Pakistan claimed that the design parameters of the Baglihar project violated the Indus Water Treaty. Finally, the World Bank held that India had not violated the Indus Water Treaty and said that the dam could be completed with slight modifications in design and without any impact on the 450 MW power component. The World Bank determined that India should reduce the freeboard in the height of the dam from 4.5 m to 3 m. India had offered to do this before Pakistan referred the dispute to the World Bank. Another objection by Pakistan was related to the width of the pondage that India could maintain in the run-of-the river project. India claimed a pondage of 37.5 million m^3. This was reduced by a neutral expert to 32.58 million m^3, while upholding India's methodology of calculation and rejecting Pakistan's suggestion of a pondage of 6.22 million m^3 (The Hindus, 2007; Press Information Bureau, 2008).

Table 6 lists the main historical events in the Indus river basin.

TABLE 4
Large dams in the Indus river basin (2010)

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m^3)	Main use *
India	Bhakra	Nangal	Sutlej	1963	226	9 620	I, H
	Nangal	Nangal	Sutlej	1954	29	20	I, H
	Pandoh	Mandi	Beas	1977	76	41	I, H
	Pong	Mukenan	Beas	1974	133	8 570	I, H
	Salal	Reasi	Chenab	1986	113	285	H
	Baglihar		Chenab	2008		33	H
					Total	**18 589**	
Pakistan	Mangla	Mangla	Jhelum	1968	116	10 150**	I, H
	Tarbela	Ghazi	Indus	1976	137	11 960	I, H
	Chashma (barrage)	Mianwali	Indus	1971	-	870	I
					Total	**22 980**	
					TOTAL	**41 569**	

* I = irrigation; H = Hydropower; ** Includes recent raising of 3.58 km^3

TABLE 5
Barrages in the Indus river basin (Source: NDMA-UNDP, 2010)

Country	Name	River basin	Year	Main use
India	Rupar	Sutlej	-	Irrigation
	Harike	Sutlej	-	Irrigation
	Ferozepur	Sutlej	-	Irrigation
	Madhopur Headwork	Ravi	-	Irrigation
Pakistan	Sulemanki & Islam	Sutlej	-	Irrigation
	Balloki & Sidhnai	Ravi	1965	Irrigation
	Marala	Chenab	1968	Irrigation
	Khanki	Chenab	-	Irrigation
	Qadirabad	Chenab	1967	Irrigation
	Trimmu	Chenab	-	Irrigation
	Punjnad	Chenab	-	Irrigation
	Rasul	Jhelum	1967	Irrigation
	Kalabagh	Indus	-	Irrigation
	Chashma	Indus	1971	Irrigation
	Taunsa	Indus	1958	Irrigation
	Guddu	Indus	1962	Irrigation
	Sukkur	Indus	-	Irrigation
	Kotri	Indus	1955	Irrigation
	Mailsi (Siphon)	Under Sutlej	1965	Irrigation

TABLE 6
Chronology of major events in the Indus river basin

Year	Plans/projects/treaties/conflicts	Countries, agencies involved	Main aspects
1859	Completion of the Upper Bari Doab Canal	British Indian Colony	Canal irrigation development began to provide water for kharif (summer) crops and residual soil moisture for rabi (winter) crops
1872	Completion of the Sirhind Canal	British Indian Colony	From Rupar Headworks on Sutlej
1886	Completion of the Sidhnai Canal	British Indian Colony	From Sidhnai barrage on Ravi
1982	Completion of the Lower Chenab Canal	British Indian Colony	From Khanki on Chenab
1901	Lower Jhelum Canal	British Indian Colony	From Rasul on Jhelum
1885-1914	Lower and Upper Swat, Kabul river and Paharpur Canals in Khyber Pakhtunkhwa (Pakistan)	British Indian Colony	Completed during 1885 to 1914
1907-1915	Triple Canal Project	British Indian Colony	Constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi.
1920	Indus Discharged Committee was established	British Indian Colony	Formed to record discharge data
1933	Sutlej Valley Project	British Indian Colony	Completed in 1933. Four barrages and two canals, resulting in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir (now in India).
1930´s	Sukkur barrage and its system of seven canals	British Indian Colony	Completed. Considered to be the first modern hydraulic structure on the downstream Indus river
1939	Completion of Haveli and Rangpur Canal	British Indian Colony	From Trimmu Headworks on Chenab
1947	Completion of the Thal Canal	British Indian Colony	From Kalabagh Headworks on Indus
1947	British Indian Colony divided into India and Pakistan		
1948	Water disputes between India and Pakistan	India and Pakistan	India unilaterally cut off supplies to Pakistan canals originating from the head-works located on the eastern rivers of Ravi and Sutlej
1954	Completion of the Nangal dam	India	On the Sutlej river
1955	Completion of the Kotri barrage	Pakistan	Was completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals (as Taunsa and Guddu)
1958	Completion of the Taunsa barrage	Pakistan	Completed to divert water to two large areas on the left and right banks of the river
1960	Indus Water Treaty (IWT)	World Bank, India, Pakistan	Resolved water disputes. Under the IWT all water of the eastern rivers shall be available for the unrestricted use of India. The three western rivers and all water while flowing in Pakistan of any tributary, which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan, shall be available for the unrestricted use of Pakistan (see "Water resources" section for details).
1962	Completion of the Guddu barrage	Pakistan	On Indus river
1963	Completion of the Bhakra dam	India	On the Sutlej river
1960-76	Indus Basin Project	Pakistan	Developed in pursuance of the IWT, including Mangla dam, five barrages (including Chashma reservoir), one syphon and eight inter-river link canals, completed during 1960-1971, and Tarbela dam started partial operation in 1975-1976.
1974	Completion of the Pong dam	India	On the Beas river
1977	Completion of the Pandoh dam	India	On the Beas river
1986	Completion of the Salal dam	India	On the Chenab river
2008	Completion of the Baglihar dam	India, Pakistan, World Bank	On the Chenab river. Disputes since the construction begun in 1999 between India and Pakistan. The World Bank finally authorized the construction

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Mekong river basin

GEOGRAPHY, POPULATION AND CLIMATE

Geography

The transboundary Mekong river basin has a total area of 795 000 km^2, ranking it the twenty-first largest river basin worldwide, distributed between China (21 percent), Myanmar (3 percent), Lao People's Democratic Republic (25 percent), Thailand (23 percent), Cambodia (20 percent) and Viet Nam (8 percent) (Table 1). The river basin can be divided into two parts: the Upper Basin in China (where the river is called Lancang) and the Lower Mekong Basin from Yunnan (China) downstream to the South China Sea.

The main river in the Upper Basin flows for almost 2 200 km from its source in China near Xizang (Tibet) and decreases in altitude by nearly 4 500 m before it enters the Lower Basin, first becoming the border between Myanmar and Lao People's Democratic Republic, then between Thailand and Lao People's Democratic Republic. This region is called the Golden Triangle. Then the river continues for another 2 600 km in Lao People's Democratic Republic before becoming the border again between this country and Thailand and then re-entering the country. Finally it enters Cambodia and from there Viet Nam where it flows by way of a complex delta system into the sea. The Upper and Lower Basins make up 24 and 76 percent respectively of the total area of the basin (MRC, 2005; MRC, 2010b).

Population

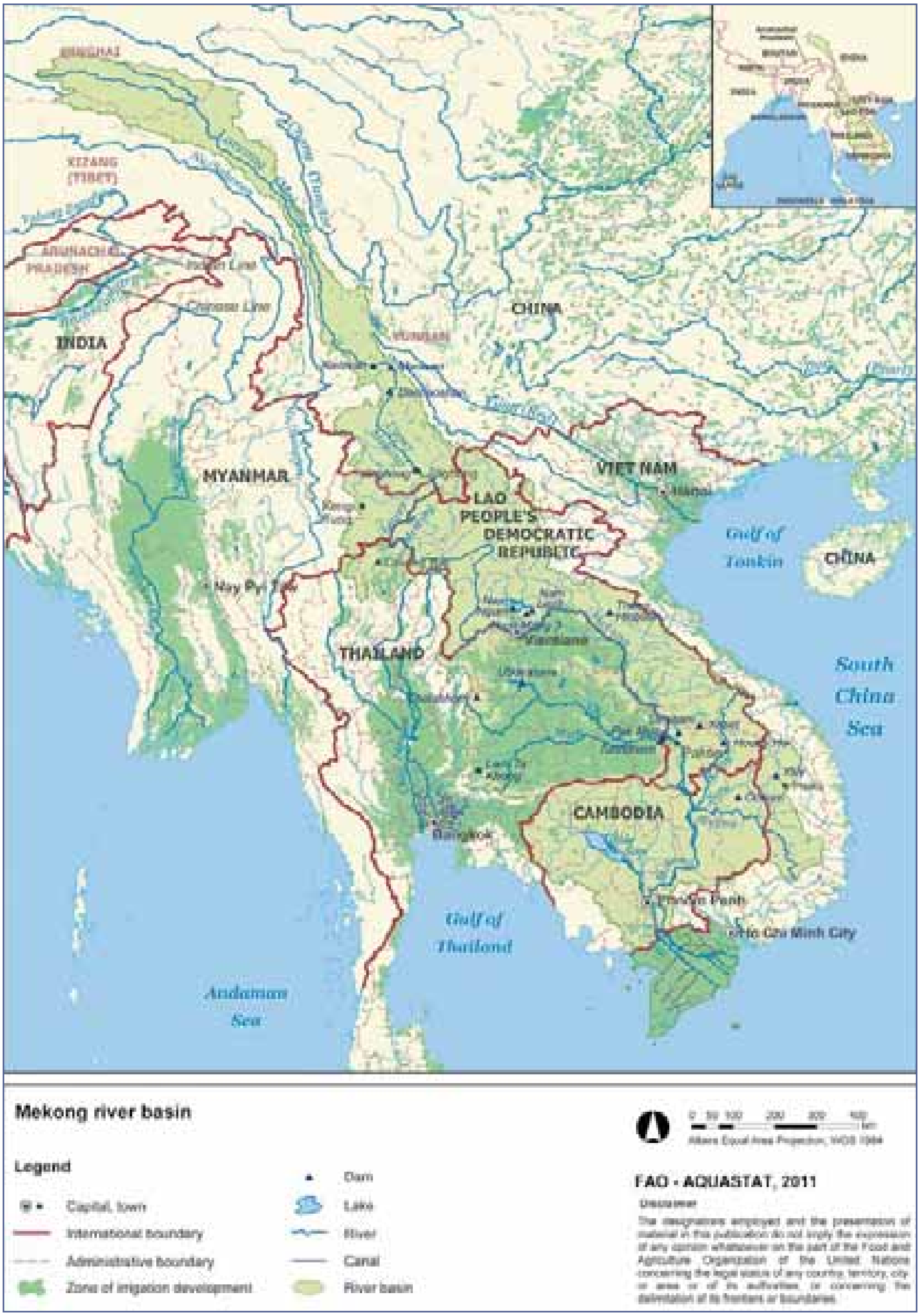
The Mekong river basin is a diverse region, in 2007 approximately 70 million people lived across the six countries (CDRI, 2008).

Compared to river basins such as the Ganges-Brahmaputra-Meghna and the Indus average population density is generally low in the Mekong river basin, around 88 inhabitants/km^2, varying from just over 50 inhabitants/km^2 in the Upper Basin to almost 100 inhabitants/km^2 in the Lower Basin. Density is highest in the Vietnamese part, 260 inhabitants/km^2, and lowest in Lao People's Democratic Republic, 24 inhabitants/km^2 (UNEP, after 2006).

Population in the Lower Basin was estimated at 60 million in 2007, with about 90 percent of the population of Cambodia (13 million), 97 percent of the population of Lao People's Democratic Republic (6 million), 37 percent of the population of Thailand (23 million), and 20 percent of the population of Viet Nam (16 million in the Delta and 2 million in the Central

TABLE 1
Country areas in the Mekong river basin

Basin	Area		Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total are of the country
	km^2	% of Southeast Asia				
Mekong	795 000	38	China	165 000	21	2
			Myanmar	24 000	3	4
			Lao PDR	202 000	25	85
			Thailand	184 000	23	36
			Cambodia	155 000	20	86
			Viet Nam	65 000	8	20


CHINA
INDIA
MYANMAR
VIET NAM
LAO PEOPLE'S DEMOCRATIC REPUBLIC
THAILAND
CAMBODIA
CHINA
Gulf of Tonkin
South China Sea
Gulf of Thailand
Andaman Sea
Nay Pyi Taw
Vientiane
Bangkok
Phnom Penh
Ho Chi Minh City
Mekong river basin
Legend
Capital, town
International boundary
Administrative boundary
Zone of irrigation development
Dam
Lake
River
Canal
River basin
FAO - AQUASTAT, 2011

Highlands) living within the basin. Annual population growth in the basin is 1-2 percent in Thailand and Viet Nam and 2-3 percent in Cambodia and Lao People's Democratic Republic. There are over 100 different ethnic groups living within the basin's boundaries, making it one of the most culturally diverse regions of the world (MRC, 2010; MRC, 2010b).

Although urbanization is occurring in all Lower Basin countries, about 85 percent of the basin's population lives in rural areas. The livelihoods and food security of most of the rural population are closely linked to the river system, with over 60 percent of the economically active population having water-related occupations that are vulnerable to water-related shocks and degradation. Most basin inhabitants are rural farmers/fishers and, while they may be resource-rich, they are money-poor. One-third of the population lives on less than US$2 per day. Often lacking access to basic government services, people in the basin are, on average, less well off than their fellow citizens outside the basin. About half of all villages are inaccessible by all-weather roads.

What makes life tolerable for these people are the aquatic resources provided by the basin's rivers and wetlands. While all Lower Basin countries are making good progress towards achieving the Millennium Development Goals (MDGs), more than 35 percent of the populations of Cambodia and Lao People's Democratic Republic have incomes below the poverty line, with much higher percentages in many rural areas. Food security and malnutrition pose great challenges. Throughout the Lower Basin, inequalities are generally increasing between urban and rural groups (MRC, 2010; MRC, 2010b).

In 2008, around 60 percent of the population in Cambodia and Lao People's Democratic Republic had access to safe water, 56 and 51 percent in rural areas of the two countries respectively. In Thailand and Viet Nam, access to safe water supplies is generally more widespread, accounting for 98 percent (both total and rural areas) and 94 percent (92 in rural areas) respectively. In Myanmar access to safe water accounts for 71 percent (69 percent in rural areas) and in China it accounts for 89 percent (82 percent in rural areas). Health conditions for children and women are among the poorest in the world, particularly in less developed areas of the Lower Basin (UNEP, after 2006).

Migrationis a transboundary issue, with social and geo-political implications. The search for employment is a major cause of migration. Seasonal and semi-permanent migration to urban areas provides important income for households in rural areas, but the largest movements are between rural areas. People relocate from densely populated rural areas to remote ones to seek new economic opportunities. Economic development in the Lower Basin, especially in urban centres, creates a strong attraction for rural people because jobs are more numerous, better paid and services are more developed (WEPA, 2010).

Climate

The climate of the Lower Basin is dominated by the southwest monsoon, which usually lasts from May until late September or early October and which corresponds to the flood period in the Lower Basin. Heavy rainfall usually occurs, lasting one or two days in most parts of the basin. Later in the season, tropical cyclones occur over much of the area so that August, September, and in the delta even October, are the wettest months of the year. Annual average rainfall is less than 1 500 mm over the Cambodian floodplain and the Mekong Delta and over twice this figure in the Central Highlands of Lao People's Democratic Republic and within the mainstream valley at Pakse.

Rainfall is less signifiant in the more temperate northern regions around Chiang Rai in northern Thailand, where July, August and September are generally the months of highest rainfall. Tropical storms and cyclones strongly affect the climate of the basin. This shows up as a double peak in rainfall distribution over most of the Lower Basin during the wet season, and the concentration of maximum rainfall during the last quarter of the year in Cambodia and Viet Nam. Tropical cyclones over central and southern Viet Nam show that the occurrence of the cyclones is more frequent from September to November (MRC, 2005).

In the Upper Basin, Yunnan province in southern China also has a monsoon climate, although there is considerable variation with local topography. The climate varies from tropical and subtropical monsoons in the south of Yunnan, to temperate monsoons in the north as the elevation rises from a mean 2 500 m to 4 000 m above sea level in the most upstream part. The rainfall pattern in the Upper Basin in China is also determined by global monsoon systems, although in Yunnan province there is a much wider variation from year-to-year in the date of the onset of the southwest monsoon. The seasonal distribution of rainfall is the same as for the Lower Basin, although annual amounts decrease towards the north to as little as 600 mm. Snow is rare in the valleys, but significant at higher altitudes and is the major source of water for the dry season and spring flows (April, May) in the upper mainstream part.

The seasonal range of mean temperatures in the lowlands and river valleys of the Lower Basin is not large. Mean summer temperatures are similar from Phnom Penh in the south of Cambodia to the north of Lao People's Democratic Republic and Chiang Rai in Thailand (MRC, 2005). At almost 2 500 m above sea level in the Upper San sub-basin in Viet Nam, Pleiku has mean summer temperatures that are only 2 to 3 °C lower than those typical of the Mekong lowlands. Winter mean temperatures, however, decrease significantly from south to north, from 26 to 27 °C in Phnom Penh and from 21 to 23 °C in Chiang Rai. Winter temperatures are much cooler within the Upper Basin in Yunnan province. At Jinhong, which is 340 km upstream of the hydrological boundary of the Lower Basin, average summer temperatures are only 2 to 3 °C lower, but in winter they are 5 to 6 °C below temperatures at Chiang Rai. However, these differences are generally far less than the changes from day to night. In the far north of Yunnan, the seasonal temperature pattern becomes truly high-altitude continental. Winter temperatures here fall below zero and summer averages may only reach 13 °C (MRC, 2005b).

WATER RESOURCES

Surface water

The Mekong river has a mean annual discharge into the South China Sea of approximately 475 km^3, or 13 000 m^3/s, ranking it eighth in the world basins (Botkosal, 2009). The per capita water resources are high relative to other international river basins. The flow from the Upper Basin contributes 16 percent of the average annual flow (13 percent according to China), but up to 30 percent of dry season flow (MRC, 2010).

The annual flow from China to Myanmar and Lao People's Democratic Republic is 73.63 km^3. Leaving China, the river first becomes the border between Myanmar and Lao People's Democratic Republic and then flows over a short distance between Thailand and Lao People's Democratic Republic before entering the latter country. The contribution of Myanmar and Thailand is 17.6 km^3 and 51.9 km^3 respectively. In the south of Lao People's Democratic Republic, near Pakse, the Mekong river enters the country with an estimated 280 km^3/year at the confluence with the Chi/Mun river coming from Thailand. Annual flow of the Mekong river entering Cambodia is 324.45 km^3. Other inflows to the Mekong-Tonle Sap system in Cambodia from outside the country amount to 29.9 km^3 from Viet Nam and 1.19 km^3 from Thailand. On average, 470 km^3/year flows out of Cambodia into Viet Nam through the Mekong channels.

The Mekong river basin comprises a large network of tributaries, forming many sub-basins. Major tributary systems develop in the Lower Basin. These systems can be divided into two groups: tributaries that contribute to the major wet season flow and tributaries that drain low relief regions of lower rainfall. To the first group belong the left bank tributaries that drain the high-rainfall areas of Lao People's Democratic Republic. To the second group belong the tributaries on the right bank, mainly the Mun and Chi rivers that drain a large part of northeast Thailand (MRC, 2005). Mainstream water transfers have long been considered by Thailand, to complement national approaches to alleviate droughts in the northeast of the country (MRC, 2010).

The Mekong Delta begins in Phnom Penh, where the river divides into its two main distributaries, the Mekong and the Bassac. The Mekong then divides into six main channels and the Bassac into three channels, to form together the 'Nine Dragons' of the outer delta in Viet Nam. The main delta is made up of a vast triangular plain, which is less than 5 m above sea level, large areas of which are flooded every year. The movement of water within this complex channel network cannot be considered natural, owing to the long history of modification. Levees were built hundreds of years ago along some of the main natural channels. Hydrology is not only dominated by the rivers but also by the tide, which has a large expansion in the dry season and which can slow down the drainage of the river during heavy flood periods, mainly downstream (MRC, 2005).

During the end of the dry season (March - April), water flows out from the Great Lake, the Tonle Sap in Cambodia, and joins the Mekong river on its way to the South China Sea. In the wet season (May - September), so much water flows down the Mekong river that it reverses the flow of the Tonle Sap and the lake triples in size. This vast floodplain may be the most productive inland fishery in the world. Its well-being is vital to the people of Cambodia and to the overall health of the basin. In 1997, UNESCO declared the Tonle Sap lake and river system a World Biosphere Reserve (MRC, 2010b). The depth of the lake increases from a dry season maximum of 3.6 m to more than 10 m, and the area of open water increases from 2 500-3 000 km^2 during the dry season up to 13 000 km^2 during the wet season (MRC, 2005).

Groundwater

Good freshwater aquifers are located in the mountainous regions of Lao People's Democratic Republic and some of these are used for irrigating coffee. Groundwater is also used to irrigate coffee in the Vietnamese highlands, but there is some indication that the groundwater resource is being overused in some areas in Viet Nam with water tables declining over time. The recharge of these aquifers is slow, with farmers sometimes digging horizontally from the base of the wells to extract more groundwater. In northeast Thailand freshwater can be found among the numerous saline aquifers but the volume is not high enough for wide-scale irrigated agriculture. Extensive shallow groundwater reserves are known to exist around Tonle Sap and the Bassac and Mekong rivers in Cambodia and these reserves appear to be constantly recharged from the river but the recharge rate is slow and there is probably insufficient water for intensive irrigation (MRC, 2003).

The Mekong Delta has six aquifers with depths ranging from 15 to 75 m and from 275 to 400 m. Water reserves are large, but exploitation requires careful siting and drilling because much of the water is either brackish or saline and recharge is poorly understood. Water in the lower aquifers is 20 000–30 000 years old and not recharged by local rainfall, which means that there is considerable risk of over-exploitation. In part of the delta, shallow groundwater aquifers have been exhausted. Water levels are thought to have declined through both abstractions and the extensive surface drainage system constructed through the 1990s. The only major areas on the Mekong Delta consuming groundwater for agricultural production are located between and along the Bassac and Mekong rivers. Although the drawdown is significant during the dry season, the shallow aquifers are recharged by floods during the wet season and directly from the river in the dry season (MRC, 2003).

WATER QUALITY, ENVIRONMENT, FISHERIES AND FOREST RESOURCES

Water quality is generally good. The composition of the river water shows no deviation from similar international rivers. However, at localized level there appear to be three commonly identified water quality issues: sediment in the water, salinity, especially in northeast Thailand and the delta in Viet Nam and eutrophication. Salinity, especially in the delta, may increase if predicted salt water intrusion occurs as a result of climate change (MRC, 2009c).

The diverse ecosystems of the basin are exceptionally productive, as are the benefits derived by the inhabitants. The maintenance of high biodiversity represents not only the biological integrity of the ecosystems but also the range of natural resources and products available to both urban and rural populations (MRC, 2009c). The water nourishes large tracts of forests and wetlands, which produce building materials, medicines and food, provides habitats for thousands of species of plants and animals. Known mineral resources include tin, copper, iron ore, natural gas, potash, gem stones and gold (MRC, 2010b). Basin fauna, including 14 critically endangered species, 21 endangered species and 29 vulnerable species, are threatened by rapid developments that will alter habitats and mechanisms that are essential to sustain high ecosystem productivity (MRC, 2010).

The Mekong river is the second most biodiverse river in the world, after the Amazon, and supports the world's largest freshwater capture fishery of about 2.3 million tonnes/year with an estimated commercial value of US$2 000 million/year (MRC, 2010; MRC, 2010b). The river's annual flood pulse continues to support a rich fishery; although there are reports of declining catches.

The basin is one of the most productive inland fisheries basins in the world. It provides a wide variety of breeding habitats for over 1 300 species of fish and the annual rise and fall of the river ensures a nutrient-rich environment for fish. The fishery provides a livelihood not just for fishers and their families but for thousands more who are employed full or part time making and selling food products and fishing gear, repairing boats and providing hundreds of related services. At the height of the rainy season, the basin is like a vast fish pond teeming with aquatic plants and animals in fields and ponds, lakes, streams and even in roadside ditches. By April and May, fields and ponds have dried up, streams have become trickles and the mainstream itself drops as much as 15 m. Researchers have only recently discovered that a number of valuable fish species have for centuries retreated to deep stretches of the river to wait out the dry season (MRC, 2010b).

The outlook for the basin's forests is not positive, with increasing demand for timber and land driving deforestation and soil degradation. Deforestation impacts on hydrology and related processes, such as flooding, soil erosion and mass soil movement, society and the economy. Progressive disappearance of the flooded forest in the downstream Tonle Sap area is a serious threat to fish reproduction and refuges. The agricultural encroachment that follows deforestation often causes the loss of traditional land-use rights and traditional conservation mechanisms. Water pollution from pesticides and chemical fertilizers used in the development of intensive agriculture is another great concern. Even though persistent pesticides are banned in riparian countries, clearly residual and illegally imported stocks continue to be used because residues of DDT, Dieldrin, and similar chemicals have been found in fish across the Mekong river basin (WEPA, 2010).

WATER-RELATED DEVELOPMENTS IN THE BASIN

Agriculture

Mekong farmers have been irrigating farmland since the first century. Today, thousands of farmers throughout the basin are producing a second and some a third rice crop per year in around 12 500 irrigation schemes. Farmers in the Mekong river basin produce enough rice to feed 300 million people per year (MRC, 2010b). Rice is the principal livelihood of people in the region (CDRI, 2008).

Today, 70 percent of the basin's population rely on agriculture for their livelihoods and an increasing population in the region is putting pressure on food security. Agriculture is vital to raising standards of living, improving livelihoods and poverty mitigation in the basin. It is currently the most dominant water-related sector, for both subsistence agriculture and export, particularly in Thailand and Viet Nam where it generates thousands of millions of annual revenue in United States dollars. Agriculture in Cambodia and Lao People's Democratic Republic is currently less intensively developed (MRC, 2009). It has been estimaed that demand for agricultural products from the basin will increase from 20 to 50 percent in the next 30 years. Agriculture, along with fishing and forestry, employs 85 percent of the people living in the basin (MRC, 2010b).

The total area equipped for irrigation in the Mekong river basin is estimated to be around 4.3 million ha, of which Viet Nam accounts for 42 percent, Thailand 30 percent, China 12 percent, Cambodia 8 percent, Lao People´s Democratic Republic 7 percent and Myanmar 2 percent. Area actually irrigated is estimated at 3.6 million ha. The equipped area irrigated by surface water accounts for 98 percent while groundwater accounts for 2 percent.

In the Lower Basin, the dry-season irrigated area of about 1.2 million ha is less than 10 percent of the total agricultural area (15 million ha) (MRC, 2010).

The Mekong Delta is one of the most productive regions in the world. Often referred to as Viet Nam's 'rice bowl', the Delta produces more than 16 million tonnes of rice annually for domestic consumption and export in addition to highly productive shrimp farms, orchards and market gardens. Every year, annual floods enrich the delta soils and bring millions of fish to spawn. Sediments carried from far upstream replace the land lost through natural erosion (MRC, 2010b).

Expansion of the present level of agriculture in the basin is limited by the availability of water in the dry season. Proposed dam development, especially reservoir dams upstream, could give a boost to the agricultural sector by redistributing some river flows from the wet to the dry season (MRC, 2009). There are plans to increase dry season irrigation by 50 percent (from 1.2 to 1.8 million ha) over the next 20 years, with Lao People's Democratic Republic planning to expand irrigation in the dry season from less than 100 000 ha to over 300 000 ha. Major irrigation expansion is being studied in Cambodia, linked to investments in flood control in the undeveloped Cambodian delta, and linked to hydropower development elsewhere (MRC, 2010).

Total water withdrawal in the Mekong river basin is estimated at 62 km^3, or 13 percent of the Mekong's average annual discharge, of which Viet Nam accounts for approximately 52 percent, Thailand 29 percent, China 9 percent, Lao People´s Democratic Republic 5 percent, Cambodia 3 percent, and Myanmar 2 percent. Irrigation withdrawal accounts for 56 km^3, or 90.5 percent of the total.

Existing reservoir storage capacity is insufficient to redistribute water significantly between seasons. Groundwater use in the basin is modest except in China, northeast Thailand and Viet Nam where surface water is scarce during the dry season. Sustainable groundwater development potential requires careful assessment. Surface water and groundwater account for 97 percent and 3 percent of total withdrawals in the Mekong river basin respectively.

The Watershed Management Project aims to put individuals and communities in charge of protecting catchments to ensure clean water. Sometimes, this may involve changing agricultural techniques or sanitation habits, which contaminate nearby water sources. The programme began its third and final phase in 2008 (MRC, 2009).

Dams and hydropower

The Mekong river basin has become one of the most active regions in the world for hydropower development (MRC, 2009c). The total potential for feasible hydropower projects in the four Lower Basin countries is approximately 30 000 MW, more than enough to meet the expected demand in the coming decade. This includes 13 000 MW on the Mekong's mainstream, and the remaining on its tributaries, of which 13 000 MW are in Lao People's Democratic Republic, 2 200 MW in Cambodia and 2 000 MW in Viet Nam (WEPA, 2010).

As shown in Table 2, hydropower projects with a total installed capacity of 2 612 MW are already in operation in the Lower Basin, while projects with a further 3 574 MW are currently under construction. All of these projects are located on the tributaries, not on the mainstream. Nearly half of them enable some degree of seasonal regulation of streamflow. Much of the electricity produced is used to power cities and industries outside the basin (MRC, 2010b).

Table 3 shows the existing large dams with details on height and capacity, where information was available. Thirteen hydropower dams have a capacity of more than 10 MW.

The governments of Cambodia, Lao People's Democratic Republic and Thailand are now actively considering building dams on the mainstream Mekong river, as well as on tributaries. Private sector interest in tributary development in Viet Nam also remains high (MRC, 2009). Over the next 20 years, further Lower Basin dams are planned, including twelve mainstream projects. Ten of these are dams planned across the river channel (eight in Lao People's Democratic Republic, two of which are on the Lao-Thailand mainstream, and two in Cambodia), one will be partial damming (Don Sahong) and one a diversion project (Thakho) in Lao People's Democratic Republic. Thirty tributary dams are planned, mostly in Lao People's Democratic Republic. All mainstream dams are classified as "run-of-river", with limited storage capacity and regulation potential. Many tributary dams include significant reservoirs, adding 21 000 million m^3 of storage (MRC, 2010).

There is also huge hydropower potential in the Upper Basin. In Yunnan Province (China), total hydropower potential is an estimated 23 000 MW (WEPA, 2010). China is completing its hydropower cascade on the Lancang mainstream. The Manwan, Dachaoshan, Jinghong and Xiaowan dams are currently operational and the Nuozhadu dam will be completed in 2014. The Xiaowan and the Nuozhadu dams, with 15 043 and 22 400 million m^3 of storage, may cause significant seasonal redistribution of flow from the wet season to the dry season and further reduce sediment transport in the Mekong mainstream, providing both opportunities and risks to downstream countries (MRC, 2010).

Table 4 shows the major existing and planned mainstream hydropower projects in the Upper Basin in China. While the first three dams constructed have limited capacity to regulate flows, Xiaowan and Nuozhadu (under construction) have major storage capacity and therefore significant influence on the seasonal distribution of flow entering the Lower Basin (MRC, 2009c).

TABLE 2
Existing, under construction and planned/proposed hydropower projects in the Lower Mekong river basin (Source: MRC, 2009c)

Country	Installed capacity (MW)			
	Existing	Under construction	Planned/ proposed	Total
Cambodia	1	-	5 589	5 590
Lao People's Democratic Republic	662	2 558	17 686	20 907
Thailand	745	-	-	745
Viet Nam	1 204	1 016	299	2 519
Total	**2 612**	**3 574**	**23 574**	**29 760**

TABLE 3

List of completed major dams in the Lower Mekong river basin (2008)

Country	Name	Nearest city	River	Year	Height (m)	Capacity (million m^3)	Capacity (MW)	Main use*
Cambodia	Ochum	Lumphat	n.a.	n.a.	n.a.	n.a.	1	H
Lao PDR**	Nam Ngum	Phonhong	Nam Ngum	1971-85	45	7 010	150	H
	Xeset	Kong	Xeset	1991	n.a.	n.a.	45	H
	Theun Hinboun	Pakxan	Kading	1998	65	20	220	H
	Houay Ho	Samakhixai	Kong	1998	80	596	150	H
	Selabam	Pakse	Se Don	1970	n.a.	n.a.	5	H
	Nam Leuk	Phonhong	Nam Leuk	2000	45	185	60	H
	Nam Mang 3	Phonhong	Nam Gnong	2004	34	550	40	H
				Sub-total			**670**	
Thailand	Sirindhorn	Ubon Ratchathanee	Lam Dom Noi	1971	42	1966	36	I, H, W, F
	Chulabhorn	Chaiyaphum	Nam Phrom	1972	70	188	15	I, H, W, F
	Ubol Ratana	Khon Kaen	Nam Pong	1966	32	2 264	25	I, H, W, F
	Pak Mun	Ubon Ratchathanee	Mun	1994	17	114	136	H
	Lam Ta Khong	Nakhon Ratchasima	Lam Takhong	1969	40	310	1 000	I, H, W, F
				Sub-total		**4 842**	**1 212**	
Viet Nam	Dray Ling	n.a.	n.a.	1995	n.a.	n.a.	13	
	Yaly	Pleiku	San	2002	69	1 037	720	H, F
				Sub-total			**733**	
				Total		**-**	**2 616**	

n.a. Information not available

* I = irrigation; H = Hydropower, W = Water Supply; F = Flood protection

** Lao PDR = Lao People's Democratic Republic

TABLE 4

Existing, under construction and planned mainstream hydropower projects in the Upper Lancang/Mekong river basin

Project	Status	Nearest city	River	Commissioning	Height (m)	Capacity (million m^3)	Capacity (MW)
Manwan	Existing	Aihua	Lancang	1995	132	662	1 750
Dachaoshan	Existing	Lishu	Lancang	2004	111	933	1 350
Jinghong	Existing	Jinghong	Lancang	2008	108	1 233	1 750
Xiaowan	Existing	Luodang	Lancang	2010-2014	292	15 043	4 200
Gonguoqiao	Construction	Yongping	Lancang	2012	130	510	750
Nuozhadu	Construction	Menga	Lancang	2014	2615	22 400	5 500
Mengsong	Planned	Jinghong	Lancang	Before 2025	65	-	600
Ganlanba	Planned	Jinghong	Lancang	Before 2025	605	-	150
Total							**14 800**

Navigation is important but largely undeveloped as an integrated transport sector. River-related tourism is important for national revenue and local income generation (MRC, 2010).

There are increasing opportunities for the private sector and foreign state-owned companies in the development of water and related resources, such as hydropower, navigation, large-scale irrigation, and industry (mining, forestry, and tourism). In many of these areas, private sector investment now exceeds that of the public sector. In comparison with conventional public sector driven developments, private sector developments are more opportunity-driven with relatively short planning cycles and assessment processes. While private sector participation is welcomed, it needs to be open to public scrutiny and sensitive to civil society concerns. This will require effective regulatory systems, including enabling legislation and regulations and enforcement capacity, as well as strong and empowered water resource management agencies (MRC, 2010).

TRANSBOUNDARY WATER ISSUES

Evolution of cooperation in the Mekong river basin

Cooperation in the Mekong river basin begins in the middle of the twentieth century with the formal signing of the Geneva Accords (1954), when the newly independent nations of Cambodia, Lao People's Democratic Republic and Viet Nam took their places on the world stage (MRC, 2010b). In 1957, the United Nations-founded Mekong Committee (Committee for Coordination of Investigations of the Lower Mekong Basin) was established by Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam during the thirteenth session of the United Nations Economic and Social Committee for Asia and the Pacific (ESCAP) to address the comprehensive development of water and related resources in the Lower Mekong Basin (ESS, 2010).

Studies of the Mekong by the United Nations Economic Commission for Asia and the Far East (ECAFE) and the United States Bureau for Reclamation (USBR) sparked interest in a grand scheme to develop what was thought of as one of the world's great 'untamed rivers'. The Mekong Project, launched in 1957, was the largest single development project the fledgling United Nations organization had ever undertaken. When the Mekong Committee began its work, there were no models to follow. In its early days, the Committee was guided and supported by ECAFE and the United Nations Development Agency (MRC, 2010b).

From 1957 through to the mid-1960s, the Mekong Committee conducted hundreds of surveys and studies. Teams of experts traveled up and down the mainstream and its tributaries in boats, in jeeps, on foot, and on the backs of elephants to map, measure, sample and catalogue a rich diversity of resources. These studies were the basis of an ever-expanding 'knowledge base', now maintained by the Mekong River Commission (MRC, 2010b).

Lack of stability in the region resulted in the interruption of Mekong Committee sessions in the late 1970s. In response to Cambodia's absence, in 1977 Lao People's Democratic Republic, Thailand and Viet Nam adopted a new statute forming the basis of the Interim Mekong Committee. When Cambodia finally requested readmission in 1991, lengthy discussions began which led to the eventual transformation of the Mekong Committee through the 1995 Mekong Agreement (MRC, 2010b).

The Mekong River Commission

The Mekong River Commission (MRC) was formed in 1995 by the Mekong Agreement between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. The four countries signed *The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin* and agreed on joint management of their shared water resources and development of the economic potential of the river. The agreement brought a change of identity to the organization, which was previously known as the Mekong Committee. The MRC consists of three permanent bodies (MRC, 2010b):

- Ø **Council**: consists of one member from each country at ministerial or cabinet level and meets once a year. It makes policy decisions and provides other necessary guidance concerning the promotion, support, cooperation and coordination of joint activities and programmes to implement the 1995 Agreement. It has overall governance of the MRC.
- Ø **Joint Committee**: consists of one member from each country at no less than Head of Department level. It is responsible for the implementation of the policies and decisions of the Council and supervises the activities of the MRC Secretariat. This body functions as a board of management.
- Ø **Secretariat**: is the operational arm of the MRC. It provides technical and administrative services to the Joint Committee and the Council, and is under the direction of a Chief Executive Officer (CEO) who is appointed by the Council. Under the supervision of the Joint Committee, the CEO is responsible for the day-to-day operations of around 155 professional and general support staff. In 2009 it was decided that the Secretariat would be permanently cohosted in two locations, one office in Vientiane (Lao People's Democratic Republic) and one office in Phnom Penh (Cambodia). The Assistant CEO is of the same nationality as the Joint Committee Chair and serves a one-year term. The main counterparts for MRC activities in the four member countries are the National Mekong Committees (NMCs).

Since the 1995 Agreement, the MRC has launched a process to ensure "reasonable and equitable use" of the Mekong river system, through a participatory process with NMCs in each country to develop procedures for water utilization. The NMCs coordinate MRC programmes at the national level and provide links between the MRC Secretariat and the national ministries and line agencies (MRC, 2010b).

In 1996 China and Myanmar became Dialogue Partners of the MRC and the countries now work together within a cooperation framework. On 1 April 2002 China signed an agreement on the provision of hydrological information on the Lancang/Mekong river. Under this agreement China now provides water level data in the flood season from two stations located on the Upper Mekong in China. This information is fed into the MRC's flood forecasting system. Talks are under way to expand this data-sharing agreement to include dry season levels (MRC, 2010b).

Programmes

The MRC promotes regional cooperation to implement the 1995 Agreement. It serves its member states by supporting decisions and promoting action on sustainable development and poverty alleviation as a contribution to the MDGs. It supports the Mekong Programme, a regional cooperation programme for the sustainable development of water and related resources in the Mekong river basin owned by its member countries (MRC, 2010b).

The 1995 Mekong Agreement charges the MRC with the formulation of a Basin Development Plan (BDP) "to promote, support, cooperate and coordinate in the development of the full potential of sustainable benefits to all riparian states and the prevention of wasteful use of the Mekong basin waters, with emphasis and preference on joint and/or basin-wide development projects and basin programmes". The first phase of the BDP (2001-2006) achieved much in terms of establishing processes and creating a framework for participatory planning. It made good progress in the improvement of the knowledge base and tools for water resources development planning. It also established a project database that contains screened and prioritized projects, some of which are being implemented or prepared for implementation with support from development partners. The second phase of the BDP Programme (2006-2010), which started full operations in 2008, is designed to institutionalize the participatory planning process established during BDP Phase 1 and further develop the assessment tools and integrated water resources management (IWRM)-based planning capacity to produce a rolling IWRM-based BDP. The four goals of the organization for 2006-2010 were to:

1. promote and support coordinated, sustainable, and pro-poor development;
2. enhance effective regional cooperation;
3. strengthen basin-wide environmental monitoring and impact assessment;
4. strengthen the IWRM capacity and knowledge base of the MRC bodies, NMCs, Line Agencies, and other stakeholders(MRC, 2010b).

The Water Utilization Programme (WUP) ran from 2000-2008, developing 'procedures' for water use that could be agreed upon by the four governments of the Lower Mekong river basin. These procedures were required under Articles 5, 6 and 26 of the 1995 Agreement. The most important were procedures for data and information exchange and sharing, for water-use monitoring, and for maintenance of flows on the mainstream approved in 2001, 2003 and 2006 respectively (MRC, 2010b).

The goals of MRC's Agriculture, Irrigation and Forestry Programme (AIFP) are to ensure that sound river basin management will preserve the natural resource benefits of catchments for the future, to develop improved irrigation and water use methods and engage in research on the best methods for monitoring land-use changes and the complete important baseline studies on river basin management, forestry and land-use planning. The AIFP completed its first phase in December 2005.

In 2010, the IWRM-based Basin Development Strategy for the Lower Mekong river basin was prepared. The participatory preparation of this strategy and its approval by the MRC Council is a major achievement in the move towards sustainable Mekong river basin development and management. The strategy is a statement of the Lower Mekong river basin countries (Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam) setting out how they will share, use, manage and conserve the water and related resources of the Mekong to achieve the goals of the 1995 Mekong Agreement. The strategy is part of MRC's response to Article 2 of the 1995 Mekong Agreement, which calls for "the formulation of a basin development plan, that would be used to identify, categorize and prioritize the projects and programmes to seek assistance for and to implement at the basin level". It provides initial directions for sustainable basin development and management that are subject to review and updating by MRC every five years (MRC, 2010).

The strategy:

1. defines the scope of opportunities for water resources development (hydropower, irrigation, water supply, flood management) and their associated risks and required actions to optimize the opportunities and minimize the risks;
2. defines other water-related opportunities (fisheries, navigation, environment and ecosystems, watershed management);
3. provides a coordinated, participatory and transparent process that promotes sustainable development (MRC, 2010).

As part of the Mekong river basin countries' push for rapid economic growth and development, there is pressure to increase access to water for electricity generation and for irrigation, and to provide water for urbanization and industrial development. Development is uneven. China, Thailand and Viet Nam are investing more in generating electricity to support local production and urbanization, while Cambodia, Lao People's Democratic Republic and Myanmar are still in the process of investing in basic irrigation systems for agricultural production. While co-riparian states tend to be more cooperative when it comes to water than other resources, the degree of cooperation still depends on self-interest and the capacity of the individual states to accommodate individual development interests. Each country needs to strictly implement internal and international environmental codes of conduct and make sure every water-related development project is compliant with human water rights. This requires stronger transboundary coordination and negotiation mechanisms including enforcement of agreed institutional arrangements, and laws and regulations for equal rights of access and sharing benefits from the Mekong river (CDRI, 2008).

Fishery resources management is the perfect example of a transboundary issue that challenges every riparian country. It is obvious that any change in the ecosystem occurring in the upstream region will affect and impact on the livelihoods of hundred of millions of people whose food supply and economic activities rely heavily on fishery resources in the downstream areas. Water quality, water availability, and preservation of the flooded forest are key conditions for the survival and sustainability of fishery resources in Cambodia (WEPA, 2010).

Among the weak points, the 1995 Mekong Agreement does not set any strict upper limits on water use, except for trans-basin diversions in the dry season, but this is not where large potentials lie. Cambodia obtained an assurance that the reversed flow of the Tonle Sap river, following the annual flooding would be allowed. It will also benefit from improved information flow and a higher concern of overall environmental protection in the basin. On the other hand, Cambodia and Viet Nam are vulnerable compared to Thailand and Lao People's Democratic Republic when it comes to trans-basin diversions and other large-scale upstream water use, such as for example hydropower development (WEPA, 2010).

An important challenge of regional cooperation is the cost of upstream effects on ecological systems downstream. Article 7 of the 1995 Mekong Agreement requires each co-riparian state to make every effort to avoid, minimize and mitigate harmful effects that might occur to the environment, especially the water quantity and quality, the aquatic (ecosystem) conditions, and the ecological balance of the Mekong river basin water resources or discharge of wastes and return flows. However, Lao People's Democratic Republic and Viet Nam, for example, have been building dams in the upper catchment of the Kong river basin, to generate electricity for sale to Thailand and Viet Nam. These hydroelectricity dams affect hydrological flows and the livelihoods of the people who live along the San and Srepok rivers, the Kong's tributaries, and the flow into the Mekong, affecting aquatic eco-systems, fish and fish production in the Tonle Sap (CDRI, 2008).

The transboundary implications of hydropower projects on water quality and quantity are numerous. The first risk of hydropower projects development in the upstream area of the Mekong river is the negative impact on the environment and society. These risks have been duly identified as:

- adverse impacts on the ecosystem (aquatic life, animals, birds, vegetation);
- blocking the flow of sediment;
- negative impacts resulting from changes in a river's flow pattern;
- negative social impacts (resettlement, loss of livelihood);
- loss of scenic landscapes (tourism potential);
- negative impacts on water quality because of storage of water (eutrophication, lower temperatures for discharged water);
- negative impacts on other users of water (navigation, fisheries);
- problems during the construction period (noise, vibration, dust, traffic problems);
- when associated with irrigation, land salinization and waterlogging; and
- danger from sudden and unexpected release of water from flood spilling or hydropower generation.

The second type of risk is geo-political, i.e. the inevitable dependence of countries that do not possess hydropower upon those that develop hydropower projects. Cambodia is particularly vulnerable because it will certainly increasingly depend on Thailand, Lao People's Democratic Republic and Viet Nam for power supply. A cut off of power supply by power producers would seriously impede any possibility for Cambodia to achieve its development goals and strategies, such as to alleviate poverty, improve the population's livelihood, welcome further foreign investments, sustain tourism development, etc. (WEPA, 2010).

Table 5 lists the main historical events in the Mekong river basin.

TABLE 5
Chronology of major events in the Mekong river basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
1954	Signing of the Geneva Accords	Cambodia, Lao People's Democratic Republic and Viet Nam	Mekong cooperation begins
1957	Mekong Committee formed	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Address comprehensive development of water resources and related resources in the Lower Mekong Basin (LMB)
1957	Mekong Project	ECAFE, United States Bureau for Reclamation and LMB countries	
1977	Interim Mekong Committee formed	Lao People's Democratic Republic, Thailand and Viet Nam	In response to Cambodia's absence, in 1977 Lao People's Democratic Republic, Thailand and Viet Nam adopted a new statute
1991	Cambodia requested readmission in the Mekoong Committee	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Lengthy discussions began which led to the eventual transformation of the Mekong Committee through the 1995 Mekong Agreement
1995	Mekong Agreement	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	The four countries signed The Agreement on the Cooperation for the Sustainable Development of the Mekong River Basin and agreed on joint management of their shared water resources and development of the economic potential of the river
1995	Mekong River Commission (MRC) formed	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Formed by the Mekong Agreement. The MRC consists of three permanent bodies: the Council, the Joint Committee and the Secretariat
1996	China and Myanmar became Dialogue Partners of the MRC	China, Myanmar, Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	The countries now work together within a cooperation framework
2002	China signed an agreement on the provision of hydrological information on the Lancang/ Mekong river	China	China now provides water level data in the flood season from two stations located on the Upper Mekong in China
2001-2006	Basin Development Plan (BDP) (Phase I)	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	The 1995 Mekong Agreement charges the MRC with the formulation of a BDP. This first phase achieved much in terms of establishing processes and creating a framework for participatory planning.
2006-2010	BDP (Phase II)	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Designed to institutionalise the participatory planning process established during BDP Phase 1 and develop the assessment tools to produce a rolling IWRM-based Basin Development Plan.
2000-2008	Water Utilization Programme (WUP)	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Developing 'procedures' for water use that could be agreed upon by the four governments of the LMB
2005	Agriculture, Irrigation and Forestry Programme (AIFP) (Phase I)	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	Prepared by the MRC
2010	IWRM-based Basin Development Strategy for the LMB has been prepared	Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam	The participatory preparation of this Strategy and its approval by the MRC Council is a major achievement in the move towards sustainable MRB development and management

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Salween river basin

GEOGRAPHY, POPULATION AND CLIMATE

The basin of the Salween river, also known as Nu river in China and Thanlwin river in Myanmar, is a transboundary basin with a total area of 320 000 km^2 distributed between China (53 percent), Myanmar (42 percent) and Thailand (5 percent) (Table 1). Approximately 2 400 km long, the Salween river is the second longest river in Southeast Asia after the Mekong river. The river originates 4 000 m above sea level on the mountain Tangula in the Himalayas on the Tibetan plateau in China, then flows southward through Yunnan province, China, down through Shan and Kayah states in the east of Myanmar, along the border between Thailand and Myanmar for about 120 km, then again enters Myanmar and passes through Kayan and Mon states before emptying into the Gulf of Martaban in the Andaman Sea. The Moei river, originating in Thailand, becomes the border between Myanmar and Thailand and joins the downstream Salween river, which has also become the border river between Myanmar and Thailand, before again entering Myanmar.

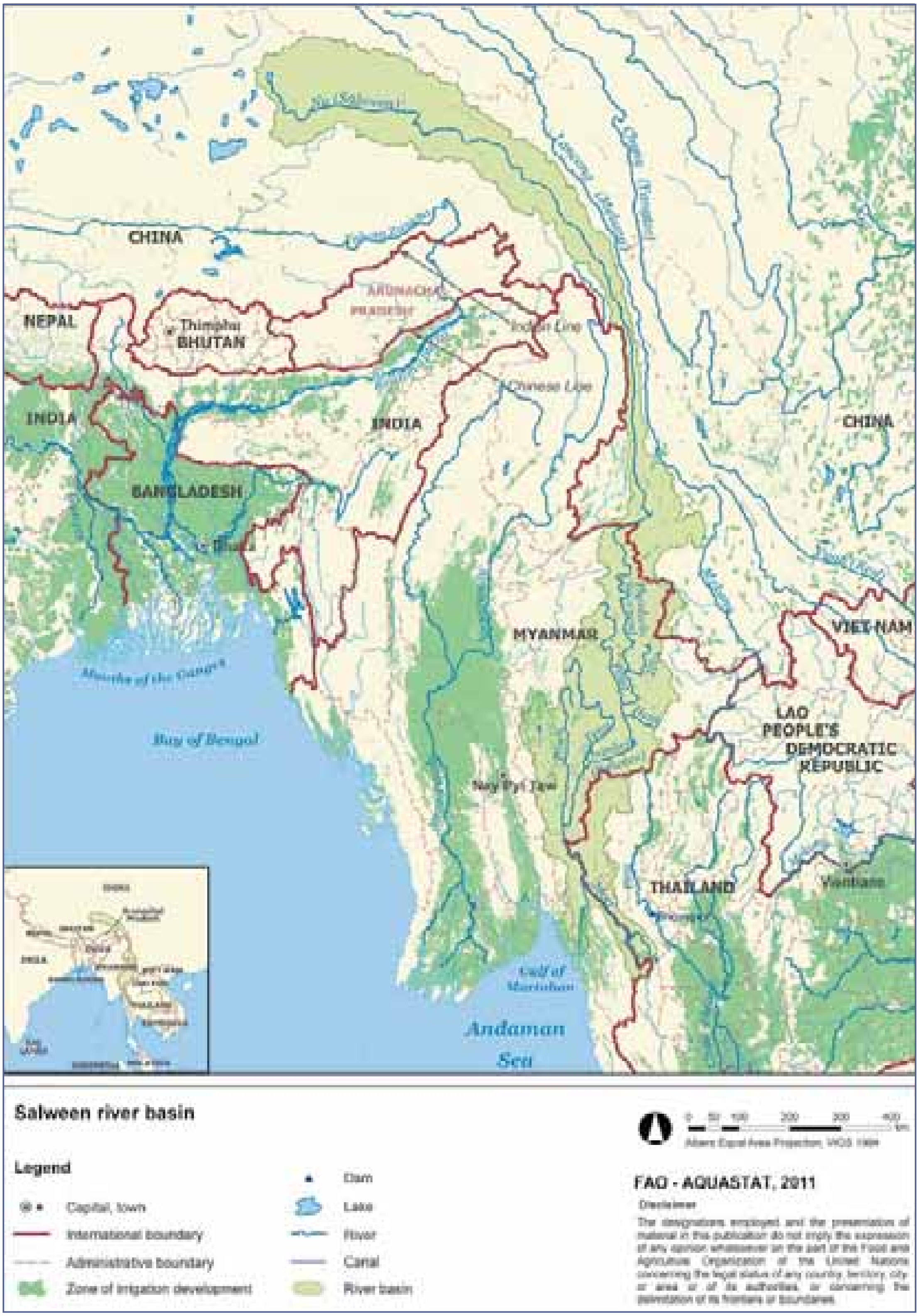
In China, the Nu river runs parallel to the upper reaches of the Mekong (also called Lancang) and Yangtze rivers in an area designated by UNESCO as a World Heritage Site for its rich biodiversity. In Myanmar and Thailand, the topography of the Salween river basin is mountainous, with long narrow river valleys. The basin is rich in natural resources, including water (both surface and groundwater), forest, wildlife, fisheries and aquatic life and minerals. Part of the basin in Thailand is a national park and wildlife sanctuary. Its beautiful landscapes include many caves, rapids, cliffs, unusual rocks and waterfalls that serve as tourist attractions. Habitats in the Salween eco-region support rich and endemic freshwater fauna. The river is home to at least 140 species of fish, of which one-third are endemic (Salween Watch, 2011).

More than 10 million people, representing at least 13 different ethnic groups, depend on the Salween river basin for their livelihoods: fisheries are a major source of dietary protein, and the river's nutrients nourish vegetable gardens in the dry season and fertilize farmland (Wolf and Newton, after 2007). In 2002, the population density in the Salween river basin was 76 inhabitants/km^2 (Earth Trends, 2002). The most populated section of the river basin is the delta's fertile floodplain that covers thousands of hectares at the mouth of the river. There, most people tend paddy fields in the rainy season and vegetable gardens on the river bank in the dry season. They also fish all year round (BRN, 2011).

The climate of the basin is influenced by the southwest monsoon in summer, from May to October, and the northeast monsoon in winter, from November to April. The middle and downstream reaches of the Salween and the Moei river basins belong to a typical tropical monsoon. The annual precipitation within the Salween river basin ranges widely, from

TABLE 1
Country areas in the Salween river basin

Basin	Area		Countries included	Area of country in basin (km^2)	As % of total area of the basin	As % of total are of the country
	km^2	% of Southeast Asia				
Salween	320 000	1.5	China	169 600	53	1.8
			Myanmar	134 400	42	19.9
			Thailand	16 000	5	3.1


CHINA
NEPAL
Thimphu
BHUTAN
ARUNACHAL PRADESH
Indian Line
Chinese Line
INDIA
INDIA
BANGLADESH
Dhaka
CHINA
MYANMAR
VIET NAM
LAO PEOPLE'S DEMOCRATIC REPUBLIC
Nay Pyi Taw
THAILAND
Vientiane
Mouths of the Ganges
Bay of Bengal
Gulf of Martaban
Andaman Sea
Salween river basin
Legend
Capital, town
International boundary
Administrative boundary
Zone of irrigation development
Dam
Lake
River
Canal
River basin
0 50 100 200 300 400 km
FAO - AQUASTAT, 2011
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around 1 200 mm midstream to over 2 000 mm upstream and downstream. In the coastal areas of the basin, the annual rainfall is as high as 4 000 to 5 000 mm (Vatcharasinthu and Babel, 1999).

The Upper Salween river basin in China covers four different climate zones (subfrigid, temperate, subtropical and tropical) whereby the northwestern highlands are marked by predominant continental conditions with a dry, cold climate and the southeastern lowlands are characterized by maritime, warm conditions. However, the distinctly seasonal nature of the monsoon planetary circulation affects to a greater or lesser extent all parts of the Upper Salween river basin.

WATER RESOURCES

The Salween river is the longest waterway without a dam in Southeast Asia. Numerous major tributaries, including the Pang, Teng, Pawn, Hka, and Hsim rivers join the Salween river in Myanmar. About 320 km from the mouth, for about 120 km the river forms the border between Myanmar and Thailand, before meeting with the Moei river (Thaungyin river) where it reenters Myanmar.

The annual flow of the Salween river basin from China (Nu river) to Myanmar (Thanlwin river) is 68.74 km^3. In Myanmar, the Salween river basin drains 20 percent of the territory, mainly the Shan plateau in the east. When becoming the border between Myanmar and Thailand, the flow is estimated at 200 km^3/year. Since it flows only over a relatively short distance on the border, the contribution from Thailand, therefore, is considered to be low over that short distance and the accounted flow of the river given to Thailand is 200/2 = 100 km^3/year.

WATER QUALITY AND ENVIRONMENT

The Salween river is among the ten most polluted rivers in the world (The Millennium Project, 2010). Natural resources are being exploited with alarming rates of environmental degradation. With civil war in Myanmar, and development project plans, the state of the Salween river basin is rapidly deteriorating. It is feared that developments on the river, including hydropower and water diversion projects, will destroy the delicate balance between the river and its catchment area. Many of the effects of a dam built on the Salween river will occur in Myanmar's downstream communities and ecosystems, but the forest, river and people in Thailand will also be affected (Salween Watch, 2011).

WATER-RELATED DEVELOPMENTS IN THE BASIN

The Salween river basin has huge potential water resources that, if well planned with careful consideration of the environment, can be developed for hydroelectric power generation and water use for different purposes within the basin or nearby basins. The basin, therefore, can serve as a major source of water and energy for the future social and economic development of Myanmar and Thailand (Vatcharasinthu and Babel, 1999).

The total area equipped for irrigation in the Salween river basin is estimated to be around 400 000 ha, of which Myanmar accounts for approximately 50 percent, China 42 percent and Thailand 8 percent. The area actually irrigated is estimated at 380 000 ha. The equipped area irrigated by surface water and groundwater account for 97 and 3 percent respectively.

Total water withdrawal in the Salween river basin is estimated at 5.1 km^3 of which Myanmar accounts for approximately 63 percent, China 32 percent, and Thailand 5 percent. Irrigation withdrawal accounts for 4.2 km^3, or 81 percent of the total.

For much of its course, the Salween river is not navigable because of rapids, but in the lower reaches, near the sea, the waterway is used to float timber downstream to sawmills.

Despite the fact that studies made after the 1950s identified tremendous hydropower potential, the Salween river is a relatively undeveloped basin, being the longest river in Southeast Asia that has yet to be dammed (BRN, 2011). However, it is likely that with economic development and further political integration in the region, development pressure in the river basin will increase, and there will be greater demand to use the water for irrigation, municipalities and industries, as well as the need for sufficient water for navigation. The power companies of Thailand and Myanmar, as well as private Japanese concerns, have pursued individual feasibility studies, however, it is only since the 1970s that the potential of the basin as a whole has been investigated. Besides power, serious plans have revolved around large-scale water diversion. Irrigation, barge transportation (to promote trade and tourism), and related surface infrastructure have also been discussed (Salween Watch, 2011).

The Chinese government plans to construct a cascade of up to 13 hydroelectric dams along the Nu river (Songta, Bingzhongluo, Maji, Lumadeng, Fugong, Bijiang, Yabiluo, Lushui, Liuku, Shitouzhai, Saige, Yansangshu and Guangpo) having a combined capacity of 23 320 MW (Salween Watch, 2011). Nine of the 13 proposed dams are in national nature reserves that are close to the World Heritage Area. The proposed dams have been the subject of an unprecedented outcry from Chinese journalists, environmentalists and everyday citizens who want to protect one of China's last dam-free rivers, and its ecological and social heritage (International Rivers Network).

The governments of Myanmar and Thailand are pushing ahead quickly with plans for a series of five giant dams on the Salween river and its tributaries, which are Hatgyi, Tasang, Wei Gyi (Upper Salween Dam), Dagwin (Lower Salween Dam) and Upper Thanlwin. The 7 110 MW Tasang Dam is the biggest of five dams planned of which the majority of the power generated will be sold to Thailand (Salween Watch, 2011). The planned dam at Tasang is proposed to be more than 180 m high, making it one of the largest dams in Southeast Asia (Wolf and Newton, after 2007).

TRANSBOUNDARY WATER ISSUES

There is no agreement between China, Myanmar and Thailand on the use of the Salween river, thus allowing each of them free use of the river. Each of these countries has unilateral plans to construct dams and development projects along the Salween river.

In 1989, a joint technical committee was established between Thailand and Myanmar, made up primarily of representatives from the power companies of the two countries. Since that time, the committee has continued to meet and to pursue feasibility studies, but no project or management body has been implemented nor a basin-wide plan created. China has not been included in discussions to date, nor has iChina included Thailand and Myanmar in its plans for projects on the Nu river (Wolf and Newton, after 2007).

In 1992, Thailand approved a plan to solve the water crisis in the Chao Phraya river basin, which encompasses the Salween Diversion Scheme and inter-basin water transfer from the Salween river basin to the Chao Phraya river basin. In 2003 several alternative plans were drawn up to divert 2.2 km^3 of water from the Salween river's major tributaries – and potentially the mainstream itself – through systems of holding dams, huge pumps and long tunnels to the Bhumipol dam on the Ping river, a tributary of Chao Phraya river that runs through central Thailand. One such plan is to divert floodwaters from the Salween river into a dam on the Yuam river, a major tributary of the Salween river, at Mae Lama Luang. The water from the Mae Lama Luang dam will then be diverted through a tunnel leading to the Bhumipol dam (Salween Watch, 2011).

In 1992, Japan's Electronic Power Development Corporation (EPDC) selected eight major hydroelectric dam projects, some of which are entirely in Myanmar and others are on shared sections within the Salween river basin.

In 2001, the Prime Minister of Thailand reversed past policy of distancing Thailand from Myanmar and pursued a policy of conciliation, cooperation and public support. Thai businesses were encouraged to invest in Myanmar, Thailand agreed to construct a bridge across the border to boost trade and tourism, and began a hydroelectric dam project on the Salween river. Thailand decided to channel water from Myanmar to solve its needs for irrigation and drinking water, and as a source of electrical power.

Since December 2002, the Myanmar Military and the Electricity Generation Authority of Thailand (EGAT) have been discussing the possibility of constructing large dam projects on the Salween river. Between October 1998 and March 1999 several teams of experts from Myanmar and Thailand, assisted by about 20 Japanese specialists, inspected three sites in the Salween river gorges about 120 km from the Thai border and carried out geological studies, test bores and feasibility studies. A quarter of the total energy production estimated would go to Myanmar and Thailand would purchase the rest. Environmental groups expressed concerns about the ecological effects of the projects, and human rights advocates warned against coinvesting with a military junta that is oppressive, unpredictable, and might not respect benefit-sharing agreements. Nonetheless, in August 2004, Thailand and Myanmar agreed to set up a joint venture to construct five hydropower dams in the Salween river basin, beginning with Tasang dam (Wolf and Newton, after 2007).

In 2003 China announced plans to build 13 hydropower projects on the Nu river in China. More than 80 environmental and human rights groups in Thailand and Myanmar petitioned China to consult downstream countries before proceeding with the project. In April 2004, the government of China purportedly suspended plans for the massive dam system, and ordered officials to conduct a review of the hydropower project and an environmental impact assessment.

Table 2 lists the main historical events in the Salween river basin.

TABLE 2
Chronology of major events in the Salween river basin

Year	Plans/projects/treaties/conflicts	Countries involved	Main aspects
1989	Joint technical committee was established between Thailand and Myanmar	Thailand and Myanmar	Made up primarily of representatives from the power companies of the two countries. The two countries enter into an agreement of cooperation in water development projects
1989	Coordinating team calls for the first meeting in Bangkok	Thailand and Myanmar	In November. Seven hydropower dam projects are proposed
1992	Eight major hydroelectric dam projects were selected	EPDC (Japan), Thailand and Myanmar	Some of which are entirely in Myanmar and others are on shared sections within the Salween river basin
1992	Salween diversion scheme	Thailand	Approval to a plan to solve the water crisis in the Chao Phraya river basin (Thailand), which encompasses the Salween Diversion Scheme
1998-1999	Inspection of three sites in the Salween gorges about 120 km from the Thai border carrying out geological studies, test bores and feasibility studies.	Thailand, Myanmar and Japan specialists	Several teams of experts from Myanmar, Thailand, assisted by about 20 Japanese specialists. A quarter of the total energy production estimated would go to Myanmar and Thailand would purchase the rest .
2001	Policy of conciliation, cooperation, and public support	Thailand and Myanmar	Thailand pursued a policy of conciliation, cooperation, and public support with Myanmar. Thai businesses were encouraged to invest in Myanmar.
2002	Discussing the possibility of constructing large dam projects on the Salween	Thailand and Myanmar	Between the Myanmar Military and the Electricity Generation Authority of Thailand (EGAT)
2003	Several alternative plans drawn to divert water from the Salween river to the Chao Phraya river		Several alternative plans were drawn up to divert 2.2 km3 of water from the Salween river's major tributaries, and potentially the mainstream itself, through systems of holding dams, huge pumps and long tunnels to the Bhumipol dam on the Ping river, a tributary of Chao Phraya river
2003	China announced plans to build a 13 hydropower projects on the Nu river in China	China, Myanmar and Thailand	
2003	Protests against dam projects on the Nu River	China, Myanmar and Thailand	In December, Groups in Thailand and Myanmar protest China's plans for 13 large dams on the Nu/Salween river
2004	Protests against dam projects on the Nu river	China, Myanmar and Thailand	In March, approximately 80 environmental and human rights organizations protested China's proposed dam projects on the Nu river
2004	Suspension of dam plan for the Nu river	China, Myanmar and Thailand	In April, China suspends dam plan for the Nu river.
2004	Agreement on construction of 5 dams	Myanmar and Thailand	Agreement to set up a joint venture for the construction of five hydro-powered dams beginning with Tasang dam

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SECTION IV
Country profiles

EXPLANATORY NOTES

In this section country profiles for Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, India, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Sri Lanka, Thailand, Timor-Leste and Viet Nam have been designated as an extra to the publication with their exclusive assigned numbers to figures and tables, and including a detailed map for each country.

The main reason for this is that these profiles have also been included on the AQUASTAT country web page (http://www.fao.org/nr/water/aquastat/countries_regions/index.stm), where each country profile can be downloaded as a stand-alone profile in PDF format.

A hyphen (-) in the country tables indicates that no information is available.

Bangladesh

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Bangladesh is a low-lying riverine country located in southern Asia, covering 144 000 km² (Table 1). The country has been formed as the largest deltaic plain at the confluence of the Ganges, the Brahmaputra (Jamuna) and the Meghna rivers and their tributaries. It has a common border to the west, north and east with India, a short border with Myanmar in the southeast, and is bounded by the Bay of Bengal in the south.

The country is divided into six administrative divisions, which are named after their respective divisional headquarters: Dhaka, Rajshahi, Chittagong, Khulna, Barisal and Sylhet. The Divisions are subdivided into 64 districts (*Zilas*) and each district is further subdivided into *Upazilas or Thanas*, of which there are 508. Finally, each *Thana* is again subdivided into Unions or Wards, of which there are 6 766.

About 80 percent of the landmass is made up of fertile alluvial lowland that becomes a part of the Greater Bengal Plain (Lower Gangetic Plain). The country is flat with some hills in the northeast and southeast. A great plain lies almost at sea level along the southern part of the country and rises gradually towards the north. The land elevation on the plain varies from 0 to 90 m above sea level (asl). The maximum elevation is 1 230 m asl at Keocradang in the Rangamati hill district. The geomorphology is comprised of almost 80 percent floodplains some terraces and hilly areas. About 7 percent of the total area of Bangladesh is covered with rivers and inland water bodies and these areas are routinely flooded during the monsoon. Forests cover about 16 percent of the total area of the country.

The total cultivable area is an estimated 8.77 million ha. In 2009, the total cultivated area was an estimated 8.55 million ha, of which 7.57 million ha was for annual crops and 0.98 million ha for permanent crops. Most farmers own less than 1 ha of land and many have less than 0.2 ha.

Climate

Bangladesh has a tropical monsoon climate with significant variations in rainfall and temperature throughout the country. There are four main seasons: the pre-monsoon (March-May), which has the highest temperatures and experiences the maximum intensity of cyclonic storms, especially in May; the monsoon (June-September), when the bulk of rainfall occurs; the post-monsoon (October-November) which, like the pre-monsoon season, is marked by tropical cyclones on the coast; and the cool and sunny dry season (December-February).

About 80 percent of the total rainfall occurs during the monsoon, and the average annual precipitation is 2 320 mm. This varies from 1 110 mm in the extreme northwest to 5 690 mm in the northeast. The country is regularly subjected to drought, floods and cyclones. The

BANGLADESH **FAO - AQUASTAT, 2011**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	14 400 000	ha
Cultivated area (arable land and area under permanent crops)	2009	8 549 000	ha
• as % of the total area of the country	2009	60	%
• arable land (annual crops + temp fallow + temp meadows)	2009	7 569 000	ha
• area under permanent crops	2009	980 000	ha
Population			
Total population	2009	147 030 000	inhabitants
• of which rural	2009	72	%
Population density	2009	1 021	inhabitants/km^2
Economically active population	2009	69 585 000	inhabitants
• as % of total population	2009	47	%
• female	2009	40	%
• male	2009	60	%
Population economically active in agriculture	2009	32 220 000	inhabitants
• as % of total economically active population	2009	46	%
• female	2009	50	%
• male	2009	50	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	89 360	million US$/yr
• value added in agriculture (% of GDP)	2009	19	%
• GDP per capita	2009	608	US$/yr
Human Development Index (highest = 1)	2010	0.469	
Access to improved drinking water sources			
Total population	2008	80	%
Urban population	2008	85	%
Rural population	2008	78	%

country's mean annual lake evaporation is approximately 1 040 mm, which is about 45 percent of the mean annual rainfall.

Mean annual temperature is about 25 °C, with extremes as low as 4 °C and as high as 43 °C. Ground frost can occur in the hills. Humidity ranges between 60 percent in the dry season and 98 percent during the monsoon.

Population

The total population in 2009 was 147 million, around 72 percent of which lived in rural areas (Table 1). Bangladesh is one of the most densely populated countries in the world with 1 021 inhabitants/km^2. Over the years, the country has succeeded in significantly reducing the population growth rate. In 1991 the population growth rate was 2.17 percent, it is currently 1.39 percent (BBS, 2008). Despite the steadily declining fertility rate, the country's population is expected to exceed 176 million by 2025, when the population density will rise to about 1 200 persons/km^2.

In 2008, access to improved drinking water sources was 80 percent (85 and 78 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total population that was economically active in agriculture was an estimated 32.22 million, amounting to 46 percent of the economically active population, of which 50 percent were women. In 2009, GDP was US$89 360 million of which agriculture accounted for 19 percent (Table 1).

Despite continuous domestic and international efforts to improve economic and demographic prospects, Bangladesh remains a developing nation. Since 1990 the country has been able to achieve a growth rate of only 5 percent owing to frequent natural disasters (such as cyclones, floods, droughts) and inefficient management of government economic policies and private sector organizations. The Government is currently focussing on agriculture and rural development, power and energy, small and medium enterprises (SMEs), human resource development, creation of employment opportunities, and increasing investment for pro-poor development activities, with a view to achieve macro-economic stability by enhancing the annual GDP growth rate.

Agriculture plays a dominant role in the growth and stability of the economy. The country has a favourable natural environment for crop production. Of the arable land, 33.3 percent is under single cropping, 45 percent double cropping, 11.5 percent triple cropping and 10.2 percent is cultivable waste and currently fallow land. Agriculture is also the prime source of raw materials for most industries.

The agriculture sector comprises crops, livestock, fisheries, homesteads and forestry. Within the crop subsector food grains, particularly rice, dominate for both cropped area and production. Yield of non-cereal crops such as pulses, oil seeds and vegetables including potatoes has almost stagnated, while that of wheat has barely increased.

Bangladesh made steady progress in crop agriculture during the post liberation period. Growth in the agricultural sector averaged over 3 percent/year during the 1970s and the early 1980s. Thereafter, the average growth rate declined to about 1.7 percent, which resulted from the slowdown in irrigation development, the unprecedented flood damage of 1987 and 1988 and the Government cutback in development expenditures for agriculture. Despite the sluggish growth rate in the agriculture sector, food grain production increased at an annual rate of 3 percent during the early 1990s. Much of the increase in production came from irrigated Boro rice.

The cropping intensity increased from 148 percent to 180 percent and food grain production almost doubled from 1970 to 1993. During 2000-2001, total rice production was 25.08 million tonnes. Since then, food grain production, particularly rice crop production, has increased steadily; though it depends on the vagaries of nature. Total rice production during 2007-2008 was 31.67 million tonnes (DAE, 2009) and wheat production in the same year was 0.74 million tonnes (BBS, 2008). Such achievements were possible owing to government efforts to introduce high-yielding varieties (HYV), small-scale irrigation, modern inputs such as fertilizers and pesticides and the use of agricultural machinery.

Despite the growth in food production and its availability, food insecurity is still a major problem because of the lack of purchasing power and therefore access to food, especially for the ultra poor. A major portion of the rural population is landless and, as labourers, they depend on casual earnings for their livelihood. As a result of the seasonal variation in agricultural employment, and limited employment opportunities in the non-farm sector, millions of people suffer from chronic and transitory food insecurity. For this reason, national level food grain availability does not mean household food security. In spite of the increased food grain production and a reduction of the real price of rice, over half of the country's population cannot afford an adequate diet. The Government has identified food security as an important factor contributing to its socio-economic stabilization and development (MoF and DM, 2006).

WATER RESOURCES AND USE

Water resources

Most of Bangladesh is located within the floodplains of three great rivers: the Ganges, Brahmaputra and Meghna (GBM), and their tributaries, such as the Teesta, Dharla, Dudhkumar, Surma and Kushiyara. The three major river systems drain into the Bay of Bengal through Bangladesh:

- The Brahmaputra river enters Bangladesh from the north and flows south for 270 km to join the Ganges river at Aricha, about 70 km west of Dhaka in central Bangladesh.
- The Ganges river flows east-southeast for 212 km from the Indian border to its confluence with the Brahmaputra, then as the Padma river for about a further 100 km to its confluence with the Meghna river at Chandpur.
- The Meghna river flows southwest, draining eastern Bangladesh and the hills of Assam, Tripura and Meghalay of India to join the Padma river at Chandpur. The Meghna then flows south for 160 km and discharges into the Bay of Bengal.

The combined discharge of the three main rivers is among the highest in the world. Peak discharges are 100 000 m^3/s in the Brahmaputra, 75 000 m^3/s in the Ganges, 20 000 m^3/s in the upper Meghna and 160 000 m^3/s in the lower Meghna.

There are 230 rivers criss-crossing the country, most of which are either tributaries or distributaries to the GBM river systems. The total length of the rivers is approximately 24 000 km and the total GBM catchment area is about 1.75 million km^2, out of which only 7 percent lies within Bangladesh. There are 57 transboundary rivers, of which 54 are shared with India and the remaining three originate in Myanmar.

On average, 1 121.6 km^3 of water crosses the borders of Bangladesh annually, of which 85 percent between June and October. Around 48 percent (537.2 km^3) is contributed by the Brahmaputra, 47 percent (525.0 km^3) by the Ganges, 4 percent (48.4 km^3) by the Meghna/Barak and nearly 1 percent (11 km^3) by other minor rivers to Chittagong in the southeast.

Because of the great disparity between the monsoon floods and the low flow during the dry season, the manageable surface water resources are considered to be 80 percent of the dependable flow in March. Surface water resources are used extensively for dry season irrigation, mainly Boro rice using low-lift pumps (LLPs) and traditional devices.

The availability of groundwater resources in Bangladesh is determined by the properties of the groundwater storage reservoir and the volume of annual recharge. Key factors that determine groundwater availability include the capacity of the country's aquifers to store water, and the characteristics that govern economic withdrawal of groundwater for irrigation, domestic and industrial needs. The source of recharge is rainfall, flooding, and stream flow in rivers. The quaternary alluvium of Bangladesh comprises a huge aquifer with reasonably good transmission and storage properties. Heavy rainfall and inundation during the monsoon substantially recharge aquifers annually.

A regional groundwater recharge assessment took place in 1987 by Master Plan Organization (MPO) under the National Water Plan (NWP) of the Ministry of Water Resources. Subsequently, MPO updated the groundwater resources assessment during the NWP Phase–II in 1991 and the average annual available groundwater recharge for the country was estimated as 21 km^3 (Table 2).

The internal renewable water resources are an estimated 105 km^3/year (Table 3). The overlap is considered negligible, this includes 84 km^3 of surface water produced internally as stream flows from rainfall and about 21 km^3 of groundwater resources produced within the country. Part of the groundwater comes from the infiltration of surface water with an external origin. Since annual cross-border river flows and entering groundwater are estimated to be 1 121.6 km^3, the total renewable water resources are therefore estimated to be 1 226.6 km^3.

In 2007 there was only one multipurpose dam, located at Kaptai in Rangamati Hill district. The total capacity of this dam is 20.3 km^3. In addition, there are three barrages constructed across the Teesta, Tangon and Manu rivers, which are used as diversion structures for irrigation only.

TABLE 2
Regional estimates of annual groundwater recharge (National Water Plan) (Source: MPO, 1987 and 1991)

Region	Area (million ha)	Usable recharge (million m^3)		Available recharge (million m^3)	
		NWP-I	NWP-II	NWP-I	NWP-II
Northwest – NW	3.016	13 400	12 100	9 480	9 786
Northeast – NE	3.569	17 800	23 100	9 615	9 594
Southeast – SE	3.007	9 000	9 800	1 538	1 498
South Central – SC	1.426	3 600	3 500	1 801	1 249
Southwest – SW	2.562	3 900	5 600	1 980	1 961
Total	**13.580**	**47 700**	**54 100**	**24 414**	**21 088**

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	2 320	mm/yr
	-	334 000	million m^3/yr
Internal renewable water resources (long-term average)	-	105 000	million m^3/yr
Total actual renewable water resources	-	1 226 600	million m^3/yr
Dependency ratio	-	91.4	%
Total actual renewable water resources per inhabitant	2009	8 343	m^3/yr
Total dam capacity	2007	20 300	million m^3
Water withdrawal			
Total water withdrawal	2008	35 870	million m^3/yr
- irrigation + livestock	2008	31 500	million m^3/yr
- municipalities	2008	3 600	million m^3/yr
- industry	2008	770	million m^3/yr
• per inhabitant	2008	247	m^3/yr
Surface water and groundwater withdrawal	2008	35 870	million m^3/yr
• as % of total actual renewable water resources	2008	2.9	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

In 1995, the installed capacity of all the country's power plants was about 2 907 MW, of which about 230 MW was hydroelectric.

International water issues

India controls the flow of the Ganges river with a dam completed in 1974 at Farraka, 18 km from the border with Bangladesh. This dam was a source of tension between the two countries, when Bangladesh asserted that the dam held back too much water during the dry season and released too much water during monsoon rains. A treaty was signed in December 1996 under which Bangladesh is ensured a fair share of the flow reaching the dam during the dry season. Such agreements for other transboundary rivers are yet to be made for equitable share of surface water resources of the country.

Water use

In 2008, the total water withdrawal was an estimated 35.87 km^3, of which 31.50 km^3 (88 percent) was for agriculture, 3.60 km^3 (10 percent) for municipalities and 0.77 km^3 (2 percent) for industries (Figure 1).

Approximately 28.48 km^3, or 79 percent of the total water withdrawal, comes from groundwater and 7.39 km^3, or 21 percent, from surface water (Figure 2).

FIGURE 1
Water withdrawal by sector
Total 35.87 km^3 in 2008

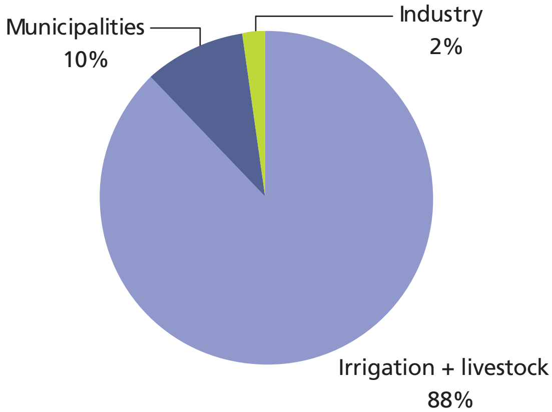
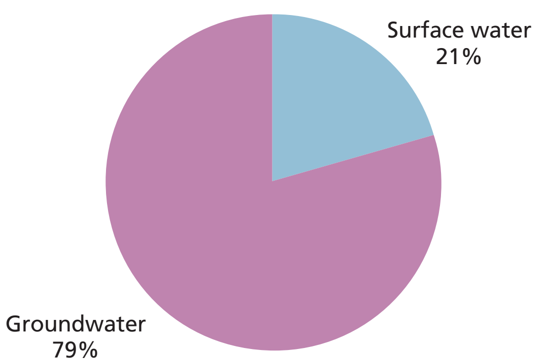


FIGURE 2
Water withdrawal by source
Total 35.87 km^3 in 2008



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation is considered to be a necessary precondition for the enhancement of agricultural production. The earliest approach to irrigation facilities was during 1960-1970 with the construction of large-scale multipurpose irrigation, flood control and drainage projects. To some extent, these projects were successful for flood control and protecting coastal areas from tidal bores and saltwater intrusion. But they played a minor role in irrigation development and only about 7 percent of the total irrigable area was covered by these very costly projects. Though the country has abundant surface water resources, particularly in the monsoon season, its flat deltaic topography and the instability of major rivers make large gravity irrigation systems both technically difficult and costly. On the other hand, during the dry season irrigation using surface water has become difficult or practically impossible owing to the limited availability of surface water. Therefore the use of groundwater for irrigation has become increasingly important.

The expansion of minor (small-scale) irrigation is a vital component of the Government's agriculture strategy. Minor irrigation consists of low lift pumps (LLP: power operated centrifugal pumps drawing water from rivers, creeks and ponds), shallow tubewells (STW: with a motorized suction mode pumping unit), deep tubewells (DTW: with a power operated force mode pumping unit), manually operated pumps (MOP: extracting water from a shallow tubewell) and traditional systems. At the end of the dry season, the water level falls beyond the suction limit of the centrifugal pump. In these situations, it is possible to draw water by placing the STW in a pit, which is called a deep-set shallow tubewell (DSSTW) or a very deep-set shallow tubewell (VDSSTW). Where static water levels fall further (over 10.7 m), a submersible or vertical turbine (FMTW: force mode tubewell) is needed.

Between 1950 and 1987, public tubewells, regulations governing private installations and public monopolies of the supply of pumps, motors and other equipment constrained irrigation development. Since 1972, the emphasis has been on minor irrigation using low lift pumps and tubewells (STW, DTW and FMTW).

From 1979 to 1984, there was a liberalized expansion of minor irrigation, mainly with STW in the private sector. In 1982, about 1.5 million ha were under food crop irrigation. The rate of minor irrigation development slowed from 39 000 STW in 1984 to less than 5 000 in 1986. This was because of a number of reasons: private sector STW sales were limited, there was official concern over reported declines in groundwater levels where STW operated, an embargo on all diesel engines was imposed in 1985, and engines were standardized.

In 1991, the National Minor Irrigation Development Project (NMIDP) was established in response to the needs of farmers and the requirement for increased private sector investment in minor irrigation technologies. The project activity mainly concentrated on VDSSTW and FMTW technology, whereas irrigation using STW was mainly controlled by the private sector. In 1994, 665 VDSSTW and 32 FMTW had been constructed by farmers as a result of the promotional action of the project. However, there has been a general reduction in the area irrigated by wells because of aquifer drawdown, and there has been an increase in salinity intrusion particularly along the coastal areas in the southwest of the country.

Currently, the irrigation potential is estimated as 6.93 million ha. During 2006, there were 29 170 DTW, 1 202 720 STW and 107 290 LLP and the total irrigated area was an estimated 4.88 million ha; where groundwater and surface water coverage were 81 percent and 19 percent, respectively. In 2008 the national irrigation coverage was 5.05 million ha, where groundwater covered 79 percent and surface water covered 21 percent of the total irrigated area (Table 4 and Figure 3). Table 5 gives a summary of irrigation methods using surface water and groundwater during 2008 is presented in Table 5.

In 1993, the total area of wetlands was 3.14 million ha, of which almost 1.55 million ha were cultivated. Thus, total water managed area is an estimated 6.59 million ha.

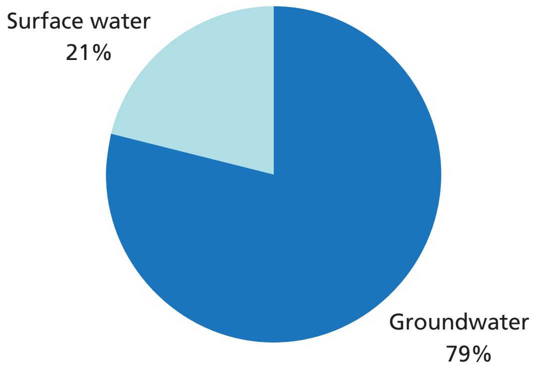
Surface irrigation is the only technology used in large irrigation schemes. In 2008, the total area equipped for full control irrigation covered by large irrigation schemes (major irrigation) was an estimated 0.14 million ha (3 percent). Small irrigation schemes covered a total area of 4.91 million ha (97 percent) (Figure 4).

In 1992, the average cost of irrigation development for large surface water schemes operated by the Bangladesh Water Development Board (BWDB) was an estimated US$522/ha as reported by the Food and Agriculture Organization of the United Nations (FAO, 2007). At that time the operation and maintenance (O&M) costs of these projects was estimated at US$100/ha; but under the 1983 Irrigation Ordinance, BWDB collected only Tk250/ha (nearly US$6/ ha) as O&M

TABLE 4
Irrigation and drainage

Irrigation potential			**6 933 000**	ha
Irrigation				
1. Full control irrigation: equipped area		2008	5 049 785	ha
- surface irrigation		2008	5 049 785	ha
- sprinkler irrigation		2008	0	ha
- localized irrigation		2008	0	ha
• % of area irrigated from surface water		2008	21	%
• % of area irrigated from groundwater		2008	79	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2008	5 049 785	ha
- as % of full control area equipped		2008	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2008**	**5 049 785**	**ha**
• as % of cultivated area		2008	60	%
• % of total area equipped for irrigation actually irrigated		2008	100	%
• average increase per year over the last 13 years		1995-2008	2.3	%
• power irrigated area as % of total area equipped		2008	97	%
4. Non-equipped cultivated wetlands and inland valley bottoms		1993	1 545 000	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2008**	**6 594 785**	**ha**
• as % of cultivated area		2008	79	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha	2008	4 910 982	ha
Medium-scale schemes				ha
Large-scale schemes	> ha	2008	138 803	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2008	5 976 810	ha
• Annual crops: total		2008	5 936 810	ha
- Wheat		2008	313 000	ha
- Rice		2008	4 341 000	ha
- Maize		2008	90 000	ha
- Millet		2008	400	ha
- Sorghum		2008	100	ha
- Barley		2008	810	ha
- Other cereals		2008	25 000	ha
- Potatoes		2008	263 000	ha
- Pulses		2008	156 000	ha
- Vegetables		2008	236 000	ha
- Cotton		2008	6 500	ha
- Tobacco		2008	18 000	ha
- Sesame		2008	30 000	ha
- Sugarcane		2008	43 000	ha
- Other annual crops		2008	414 000	ha
• Permanent crops: total		2008	40 000	ha
- Tea		2008	40 000	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)		2008	118	%
Drainage - Environment				
Total drained area		1993	1 501 400	ha
- part of the area equipped for irrigation drained		1993	118 400	ha
- other drained area (non-irrigated)		1993	1 383 000	ha
• drained area as % of cultivated area		1993	17	%
Flood-protected areas			-	ha
Area salinized by irrigation		1993	100 000	ha
Population affected by water-related diseases			-	inhabitants

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 5 049 785 ha in 2008



fees. The average cost of irrigation development in minor irrigation schemes including O&M was estimated at US$50/ha in 1990-1991; recently this has risen to US$113/ha (BBS, 2008).

Role of irrigation in agricultural production, economy and society

In 2008, total harvested irrigated cropped area was estimated at 5.98 million ha, of which the most important crops are rice accounting for 4.34 million ha (73 percent), wheat 0.31 million ha (5 percent), potatoes 0.26 million ha (4 percent) and vegetables 0.24 million ha (4 percent) (Table 4 and Figure 5).

Improved irrigation water management (IWM) practices, increased use of modern variety (MV) seeds and fertilizers have made a major break through in achieving almost self-sufficiency for cereal crop production. Irrigation is mainly practiced in the dry season to cultivate Boro rice and wheat. Supplementary irrigation could appreciably increase transplanted Aman rice production by mitigating the effects of drought.

Irrigated paddy yield is moderately high, ranging from 3.85 to 4.75 tonnes/ha. During 2007-2008 total Boro rice production (including HYV, hybrid and local varieties) amounted to 18.67 million tonnes and the total rice (Aus, Aman and Boro together) was 31.67 million tonnes (DAE, 2009). The total irrigated rice production was about 58 percent of the country's total rice production.

Status and evolution of drainage systems

Because of the low-lying topography, about 26 500 km^2 or 18 percent of the country is inundated during the monsoon season each year. During severe floods the affected area may exceed 53 000 km^2 or 37 percent of the country and in extreme events, such as in the 1998 flood, about 66 percent of the country is inundated. Floods are caused by overspills from main

TABLE 5
Irrigation using surface water and groundwater by different modes (2008) (Source: MoA, 2008)

	Mode of Irrigation	Number of equipment	Area irrigated (ha)	as % of total irrigated area	Area irrigated (ha) per equipment
A.	**Irrigation through utilization of surface water**				
1	Low-lift pump	138 630	903 867	17.90	6.52
2	Gravity flow		138 803	2.75	
3	Traditional method		19 044	0.38	
	Sub-total	**138 630**	**1 061 714**	**21.02**	
B.	**Irrigation through utilization of groundwater**				
1	Deep tubewell	31 302	785 680	15.56	25.10
2	Shallow tubewell	1 304 973	3 197 184	63.31	2.45
3	Manual and artesian wells		5 207	0.10	
	Sub-total	**1 336 275**	**3 988 071**	**78.98**	
	Grand total	**1 474 905**	**5 049 785**	**100.00**	

rivers and their distributaries, overspills from tributaries and by direct rainfall. Flood control works can reduce floods caused by the first two, but only drainage can have any effect on the latter two. The basic benefit of drainage is water control – supply as well as removal. The particular benefits can be:

1. potential increase in cropped area with earlier drainage;
2. higher yields from transplanted Aman rice with early planting;
3. crop diversification in the wet season with better drainage; and
4. more control over crop calendars and patterns with control of the water regime.

In 1964, a master plan was developed for water resources development. This envisaged the development of 58 flood protection and drainage projects covering about 5.8 million ha of land. Three types of polders were envisaged: gravity drainage, tidal sluice drainage and pump drainage.

Flood control and drainage projects have accounted for about half of the funds spent on water development projects since 1960. They include:

- large-scale projects such as the Coastal Embankment Project (949 000 ha), the Manu River Project (22 500 ha), the Teesta Right Embankment (39 000 ha), the Ganges-Kobadak Project (141 600 ha), the Brahmaputra Right Flood Embankment (226 000 ha), the Chandpur Irrigation Project (54 000 ha), and the Chalan Beel Project (125 000 ha);
- medium-scale projects such as the Sada-Bagda, Chenchuri Beel and Bamal-Salimpur-Kulabasukhali projects implemented under the Drainage and Flood Control Projects (DFC I to DFC IV) and financed by the World Bank. These projects typically cover areas of 10 000-30 000 ha and involve flood control and drainage with limited irrigation development; and
- small-scale projects such as those implemented under the Early Implemented Project, the Small-scale Irrigation Project and the Small-scale Drainage and Flood Control Project.

During the National Water Plan Phase I and Phase II period (1986-1991) the Master Plan Organization (MPO) made a comprehensive assessment of the ongoing water resources development projects (large-scale irrigation projects, flood control and drainage (FCD) projects, and flood control, drainage and irrigation (FCDI) projects. It was noted that the performance of FCD and FCDI projects needs to be improved under the NWP. The FCD projects under this NWP strategy would focus on gravity drainage schemes in shallow to medium flooded areas, and submersible embankments in deeply flooded areas. After 1991, FCD projects were implemented under the Flood Action Plan (FAP) by the MoWR. This was a comprehensive plan for the progressive reduction of floods from major rivers in association with improved drainage systems. Under the existing Five Year Plan (Planning Commission, 2009), the Government approved 12 FC and FCD investment projects in the Annual Development Programme (ADP) (2009-2010).

In 1993, the total area of wetlands was 3.14 million ha, of which 1.55 million ha were cultivated and 1.38 million ha were drained by surface drains. In 1992, the average cost of drainage development was US$192/ha.

FIGURE 4
Type of full control irrigation schemes
Total 5 049 785 ha in 2008

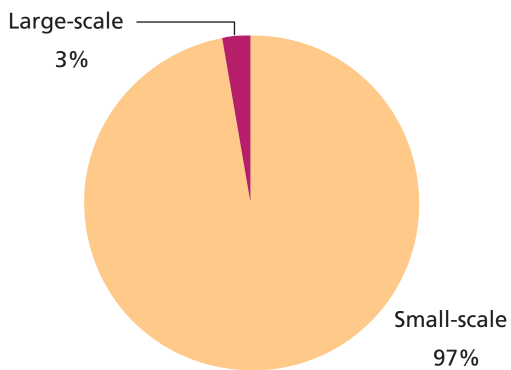
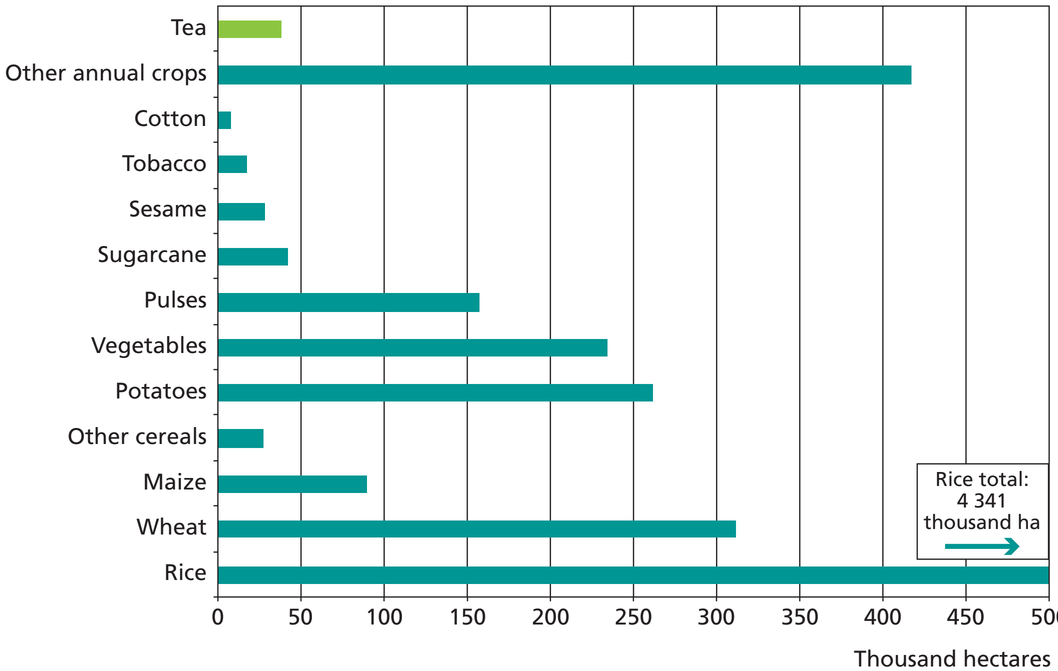


FIGURE 5
Irrigated crops on area equipped for full control irrigated
Total harvested area 5 976 810 ha in 2008 (cropping intensity on full/control equipped area: 118.3%)



Different types of floods occur in Bangladesh. Of the total cropped area, about 1.32 million ha are severely flood-prone and 5.05 million ha are moderately flood-prone. The flood protected area in 1990 was an estimated 4.20 million ha.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

In Bangladesh, public sector involvement in irrigation water management (IWM) is shared between three ministries. Minor irrigation and small-scale surface irrigation schemes are under the jurisdiction of the Ministry of Agriculture (MoA) and the Ministry of Local Government, Rural Development and Cooperatives (LG&RD), respectively. Large-scale irrigation schemes, including FCD projects, are under the Ministry of Water Resources (MoWR).

The MoA is mainly concerned with agricultural policy development, planning and monitoring. Project delivery is the responsibility of its various agencies, the most important being the Bangladesh Agricultural Development Corporation (BADC). In the past, the BADC was directly involved in supplying inputs to minor irrigation and looked after the O&M of all sorts of equipment. It has now withdrawn from all commercial operations relating to minor irrigation, leaving them to the private sector. The Department of Agriculture Extension (DAE) demonstrates and extends information to farmers on crops, agronomic practices and use of on-farm water management and agricultural machinery. The Barind Multipurpose Development Authority (BMDA), under the MoA is also responsible for water resources management in agricultural development of the Barind Tracts region.

The Local Government Engineering Department (LGED), under the MoLG&RD, implemented Small-Scale Water Resources Development (SSWRD) projects Phase I and II by constructing 26 rubber dams in the medium and small rivers in different parts of the country. LGED was also responsible for participatory management of these projects, which was achieved by forming the Water Management Cooperative Associations (WMCAs) for each project. The Bangladesh Rural Development Academy (RDA), under the MoLG&RD, is currently implementing a package model of Multipurpose Low-Cost DTW Projects in different parts of the country with a view to achieving optimum utilization of water resources for irrigation, domestic and other purposes such as fisheries, livestock rearing and nurseries. These multiple uses bring significant benefits and contributions to livelihoods, especially for poor households.

Under MoWR, the Bangladesh Water Development Board (BWDB) is responsible for the planning, implementation and operation of medium- and large-scale surface water irrigation schemes, FC and FCD projects. The Water Resources Planning Organization (WARPO), under the same ministry, has a mandate to ensure coordination of all relevant ministries through the National Water Council and to plan all aspects of water resources development including large-scale and minor irrigation, navigation, fisheries and domestic water supplies.

Water management

Water Management (WM) is considered to be the planned development, distribution and use of water resources, in accordance with predetermined objectives with respect to both quantity and quality of water. WM deals with integration of all activities having the aim of systematically controlling the inter-relationship between water and society. The the main purpose is to limit damage caused by water and reduce its exploitation both technically and economically. Therefore, WM has become important for addressing increasing pressure on available water resources. Agriculture is the greatest consumer of water resources, accounting for approximately 88 percent of all the freshwater withdrawn (Figure 1). Modern high-yield and diversified crop production systems can be sustained only with the proper utilization of irrigation water and management at the farm level.

Though there has been a significant increase in irrigated agriculture over the last decade, most minor and major irrigation systems have shown poor field performances owing to a lack of technical know-how, as well as poor on-farm water management (OFWM) practices. The Government has recognized the importance of introducing appropriate water management techniques and technologies at farm level as key to ensuring food security, employment generation and eliminating poverty through intensification and diversification of agricultural production. With this view, MoA has undertaken some development projects for improving the efficiency and overall performance of irrigation systems with better OFWM practices. Few investment projects have been initiated by the Government, some have been financed by donor agencies under the Technical Assistance (TA) programme.

Participation of women in IWM activities has not been encouraged; though in many villages they are active in other agricultural practices such as post-harvest processing, home gardening, rearing of livestock and poultry. However, here and there women operate treadle pumps for irrigation. Moreover, indigenous and tribal women are involved in collecting water for domestic purposes and irrigating homestead gardens.

Policies and legislation

There are no policies or acts related to irrigation or water management. This is because of rapid growth during the 1980s of minor irrigation using DTW and STW. In 1985, the MoA enacted the Groundwater Management Ordinance, which controlled the spacing for installation of irrigation equipment. This Ordinance was suspended in 1987 with a view to expansion of minor irrigation (mainly STW irrigation) to the private sector. Because of the suspension of space requirements for irrigation equipment, optimum utilization of groundwater resources has been impeded. In recent years, however, Government policies such as the National Agriculture Policy – NAP (MoA, 1999), National Water Policy – NWPo (MoWR, 1999) and the National Water Management Plan – NWMP (MoWR, 2001) have, to some extent, addressed the minor irrigation and water management issues.

Minor irrigation has been in the domain of private sector agriculture, where there has been a rapid expansion of irrigated agriculture, which resulted in a significant increase in crop production. In this regard, the Government has given special emphasis to minor irrigation development in the NAP, which was formulated in 1999. In relation to irrigation water management the mandate of the NWPo (MoWR, 1999) is to focus on increasing efficiency by recycling drainage water; rotational irrigation; introducing cropping patterns that conserve water; the conjunctive use of both surface water and groundwater; addressing the non-point pollution of water systems by fertilizer and pesticides, and issues of equity and social justice.

The NWMP, which was formed by the MoWR in 2001, has the mandateto address the overall issues of water resources management. It provides direction to short-, medium- and long-term action plans. The NWMP has emphasized the expansion of private STW irrigation in slow-growth regions, and issues are to be addressed that are related to arsenic pollution and salinity; especially in the coastal areas.

ENVIRONMENT AND HEALTH

Bangladesh is now widely recognized as one of the countries that is most vulnerable to climate change. Increased variability of temperatures and rainfall and increased occurrence of natural hazards are expected to affect the availability of both surface water and groundwater. Investment is required to ensure a continuous and sustainable access to water resources.

As a result of the limited availability of surface water during the dry season, the use of groundwater has become increasingly important as a source of water for irrigation, municipal and industrial purposes. In many areas environmental hazards have been encountered, and a number of adverse effects have emerged owing to the overexploitation of groundwater, such as lowering of water tables, reduction in dry season flows of rivers and streams, groundwater pollution, intrusion of saline water in coastal areas, ecological imbalance and possible land subsidence. There is evidence of permanent depletion of groundwater levels in some locations, particularly in the Dhaka metropolitan area, where the water level's average annual decline is about 3 m (BADC, 2006), and in the northwest region of the country.

In 1993, the estimated area affected by salinity caused by by irrigation was 100 000 ha.

Irrigation water quality has deteriorated in some locations because of pollution caused by agrochemicals, industrial waste and other sources. Arsenic contamination of groundwater, particularly water from STW and HTW, in 59 out of 64 districts, has been reported by many government and donor agencies (GoB, UNICEF, WB, FAO). In most regions, maximum arsenic concentration has been found within the upper 50 m depth of aquifers (Water Aid, 2000). In many places, concentration of iron and arsenic in irrigation water has gone beyond the limit of the safe water quality standards of Bangladesh and the World Health Organization (WHO). Some diseases and health hazards such as arsenicosis, blindness, physical disability, occur as a result of arsenic toxicity to human body (RDA, 2001). Throughout the country, about 1.44 million tubewells (STWS and HTWs have been affected by arsenic contamination and about 30 million people are exposed to arsenic toxicity (Ahmed, 2007).

In some parts of the country, particularly the Barind Tracts in the northwest region, there are already symptoms of deterioration in the natural hydrological regime. Declining groundwater levels have affected water quality causing it to affect soils, the growth of agricultural crops, flora and fauna and to increase health hazards. Therefore, careful consideration should be given to these environmental issues in order to harness the beneficial uses of irrigation water comprising both surface water and groundwater resources.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Under climate change and the related increased temperatures, evapotranspiration will increase and the river system will suffer during dry months because of the acute low-flow condition. Consequently, the dry season water demand for irrigated agriculture, salinity control, and stream flow maintenance will increase significantly leading to the escalating shortfall in water supplies. Greater cooperation is required between the riparian countries to augment dry season flows in the transboundary rivers so as to meet the increasing gaps in water availability.

The main source of irrigation water during the last decade has been groundwater. There is a question of risky over-dependence, and over use of this water resource, and related quality constraints and emerging environmental concerns. The NWMP (MoWR, 2001), therefore, focuses on short-term and long-term strategies for agricultural water management, such as:

1. balanced conjunctive use of surface water and groundwater resources;
2. future growth of tubewell irrigation with FMTWs;
3. surface water conservation and rainwater harvesting using rubber dams in small and medium rivers;
4. new low-cost major irrigation schemes (gravity flow system); and
5. larger floating pumps, particularly in the southeastern part of the country.

On-farm water management (OFWM) can be considered as a potentially useful measure to save irrigation water use per hectare and to expand the irrigation command area, mainly for STW and LLP irrigation within the coastal zone and other water crisis areas. Wherever feasible, tubewell irrigation should be integrated with domestic water supply. The RDA developed multipurpose low-cost DTW technology package is one that can be replicated in suitable areas.

According to NWP estimates in 1991, the expansion of irrigation coverage would reach its maximum potential limit by 2025. However, the rate of increase in water demand is expected to decline in response to demand-management practices such as conservation, water-use efficiency, recycling.

The strategy of water resources development has so far been centered on flood control and irrigation expansion to promote food grain production. Without denying the importance of food production and food security, it is now widely recognized that conflicts among alternative and competing uses of water are becoming sharper as the demand for water has been increasing. It is, therefore, necessary to formulate a long-term vision for IWRM to address the demands of all water using sectors in order to sustainably maintain the environment.

Some challenging issues that are related to agricultural water management, such as arsenic pollution, climate change, salinity, have been found in many locations. The impacts of which have already been discussed. As a result of reduced freshwater flows, caused by upstream abstraction of the Ganges water, the salinity front in the coastal areas of Bangladesh has already advanced. About 10 percent of the southwest region has experienced increased salinity in the wet season, which rises to 40 percent in the dry season (BWP, 2000).

The salinity problem adversely affects the availability of required irrigation water in this region. The possible solution to this particular problem could be to take advantage of the Ganges Water

Sharing Treaty of 1996 between India and Bangladesh, which specified the amount of water to be released downstream of Farraka during the dry season. A major endeavour, to meet this end, is the Gorai Restoration Project. Moreover, assured in-stream flows in the Ganges have increased the potential for surface water augmentation in the southwest region after construction of the Ganges Barrage.

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Bhutan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Kingdom of Bhutan has a total area of 38 390 km^2 and is landlocked between the extensive borders of China and India (Table 1). The country shares a470 km long border with Tibet, China's Xizang Autonomous Region, to the north and northwest and 605 km with the Indian states of Sikkim to the west, West Bengal to the southwest, Assam to the south and southeast, and Arunachal Pradesh to the east. Sikkim is 88 km wide, and separates Bhutan from Nepal, while West Bengal, which is 60 km wide, separates Bhutan from Bangladesh. The border with Tibet follows the watershed of the Chumbi valley in the northwest and the crest of the Himalayas in the north, while the southern border with India was established by treaty with the British in the nineteenth century and follows the line made by the Himalayan foothills with the plains. For administrative purposes, Bhutan is divided into 20 *dzongkhag* (districts).

Bhutan, being in the eastern Himalayas, is mostly mountainous, with flat land limited to the broader river valleys and along the foothills bordering the Indian subcontinent. Altitudes range from 7 500 m at the summit of Kula Kangri on the northern border to about 200 m at the Indian border in the south. The country has three major landform features: the southern foothills, the inner Himalayas and the higher Himalayas.

Owing to the extremely rugged mountainous terrain, only 100 000 ha or 3 percent of the total area is cultivated in 2009, of which 25 000 ha is under permanent crops. The country is heavily forested, 72.5 percent being under forests, and 10 percent is covered with year-round snow and glaciers.

Climate

Bhutan has perhaps the greatest diversity of climate of any country of its size in the world. The climate is humid and subtropical on the southern plains and in the foothills, temperate in the inner Himalayan valleys of the southern and central regions, and cold in the north, with year-round snow on the main Himalayan summits. Bhutan's generally dry spring starts in early March and lasts until mid-April. Summer weather starts in mid-April with occasional showers and continues through the early monsoon rains of late June. Autumn, from late September or early October to late November, follows the rainy season. It is characterized by bright, sunny days and some early snowfall at higher elevations. Winter sets in from late November until March, with frost throughout much of the country and snowfall common above elevations of 3 000 m.

Temperatures vary according to elevation. In the capital Thimphu, located at 2 320 m above sea level in west-central Bhutan, temperatures range between 14 °C to 25 °C during the monsoon season of June through September but drop to about –4 °C and 14 °C in January. Most of the central portion of the country experiences a cool, temperate climate year-round.

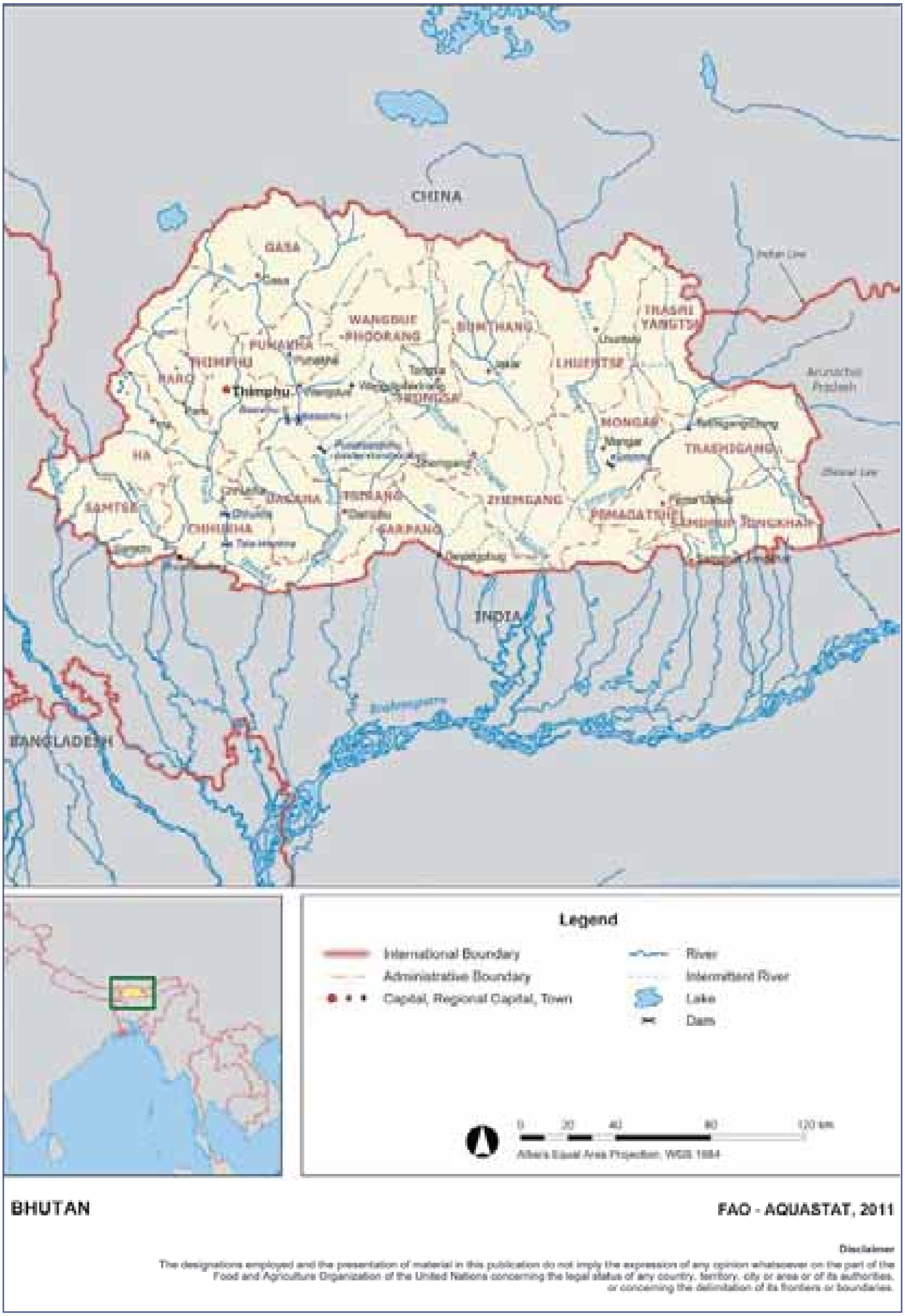
CHINA
GASA
WANGDUE PHODRANG
BUMTHANG
PUNAKHA
THIMPHU
PARO
Thimphu
TRONGSA
LHUENTSE
TRASHI YANGTSE
MONGAR
TRASHIGANG
HA
SAMTSE
CHHUKHA
DAGANA
TSIRANG
SARPANG
ZHEMGANG
PEMAGATSHEL
SAMDRUP JONGKHAR
Arunachal Pradesh
INDIA
BANGLADESH
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Intermittent River
Lake
Dam
0 20 40 80 120 km
Albers Equal Area Projection, WGS 1984
BHUTAN
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	3 839 000	ha
Cultivated area (arable land and area under permanent crops)	2009	100 000	ha
• as % of the total area of the country	2009	2.6	%
• arable land (annual crops + temp fallow + temp meadows)	2009	75 000	ha
• area under permanent crops	2009	25 000	ha
Population			
Total population	2009	714 000	inhabitants
• of which rural	2009	66	%
Population density	2009	19	inhabitants/km^2
Economically active population	2009	324 000	inhabitants
• as % of total population	2009	45	%
• female	2009	33	%
• male	2009	68	%
Population economically active in agriculture	2009	301 000	inhabitants
• as % of total economically active population	2009	93	%
• female	2009	34	%
• male	2009	66	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	1 259	million US$/yr
• value added in agriculture (% of GDP)	2009	18	%
• GDP per capita	2009	1 763	US$/yr
Human Development Index (highest = 1)		-	
Access to improved drinking water sources			
Total population	2008	92	%
Urban population	2008	99	%
Rural population	2008	88	%

In the south, a hot, humid climate helps maintain a fairly even temperature range of between 15 °C and 30 °C year-round; although temperatures sometimes rise above 35 °C in the valleys during the summer.

Average annual precipitation in Bhutan is roughly 2 200 mm. It varies widely in various parts of the country, from a low of 477 mm at Gidakhom in Thimpu district to as high as 20 761 mm at Dechenling in Samdrup Jhongkhar district. The climate of the north is severe and cold with only about 40 mm of annual precipitation, primarily snow. In the temperate central regions, a yearly average rainfall of around 1 000 mm is more common and 7 800 mm has been registered at some locations in the humid, subtropical south, giving rise to the thick tropical forest. Thimphu experiences dry winter months from December through February and almost no precipitation until March, when rainfall averages 20 mm/month and increases steadily thereafter to a high of 220 mm in August making a total annual rainfall of about 650 mm. The summer monsoon lasts from late June through late September with heavy rains from the southwest. The monsoon weather, blocked from its northward progress by the Himalayas, brings heavy rains, high humidity, flash floods and landslides, and numerous misty, overcast days. Western Bhutan is particularly affected by monsoons that bring between 60 and 90 percent of the region's rainfall. The winter northeast monsoon brings gale-force winds down through high mountain passes.

Bhutan is divided into six agro-climatic regions as shown in Table 2.

TABLE 2
Agro-climatic regions in Bhutan

Agro-ecological zone	Altitude (m)	Temperature ^{0}C			Rainfall (mm)
		Max	Min	Mean	
Alpine	>3 500	12.0	-1.0	5.5	< 650
Cool temperate	2 500-3 500	22.0	1.0	10	650-850
Warm temperate	1 800-2 500	26.0	1.0	13	650-850
Dry Sub-tropical	1 200-1 800	29.0	3.0	17	850-1200
Humid Sub-tropical	600-1200	33.0	5.0	20	1 200-1 500
Wet Sub-Tropical	150-600	35.0	12.0	24	2 500-5 500

Population

In 2009, the total population was an estimated 714 000 inhabitants, of which 66 percent live in rural areas. During the period 1999-2009, the annual population growth rate was around 2.6 percent. With an average of 19 inhabitants/km^2, the population density is relatively modest by regional standards. The population is unevenly distributed with the highest population densities at the lower altitudes. About 95 percent of the population lives in the southern subtropical zone or in the central mid-mountainous zone, mainly in the relatively gentle sloping areas of the river valleys.

In 2008, 92 percent of the population had access to improved water sources (99 and 88 percent in urban and rural areas respectively) and 65 percent of the population had access to improved sanitation coverage (87 and 54 percent in urban and rural areas respectively). In 2003, about one-quarter of Bhutan's population was classified as living below the poverty line.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009 the gross domestic product (GDP) was US$1 259 million (Table 1). Agriculture accounted for around 18 percent of GDP, while in 1999 it accounted for 30 percent.

In 2009, the total economically active population was 324 000 inhabitants, or slightly more than 45 percent of the total population. Agriculture has a dominant role in the economy and is the primary source of livelihood many. About 301 000 (93 percent of the total active population) are economically active in agriculture; of which 34 percent are women. Agriculture in Bhutan is labour intensive with relatively low farm inputs.

Major crops are cereals, which cover around 70 percent of the cultivated area, mainly maize (30 percent), rice (25 percent), wheat (9 percent) and other cereals (16 percent). Rice is the major staple crop, which is irrigated. Maize is mainly cultivated in dryland regions at lower elevations. Other crops are potatoes or tuber crops, oilseeds, pulses, apples. Production of cash crops such as apples, oranges and cardamom have increased and have become profitable. In several areas shifting cultivation is being replaced by orchards.

In Bhutan, the primary goal of agriculture is to raise the per capita income of people living in rural areas, to enhance self-sufficiency in staple crops, and to increase the productivity per unit of farm labour and agricultural land. Agriculture is constrained because of problems related to irrigation, rough terrain, poor soil quality, limited extent of arable land, lack of improved quality seeds for cereals, oilseeds, vegetable crops, fertilizers, farm machinery and agricultural experts.

WATER RESOURCES AND USE

Water resources

Total annual internal renewable surface water resources are an estimated 78 km^3 (Table 3). Because of the mountainous character of the country, groundwater resources are probably limited and are drained by the surface water network, which means they are more or less equal to overlap between surface water and groundwater. Surface water leaving the country to India is an estimated 78 km^3.

Nearly every valley in Bhutan has a swiftly flowing river or stream, fed either by the perennial snow, the summer monsoon or both. Except for a small river in the extreme north, which flows north, all rivers flow south towards India. The river basins are oriented north-south and are, from west to east, the Jaldhaka, Amo (Torsa), Wang (Raidak), Mo, Puna Tsang (Sankosh), Mao Khola/Aie, Manas (Lhobrak) and eastern river basins, this last basin is composed of the Bada and Dhansiri rivers.

Most rivers are deeply incised into the landscape and hence the possibilities for run-of-the-river irrigation are limited.

There are only two wastewater collection and treatment projects in the cities of Thimphu and Phuntsholing.

There are numerous natural lakes, many are located above 3 300 m and some above 4 200 m, which are primarily used to raise fish.

Several large dams have been constructed to generate hydroelectric power. These include the 40 m high Chhuka dam (CHPP) on the Wang river in Chhukha district in the southwest, the

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)		2 200	mm/yr
		84 500	million m^3/yr
Internal renewable water resources (long-term average)		78 000	million m^3/yr
Total actual renewable water resources		78 000	million m^3/yr
Dependency ratio		0.0	%
Total actual renewable water resources per inhabitant	2009	109 244	m^3/yr
Total dam capacity	-	-	million m^3
Water withdrawal			
Total water withdrawal	2008	338	million m^3/yr
- irrigation + livestock	2008	318	million m^3/yr
- municipalities	2008	17	million m^3/yr
- industry	2008	3	million m3/yr
• per inhabitant	2008	482	m^3/yr
Surface water and groundwater withdrawal	2008	338	million m^3/yr
• as % of total actual renewable water resources	2008	0.43	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

91 m high Tala-Wankha dam further downstream on the Raidak river near Phuntsholing town, the 33 m high Kurichhu dam on the Kuri river in Mongar district in the east, the Basochu dam (BHPP) near Wangduephodrang town in the centre-west. The 141 m high Punatsangchu dam on Puna Tsang river downstream of Wangduephodrang town is under construction.

Total hydropower generation capacity was 477 MW in 2006, of which 336 MW from the Chhukha hydropower plant, 60 MW from the Kurichu hydropower plant and 24 MW from the Bashocu hydropower plant. Hydropower represented 96 percent of the country's electricity generating capacity and 99.9 percent of its electricity generation in 2006. With the commissioning of the first two units of the Chhukha hydroprojects in 1986, and the other two units in 1998, the electricity generation capacity substantially increased and Bhutan became a significant exporter of electricity to India. With the commissioning of the Tala Hydro Power Project in 2007, there has been a substantial improvement in the country's energy generation.

The expansion of hydropower production capacity has had an enormous impact as, by the end of the Ninth Five-year Plan (2002-2007), the energy sector contributed to around one-quarter of GDP. With a further doubling of capacity envisaged by the end of the Eleventh Five-year Plan (2014-2019), the energy sector will probably contribute close to half of GDP.

The following hydroelectric projects have been identified for future development:

- Mangdue Chu Hydroelectric Project, with the cooperation of Norway, was planned in the Ninth Five-year Plan (2002-2007) and it is expected to be completed in the Tenth Five-year Plan (2008–2013). The project comprises two dams.
- Sunkosh Multipurpose Project (SMP) is the largest proposed hydroelectricity project in Bhutan.

International water issues

The Chhukha Hydropower Corporation (CHPC) was entirely funded by the Government of India. The construction of the Chhukha hydroelectric plant started in 1978 and was operational in 1988.

The Tala Hydroelectric Project Authority (THPA) is the biggest Indo-Bhutan joint project, entirely funded by the Government of India (GOI) by way of grants and loans and has been fully operational since 2007.

The Basochu Upper Stage Hydropower Project, commissioned in 2005, is financed by the Austrian Government.

The Punatsangchu Hydroelectric Power Project (PHPP) is a proposed project between Bhutan and India signed in 2003. It is a run-of-the-river scheme along the course of the Puna Tsang river, downstream from the town of Wangduephodrang. It will have an installed capacity of 870 MW with an annual average generation of 4 330 GWh.

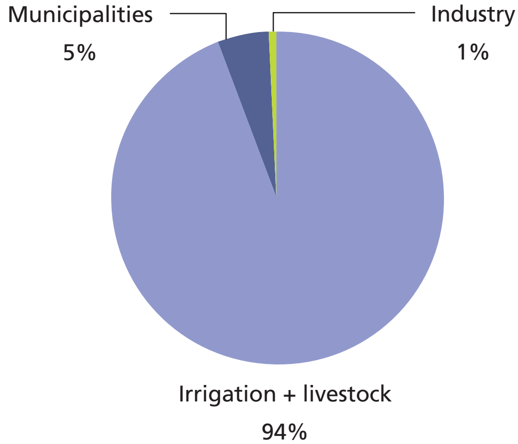
Water use

In 2008, total water withdrawal was about 338 million m^3, all surface water. This represents a mere 0.43 percent of the annual renewable water resources. About 94 percent of this water withdrawn is used for agriculture, while domestic and industrial sectors use 5 percent and 1 percent respectively (Figure 1).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

FIGURE 1
Water withdrawal by sector
Total 0.338 km^3 in 2008



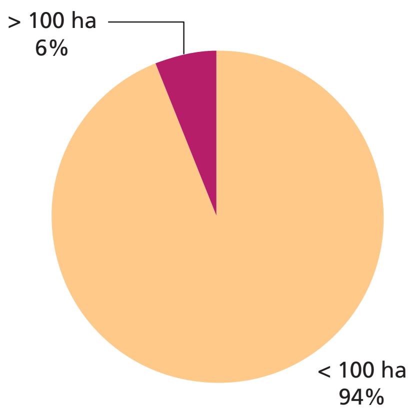
Wherever irrigation water is available on arable lands below 2 600 m, farmers have traditionally chosen to grow rice. Irrigated rice cultivation takes place during the summer-autumn period. Other irrigated crops, though at a very limited scale, are wheat, barley, oil seeds, potato and different vegetables. Maize is mainly cultivated in dryland regions at lower elevations.

There are an estimated 1 500-1 800 irrigation schemes. Irrigation systems in Bhutan are typically less than 100 ha in extent. Only two large-scale systems have been developed by the Government: the Taklai Irrigation Scheme (1 350 ha) and the Geylegphug Lift Irrigation Scheme (800 ha). There is little possibility of further development of large schemes owing to the geographical conditions. River diversion is the source of water for almost all Bhutanese schemes (98 percent of the irrigated area), except in the Geylegphug lift irrigation scheme (2 percent). Generally, the diversion structures are temporary, and in a large number of rehabilitated schemes part of the project consists of improving the intake structure to make it permanent.

Two types of small-scale schemes can be found:

- valley bottom schemes, located on relatively gently sloping terraces next to the major rivers, where water is usually reliably provided by purely gravity fed channels from secondary rivers; and
- hill schemes, located at higher elevations, on more steeply sloping land where tertiary streams and rivers are the sources of water.

FIGURE 2
Type of full control irrigation schemes
Total 27 020 ha in 1995



The irrigated areas are called wetland in the local classification. This means that they have been terraced for basin irrigation. In 2007, these areas were an estimated 27 685 ha, which corresponds to actually irrigated area.

In 1995, total irrigated area was an estimated 27 020 ha and large schemes (> 100 ha) represented 6 percent of the total irrigated area, while small schemes (< 100 ha) represented 94 percent (Table 4 and Figure 2).

TABLE 4
Irrigation and drainage

Irrigation potential				ha
Irrigation				
1. Full control irrigation: equipped area		2007	27 685	ha
- surface irrigation		2007	27 685	ha
- sprinkler irrigation		2007	0	ha
- localized irrigation		2007	0	ha
• % of area irrigated from surface water		1995	100	%
• % of area irrigated from groundwater		1995	-	%
• % of area irrigated from mixed surface water and groundwater		1995	-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2007	27 685	ha
- as % of full control area equipped		2007	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2007**	**27 685**	**ha**
• as % of cultivated area		2007	18	%
• % of total area equipped for irrigation actually irrigated		2007	100	%
• average increase per year over the last 12 years		1995-2007	0.2	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2007**	**27 685**	**ha**
• as % of cultivated area		2007	18	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	1995	25 400	ha
Medium-scale schemes		-	-	ha
Large-scale schemes	> 100 ha	1995	1 620	ha
Total number of households in irrigation		-	-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
- as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		1994	27 900	ha
• Annual crops: total		1994	27 900	ha
- Rice		1994	27 400	ha
- Potatoes		1994	500	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)		1994	103	%
Drainage - Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

Irrigation schemes, all managed by farmers, can be classified according to their origin:

- indigenous irrigation systems, which have evolved with little or no government assistance. No technical assistance has been provided, and the maximum involvement of the government may have been the provision of a few bags of cement;
- assisted farmer-initiated irrigation systems, which have been constructed by the beneficiaries, but which have received technical and other government assistance on one or more occasions to restore or improve the system; and
- government-initiated irrigation systems, which have been constructed under the government assistance programme.

Irrigation canals have an acute sedimentation problem, caused by sand accumulation from subsidiary sources and runoff into irrigation canals during heavy monsoon rains. Generally, sand and silt traps are constructed and periodically flushed to alleviate this problem.

Role of irrigation in agricultural production, economy and society

In summer, almost all wetland is under rice cultivation. Double cropping of rice is limited to the lowest altitudes where the winter temperatures allow its cultivation. Where rice cannot be cultivated, wheat, buckwheat, mustard and potatoes are cropped on wetland areas during the winter season (Table 5). The wetland areas can be cropped during the winter season, though watering of these winter crops is generally limited to one irrigation at the time of land preparation. To a limited extent, farmers have started to irrigate horticultural crops, including orchards, using hose pipes and surface irrigation methods. In 1994, total irrigated cropped area was around 27 900 of which 98 percent was rice and 2 percent potatoes (Figure 3).

The average cost of irrigation development varies widely depending on the region. The National Irrigation Policy (1992) suggests that the maximum capital investment for the main canal development should be US$630/ha and US$950/ha for renovation schemes and new schemes respectively, while it should be US$160/ha for the development of the distribution system.

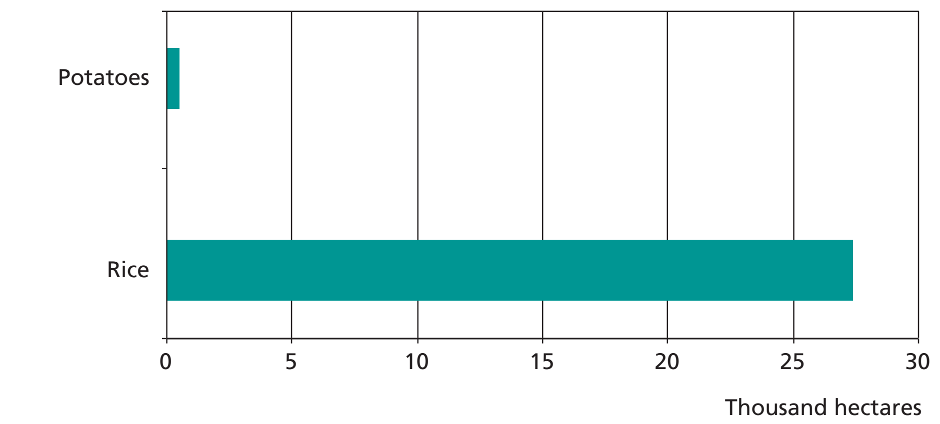
Status and evolution of drainage systems

As most of the schemes are terraces, no drainage network has been constructed.

TABLE 5
Cropped areas irrigated and un-irrigated during summer and winter seasons in Bhutan (ha) (1994)

Crop	Cropped area (ha)		
	Summer	Winter Irrigated	Winter Unirrigated
Rice	27 020	380	-
Maize	-	-	1 600
Wheat and Barley	-	-	4 900
Buck wheat and Millets	-	-	1 400
Mustard	-	-	400
Potatoes	-	500	-
Other crops	-	-	200
Total	**27 020**	**880**	**8 500**

FIGURE 3
Irrigated crops on area equipped for full control irrigation
Total harvested area 27 900 ha in 1994 (cropping intensity on equipped area actually irrigated: 103.3 % in 1994)



WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

No institution is specifically responsible for water resources. Because of the high hydropower potential, the Department of Power has been given responsibility for hydrological and meteorological data collection.

The Irrigation Agency is composed of irrigation offices at three levels:

1. Central level: the Irrigation Section of the Research, Extension and Irrigation Division under the Ministry of Agriculture, which is responsible for the coordination of all sector activities, including policy formulation, monitoring and evaluation.
2. Regional level: the Project Facilitation Offices, which provide technical, logistic, communication and accounting support for two IFAD financed projects covering three and six districts of Bhutan.
3. District level: the District (Dzongkhag) Irrigation Offices, which are fully responsible for the planning and implementation of all irrigation facilities in their district.

A National Environment Commission (NEC) received the mandate to ensure effective coordination of national-level planning and development for all natural resources including water resources, formulation of water policy and the necessary legislation, setting up of water quality standards and guidelines, monitoring, evaluation and regulation of water use. It is also responsible for research and development, capacity building and human resources development, technical backstopping, data collection and dissemination, flood disaster management, etc.

Water management

Until the 1970s, all irrigation schemes had been constructed and maintained by the beneficiaries themselves. With the start of the government's irrigation development programme in the late 1960s and early 1970s, many schemes were built or improved with external assistance, while management remained in the hands of water users. With the irrigation policy, adopted in 1992, government assistance to the irrigation sector has been redefined, with three basic principles: meaningful farmer participation, support to water user associations (WUAs), and multidisciplinary teamwork. The emphasis is on scheme renovation rather than new irrigation development.

Currently, Bhutan experiences localized and seasonal water shortages for drinking and irrigation even though the nation is bestowed with substantial water resources. There is uneven spatial distribution of precipitation, increasing sediment load in the rivers and wide variation between lean season and monsoon flows. Furthermore, the pressure on water resources is gradually increasing as a result of competing demands from various sectors. Floods and land slides accentuate the problem of water resources management.

The existing water-related institutions have weak functional linkages with other subsectors relevant to water at policy, planning and implementation levels. This required the formulation of a national perspective on water resources and a Bhutan Water Policy was formulated in 2003.

The Tenth Five-year Plan (2008–2013) for the Renewable Natural Resources (RNR) Sector (or the agricultural sector) has a goal to increase national rice self-sufficiency from about 50 percent to 65 percent by the end of the Plan. The policy, as defined in the Plan, also emphasizes the need for a greater degree of commercialization of agriculture, with efforts to enhance household food security through the market rather than through complete dependence on self-reliance. A total of 29 programmes are defined in the Plan. The Irrigation and Water Management Programme has a goal to increase the portion of wetland with dry season irrigation (Tillier *et al.*, 2010).

Policies and legislation

The Bhutan Water Policy (2003) recognizes that water is a precious natural resource that is basic to all social, economic and environmental well-being and, as such, the water resources need to be conserved and managed efficiently, while ensuring sustainability and without damaging the integrity of the environment. The Policy adopts an integrated approach that recognizes natural linkages and covers all forms of resources including snow, glaciers, rivers, lakes, streams, springs, wetlands, rainwater, soil moisture and groundwater, to achieve poverty alleviation and increase Gross National Happiness (GNH). The Policy was framed within a broad multi-sectoral perspective which recognizes the responsibilities of the sub-sectors to play their role in meeting policy objectives. The Policy primarily addresses the following components:

1. water user interests and priorities,
2. principles for water resources development and management,
3. international waters and
4. institutional development for water resources management.

The first component includes the issues of water allocation, water for drinking and sanitation, water for food production, water for hydropower development, water for industrial use, and resolution of conflicting user interests. The second component includes water resources that are developed to ensure sustainability by adopting appropriate technologies and good management practices. The water resources are planned to be developed in an environmentally sustainable, economically feasible and socially acceptable manner with full participation of all stakeholders. Prevention and control of pollution and flood management are to be incorporated into the planning.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The research and development needs, identified in the Bhutan Water Policy, include: hydro-meteorology, assessment of national water resources, surface water resources and watershed protection, groundwater hydrology and recharge, water-harvesting, water balance studies, crop–water requirements and cropping systems, soil erosion and bio-engineering, flood control and mitigation, erosion of the water course and sedimentation of the reservoirs, safety of hydraulic structures, recycling and reuse of water, best practices, economic and financial planning, wastewater handling, water pollution and prevention.

The government plans to effectively use the water resources for sustainable agricultural development, harnessing hydropower potential and industrial development for socio-economic development.

In 2009, Bhutan requested support from FAO to explore the feasibility of irrigation in the southern zone of Bhutan (districts of Sarpang, Samdrup Jongkhar and Samtse). The original proposal aimed to increase rice production to meet an enhanced share of domestic needs through expansion of the cultivated area and double cropping. Its objective was:

1. to conduct a comprehensive study on irrigation development in the southern belt to assess its potential to contribute to national food security and local livelihoods; and
2. to conduct a groundwater study to explore its potential as an alternative to surface water for their joint use. After a reconnaissance mission, fielded by FAO at the end of 2009, the conclusions were (Tillier *et al.*, 2010):

    - Southern Bhutan offers much potential for irrigation. The climate is favourable, surface water resources are abundant, groundwater is possibly available in some parts, multiple use of water is possible (water diverted for irrigation can also be used for other purposes such as fisheries, livestock, etc.), there is scope for increasing yields, and there is sufficient market for agriculture products both within the country and in the neighbouring Indian market.
    - Investment in irrigation in the southern zone is warranted from an agronomic viewpoint. The difference in yields between irrigated and non-irrigated crops was observed in the field. Yields of up to 4.4 tonnes/ha were reported from the best farmers under fully irrigated conditions, which is better than the average yields in neighbouring India (3.1 tonnes/ha), while the average in Bhutan is 2.4 tonnes/ha. However, to fully maximize the benefits from investment in irrigation (and rice production) farmers will need to improve their farming practices, including water management, varieties, fertility (and soil) management and pest management.
    - While potential for irrigation development exists, there is also much potential and requirement for improvement of water management both in the distribution systems and at field level and there is much potential for both irrigated and rainfed productivity gains by introducing the System of Rice Intensification (SRI) and Conservation Agriculture (CA).

Note:

The expressions 'Chu' and 'Chhu' that are often added to the names of rivers, mean 'river. Therefore, in this English version of the country profile, these words have been removed from the name of the river and replaced by the word "river". As an example, Wang Chu has been changed to Wang river.

MAIN SOURCES OF INFORMATION

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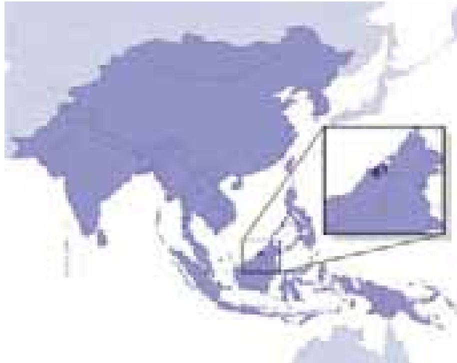
Tillier, S., O'Brien, B., Upadhyay, B.M. & Sijapati, S. 2010. *Bhutan. Southern zone irrigation. Reconnaissance mission.* Rome. FAO.

Brunei Darussalam



GEOGRAPHY, CLIMATE AND POPULATION

Geography

Brunei Darussalam lies in Southeast Asia, on the northwest coast of the island shared with Indonesian Borneo and Sabah and Sarawak states of Malaysia. It is bordered on the landward side by Sarawak. The country is composed of two enclaves separated from each other by the valley of the Limbang River in Sarawak. Brunei Darussalam is divided into four districts having an area of 5 770 km² (Table 1).

The districts of Brunei-Muara, Tutong and Belait, which form the larger western portion, are dominated by hilly lowlands, swampy plains and alluvial valleys. Mountainous terrain abounds in the eastern district of Temburong. The highest elevation is Bukit Pagon, at 1 850 m.

The cultivable area is estimated as 13 000 ha, which is about 2.5 percent of the total land area. In 2009, the cultivated area was an estimated 8 000 ha, about 61.5 percent of the cultivable area. About 5 000 ha were under permanent crops, the remaining 3 000 ha being under annual cultivation. In 1997, the cultivated area was estimated as 6 000 ha, of which 4 000 ha was for permanent and 2 000 ha annual crops.

Climate

Brunei Darussalam has a tropical climate characterized by high rainfall and temperatures throughout the year. Climatic variations follow the influence of the monsoon winds. The northeast monsoon blows from December to March, while the southeast monsoon occurs around June to October.

The total average annual precipitation is an estimated 2 722 mm. There are two rainy seasons: from September to January and from May to July.

The temperature is relatively uniform throughout the year, with an annual average of 27.9 °C, ranging from 23.8 to 32.1 °C. The drought months of March and April are the warmest. Owing to high temperatures and rainfall, humidity is high throughout the year with an average of 82 percent.

Population

In 2009, Brunei Darussalam had a population of 392 000, about 25 percent of which lived in rural areas (Table 1). In 1999, the population was 320 000, thus the annual population growth rate during the period 1999-2009 is estimated as 2.1 percent. In 1996, the district of Brunei-Muara, which includes the capital, Bandar Seri Begawan, had the largest population with 201 100 inhabitants, while Temburong district in the east was sparsely populated with a total of 8 700. The average population density is 68 inhabitants/km².

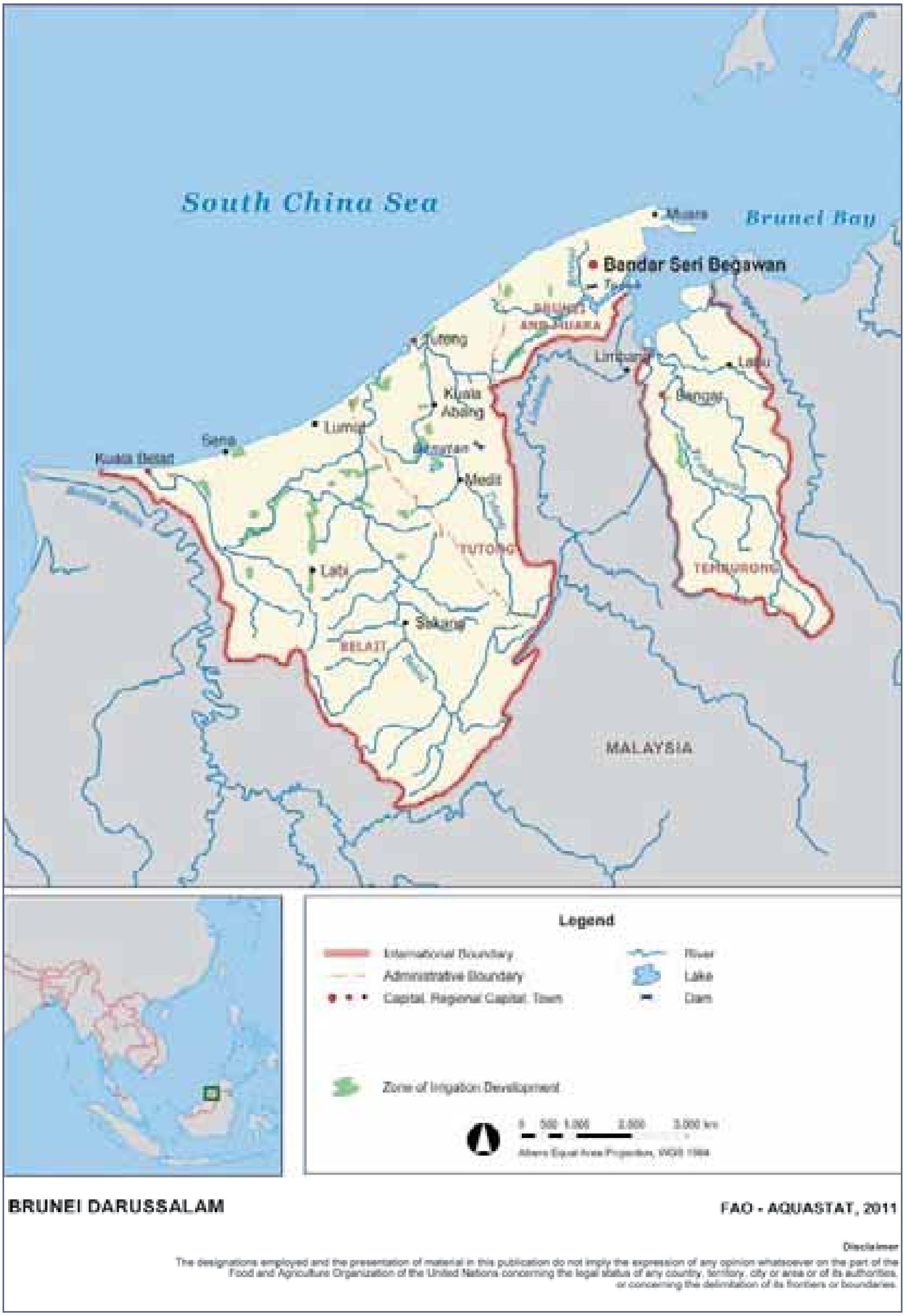

South China Sea
Brunei Bay
Muara
Bandar Seri Begawan
BRUNEI AND MUARA
Tutong
Kuala Abang
Lumut
Seria
Kuala Belait
Medit
TUTONG
Labi
Sukang
BELAIT
Limbang
Labu
Bangar
TEMBURONG
MALAYSIA
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
BRUNEI DARUSSALAM
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	577 000	ha
Cultivated area (arable land and area under permanent crops)	2009	8 000	ha
• as % of the total area of the country	2009	1.4	%
• arable land (annual crops + temp fallow + temp meadows)	2009	3 000	ha
• area under permanent crops	2009	5 000	ha
Population			
Total population	2009	392 000	inhabitants
• of which rural	2009	25	%
Population density	2009	68	inhabitants/km^2
Economically active population	2009	187 000	inhabitants
• as % of total population	2009	48	%
• female	2009	44	%
• male	2009	56	%
Population economically active in agriculture	2009	1 000	inhabitants
• as % of total economically active population	2009	0.5	%
• female	2009	0	%
• male	2009	100	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2006	11 471	million US$/yr
• value added in agriculture (% of GDP)	2007	0.7	%
• GDP per capita	2006	31 002	US$/yr
Human Development Index (highest = 1)	2010	0.805	
Access to improved drinking water sources			
Total population		-	%
Urban population		-	%
Rural population		-	%

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total economically active population was 187 000, or slightly more than 48 percent of the total population. In the agricultural sector the economically active population is an estimated 1 000 inhabitants, which is 0.5 percent of the total economically active population, of which 100 percent are male. In 2006, the gross domestic product (GDP) was US$11 471 million (Table 1). In 2007, agriculture accounted for 0.69 percent of GDP.

Some 55 percent of the cultivated land is under ruminant livestock production with the rest being horticulture, mixed cropping and poultry farming. Crop production is dominated by horticulture, which includes the cultivation of vegetables, production of fruits, floriculture and ornamental plants. Vegetable growing is mainly concentrated on the urban fringes, while fruit orchards are scattered across the country. In 2003, almost 10 360 tonnes of mainly tropical leafy vegetables were produced. In the same year, crop production registered over 4 600 tonnes of fruits and nearly 547 tonnes of rice. Floriculture produces small quantities of orchid flowers and an assortment of tropical ornamental plants (MIPR, 2009).

Brunei Darussalam gives much importance to agriculture and agri-food development to ensure the security of food supply and enhance economic contributions to the GDP. Agricultural development is the main factor that sustains national food supply and agri-food production.

For the past decade, there has been an impressive increase in the value of primary production from US$82.56 million in 1996 to US$158.98 million in 2005. In 2005, the livestock sector, including processed products, continued to dominate agricultural sector development with a market value of US$104.9 million. This is in comparison to the crop sector and its processed products, which had an output value of U$54.08 million, contributing about 66 percent from livestock and 34 percent from crops to the total agriculture output. Poultry, eggs and leafy vegetables are commodities that have attained self-sufficiency level (MIPR, 2009).

WATER RESOURCES AND USE

Water resources

There are four main river basins in Brunei Darussalam: Temburong, Belait, Tutong and Brunei:

- Ø The Temburong, which is the smallest of the rivers, drains a catchment area of about 430 km².
- Ø The Belait is the largest basin, with an area of 2 700 km². The lower catchment is composed of an extensive area of peat swamp forest. The river narrows at the town of Kuala Belait and a sandbar restricts the discharge of water into the South China Sea. Some areas in the upper catchment have been cleared for agriculture.
- Ø The Tutong basin, which is about 1 300 km², has a complex estuary system that has formed between two sand spits. Subject to fairly high tidal influence, its lower catchment is mainly floodplain. The upper catchment is jungle with patches of agriculture.
- Ø The Brunei river flows into Brunei Bay. The upper reaches of the river are a major freshwater source particularly for the western part of the country.

In relation to the whole island, the runoff coefficient is estimated as 1.5 m/year corresponding to a surface flow of 8.5 km^3. Limited reserves of groundwater have been identified in the Liang and Seria areas of the Belait district and in the Berakas area of the Brunei-Muara district. The estimated safe yield is 17.3 million m^3/year. Also, in relation to the whole island, the total groundwater resources are estimated as 0.1 km^3/year, all being drained by the rivers. Internal renewable water resources are around 8.5 km^3 (Table 2).

Brunei Darussalam has two dams that have a total storage capacity of just over 45 million m^3. The Tasek reservoir is used for water supply and has a total capacity of 13 000 m^3; its catchment area is 2.8 km^2. The Benutan dam, which is an impounded reservoir, used to regulate the Tutong river, has a total storage capacity of 45 million m^3 and a catchment area of 28.6 km^2.

There is no hydropower dam, though one suitable site has been located within the National Forest Reserve of Temburong.

Water use

In 1994, total water withdrawal was approximately 92 million m^3 (Table 2). Urban water is supplied entirely from surface water. The major use of water in industrial processes is for the liquefied natural gas industry, which abstracts and treats its own water from the Belait river. Other industrial uses are on a smaller scale for timber and sawmills, dairy farms, soft-drink manufacture and workshops, which account for about 25 percent of overall water demand.

Initially, groundwater abstraction was undertaken in the 1950s for use by the oil and gas industries. This has been replaced by surface water resources. Groundwater abstraction, which accounts for 0.5 percent of total water supply, is currently limited to the local bottled water industry (Figure 1).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)		2 722	mm/yr
		15 710	million m^3/yr
Internal renewable water resources (long-term average)		8 500	million m^3/yr
Total actual renewable water resources		8 500	million m^3/yr
Dependency ratio		0	%
Total actual renewable water resources per inhabitant	2009	21 684	m^3/yr
Total dam capacity	1995	45.1	million m^3
Water withdrawal			
Total water withdrawal	1994	92	million m^3/yr
- irrigation + livestock		-	million m^3/yr
- municipalities		-	million m^3/yr
- industry		-	million m3/yr
• per inhabitant	1994	326	m^3/yr
Surface water and groundwater withdrawal	1994	92	million m^3/yr
• as % of total actual renewable water resources	1994	1.08	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

Drinking water is treated at six government treatment plants, which are located in different parts of the country (WHO, 2004).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

All irrigation facilities were equipped in 1980. There are only small-scale irrigation schemes (up to 0.9 ha). In 1995, the area equipped for irrigation was 1 000 ha, all surface irrigation (Table 3). The existing infrastructure and facilities are being upgraded in rural areas, but the irrigated area has remained unchanged since 1980.

Of the total irrigated area of 1 000 ha, 48 percent is irrigated only in the first season, 37 percent only in the second season and 15 percent is a continuously irrigated area.

FIGURE 1
Water withdrawal by source
Total 0.09159 km^3 in 1994

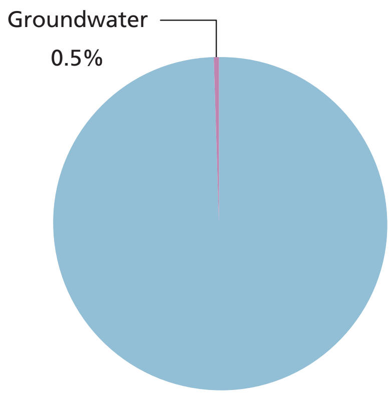

TABLE 3
Irrigation and drainage

Irrigation potential			-	ha
Irrigation				
1. Full control irrigation: equipped area		1995	1 000	ha
- surface irrigation		1995	1 000	ha
- sprinkler irrigation			-	ha
- localized irrigation			-	ha
• % of area irrigated from surface water		1995	100	%
• % of area irrigated from groundwater			-	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		1995	**1 000**	**ha**
• as % of cultivated area		1995	17	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 14 years		1985-1995	0	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**1995**	**1 000**	**ha**
• as % of cultivated area		1995	17	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 0.9 ha	1995	1 000	ha
Medium-scale schemes			-	ha
Large-scale schemes	> 0.9 ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
- as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area			-	ha
• Annual crops: total			-	ha
- Rice		1997	375	ha
- Other annual crops			-	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on full control area equipped)			-	%
Drainage - Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (cultivated non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

The Ministry of Industry and Primary Resources (MIPR) is currently working to improve the irrigation system to address farmers' needs for rice planting (Goh De No *et al.,* 2009).

Role of irrigation in agricultural production, economy and society

In 1997, the major irrigated crops were rice, vegetables and fruits. Rice is grown on 375 ha. The figures for rice show that the country is able to meet only 3.6 percent of the total demand of 27 500 tonnes/year. Lack of labour is the main constraint to the country's agricultural development.

Status and evolution of drainage systems

MIPR is working towards improving the irrigation system, as it is recognized as one of the major issues. Dykes and drainage systems have already been introduced to improve the water flow into and out of the fields (Goh De No *et al.,* 2009).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The main institutions related to water management are:

- Ø The Ministry of Industry and Primary Resources (MIPR) is responsible for facilitating and developing industries and primary resources for local markets and export.
- Ø The Department of Agriculture at the MIPR is responsible for irrigation and drainage as well as water and electricity supplies. It actively promotes the development of various agricultural commodities and facilitates the outsourcing of raw materials and food supply.
- Ø The Technical Services Division of the MIPR is responsible for coordination and facilitation of agricultural infrastructure development in the Agricultural Development Area (ADA land) and Department of Agriculture premises. The responsibilities cover mechanical and agricultural engineering support, development and maintenance of agricultural infrastructure such as buildings, access and farm roads and irrigation and drainage systems, the supply of main electrical and domestic water requirements.
- Ø The Departments of Water Services and of Public Works and the Ministry of Development are responsible for monitoring treated water at treatment plants, storage points and end-points.
- Ø The Department of Health Services audits the quality of water at the treatment plant and end-points.

Water management

Efforts have been made to diversify the economy and to shift from the country's current heavy dependence on oil and gas towards a more independent agriculture sector. The first of the Government's four major objectives for agriculture is to enhance the domestic production of rice, vegetables, poultry and livestock. The Government is stimulating greater interest in agriculture by establishing model farms, and by providing training, advice and support.

The Government supports the development of agro-industries through provision of various kinds of agricultural infrastructure. In this context, the Department of Agriculture has spent a large sum of money on farm roads, irrigation and drainage infrastructure as well as on the supply of water and electricity to help entrepreneurs develop their farmlands. The Department is also actively involved in facilitating inflow of technology and provides various kinds of technical services to boost the productivity and quality of domestic agriculture.

ENVIRONMENT AND HEALTH

As stated above, Brunei Darussalam has excellent facilities for the treatment of its drinking water. In addition, Brunei Shell Petroleum (BSP) and Brunei Shell's Liquefied Natural Gas (LNG) manage two other facilities privately. There are also bottled water factories using advanced technology to produce purified water.

Monitoring of treated water at treatment plants, storage points and end-points is carried out daily by the Departments of Water Services and of Public Works, and by the Ministry of Development. In addition, the Department of Health Services audits the quality of water at the treatment plant and end-points.

Brunei Darussalam was declared malaria-free in 1987 by the World Health Organization. Seventeen new cases were reported in 2003 but they were all imported. Malaria vigilance activities continue to be maintained and are carried out by the Department of Health Services. Water supply and sanitation-related diseases such as diarrhoeal diseases, hepatitis, cholera and typhoid occur in Brunei Darussalam (WHO, 2004).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The future direction of the Department of Agriculture is to strengthen the primary production sectors and to develop the agri-food processing industry by creating a macro-business environment that is attractive to investors. The Department is committed to reforming itself so that it can better serve the needs of the agricultural sector, which includes the water sector.

The Department of Agriculture is currently working on improving system implementation in the department. This includes reassessing agricultural policies, supportive programmes, marketing system, legislation and other matters that affect the progress of this new initiative.

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Cambodia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Cambodia is situated in southeast Asia on the coast of the Gulf of Thailand and has a total area of 181 040 km^2 (Table 1). It is bordered by Thailand in the west, Lao People's Democratic Republic in the north and Viet Nam in the east. Together, with these countries and China and Myanmar, Cambodia shares the Mekong river basin. Water surfaces, including Lake Tonle Sap, occupy approximately 2.2 percent of the total area of the country. For administrative purposes the country is divided into 23 provinces (*khett*), which are Banteay Mean Chey, Battambang, Kandal, Kampot, Kampong Cham, Kampong Chhnang, Kampong Speu, Kampong Thom, Koh Kong, Kep, Kratie, Mondulkiri, Otdar Mean Chey, Pailin, Preah Sihanouk (Sihanoukville), Preah Vihear, Prey Veng, Pursat, Rotanakiri, Siem Reap, Stueng Treng, Svay Rieng and Takeo, and one municipality (*krong*), which is Phnom Penh.

Physiographically, the country is composed of an undulating plateau in the east, a continuous flat plain (the Lake Tonle Sap lowland) interrupted only by isolated hills (*Phnoms*) and the Mekong river in the central part, and the Cardamone mountains in the southwest.

The cultivable area is approximately 4.63 million ha, or 25 percent of the total area. In 2009, the total cultivated area was about 4.055 million ha of which 3.900 million ha or 96.2 percent for annual crops and 0.155 million ha or 3.8 percent of permanent crops.

Climate

Cambodia has a tropical monsoon climate and is influenced by various factors, including its location within the Inter-Tropical Convergence Zone and the monsoon. There are two distinct seasons:

1. the dry season from November to April associated with the northeast monsoon, which sends drier and cooler air, with February being the driest month;
2. the wet season from May to October, in which rainfall is largely derived from the southwest monsoon drawn inland from the Indian Ocean;

the rainfall pattern is bi-modal in this season with peaks in June and September/October.

In Phnom Penh, monthly rainfall ranges from 5 mm in January to 255 mm in October. Average annual rainfall is an estimated 1 400 mm, but varies from about 1 000 mm in Svay Chek in the western province of Banteay Mean Chey to nearly 4 700 mm in Bokor in the southern province of Kampot. Precipitation varies widely from year-to-year. Mean annual evaporation varies from 1 000 to 2 300 mm. April is the warmest month of the year with a maximum temperature of 36 °C, while January is the coldest with 21 °C.

From the latter part of July, there may be periods without significant rainfall for ten or more days at a time. This is referred to as the 'short dry season'. Farmers tend to delay planting during this time to minimize the risk of damage to rice or crop seedlings, which are not irrigated.

CAMBODIA **FAO - AQUASTAT, 2011**

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	18 104 000	ha
Cultivated area (arable land and area under permanent crops)	2009	4 055 000	ha
• as % of the total area of the country	2009	22	%
• arable land (annual crops + temp fallow + temp meadows)	2009	3 900 000	ha
• area under permanent crops	2009	155 000	ha
Population			
Total population	2009	13 978 000	inhabitants
• of which rural	2009	80	%
Population density	2009	77	inhabitants/km^2
Economically active population	2009	7 386 000	inhabitants
• as % of total population	2009	53	%
• female	2009	49	%
• male	2009	51	%
Population economically active in agriculture	2009	4 895 000	inhabitants
• as % of total economically active population	2009	66	%
• female	2009	51	%
• male	2009	49	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	9 872	million US$/yr
• value added in agriculture (% of GDP)	2009	35	%
• GDP per capita	2009	706	US$/yr
Human Development Index (highest = 1)	2010	0.494	
Access to improved drinking water sources			
Total population	2008	61	%
Urban population	2008	81	%
Rural population	2008	56	%

Population

In 2009, the total population was 13 978 000, around 80 percent lived in rural areas (Table 1). Population density is 77 inhabitants/km^2. Annual population growth rate during the period 1999-2009 is an estimated 1.4 percent.

In 2008, access to improved drinking water sources covered 61 percent (81 and 56 percent for the urban and rural population respectively). Access to improved sanitation reached 29 percent (67 and 18 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, around 4.9 million of the total population was economically active in agriculture, which amounted to 66 percent of the economically active population. Of these 51 percent were women. In 2009, the gross domestic product (GDP) was US$9 872 million of which agriculture accounted for 35 percent (Table 1).

Cambodian farming systems are largely subsistence oriented and most agricultural activity is based on low input and rainfed production systems centered on paddy rice production. In spite of Cambodia being self-sufficient in rice and having an exportable surplus, the rice-based farming systems are characterized by low income. Furthermore, despite the overall surplus of rice production food insecurity remains a major concern in some parts of the country, especially at administratively disaggregated levels, such as province, district, commune and household, where droughts and floods occur frequently (WFP, 2010).

In 2006, the total harvested rice area was 2.4 million ha, of which 2.1 million ha in the wet season and 0.3 million ha in the dry season (MAFF, 2006).

Cambodia has recently re-entered the world market as a rice exporting nation, following a 30-year hiatus caused by war, political isolation, and a decimated agricultural sector. A resurgence of rice cultivation is occurring across the nation's vast lowlands, as the rural population expands and as previously abandoned or mined farmland is brought back into production. Recent public statements by government ministers indicate that Cambodia wants to double rice production by 2015 to approximately 15 million tonnes (which is 9.5 million tonnes of milled rice) and export 8 million tonnes (5 million tonnes of milled rice) (USDA, 2010).

The United States Department of Agriculture (USDA) estimates Cambodian milled rice production in 2009/2010 was a record of more than 4.6 million tonnes, up 2.4 percent from 2008/2009, the fifth consecutive record harvest. Over the past 12 years national rice production has more than doubled, rising 110 percent over the period from a level of 2.2 million tonnes in 1998/1999. The scale of improvement in the past 5 years has been unprecedented, with average milled rice production reaching 4.2 million tonnes or a 74 percent increase over the previous ten-year period, when production had already recovered to pre-war levels. The unusually strong recent growth has been attributed, by both private and public sector officials, to a significant increase in cultivated rice area (26 percent) and in crop yields (40 percent). Government statistics indicate that wet season crop area and production increased by 2.2 percent and 7.2 percent per year respectively, while dry season crop area and production increased by 5.5 percent and 10.5 percent respectively (USDA, 2010).

WATER RESOURCES AND USE

Water resources

The main hydrological system is the Tonel Sap/Mekong system. The Mekong river and Lake Tonle Sap are connected by the Tonle Sap river, which is approximately 120 km long and twice a year reverses its direction of flow. From July to the end of October, when the level of the Mekong is high, water flows into the Tonle Sap river, which fills Lake Tonle Sap, thereby increasing the size of the lake from 2 600 km^2 to about 10 500 km^2 at its maximum. The storage capacity of Lake Tonle Sap is about 72 km^3. In early November, when the level of the Mekong decreases, the Tonle Sap river reverses its flow, and water flows from Lake Tonle Sap to the Mekong river and thence to the Mekong Delta.

The Tonle Sap Great Lake has several input rivers, the most important being the Tonle Sap river during the rainy season, which contributes 62 percent of the total water supply. The other rivers in the sub-basin and direct rainfall on the lake contribute the remaining 38 percent. Other major rivers are the Sen river, Sreng river, Pursat (Pouthisat) river, Sisophon river, Mongkul Borey river, and Sangker river.

In Cambodia, the Mekong river flows from north to south, over a distance of around 480 km. About 86 percent of Cambodia's territory (156 000 km^2) is included in the Mekong river basin, the remaining 14 percent draining directly towards the Gulf of Thailand. The Kong river is one of the largest tributaries of the Mekong. It originates in Viet Nam, runs through Lao PDR and joins the San river and Mekong river near Stoeng Treng in Cambodia.

Cambodia was a member of the Mekong river Committee between 1957 and 1975. On 5 April 1995, Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam signed an agreement for the development of the Mekong river. Under the agreement, the Mekong River Committee became the Mekong River Commission. Cambodia represents 20 percent of the total catchment area of the Mekong river basin.

This river system flowing into the Gulf of Thailand is less important, but retains its potential for future development of water resources, owing to much rain and steep slopes in this area (WEPA, 2010).

The average annual discharge of the Mekong river entering Cambodia is estimated to be close to the discharge at Paksé (324.45 km^3/year) in Lao People's Democratic Republic, some 120 km upstream from the border with Cambodia. Other inflows to the Mekong-Tonle Sap system from outside the country amount to 29.9 km^3 from Viet Nam and 1.19 km^3 from Thailand. On average, 471.51 km^3/year flows out of the country to Viet Nam through the Mekong channels (470 km^3/year) and tributaries (1.41 km^3/year).

The internal renewable surface water resources (IRSWR) have been computed as the difference between outflow and inflow, i.e. 115.97 km^3. This figure does not include the unknown discharge of small rivers to the Gulf of Thailand and is thus probably an underestimate. Annual groundwater resources are about 17.6 km^3 most of which, an estimated 13 km^3, is drained by the rivers and cannot be considered as additional water resources. The total internal renewable water resources of Cambodia are, therefore, approximately 120.57 km^3/year (115.97+17.6-13.0) and total renewable water resources at 476.11 km^3/year (Table 2).

The alluvial deposits in the Tonle Sap and Mekong floodplain/delta are believed to be excellent shallow aquifers, with high recharge rates and a water table generally within 5-10 m of the surface water. Shallow wells could be used in an estimated 48 000 km^2 of the country (WEPA, 2010).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 400	mm/yr
	-	253 000	million m^3/yr
Internal renewable water resources (long-term average)	-	120 470	million m^3/yr
Total actual renewable water resources	-	476 110	million m^3/yr
Dependency ratio	-	74.7	%
Total actual renewable water resources per inhabitant	2009	34 061	m^3/yr
Total dam capacity	-	-	million m^3
Water withdrawal			
Total water withdrawal	2006	2 184	million m^3/yr
- irrigation + livestock	2006	2 053	million m^3/yr
- municipalities	2006	98	million m^3/yr
- industry	2006	33	million m^3/yr
• per inhabitant	2006	162	m^3/yr
Surface water and groundwater withdrawal	2006	2 184	million m^3/yr
• as % of total actual renewable water resources	2006	0.5	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater	1994	0.157	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

The capacity of the existing dams is very low and has not been estimated. In 2008, there were only two dams. One small dam (Ochum, in the northeastern province of Rotanakiri) is used as a hydropower station with an installed capacity of 1 MW. The Kirirom power plant, which was installed in 1968 in Kampong Speu province with a capacity of 10 MW has not been in operation since 1970, because of war damage but has been reconstructed with a capacity of 12 MW (Sereyvuth, 2008). The government is preparing to build ten hydroelectric and irrigation dams in the northwest provinces. It is hoped that the US$4 000 million project will supply more than 100 000 rural families with water and electricity (ABC, 2008).

The country's demand for electrical power is projected to increase from 251 MW in 2000 to 746 MW in 2016 (WEPA). Projects under implementation are the 193 MW Kamchay Hydro-project (2010), the 120 MW Atay Hydropower Plant (2012), the 338 MW Lower Russei Chhrum Hydropower Plant (2014), the 18 MW Kirirum III and the 246 MW Tatay Hydropower plant by (2015) (Sereyvuth, 2008).

There are plans to construct a large hydropower dam near the confluence of the San and Srepok rivers in Sesan District, Stueng Treng Province. However, civil society and local communities say that the plan has not adequately considered the project's negative environmental and social impacts and the needs of affected communities living upstream and downstream of the proposed dam site. The 75 m high dam is expected to inundate more than 30 000 ha of land and forest and to result in the resettlement of an estimated 5 000 people (International Rivers, 2009).

In 1994, the average treated sewage flows were about 157 000 m^3/year. Most of the systems combine sewage and drainage water and are in a poor condition and not functioning properly. Drainage water often mixes with drinking water with obvious health implications. Floods are frequent during the rainy season as the sewers clog rapidly.

International water issues

The Mekong River Commission (MRC) came into existence on 5 April 1995 with an agreement between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. These four countries signed the "Agreement on the cooperation for the sustainable development of the Mekong river basin" and agreed on the joint management of their shared water resources and development of the economic potential of the river. The MRC has been built on a foundation of nearly 50 years of knowledge and experience in the region, starting in 1957 as the United Nationsfounded Mekong Committee. In 1996, China and Myanmar became Dialogue Partners of the MRC and the countries now work together within a cooperation framework.

The transboundary implications of hydropower projects on water quality and quantity are numerous. The first risk of hydropower project development in the upstream area of the Mekong river is the negative impact on the environment and society. The second type of risk is geo-political, meaning the inevitable dependence of countries that do not possess hydropower upon those who develop hydropower projects. Cambodia is particularly vulnerable because it will certainly increasingly depend on Thailand, Lao People's Democratic Republic and Viet Nam for its power supply. A cutoff of power supply by power producers would seriously impede any possibility for Cambodia to achieve its development goals and strategies, such as alleviate poverty, improve the population's livelihood, welcome further foreign investments, sustain tourism development, etc. (WEPA, 2010).

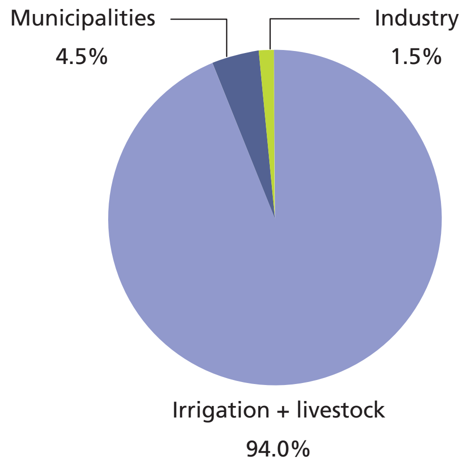
Water use

In 2006, total water withdrawal was about 2.184 km^3, of which 2.053 km^3 (94 percent) for agriculture, 0.98 km^3 (4.5 percent) for municipalities and 0.33 km^3 (1.5 percent) for industries (Table 2 and Figure 1).

The consumption of water in the Mekong Delta for aquaculture is approximately 6 000 m^3/ha per month (WEPA, 2010).

Most manufacturing and warehouses in Phnom Penh are located along the embankment of the Tonle Sap river north or the Bassac river south of the city, with mixed commercial and residential areas. Such locations allow direct access to river transport and high consumption of water. The industrial sector's water requirements are based upon the size of the factory. An estimate of water use volume for different sizes and types of factories are as follows (WEPA, 2010):

FIGURE 1
Water withdrawal by sector
Total 2.184 km^3 in 2006



- major industry: 1 000–20 000 m^3/day (paper making, chemical manufacture, iron and steel production, oil refining, etc.);
- large-scale industry: 100–500 m^3/day (food processing, vegetable washing, drinks bottling, ice making, chemical products, etc.); and
- medium- and small-scale industry: 50 m^3/day.

Most provinces include significant areas where groundwater is used as the main source of domestic water supply. As of 2001, withdrawal of groundwater for domestic and drinking water supply was approximately 2 147 m^3/day (WEPA, 2010).

Groundwater is being exploited at ever-increasing rates, particularly by shallow tubewells for community and household water supply, as well as for irrigation. There are at least 25 000 community water supply tubewells and large diameter motorized tubewells for irrigation. About 2 000 manually operated shallow wells are being installed annually. Besides the use of groundwater resources for domestic consumption and livestock watering, it is also being used widely in the industrial sector. Data and information relevant to the use of groundwater and its quality is not available. Informal estimations by concerned stakeholders, however, show that if the agricultural and industrial sectors continue to extract groundwater to meet water demands without being charged, and responsible institutions do not exert regular control over this sector, there may be adverse effects from over-extraction (WEPA, 2010).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Cambodia's history of hydraulic control goes back to before the Angkor period (tenth century). The famous Angkor Wat irrigation system was based on four reservoirs, built between the tenth and twelfth century, which stored some 100-150 million m^3 of water to irrigate approximately 14 000 ha.

Modern irrigation systems were first developed in the period 1950-1953. Many of the structures built during that period functioned until 1975. Most of these structures, such as the 'colmatage' canals, have become non-functional as a result of the network of irrigation and drainage systems built during the period of the Democratic Kampuchea (1975-1979), when the regime put practically the entire population to work planting rice and digging irrigation dykes and canals during which over 20 percent of the population died of exhaustion, starvation, disease and execution (Himel, 2007).

The nation's irrigation infrastructure has grown gradually over the past two decades. This has been a major focus of the government to enable farmers to achieve higher crop yields, reduce vulnerability to drought, stabilise rice production potential, and increase national food security or self-sufficiency. Despite this growth, Cambodia's irrigation remains significantly underdeveloped. In comparison to similar rice cultivation environments in the lowlands of Thailand or the Mekong Delta in Viet Nam, Cambodia has little rice land under irrigation. The Ministry of Water Resources and Meteorology (MOWRAM) estimates that approximately 24 percent of the country's rice land is irrigated (USDA, 2010).

Recently, some 946 operating irrigation systems have been inventoried. However, many are not operational. The area equipped for full control irrigation in 2001 was around 284 177 ha (MRC, 2003). Rice was cultivated on 275 177 ha; sugarcane on 8 000 ha and citrus on 1 000 ha. In the dry season, rice cultivated in flood recession areas covered around 63 000 ha and in the wet season deep floating rice covered around 137 753 ha (MAFF, 2006). This brings the total water managed area for 2001 to 484 870 ha. The area equipped for full control irrigation in 2006 was about353 566 ha. Rice cultivated in flood recession areas covered 367 688 ha, of which 63 000 ha in the dry season. This brings the total water managed area in 2006 to 721 254 ha (Table 3).

Irrigation potential has never been estimated for the physical area that could be irrigated considering water and land resources. However, it could be at least 1 million ha.

The operating irrigation schemes can be divided into four main categories:

- River, lake or stream diversion by gravity. These systems are used for wet season supplementary irrigation as there are no storage facilities. Offtakes are generally uncontrolled, although in some cases, water level control is provided by diversion weirs.
- Water pumping from rivers. These systems can provide water for both the wet and dry seasons. Pump stations have been provided by the Government.
- Reservoirs storing water from runoff, streams or rivers for wet season supplementary irrigation. Water is abstracted from the reservoir by gravity or mobile pumps provided by farmers.
- Reservoirs storing flood waters from the Tonle Sap/Bassac/Mekong system and released by gravity or mobile pumps for a dry season recession crop only. These areas also benefit from natural flooding for land preparation. The crop is transplanted as the floodwater recedes and is irrigated during the growing season with water stored in nearby reservoirs. This system takes advantage of the large range of water levels in the Tonle Sap/Bassac/Mekong system to fill the reservoirs during the flood to a level sufficient to give gravity command of the paddy fields. Although they are equipped for irrigation, these areas are often termed flood recession areas as they use natural flooding at the beginning of the season for land preparation and the filling of the reservoirs.

Another classification, used by the Department of Hydrology, defines three irrigation systems with the following areas in 1993 (Figure 2):

- Large-scale projects, where water is supplied from a multipurpose dam (generally irrigation and hydropower). The annual irrigated area in 1993 for these schemes is an estimated 118 225 ha in the wet season and 63 241 ha in the dry season.
- Medium-scale projects, with an irrigated area of 100 ha or more, where water is supplied by single-purpose dams or 'colmatage' canals. The 'colmatage' system uses dykes and

TABLE 3
Irrigation and drainage

Irrigation potential			-	ha
Irrigation				
1. Full control irrigation: equipped area		2006	353 566	ha
- surface irrigation		2006	353 566	ha
- sprinkler irrigation		2006	0	ha
- localized irrigation		2006	0	ha
• % of area irrigated from surface water		1993	100	%
• % of area irrigated from groundwater		1993	0	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2006	317 225	ha
- as % of full control area equipped		2006	90	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2006**	**353 566**	**ha**
• as % of cultivated area		2006	9	%
• % of total area equipped for irrigation actually irrigated		2006	90	%
• average increase per year over the last 5 years		2001-2006	4	%
• power irrigated area as % of total area equipped		1995	3.5	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area		2006	367 688	ha
Total water-managed area (1+2+3+4+5)		**2006**	**721 254**	**ha**
• as % of cultivated area		2006	18	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 0.9 ha	1993	17 090	ha
Medium-scale schemes		1993	77 820	ha
Large-scale schemes	> 0.9 ha	1993	181 500	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2006	384 531	ha
• Annual crops: total		2006	383 287	ha
- Rice		2006	373 331	ha
- Sugarcane		2006	9 956	ha
• Permanent crops: total		2006	1 244	ha
- Citrus		2006	1 244	ha
Irrigated cropping intensity (on full control equipped area)		2006	121	%
Drainage - Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases		1994	507 000	inhabitants

- Ø sluices to provide controlled annual inundation. Intake and drainage are controlled, allowing a fertile layer of silt to settle on the fields. The annual irrigated area in 1993 for these schemes is an estimated 46 599 ha in the wet season and 31 225 ha in the dry season.
- Ø Small-scale projects, are less than 100 ha. The annual irrigated area in 1993 for these schemes is an estimated 7 903 ha in the wet season and 9 190 ha in the dry season.

All irrigation in Cambodia is surface irrigation. During the 1990s, sprinkler and localized irrigation was introduced on very small areas.

In 2010, the government implemented the 'Hegemonization of Irrigation System Strategy'. The project cost US$61 million, including a credit loan of US$47 million from China and US$14 million from the government of Cambodia. Once completed, the project will be capable of irrigating over 49 000 ha of agricultural land.

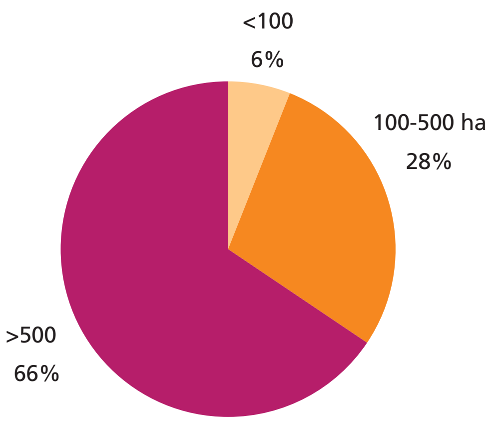
The Asian Development Bank (ADB) in 2003 approved a loan of US$18 million to develop irrigated agriculture to boost production in poor and neglected rural areas of northwest Cambodia. The loan for the Northwest Irrigation Sector Project assists in improving water resource management, providing rehabilitation and improvement of irrigation schemes and other water control infrastructure, and strengthening management of the irrigation infrastructure. The project focuses on four northwest provinces, Pursat, Battambang, Banteay Mean Chey and Siem Reap, which are among the poorest and most isolated areas in Cambodia. The total cost of the project is an estimated US$30.9 million. Agence Francaise de Developpement provided a grant of about US$3.7 million, while the Government of Cambodia contributed US$6.9 million equivalent and beneficiaries US$2.3 million. MOWRAM is the executing agency for this project, which had a completion date of 2010 (ADB, 2003).

Male-headed households irrigate on average 0.15 ha more than female headed households (FAO/SIDA, 2010).

Role of irrigation in agricultural production, economy and society

Total harvested irrigated cropped area in 2006 on full control irrigation schemes is an estimated 384 531 ha, of which the most important crop is rice accounting for 373 331 ha (97.1 percent), followed by sugarcane on 9 956 ha (2.6 percent) and citrus on 1 244 ha (0.3 percent) (Table 3 and Figure 3). Double cropping is practiced on a small area. Only a few irrigation schemes are capable of irrigating year round (WEPA, DATE).

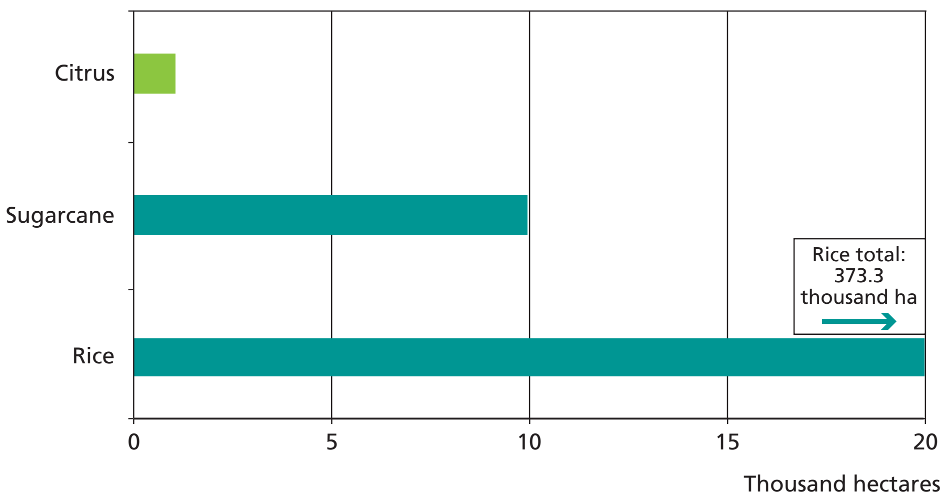
FIGURE 2
Type of full control irrigation schemes
Total 276 410 ha in 1993



Rice ecosystems in Cambodia are influenced by rainfall and flooding patterns, soil suitability and the country's topography. As a result, rice growing ecosystems can be grouped into the following broad categories, considering a total cultivated rice area of 2.44 million ha (WFP, 2010):

- Ø **Rainfed lowland rice:** Represents 82 percent of the total annual rice cropping area. It is characterized by flat

FIGURE 3
Irrigated crops on area equipped for full control irrigation
Total harvested area 384 531 ha in 2006 (cropping intensity on area actually irrigated: 121%)



bounded rice fields, which mostly depend on rainfall or surface runoff for their water supply. It includes areas with supplementary irrigation. In the higher fields, where the water depth is 15-20 cm, short duration (fast growing) varieties are normally grown, while in the lower fields, where the water depth is 20-60 cm, medium and long duration varieties are normally grown.

- **Rainfed upland rice**: Represents 2 percent of the total annual rice cropping area. The areas are unbounded fields in the mountainous and rolling hill areas (Mondulkiri, Rotanakiri, Kratie, Koh Kong, Kampong Cham and Kampong Thom). In the shifting cultivation areas of the northeast of Cambodia upland rice is an integral part of the 'chamkar farm', practiced mostly by ethnic minority groups. It is also known as swidden agriculture, which is the common practice of clearing and using a plot of land for 1-5 years and then clearing another plot of land. As it is associated with burning, it is also called 'slash and burn'. Permanent upland rice production is commonly practiced by Khmers, where a field of rice is grown annually either on its own or as an intercrop or in rotation with other upland crops.
- **Deepwater or floating rice**: Represents 4 percent of the total annual rice cropping area. This is practiced in low lying areas and depressions that accumulate flooded water to a straw length of 1-2 m (deepwater rice) or with a straw length up to 4 m (floating rice) at least one month during the growing period. Both subcategories are adapted to continuous, unregulated flooding. These areas are located mainly around the Tonle Sap Lake (Battambang, Banteay Mean Chey, Pursat, Siem Reap, Kampong Thom and Kampong Cham) and along the Mekong and Bassac rivers. The rice varieties have a rapid elongation with increase in water depth, and submergence tolerance to flash floods.
- **Irrigated rice**: Represents 12 percent of the total annual rice cropping area. The distribution of dry season production is primarily in those areas close to the major rivers and their floodplains. Dry season rice production is associated with higher yields than wet season production because of higher solar radiation, better water control and the cultivation of more fertilizer-responsive varieties of rice.

In the Tonle Sap area, irrigation schemes are largely designed to manage floodwater to supplement rainfall for wet season rice production at the start and/or the end of the wet season from May to November. Only a few schemes are designed to divert water from the Mekong or Tonle Sap catchment for dry-season crops during the main part of the dry season or for flood recession irrigation early in the dry season (CDRI, 2008).

Dry season irrigated rice usually includes improved varieties of rice grown for cash income, while wet season rice includes traditional varieties cultivated for subsistence and food security (WFP, 2010).

In 2006, the average rice yield was an estimated 2.26 tonnes/ha and 3.90 tonnes/ha in the wet and dry season respectively (MAFF, 2006). In 1993, the average rice yield was an estimated 1.39 tonnes/ha under rainfed conditions and 2.07 tonnes/ha under irrigated conditions.

A survey in 1999 estimated that the development of one hectare irrigated by pumping would require an investment of US$2 800, and US$85/year for O&M, while for a hectare irrigated from a reservoir this would be US$3 600-4 300 and US$40-65/year.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The public institutions involved in the water sector are (ADB, 2005 and CDRI, 2008) the:

- Ministry of Water Resources and Meteorology (MOWRAM): established in 1999 as lead water sector agency, exercises overall responsibility for water management and conservation including IWRM. It includes the Department of Water Resources Management and Conservation;
- Cambodia National Mekong Committee (CNMC): coordinates with the water-related Ministries and the Mekong River Commission (MRC);
- Ministry of Industry, Mine and Energy (MIME): provides drinking water supply to cities and towns;
- Ministry of Rural Development (MRD): provides clean water to rural areas;
- Ministry of Environment (MoE): is in charge of wastewater treatment in cities and towns. It includes the Department of Nature Conservation and Protection;
- Forestry Administration (FA) and the Department of Planning, both belonging to the Ministry of Agriculture, Forestry and Fisheries (MAFF);
- Natural Resources and Environment Unit (NRE) of the Cambodia Development Resource Institute (CDRI);
- plans to establish The Basin Management Council and the Office of Basin Management are underway.

Water management

Key issues affecting Cambodia's water sector are:

- an inadequate legislative framework,
- limited coordination among water-related institutions,
- weak water resources management,
- severe pressure on the Tonle Sap ecosystem,
- unplanned urban and industrial development (ADB, 2005).

Following the shift in the water management paradigm from large centrally managed schemes to small locally managed schemes, the ADB in 1999 introduced Participatory Irrigation Management and Development (PIMD) in Cambodia. This involves people at all levels, especially locals who are directly concerned with irrigation water, in the planning, development and management of water. Central to PIMD in Cambodia has been the establishment of Farmer Water User Communities (FWUC), set up to take over management of irrigation schemes from the government. The FWUC are in charge of everyday management of irrigation schemes, which includes regulating access to water, fee collection and monitoring, interdiction and prosecution of those who violate the FWUC statue (CDRI, 2008).

Under the National Socio-Economic Development Plan, 1996-2000, water supply and wastewater treatment were set as priorities by the Government.

Development of new irrigation scheme has a low economic internal rate of return (1-6 percent), therefore over the last decade government priority has been to rehabilite existing schemes. Priority was given to small-scale schemes, as large-scale schemes have serious O&M problems. The estimated potential of irrigated agriculture production is high for small-scale irrigation schemes with active community participation and in combination with other agricultural technology packages, especially balanced fertilizer use. Indeed, soil fertility is a major problem in Cambodia and production increase with irrigation alone would be limited.

The development of groundwater irrigation in the Mekong Delta might be a valid alternative to the current water managed systems (in certain areas with sufficient and easily accessible groundwater reserves), the efficiency of which depends heavily on the fluctuations of the Mekong river.

Another priority is the development of well-designed flood control devices in conjunction with irrigation facilities to enable drainage in times of flooding, and irrigation in the dry season. Another priority is the construction of several dams, mainly for hydropower.

Some of MOWRAM's achievements to date have been: the preparation of a *Strategic Plan on Water Resources Management and Development 2005–2008*, the formation of a Technical Working Group on Agriculture and Water, and a *Water Law* approved in 2007. MOWRAM works in conjunction with key agencies to jointly govern and manage the optimal and sustainable use of water resources. However, the primary role of MOWRAM is to protect the hydrological cycle (surface and underground flow and storage), and water quality for consumption. MOWRAM still faces many challenges, since it is still a new agency compared to similar institutions in the other co-riparian Mekong countries. It is inexperienced in dealing with transboundary water cooperation, conflict prevention and protecting the development interests of Cambodia. Government officials often have limited knowledge or skills, and they tend to sway river basin management and conservation to their own mandates. Cambodian officials need training in water catchment management knowledge and skills. The experiences of the neighbouring countries should also be thoroughly studied and used in Cambodian river basin management, if Cambodia is to avoid some of the difficulties and problems faced elsewhere in the past (CDRI, 2008).

There are also problems with the inter-ministerial set up. The roles and responsibilities of the relevant agencies in the ministries and the mechanism by which they contribute to river basin management are still unclear. To deal with the coordination issue, a Technical Working Group on Agriculture and Water (TWGAW) was established in 2000 to jointly plan and coordinate the water and agriculture development programme. This TWGAW has proposed a *Medium Term Strategy for Agriculture and Water (2006–2010)*, which was approved by MOWRAM in 2007 (CDRI, 2008).

In 2005, the ADB proposed the Tonle Sap Rural Water Supply and Sanitation Project, which aims to provide rural water supply and sanitation facilities to approximately 2 200 villages in five provinces around the Tonle Sap basin. The project should provide a million people with safe drinking water and 750 000 with improved sanitation facilities (ADB, 2005).

The framework and principles of integrated water resources management (IWRM) was adopted by MRC at the end of 2005 under the Basin Development Plan (BDP). CNMC has recently conducted several workshops on IWRM at the central, provincial and basin levels.

The Water Resources Management Research Capacity Development Programme (WRMRCDP) focuses on research capacity development and knowledge dissemination in the field of water resources management in catchment areas surrounding the Tonle Sap Lake. The programme ran for five years (2006–2011) and was implemented by the Natural Resources and Environment Unit (NRE) of the Cambodia Development Resource Institute (CDRI), with financial support from AusAID and involved collaborating research partners: the University of Sydney (USyd), the Royal University of Phnom Penh (RUPP), the Ministry of Water Resources and Meteorology (MOWRAM) and the Ministry of Agriculture, Forestry and Fisheries (MAFF) (CDRI, 2008).

Recently, an *Action Plan on Management and Development of Water Resources 2009-2013* has been presented (Yem, 2010).

Finances

The government has had a very proactive campaign in recent years to acquire financial assistance (grants and loans) from international donors and foreign governments for major construction projects directed at the agricultural and energy sectors. In total, MOWRAM acknowledged that it had received commitments totalling US$1 100 million for irrigation infrastructure development, with an additional US$850 million pledged in October 2009 from the Chinese Government for the construction of dams for hydropower, irrigation, roads, and port upgrades. The roughly US$2 000 million in pledged development assistance has the potential, given it is leveraged wisely, to substantially alter the status quo in the agricultural sector. Cambodia is one of the poorest nations in Asia and this scale of investment could help underpin additional agricultural and economic expansion (USDA, 2010).

Policies and legislation

Laws and policies related to water resources management in Cambodia are many and varied. They include (CDRI, 2008) the:

- New Constitution of the Kingdom of Cambodia 1993, Articles 58 and 59 (Jennar, 1995);
- Royal Decree on the Creation and Designation of Protected Areas (1993), which designated 23 areas covering about 3.3 million ha, equal to 18 percent of the total land area, including the Tonle Sap Great Lake. The objectives of the Royal Decree state that the management process can closely parallel those recommended in the United Nations List of National Parks and Protected Areas. This Royal Decree determined that the Ministry of Environment is responsible for the supervision of the development planning and management of a Natural Protected Area System in cooperation with the protection of the terrestrial, wetland and coastal environments;
- Law on Environmental Protection and Natural Resources Management, 1996;
- Royal Decree on Watershed Management, 1999;
- Circular No. 01 (11 January 1999) on the Implementation Policy of Sustainable Irrigation Systems;
- Subdecree on Watershed Management by MAFF, 2000;
- Sustainability of Operation and Maintenance of Irrigation System Policy, 2000;
- National Water Sector Profile, 2001;
- Natural Water Resource Policy, 2004; and the
- Law on Water Resources Management, 2007, with four subdecrees identified: river basin management, water allocation and licensing, water quality, and farmer water user community.

ENVIRONMENT AND HEALTH

The living environment, especially human health, is affected by the discharge of untreated and low quality treated wastewater. Major urban sanitation problems in Cambodia are technical, financial and institutional. There is no public investment in public infrastructure dedicated solely for sewage. The existing storm drainage system is also used for sewage collection and conveyance. Existing septic tank systems are inadequate and are required by law to be installed in all new buildings. Therefore, the waste from these septic tanks flows into the storm drainage system for discharge into receiving waters without any treatment, thus creating potential environmental pollution problems (WEPA, 2010). Only some effluents from the industrial sector are treated before being discharged into a sewage system and finally to the receiving sources (Sokha, 2008).

During the rainy season, there is enough dilution water to eliminate or reduce pollution in the receiving bodies of water. During the dry season, the drains mainly convey sewage and the concentration of pollutants is higher than in the rainy season, because raw sewage is discharged into the receiving bodies of water at a time when they would have lower amounts of water for dilution. There are reports that the above-mentioned situation is causing growing pollution in the Mekong river and other main water bodies.

A second problem with the sewerage systems is that they are not designed to prevent the deposition of solids within the storm drains during the dry season when they convey only sewage. Hence, organic solids (such as excreta) tend to be deposited in the drains during the dry season. The decomposition of these solids causes widespread odours at street inlets to the drains. It also generates corrosive gases such as hydrogen sulphide that attacks concrete storm drains, thus shortening their design lives because of premature deterioration.

Problems are not only limited to the dry season, however. There are reports that during wet seasons a mixture of sewage and storm water often backs up into houses in low-lying areas. Lack of awareness of alternative solutions to urban sanitation problems is another significant issue for urban sanitation in Cambodia. Another problem is lack of access by the poor to public storm drainage systems used as combined sewerage for both storm water and sewage. For the poor, the cost of connecting to storm drains is too high. Commercial forestry, agriculture and mining also affect the country's surface water system (WEPA, 2010).

The outcomes of analyses of water samples in 2001, 2002 and 2003, taken from designated sampling points in the Mekong, Tonle Sap and Bassac rivers, have shown that these natural water sources are generally less polluted than in other riparian countries. During the rainy season (July to October) the river water is turbid with a high concentration of silt resulting from soil erosion in the upstream and local catchment areas. In the dry season, especially in April, BOD values noticeably exceed water quality standards for public water areas set by the Ministry of Environment. Coliform also increases from February to July (WEPA, 2010).

Groundwater quality is generally satisfactory. However, unpalatably high iron levels are found in about 10 percent of the tubewells, particularly in Kandal Province. Increased salinity is seen in parts of the southernmost (delta) provinces, most likely the result of contamination by salt contained in the original deltaic deposits, and recent measurements indicate that water drawn from aquifers in some locations may cause health problems because of the high concentration of chemical substances. However, the status of groundwater contamination is not widely disseminated owing to a lack of human resources, analytical facilities, technical skills, etc. (WEPA, 2010).

ADB provided nearly US$11 million for a new wastewater and sewerage treatment facility in Siem Reap to help end bouts of serious flood in the country's biggest tourist destination. The project was inaugurated recently in Siem Reap, which has been subjected to frequent floods in the central commercial and tourist accommodation areas, because the old and defective drainage and sewerage system was unable to cope. The project includes the construction and installation of thousands of meters of sewer lines as well as the rehabilitation of more than 2 100 m of drainage pipes. The defective drain covers in the city's centre have been replaced and irrigation canals upgraded (Dap News, 2010).

Two of the most common water-related diseases linked to the development of irrigation are malaria and schistosomiasis. Malaria is already a serious problem throughout the country because of the natural ecosystem. In 1999, estimates of about 500 000 cases of malaria per year were common. Each year, 5 000-10 000 people die from malaria. Schistosomiasis was reported in the Kratie area in 1993. Dengue fever became, in the 1990s, an important cause of child morbidity. In 1990, about 7 000 cases resulting in 340 deaths were recorded.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The core constraints to rice production growth are:

1. underfunding of agricultural crop extension programmes;
2. inadequate funding for scientific agricultural research;
3. low production and availability of improved rice seed;
4. lack of commercial farm credit system;
5. stagnating rice crop yield growth rates;
6. stagnating irrigation expansion (USDA, 2010)

MOWRAM and MAFF are working to increase investment in irrigation and research to promote agricultural production for poverty reduction. MOWRAM has shown a strong commitment to increase the irrigated area in Cambodia by 20 000 ha/year. Increasing investment in irrigation to increase rice production and encourage agricultural diversification for food security and higher value-added crops is essential, but these are not the only goals of water resources management. Integrated water resources management involves agriculture, fish production, biodiversity, water supply and sanitation, and transport and hydropower. Thus it is crucial that basin-wide management issues are considered when planning irrigation development (CDRI, 2008).

MOWRAM has begun preliminary studies for constructing dams across four provinces, which will cost US$4 000 million. The ministry is planning to build more than ten dams and related irrigation systems in four northwestern provinces to ensure rice production during both the rainy and the dry seasons. The proposed dams would provide the country with a more modern irrigation system as well as generate electricity for rural communities. The ministry aims to build four dams in Pursat province that would supply irrigation to more than 35 000 ha of land and generate as much as 300 MW of power for local communities. Other proposed dam sites include locations in Battambang, Kampong Chhnang and Banteay Mean Chey provinces. Though, the government must look outside the country for the money needed to complete the ambitious project (Asean Affairs, 2008).

Note:

The expression 'Stung', which is often added to the names of rivers, means 'river'. Therefore, in this English version of the country profile, this word has been removed from the name of the river and replaced by the word 'River'. As an example, 'Stung Pursat' and 'Stung Sisophon' have been changed to Pursat river and Sisophon river.

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China

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The People's Republic of China is located in the southeast of the Eurasian landmass, bordered by Mongolia and the Russian Federation to the north, the Democratic People's Republic of Korea and the Pacific Ocean to the east, Viet Nam, the Lao People's Democratic Republic, Myanmar, Bhutan, Nepal and India to the south, and Pakistan, Afghanistan, Tajikistan, Kyrgyzstan and Kazakhstan to the west. The average altitude in China ranges from over 4 000 m in the west to less than 100 m in the east. The total area is about 9.6 million km^2 and is composed of mountains (33 percent), plateaux (26 percent), valleys (19 percent), plains (12 percent) and hills (10 percent). For administrative purposes, China is divided into 23 provinces, 3 municipalities and 5 autonomous regions, in addition to the special administrative regions of Hong Kong and Macau.

In 2009, arable land was an estimated 110.0 million ha. Adding to this the 14.3 million ha under permanent crops gives a total cultivated area of 124.3 million ha (Table 1). Of the total cultivated land, around 86 percent was cropped for food. Of these food crops, 78 percent were cereals (rice, maize, wheat, barley, sorghum), 10 percent beans, 8 percent sweet potatoes and 4 percent other crops. Of the cereals, 36 percent was rice, 33 percent maize, 28 percent wheat, 3 percent barley and 1 percent sorghum.

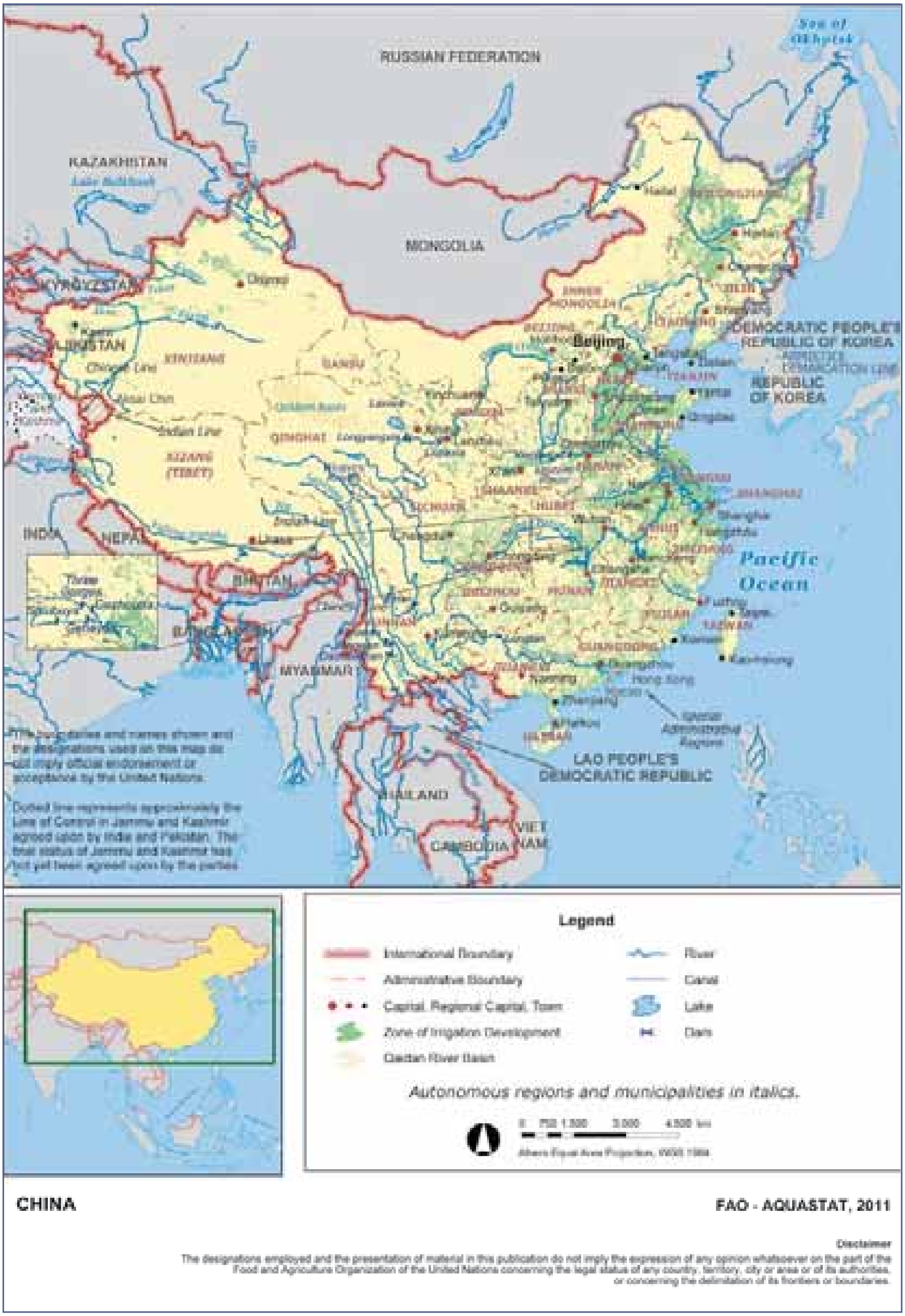
Climate

Vast areas of east China and most of south China are affected by the East Asia monsoon climate. Mountains and plateaux prevent the monsoon from penetrating deeply into the northwest of the continent, resulting in low precipitation there. In winter, the mainland is generally under the influence of dry cold air masses from Siberia.

Mean annual precipitation is 645 mm (Table 2). In some regions of the southwest and in the coastal areas of the southeast, the mean annual precipitation exceeds 2 000 mm. It exceeds 1 000 mm to the south of the middle and lower reaches of the Yangtze river, flowing into the sea just north of Shanghai. It is between 400 and 900 mm in the Huai river basin, in the northern plains, northeast and central China It is less than 400 mm in parts of northeast China and most of the hinterland in the northwest. And it is less than 25 mm in the Tarim river basin in the northwest (the longest inland river) and the Qaidam river basin in the west, of which one-third is desert. Precipitation is greater in the summer months, from April-May to July-August in the south and from June to September in the north.

China is conventionally divided into four main agro-climatic zones (Wang *et al.,* 1999):

- Ø The *arid zone* is located mainly in the inland river basins in the west and northwest. This zone is suitable for irrigated cotton, grains, vegetables and fruits. Livestock is the predominant land use.
- Ø The *semi-arid zone* is located largely in the upper and middle reaches of the Huang


RUSSIAN FEDERATION
KAZAKHSTAN
MONGOLIA
KYRGYZSTAN
Beijing
DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
REPUBLIC OF KOREA
Pacific Ocean
INDIA
NEPAL
BHUTAN
MYANMAR
LAO PEOPLE'S DEMOCRATIC REPUBLIC
THAILAND
CAMBODIA
VIET NAM
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
Zone of Irrigation Development
River
Canal
Lake
Dam
Autonomous regions and municipalities in italics.
CHINA
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(Yellow) river basin in central China. The main irrigated crops are wheat, maize and cotton. Rainfed cropping occurs, but is generally marginal.

- Ø The *semi-humid zone* is subject to both floods and droughts. The North East subzone (NE) comprises the Songhua-Liao river basin in the northeast of the country. Though potentially fertile, it has a short growing season and the western part of the NE plains suffer from waterlogging and alkaline soils. Major crops include wheat, maize and soybean, with rice grown primarily under irrigated conditions. The Huang-Huai-Hai subzone (HHH) comprises the North China plain and neighbouring areas. A longer growing season than the NE permits double cropping where irrigation is provided. Wheat is the main crop followed by maize, rice and other crops.
- Ø The *humid zone* lies in the south and southwest. Rice is the predominant crop. The flood season lasts from July to September, but early or late season droughts can limit crop yields. The mid-lower Yangtze subzone has a subtropical climate allowing double cropping. The Zhu-Min subzone comprises the Zhu (Pearl) and southeast river basins. It has a tropical monsoon climate that allows year-round cropping. The mountainous South West subzone has a mixed tropical/subtropical climate, with rice dominant in the lowlands, and wheat and other grains in the highlands.

Population

Total population is about 1 366 million (2009), of which 54 percent are living in rural areas (Table 1). The average population density is 142 inhabitants/km^2. In 1996 the average

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	960 000 000	ha
Cultivated area (arable land and area under permanent crops)	2009	124 320 000	ha
• as % of the total area of the country	2009	13	%
• arable land (annual crops + temp fallow + temp meadows)	2009	109 999 000	ha
• area under permanent crops	2009	14 321 000	ha
Population			
Total population	2009	1 365 580 000	inhabitants
• of which rural	2009	54	%
Population density	2009	142	inhabitants/km^2
Economically active population	2009	818 009 000	inhabitants
• as % of total population	2009	60	%
• female	2009	46	%
• male	2009	54	%
Population economically active in agriculture	2009	502 691 000	inhabitants
• as % of total economically active population	2009	61	%
• female	2009	48	%
• male	2009	52	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	4 985 461	million US$/yr
• value added in agriculture (% of GDP)	2009	10	%
• GDP per capita	2009	3 651	US$/yr
Human Development Index (highest = 1)	2010	0.663	
Access to improved drinking water sources			
Total population	2008	89	%
Urban population	2008	98	%
Rural population	2008	82	%

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	645	mm/yr
	-	6 189 000	million m^3/yr
Internal renewable water resources (long-term average)	-	2 812 400	million m^3/yr
Total actual renewable water resources	-	2 839 700	million m^3/yr
Dependency ratio	-	1	%
Total actual renewable water resources per inhabitant	2009	2 079	m^3/yr
Total dam capacity	2005	562 379	million m^3
Water withdrawal			
Total water withdrawal	2005	554 100	million m^3/yr
- irrigation + livestock	2005	358 020	million m^3/yr
- municipalities	2005	67 530	million m^3/yr
- industry	2005	128 550	million m^3/yr
• per inhabitant	2005	414	m^3/yr
Surface water and groundwater withdrawal	2005	554 089	million m^3/yr
• as % of total actual renewable water resources	2005	19.5	%
Non-conventional sources of water			
Produced wastewater	2006	53 700	million m^3/yr
Treated wastewater	2004	22 100	million m^3/yr
Reused treated wastewater	1995	13 390	million m^3/yr
Desalinated water produced	2008	10.95	million m^3/yr
Reused agricultural drainage water	-	-	million m^3/yr

population density was 131 inhabitants/km^2, varying from less than 10 inhabitants/km^2 in the west to 670 inhabitants/km^2 in the east and 2 042 inhabitants/km^2 in Shanghai. The annual demographic growth rate was an estimated 1.1 percent over the period 1989-1999, which decreased to 0.6 percent over the period 1999-2009.

In 2008, 89 percent of the population had access to improved drinking water sources (98 and 82 percent for urban and rural population respectively), while 58 and 52 percent of urban and rural population respectively had access to improved sanitation.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009 the gross domestic product (GDP) was US$4 985 461 million (Table 1). In 2009, agriculture accounted for around 10 percent of GDP, while in 1999 and 1989 it accounted for 16 percent and 25 percent respectively. The economically active population is about 818 million (2009) of which 54 percent is male and 46 percent female. The agriculture sector employed 503 million inhabitants, 61 percent of the economically active population, of which 52 percent were men and 48 percent women, while in 1998 and 1988, the agriculture sector employed 67 and 72 percent respectively of the economically active population.

China has about 21 percent of the world population, with about 6 percent of the world's freshwater and 9 percent the world's farmlands. Per capita freshwater availability was 2 079 m^3 in 2009, compared to a global average of 6 225 m^3 per capita. To feed the increasing population, China has to increase total agricultural products by almost 30 percent in 2030 (Yuanhua Li, 2006).

Irrigation makes a major contribution to food security, producing nearly 75 percent of the cereals and more than 90 percent of cotton, fruits, vegetables and other agricultural commodities on around half of the farmlands in China. Because of the development of irrigation, food production has kept pace with population growth in recent decades. In the future, as population increases, irrigation would have to play an even more important role in China to increase production, since farmland expansion becomes a limiting factor (Li, 2006).

Northern China, although it has only 20 percent of the nation's water resources, contains 65 percent of China's cultivated land and produces roughly half of its grain and nearly all of its wheat and maize. This region accounts for more than 45 percent of the nation's GDP (Wang *et al.,* 2005).

Drought affects an average of 15.3 million ha of farmland every year, nearly 13 percent of the total farming area (Yao, 2009).

WATER RESOURCES AND USE

Surface water resources

The average annual river runoff generated within the country is 2 711.5 km^3. Precipitation makes up 98 percent of total river runoff, the remaining 2 percent coming from melting glaciers.

China can be divided into nine main river basin groups (Table 3). In the north there are the Song-Liao or Heilong (Amur)-Songhua, the Huai, the Huang (Yellow), the Hai-Luan and the interior or endoreic river basin groups. The total average annual internal renewable surface water resources (ISRWR) in these five river basin groups are an estimated 535.5 km^3, which is almost 20 percent of the country's IRSWR. In the south there are the Chang (Yangtze), the Zhu (Pearl), the southwest and the southeast river basin groups. The total average annual ISRWR in these four river basin groups are an estimated 2 176.2 km^3, which is just over 80 percent of the country's IRSWR.

TABLE 3
River basins in China (Compiled from: FAO, 1999, and World Bank, 2006)

Major river basin	Internal renewable surface water resources (km^3/year)	As % of total	Percentage of national		Surface water resources (m^3/year)	
			Population	Arable land	per capita (2006)	per hectare arable land
North						
Song-Liao [a]	192.2	7.1	9.6	20.2	1 510	8 600
Huai	96.1	3.5	16.2	15.2	450	5 700
Huang (Yellow)	74.4	2.7	8.5	12.9	660	5 200
Hai-Luan	42.2	1.6	10.0	11.3	320	3 400
Interior basins [b]	130.4	4.8	2.1	5.7	4 670	20 800
Sub-total North	**535.3**	**19.7**	**46.4**	**65.3**	**870**	**7 400**
South						
Chang (Yangtze) [c]	999.9	36.9	34.3	23.7	2 190	38 300
Zhu (Pearl)	333.8	12.3	12.1	6.7	2 080	45 300
Southwest [d]	583.3	21.5	1.6	1.8	27 440	294 600
Southeast [e]	259.2	9.6	5.6	2.5	3 480	94 200
Sub-total South	**2176.2**	**80.3**	**53.6**	**34.7**	**3 060**	**57 000**
Total China	**2711.5**	**100.0**	**100.0**	**100.0**	**2 040**	**24 600**

Notes (figures between brackets are surface water resources expressed in km^3/year):
a Includes Heilong (Amur), Songhua, and Liao, Wusuli, Suifen, Tumen, Yalu (draining into the Yellow Sea)
b Includes Ertrix (10.0), Aksu, Emin, Ili
c Includes Min (58.6)
d Includes Yarlung Zangbo (165.4)
e Includes Nu (68.7), Lancang (73.6), Yuan (44.1)

In total, there are more than 50 000 rivers with a basin area of over 100 km^2, 1 500 rivers have a basin exceeding 1 000 km^2. Rivers can be classified into two categories: rivers discharging into seas (outflowing rivers), and inland rivers running into depressions in the interior (endoreic basins). The total drainage area of rivers flowing to the sea cover about 65 percent of the territory, most drains into the Pacific Ocean and small areas to the Indian Ocean and the Arctic Ocean. Endoreic river basins cover the remaining 35 percent of the country's total area.

The volume of water flowing to nine neighbouring countries (Bhutan, India, Kazakhstan, Kyrgyzstan, Lao People's Democratic Republic, Mongolia, Nepal, Pakistan, and Viet Nam) is an estimated almost 719 km^3/year (Table 4). To the north, the Heilong river enters the Russian Federation before it empties into the Sea of Okhotsk, the Ertix river joins the Ob River in Kazakhstan, the Ili river discharges into Lake Balkhash in Kazakhstan, and the Suifen river flows through the Russian Federation to the sea at Vladivostok. To the south, the Yuan, Lixian, Panlong rivers are the upper reaches of the Red river in Viet Nam, the Lancang river becomes the Mekong river after it enters Lao People's Democratic Republic, the Nu river becomes the Salween river after it enters Myanmar, the Yalung Zangbo river is called the Brahmaputra river after it enters India, and the Langqen Zangbo and Sengge Zangbo rivers of west Tibet and the Qipuqiapu river of Xinjiang are the upper reaches of the Indus river flowing through India and Pakistan into the Indian Ocean.

There are 12 main rivers that enter China from six neighbouring countries (India, Kazakhstan, Kyrgyzstan, Mongolia, Pakistan, and Viet Nam). The mean annual volume of water entering the country is just over 17 km^3, of which 4.2 percent in the Heilong river basin from Mongolia, 52.9 percent in inland rivers, 42.2 percent in the Zhu river basin from Viet Nam, and 0.7 percent in rivers in the southwest (Table 5).

TABLE 4
Rivers flowing to neighbouring countries

Region	River	Destination	Average runoff flowing out of the country (km^3/year)
Heilong	Suifen and Amur	Russian Federation	119.040
		Sub-total	**119.040**
Southeast	Nu	Myanmar	68.740
	Lancang	Lao PDR* and Myanmar	73.630
	Yuan	Viet Nam**	44.100
	Rivers in west Yunan	Myanmar	31.290
		Sub-total	**217.760**
Southwest	Yarlung Zangbo (to Brahmaputra)	India	165.400
	Rivers in south and west Tibet (to Indus)	India	181.620
	Other rivers	Nepal	12.000
		Sub-total	**359.020**
Inland rivers	Emin	Kazakhstan	0.310
	Ili	Kazakhstan	11.700
	Rivers on west slope of Barluke mountain	Kyrgyzstan	0.558
	Aksu	Kazakhstan	0.927
	Ertix (attached)	Kazakhstan	9.530
		Sub-total	**23.025**
		Total	**718.845**

* Lao PDR = Lao People's Democratic Republic
** According to some Chinese data the outflow to Viet Nam would be 47.89 km^3/year

There are also a number of border rivers (Table 6). The main course of the Heilong river and its upstream tributaries (the Ergun and Wusuli rivers) flow along the border between China and the Russian Federation. After receiving the flow of the Songhua river (10.9 km^3/year), the Heilong river flows into the Russian Federation. The total flow of the Heilong and Songhua rivers (117 km^3/year) is considered as flowing out of China, while the resources before flowing out have already been included in the IRSWR. The Tumen and Yalu rivers flow along the border between China and the Democratic People's Republic of Korea. However, the corresponding flow is not considered as outflowing as these rivers do not leave Chinese territory. Half of the total flow of 20.3 km^3/year of these rivers, 10.15 km^3/year, is counted for each country.

Glaciers

The total area of glaciers in China is about 58 651 km^2 extending over six northwestern and southwestern provinces or autonomous regions (Gansu, Qingha, Xinjiang, Tibet, Sichuan and Yunnan). In total the country's glacier storage is around 5 100 km^3 in total. The amount of mean annual glacier melt water is about 56 km^3.

TABLE 5
Rivers entering China from neighbouring countries

Region	River	Coming from		Average runoff flowing out of the country (km^3/year)	
Heilong	Herlen	Mongolia		0.578	
	Wursun	Mongolia		0.145	
			Sub-total		**0.723**
Southeast (Pearl)	Upper reaches of the Zhu (Pearl)	Viet Nam		7.250	
			Sub-total		**7.250**
Southwest	Ruxu Zangbo	India		0.117	
			Sub-total		**0.117**
Inland rivers	Kara Ertix	Mongolia		0.450	
	Haba	Kazakhstan		1.370	
	Bulgan	Mongolia		0.228	
	Tekes	Kazakhstan		0.957	
	Kunmalike	Kyrgyzstan		3.580	
	Guokeshar	Kyrgyzstan		1.220	
	Kizi	Kyrgyzstan		0.556	
	Keleqing	Pakistan		0.718	
			Sub-total		**9.079**
			Total		**17.169**

TABLE 6
Border rivers between China and neighbouring countries

Region	River	Catchment area within China (km^2)	Bordering country	River discharge along border (km^3/year)
Heilong	Heilong (incl. Erguma and Wusuli)	891 093	Russian Federation	106.1
	Tumen	22 861	DPR Korea*	15.4
Liaohe	Yalu	32 466	DPR Korea*	4.9
		946 420	**Total**	**126.4**

* DPR Korea = Democratic People's Republic of Korea

Groundwater resources

The average annual groundwater resources for the whole country are an estimated 828.8 km^3. That part which reaches the rivers as baseflow, or comes from river seepage, called 'overlap', is an estimated 727.9 km^3.

About 70 percent of the groundwater resources are in southern China and 30 percent in northern China. The aquifers vary greatly across northern China and are geologically complicated. Unlike the south, where villages in mountainous areas can tap groundwater resources, mountainous areas in northern China are often groundwater deficient. In the flat plains, especially in the areas near the coast and especially in the Hai river basin many of the aquifers are multilayered. These multilayered aquifers typically have two to five layers. The first and third layers are the most water resource rich. The first layer is an unconfined aquifer made up of large grained homogeneous sand and gravel. The other layers are confined aquifers. In some areas, especially in the eastern parts of the Hai river Basin, there is a naturally occurring saline layer. Created during a previous Ice Age, saline water is often found in the second layer, is confined and has a high enough salt content that it must be treated before being used for agriculture (Wang *et al.,* 2005).

Total renewable water resources

The total internal renewable water resources (IRWR) of China are around 2 812.40 km^3/year and are summarised in Table 7. The total renewable water resources (TRWR), considering external flows, are equal to 2 839.72 km^3/year, giving a dependency ratio of about 1 percent.

Lakes and dams

There are about 2 300 natural lakes (excluding seasonal ones) with a total storage of 708.8 km^3, of which the freshwater portion is 31.9 percent (226.1 km^3). There are five major lake districts (Table 8).

At the end of 2005, the total number of artificial lakes or reservoirs was 85 108 with a total capacity of 562 km^3. Of these, 470 were classified as large reservoirs (> 100 million m^3) with a total capacity of 419.7 km^3, 2 934 were medium reservoirs (10 – 100 million m^3) with a

TABLE 7
Internal renewable water resources of China by catchment area

Major river basin	Area (km^2)	Long-term annual average		
		Precipitation (mm)	Precipitation (km^3)	Internal renewable water resources (IRWR) (km^3)
North				
Songh-Liao	1 248 445	510	638	192.85
Huai	329 211	860	283	96.10
Huang (Yellow)	794 712	465	369	74.36
Hai-Luan	318 161	560	178	42.11
Other interior basins	3 394 443	155	532	130.39
Sub-total North	**6 084 972**	**330**	**2 000**	**535.81**
South				
Chang (Yangtze)	1 808 500	1 070	1 936	961.34
Zhu (Pearl)	580 641	1 545	897	470.81
Southwest	871 406	1 070	934	585.31
Southeast	252 569	1 670	422	259.17
Sub-total South	**3 513 116**	**1 190**	**4 189**	**2 276.63**
Total China	**9 598 088**	**645**	**6 189**	**2 812.44**

TABLE 8
Natural lake

Lake district	Area (km^2)	Storage (km^3)	Freshwater storage (km^3)
Qinghai-Tibet plateau	36 889	518.2	103.5
Eastern plains	21 641	71.1	71.1
Mongolia Xin plateau	9 411	69.7	2.4
Northeast plains and mountains	2 366	19.0	18.8
Yunnan-Guizhou plateau	1 108	28.9	28.8
Others	372	2.0	1.5
Total	**71 787**	**708.8**	**226.1**

total capacity of 82.6 km^3, and 81 704 were small reservoirs (0.1 – 10 million m^3) with a total capacity of 60.2 km^3.

The Three Gorges Dam on the Chang (Yangtze) river, situated at Sandouping of Yichang City, Hubei Province, was completed in 2006 and is considered to be the largest hydropower project in the world. Besides hydropower, its main purpose is flood control and navigation improvement. The dam is nearly 200 m high and the water level in the reservoir is to be kept at 175 m above sea level during the dry winter months, and lowered to 145 m for the summer flood season. The dam is about 600 m long and the total storage capacity of the reservoir is 39.3 km^3.

Until the Three Gorges Dam project (TGP) got under way, the most ambitious project completed was the Gezhouba hydroelectric dam, which was the first structure to block the flow of the Chang river. The dam is located in the suburbs of Yichang, 38 km downstream the TGP. The construction of the dam started in 1970 and ended in 1988. The dam is 54 m high with a total storage capacity of 1.58 km^3.

The Geheyan Dam, designed in 1987 and completed in 1994, is the first large dam on the Qing river, a tributary of the Chang river, in Yichang, Hubei. There were many problems with the non-functioning of the ship lift until 1998. This dam has recently fallen foul of many planning permit disputes, and is set to be demolished in June 2011.

The Liujiaxia dam, with a total capacity of 5.7 km^3, is a hydroelectric dam on the upper Huang (Yellow) river, in Liujiaxia Town, Gansu Province. The dam is located just downstream from the fall of the Tao river into the Huang river and has the largest water body within Gansu. The primary purpose of the dam is to generate electricity and for flood control, irrigation, and 'ice flood prevention'. When it became fully operational in 1974, it became the country's largest hydroelectric power plant, and remained so until the 1980s.

There are four hydropower projects on the Lancang river, which are the Manwan dam (1 500 MW and 0.66 km^3 of capacity), the Dachaoshan dam (1 350 MW), the Jinghong dam (1 750 MW) and the Xiaowan dam (4 200 MW and 15 km^3). Four more dams are under construction or are being planned on the Lancang river with a total capacity of 7 000 MW.

Other important dams are the Ertan dam (5.8 km^3 of capacity) on the Yalong river (Yangtze Basin), the Shuibuya dam (4.6 km^3) on the Qing river (Yangtze basin), the Longtan dam (27.3 km^3) on the Hongshui river, the Longyangxia dam (24.7) on the Yellow river, the Laxiwa dam (1.08 km^3) on the Yellow river and the Xiaolangdi dam (12.8 km^3) on the Yellow river.

In 2010, other important dams were being constructed, such as the Jinping 1 dam.

In 2006, the total installed capacity of hydropower was 52.93 GW and the annual generation of hydropower was 163.6 billion kWh (MWR, 2007b).

Non-conventional sources of water

Total wastewater produced accounts for 53.7 km^3 in 2006, of which only 56 percent (30.07 km^3) had some form of treatment. However, this rate reflects the installed wastewater treatment capacity rather than the actual treatment, which is likely to be lower owing to the lack of sewage networks and funds for operation and maintenance in many cities (World Bank, 2009a). In 2004, actual treated wastewater was about 22.10 km^3 (World Bank, 2006).

The research of engineering technology of seawater desalination in China began in 1958. There have been more than 20 seawater desalination projects to date, among which are Shandong Huangdao power plant, Hebei Huanghua power plant, the No. 7 Petroleum Factory of China Petroleum Dalian Petrochemical Corporation, Tianjin economic-technological development area, Shandong Yantai city and Hebei Wangtan power plant are relatively large-scale seawater desalination enterprises that are in, or will be put into, production (Ji *et al.*, 2006). In 2008, the accumulative production capacity of these projects was around 30 000 m^3/day, which would be around 10.95 million m^3/year (World Bank, 2009a).

Water scarcity

Although China has the fifth largest amount of internal renewable water resources in the world, after Brazil, the Russian Federation, Canada and Indonesia, it is faced with a regional water crises. Total actual renewable water resources per capita account for 2 079 m^3/year in 2009, while the world average is an estimated 6 225 m^3/year, and is expected to decline to 1 890 m^3/year as its population rises to a projected peak of 1.5 billion by around 2033. Moreover, there is much variation within the country, from less than 500 m^3/year per inhabitant in the Huai and Hai-Luan river basins in the north, to over 25 000 m^3/year per inhabitant in river basins in the southwest.

The precipitation pattern further intensifies the uneven distribution of water resources. With a strong monsoonal climate, China is subject to highly variable rainfall that contributes to frequent droughts and floods, which also occur simultaneously in different regions (Yunlong, 2009).

The water shortages are largely concentrated in the dry north, which has only one-fifth of China's water. This area, which includes the Huang, Liao, Hai and Huai rivers, boasts two-thirds of China's cropland (Table 3). Irrigation demands are high, rapid economic growth and urbanization are fuelling additional water consumption, and water use and demand management is inefficient. In contrast, the south is well supplied with water. It encompasses the vast Chang river and has four times the groundwater resources of the north. But it has its own problems, exemplified by summer devastating flooding by the Chang river. While the south faces flooding every year, the north, where most agricultural activities exist with very dense population, faces severe water shortages. Nearly half of the 640 cities in China face water shortages, and 100 of them face serious water scarcity (Burke, 2000).

Signs of water stress are not hard to find. Perhaps the starkest example is the Huang river. In 1972, for the first time in China's history, it dried up before reaching the sea. Since 1985, it has run dry part of each year. During the droughts of 1997 it didn't reach the sea for 228 days, depriving the last province before the sea, Shandong, which produces one-fifth of China's maize and one-seventh of its wheat, of half its irrigation supply. However, since the beginning of the 2000s, after a river basin approach was adopted in the Huang river basin, the river has not dried up. Groundwater also faces severe pressure, over-extraction is a serious problem in a number of cities, including Nanjing, Taiyuan, Shijiaxhuang, and Xi'an. Levels in Shanghai and Beijing are falling by 1 m/year. In coastal cities, such as Delian and Qingdao, saltwater intrusion compounds the problem (Burke, 2000).

Internal water transfer projects

The uneven distribution of China's water resources between the water scarce north and water abundant south is forcing the Chinese Government to seek measures to ensure sufficient water availability for people living in northern regions. One such measure is the 'South to North Water Transfer Project'. At the time of completion (2050), this three route project will channel 44.8 km^3 of water per year from the Chang river to drought-stricken northern China. The project is designed to divert 13.4 km^3/year from the Chang river system to Beijing and will supply many other cities along the route. Work began in 2000 and the first supplies reached Shandong and Beijing in 2007 and 2010 respectively. Total project expenses, which were initially projected at US$60 000 million, have been increasing.

The project faces a number of logistical challenges, including the need to clean up water bodies at intersections through which the canals will pass. The 1 154 km eastern route of the project largely follows the Grand Canal route from the Chang river through Jiangsu and Shandong provinces to Hebei and Tianjin, will divert 14.8 km^3 annually, it crosses through 53 river sections in China's most heavily water-polluted area. Cleanup operations will account for 37 percent of the total investment. If completed on schedule, it will represent one of the most comprehensive water cleanup operations in the world.

Challenges include implementation and effectiveness of wastewater treatment plants, ensuring inter-provincial dialogue, and agreement on project components. The vast cost of the projects may mean that water pricing will be a problem for some consumers (between 3.2 and 4.8 Yuan/m^3 in many cities and as high as 7 Yuan/m^3 in Beijing). The central route of the project will divert 13 km^3/year, will submerge 370 km^2 of land and will require the relocation of 330 000 people in Henan and Hubei provinces. The western route will divert 17 km^3/year from the upper reaches of the Chang river to the Huang river (Chao, 2009).

The Shanxi Wanjiazhai Huang (Yellow) river diversion project is an all-encompassing project to alleviate the water shortages in three of China's industrial areas: Taiyuan, Pingsuo and Datong. The project started in 1997 and in November 2001 the first major step was inaugurated when water from the Huang river ran to the Fenhe reservoir. The cost of the entire enterprise is about US$1 500 million, US$400 million of which came from the World Bank.

The diversion project, which brings water from the Huang river to Qingdao in Shandong province, is the largest water conservancy and city water supply project since the founding of the People's Republic of China. Water diversion began in 1989 to guarantee supplies to Qingdao city, whichhas the most serious water shortages in northernChina. It has received more than 1.1 km^3 of water so far. Greater Qingdao covers an area of 10 654 km^2 and has a population of 7.5 million, more than one-third of whom live in its urban areas. The shortfalls have been exacerbated over the past decade as its population and economy have grown (China Daily, 2007). A second phase of the project is to divert water from Huang river to Qingdao and will increase the volume of diverted water by 140 million m^3/year to 250 million m^3/year. (ACCA21, not dated).

International water issues

In 1994, an agreement was signed between China and Mongolia on the protection of transboundary water resources concerning Lake Buir, the Kherlen, Bulgan, Khalkh rivers, and 87 small lakes and rivers located near the border.

Water use

In 2005, total water withdrawal was an estimated 554.1 km^3 of which 65 percent (358.0 km^3) was for irrigation, 12 percent (67.5 km^3) for municipal use and 23 percent (128.6 km^3) for industry (Table 2 and Figure 1). In 1993, total water withdrawal was 525.5 km^3, of which 77 percent (407.7 km^3) was for irrigation, 5 percent (25.2 km^3) for municipal use, and 18 percent (92.6 km^3) for industrial use.

Agriculture is the main sector that withdraws water water; although only 45 percent is actually consumed by crops, owing to the low efficiency of the irrigation systems. On the other hand, however, this figure is comparatively high considering the cropping structure. The relatively poor water productivity, US$3.6 per m^3, is lower than the average of US$4.8 per m^3 in middle income countries, and much lower than the US$35.8 per m^3 in high-income countries (World Bank, 2009a). The United Nations predicts that China's population will increase from 1.2 billion to 1.5 billion between 2000 and 2030. The rapidly urbanizing population is expected to push demand to new heights. The expanding industrial sector is also greedy for water (Burke, 2000). The recycling rate in the industrial sector is only 40 percent, compared to 75-85 percent in developed countries (World Bank, 2009a).

In 2005, primary surface water withdrawal represented 80 percent of total water withdrawal (Figure 2). In 1995, the reused treated wastewater volume was 13.4 km^3. In 2008, desalinated water accounted for 10.95 million m^3. In addition to water withdrawal by the three main sectors (agriculture, municipalities, industry), China reserved 9.28 km^3 of surface water in 2005 for ecosystems.

FIGURE 1
Water withdrawal by sector
Total 554.1 km^3 in 2005

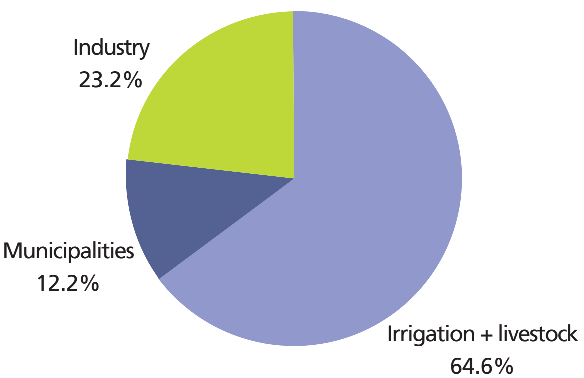
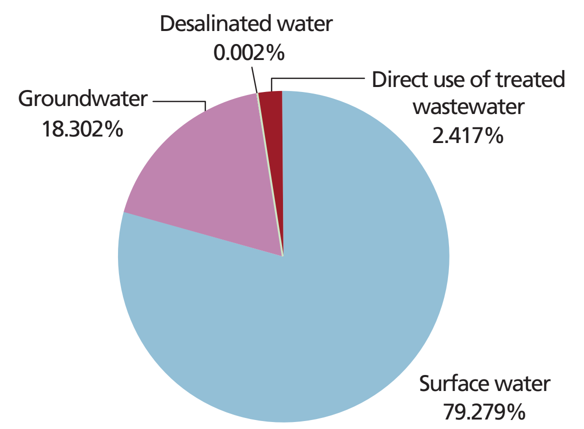


FIGURE 2
Water withdrawal by source
Total 554.1 km^3 in 2005



In southern China, the main source of water is primary surface water, which represents over 90 percent of the water withdrawal. Northern China is the region that uses the majority of China's primary groundwater. In the five northern provinces, Beijing, Tianjin, Hebei, Shanxia and Inner Mongolia, 65 percent of the water withdrawal was from groundwater in 2005. In the three northeastern provinces, Liaoning, Jilin and Heilongjiang groundwater withdrawal accounted for almost 45 percent of total water withdrawal. In the Hai river basin, groundwater accounted for 67 percent and was being withdrawn from the aquifer at a rate of 95.5 percent. To compensate for the deficit of surface water in meeting demand, northern China has increasingly relied on groundwater.

This intensive use of groundwater resources has resulted in the lowering of water tables and the rapid depletion of groundwater reservoirs. For example, the annual sustainable withdrawal of groundwater in the Hai river basin is an estimated 17.3 km^3, while withdrawals are 26.1 km^3, which indicates an annual over-extraction as high as 8.8 km^3. As a result, deep groundwater tables have dropped by up to 90 m and shallow groundwater tables by up to 50 m. In Beijing, groundwater tables have dropped by 100–300 m (World Bank 2009a). In contrast, less than 30 percent of the known groundwater resources in southern China are being used (Wang *et al.*, 2005).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

China has a long history of irrigation and drainage. The first canals to divert and wells to lift water for irrigation were constructed 4 000 years ago. Since the founding of the People's Republic of China in 1949, irrigation has experienced a period of vigorous development. From 1958 to 1985, about 64 368 million Yuan have been spent on irrigation and drainage projects. The area equipped for irrigation increased from 16 000 000 ha in 1949 to 62 938 226 ha in 2006 of which 62 559 130 in Mainland China, 378 096 ha in Taiwan and 1 000 ha in Hong Kong (Table 9 and Table 10).

After 1949, irrigation using groundwater was developed rapidly to promote agricultural production. In north China, insufficient surface water resources have meant that since 1950 the Government has had to rely on groundwater for the development of irrigation projects. In 1985, an area of 11.1 million ha was irrigated using tubewells. In 2006, groundwater irrigation using around 4.8 million tubewells was an estimated 19 million ha, 31 percent of the total area equipped for irrigation was 63 million ha (Figure 3). In addition, 17 million ha is power irrigated using surface water. This means that 57 percent of the total area equipped for irrigation, or 36 million ha, used power irrigation (Table 9 and Table 11). In 1995, the power irrigation area was 29 million ha and the total installed capacity of water-lifting machines for irrigation and drainage was 68 240 MW.

China can be divided into three irrigation zones:

- The zone of perennial irrigation, where annual precipitation is less than 400 mm and irrigation is necessary for agriculture. It covers mainly the northwest regions and part of the middle reaches of the Huang river.
- The zone where annual precipitation ranges from 400 to 1 000 mm, strongly influenced by the monsoon, with a consequently uneven precipitation distribution. Irrigation here is necessary to secure production. This zone includes the Hangh Huai Hai plain and northeast China.
- The zone of supplementary irrigation, where annual precipitation exceeds 1 000 mm. Irrigation is still necessary for rice (especially to improve cropping intensity), and supplementary irrigation is sometimes required for upland crops. This zone covers the middle and lower reaches of the Chang, Zhu and Min rivers and part of southwest China.

The irrigation potential is roughly 70 million ha. The maximum possible area that could be equipped for irrigation by 2050 isabout 66 million ha, of which 63 million ha for annual or food crops (Zhanyi Gao, 2009). China uses the expression effective irrigation to indicate the area of food (annual) crops, not to be confounded with the area actually irrigated.

In 1996, the total area equipped for irrigation, including farmland (area regularly ploughed for growing agricultural crops, also called the area under effective irrigation in China), forests, orchards and pastures, was 52.9 million ha.

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 62 938 226 ha in 2006

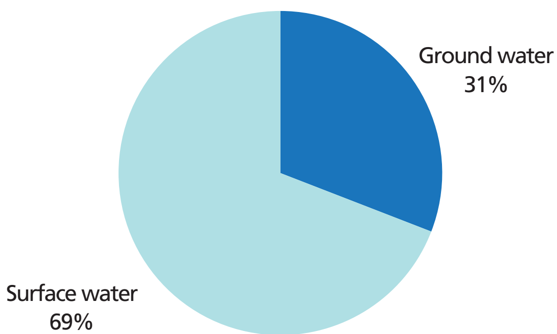


TABLE 9
Irrigation and drainage

Irrigation potential		-	70 000 000	ha
Irrigation				
1. Full control irrigation: equipped area		2006	62 938 226*	ha
- surface irrigation		2006	59 337 789	ha
- sprinkler irrigation		2006	2 840 952	ha
- localized irrigation		2006	759 485	ha
• % of area irrigated from surface water		2006	69	%
• % of area irrigated from groundwater		2006	31	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2006	54 218 976	ha
- as % of full control area equipped		2006	86	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2006**	**62 938 226**	**ha**
• as % of cultivated area		2006	48	%
• % of total area equipped for irrigation actually irrigated		2006	86	%
• average increase per year over the last 10 years		1996-2006	1.7	%
• power irrigated area as % of total area equipped		2006	57	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	-	ha
5. Non-equipped flood recession cropping area		-	-	ha
Total water-managed area (1+2+3+4+5)		**2006**	**62 938 226**	**ha**
• as % of cultivated area		2006	48	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 667 ha	2006	35 553 278	ha
Medium-scale schemes	667 ha - 20 000 ha	2006	12 684 402	ha
Large-scale schemes	> 20 000 ha	2006	14 700 546	ha
Total number of households in irrigation		-	-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production		2005	323 209 000	metric tons
• as % of total grain production		2005	73	%
Harvested crops**				
Total harvested irrigated cropped area		2006	93 382 000	ha
• Annual crops: total		2006	88 541 000	ha
- Rice		2006	31 347 000	ha
- Wheat		2006	22 250 000	ha
- Maize		2006	9 500 000	ha
- Other cereals (millet, sorghum, barley)		2006	815 000	ha
- Vegetables		2006	9 000 000	ha
- Cotton		2006	2 632 000	ha
- Rape		2006	6 000 000	ha
- Soybean		2006	2 600 000	ha
- Groundnuts		2006	1 900 000	ha
- Roots (potatoes, sweet potatoes)		2006	629 000	ha
- Sugarcane		2006	472 000	ha
- Other annual crops (tobacco, sunflower, sesame, pulses, beet)		2006	1 396 000	ha
• Permanent crops: total		2006	4 841 000	ha
- Fruits and citrus		2006	3 645 000	ha
- Other permanent crops		2006	1 196 000	ha
Irrigated cropping intensity (on actually irrigated area)		2006	172	%
Drainage - Environment				
Total drained area**		-	-	ha
- part of the area equipped for irrigation drained		2006	4 471 950	ha
- other drained area (non-irrigated)		-	-	ha
• drained area as % of cultivated area		-	-	%
Flood-protected areas		2005	44 120 000	ha
Area salinized by irrigation		1999	6 700 000	ha
Population affected by water-related diseases			-	inhabitants

* of which 62 559 130 in Mainland China, 378 096 ha in Taiwan and 1 000 ha in Hong Kong
** Mainland China

TABLE 10
Irrigation by major river basin in Mainland China in ha (Source: MWR, 2007/2006/2005)

River basin	Total area equipped for irrigation	Annual crops (effective irrigation)*	Forests	Orchards	Pasture	Other	Actually irrigated total (part of 2)	Actually irrigated annual crops (part of 3)	Actually irrigated other (part of 4+5+6+7)
[1]	[2]=[3+4+5+6+7]	[3]	[4]	[5]	[6]	[7]	[8]=[9+10]	[9]	[10]
North									
Songhua	4 558 990	4 501 860	5 130	4 070	34 790	13 140	3 656 258	3 610 440	45 818
Liao	3 163 550	2 692 640	84 300	98 750	175 110	112 750	2 383 753	2 028 920	354 833
Huai	11 488 450	10 929 480	144 920	344 710	4 520	64 820	9 287 440	8 835 560	451 880
Huang (Yellow)	5 853 500	5 222 310	189 760	199 140	209 850	32 440	5 024 475	4 482 680	541 795
Hai-Luan	8 234 790	7 519 310	182 290	476 700	21 380	35 110	7 357 584	6 718 320	639 264
Northwest	5 981 900	4 202 220	680 850	401 290	588 890	108 650	5 792 901	4 069 450	1 723 451
Sub-total North	**39 281 180**	**35 067 820**	**1 287 250**	**1 524 660**	**1 034 540**	**366 910**	**33 502 411**	**29 745 370**	**3 757 041**
South									
Chang (Yangtze)	15 478 760	14 924 050	193 230	200 950	62 310	98 220	13 507 745	13 023 670	484 075
Zhu (Pearl)	4 577 320	4 177 580	32 050	144 720	3 060	219 910	3 873 133	3 534 890	338 243
Southwest	1 025 870	869 080	28 050	19 980	100 620	8 140	912 787	773 280	139 507
Southeast	2 196 000	2 039 870	21 570	98 340	640	35 580	2 096 323	1 947 280	149 043
Sub-total South	**23 277 950**	**22 010 580**	**274 900**	**463 990**	**166 630**	**361 850**	**20 389 988**	**19 279 120**	**1 110 868**
Total 2006	**62 559 130**	**57 078 400**	**1 562 150**	**1 988 650**	**1 201 170**	**728 760**	**53 892 399**	**49 024 490**	**4 867 909**
Total 2005	61 897 940	56 562 360	1 636 610	1 860 940	1 172 020	666 010	52 758 103	47 968 730	4 789 373
Total 2004	61 511 150	56 252 070	1 573 310	1 862 460	1 184 990	638 320	52 251 258	47 783 880	4 467 378

* In China, irrigation of annual (food) crops is called "effective irrigation"

TABLE 11
Power irrigation major river basin in Mainland China in ha (Source: MWR, 2007/2006/2005)

River basin	Tubewell	Pumping station	Moveable machine	Total pumped effect. irrigation	Total pumped irrigation	Total irrigation	Groundwater irrigation	Surface water irrigation	Pumped drained
[1]	[2]	[3]	[4]	[5]=[2+3+4]	[6]	[7]	[8]	[9]	[10]
North									
Songhua	2 627 723	812 553	112 243	3 552 519	3 597 603	4 558 990	2 661 070	1 897 920	907 680
Liao	1 437 147	427 407	83 017	1 947 571	2 288 176	3 163 550	1 688 486	1 475 064	479 980
Huai	4 379 877	3 309 447	1 378 777	9 068 101	9 531 873	11 488 450	4 603 878	6 884 572	492 530
Huang (Yellow)	2 151 923	1 113 843	52 643	3 318 409	3 719 487	5 853 500	2 412 014	3 441 486	805 330
Hai-Luan	5 399 087	599 667	688 247	6 687 001	7 323 284	8 234 790	5 912 822	2 321 968	312 400
Northwest	947 620	163 650	129 430	1 240 700	1 766 148	5 981 900	1 348 946	4 632 954	17 860
Sub-total North	**16 943 377**	**6 426 567**	**2 444 357**	**25 814 301**	**28 226 571**	**39 281 180**	**18 627 216**	**20 653 964**	**3 015 780**
South									
Chang (Yangtze)	389 300	4 719 910	688 580	5 797 790	6 013 287	15 478 760	403 770	15 074 990	993 610
Zhu (Pearl)	131 400	390 120	139 140	660 660	723 877	4 577 320	143 973	4 433 347	378 340
Southwest	16 770	24 520	810	42 100	49 695	1 025 870	19 795	1 006 075	1 190
Southeast	53 083	524 823	198 643	776 549	835 987	2 196 000	57 146	2 138 854	83 030
Sub-total South	**590 553**	**5 659 373**	**1 027 173**	**7 277 099**	**7 622 846**	**23 277 950**	**624 684**	**22 653 266**	**1 456 170**
Total 2006	**17 533 930**	**12 085 940**	**3 471 530**	**33 091 400**	**35 849 417**	**62 559 130**	**19 251 900**	**43 307 230**	**4 471 950**

The total area equipped for irrigation is an estimated 62.9 million ha (2006). The area equipped for irrigation represents just over half of the total cultivated area. The area actually irrigated in 2006 was 54.2 million ha, which accounts for 86 percent of the total area equipped for irrigation.

Surface irrigation, mainly for cereals, vegetables and cotton, is practised on 59.3 million ha (59.0 million ha in Mainland China), which was 94.3 percent of the total area equipped for irrigation in 2006 (Table 9, Table 12 and Figure 4). Sprinkler irrigation was introduced into China in the early 1950s. The first sprinkler irrigation project was constructed in Shanghai in 1954. Sprinkler and localized irrigation were considerably developed in the late 1970s. In 1976, the area of sprinkler irrigation was about 67 000 ha. It increased until 1980, but then large areas were abandoned owing to the poor quality of equipment and poor management. Then, in 2006, the area expanded to about 2.8 million ha, which is 4.5 percent of the total area equipped for irrigation. Localized irrigation was practiced on about 0.8 million ha or 1.2 percent.

China uses the following categories (1 ha = 15 mu):

- very large irrigation schemes: > 500 000 mu or > 33 333 ha
- large irrigation schemes: 300 000 – 500 000 mu or 20 000 – 33 333 ha
- medium irrigation schemes: 10 000 – 300 000 mu or 667 – 20 000 ha
- small irrigation schemes: < 10 000 mu or < 667 ha

The very large, large and medium irrigation schemes are generally administrated by special governmental organizations. The small ones are usually farmer-managed. Some small ponds, wells and pumping stations are owned by individuals. In 2006, very large schemes covered 10.6 million ha (10.5 million ha in Mainland China), large schemes 4.1 million ha (4.1 million ha in Mainland China), medium schemes 12.7 million ha (12.6 million ha in Mainland China) and small schemes 35.6 million ha (35.3 million ha in Mainland China) (Table 9, Table 13 and Figure 5).

Role of irrigation in agricultural production, economy and society

China makes a distinction between the area irrigated for annual or food crops, and the area under other crops, which include irrigated forests, orchards and pasture. In 2006, of the 62.6 million ha, which was the total area equipped for irrigation in Mainland China, 57.1 million ha were under annual or food crops, 1.6 million ha forests, 2.0 million ha orchards, 1.2 million ha pasture and 0.7 million ha other crops. This means that 91.2 percent of the area equipped for irrigation was covered by annual or food crops.

In Mainland China, of the total area, 62.6 million ha equipped for irrigation, 53.9 million ha or 86 percent was actually irrigated in 2006. Of the 57.1 million ha area equipped for irrigation for annual or food crops, 49.0 million ha was actually irrigated, which is also 86 percent.

In 2006, the total harvested irrigated crop area in Mainland China was about 93.4 million ha, meaning an irrigated cropping intensity of 1.72 (Table 9 and Figure 6). The most important harvested irrigated crop is rice, followed by wheat and maize. The importance of irrigated vegetables is increasing. In 2005, almost three-quarters of grain production was

FIGURE 4
Irrigation techniques on area equipped for full control irrigation
Total 62 938 226 ha in 2006

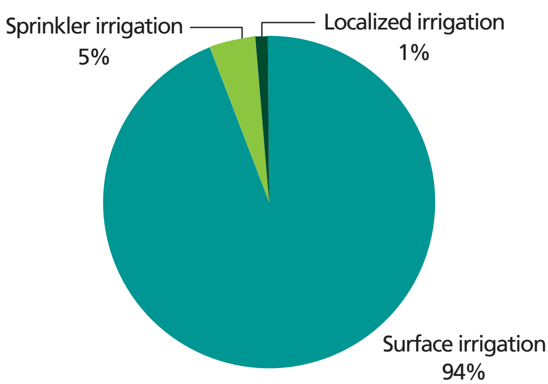


TABLE 12
Irrigation technology by major river basin in Mainland China in ha (Source: MWR, 2007/2006/2005)

River basin	Total irrigation	Sprinkler irrigation	Localized irrigation	Surface irrigation[1]	Low pressure pipe	Canal lining	Other engineering options	Non-improved surface irrigation[2]
[2]	[3]	[4]	[5]	[6]=[3-4-5]	[7]	[8]	[9]	[10]=[6-7-8-9]
North								
Songhua	4 558 990	1 052 020	8 170	3 498 800	112 150	69 650	967 190	3 317 000
Liao	3 163 550	335 610	32 700	2 795 240	389 300	195 500	13 180	2 210 440
Huai	11 488 450	267 830	49 520	11 171 100	931 940	981 590	1 196 260	9 257 570
Huang (Yellow)	5 853 500	222 700	59 230	5 571 570	991 140	1 468 350	255 310	3 112 080
Hai-Luan	8 234 790	572 130	36 770	7 625 890	2 199 520	755 630	457 480	4 670 740
Northwest rivers	5 981 900	198 210	514 750	5 268 940	160 830	1 722 780	119 190	3 385 330
Sub-total North	**39 281 180**	**2 648 500**	**701 140**	**35 931 540**	**4 784 880**	**5 193 500**	**3 008 610**	**25 953 160**
South								
Chang (Yangtze)	15 478 760	110 380	26 610	15 341 770	342 850	2 750 320	482 240	12 248 600
Zhu (Pearl)	4 577 320	18 540	4 160	4 554 620	39 950	636 380	383 020	3 878 290
Southwest	1 025 870	620	880	1 024 370	5 270	162 030	18 790	857 070
Southeast	2 196 000	45 800	22 120	2 128 080	90 800	851 430	97 180	1 185 850
Sub-total South	**23 277 950**	**175 340**	**53 770**	**23 048 840**	**478 870**	**4 400 160**	**981 230**	**18 169 810**
Total 2006	**62 559 130**	**2 823 840**	**754 910**	**58 980 380**	**5 263 750**	**9 593 660**	**3 989 840**	**44 122 970**
Total 2005	61 897 940	2 746 280	631 760	58 519 900	4 991 850	9 133 170	3 845 120	40 549 760
Total 2004	61 511 150	2 674 830	479 640	58 356 680	4 706 290	8 561 950	3 923 530	41 164 910

1. Data on sprinkler and irrigation localized technologies were only available for effective irrigation area. It was considered that for all the others surface irrigation was used.
2. It was considered that non-improved surface irrigation [10] is equal to surface irrigation [6] minus low pressure pipe [7] and canal lining irrigation [8] and other engineering options [9].

TABLE 13
Irrigation scheme sizes by major river basin in Mainland China in ha (Source: MWR, 2007/2006. China statistics on water resources 2006/2005)

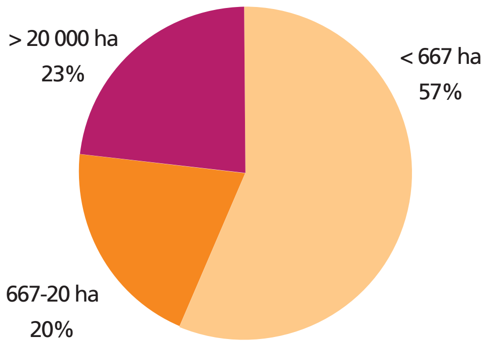
River basin	Effective very large (>33333 ha)	Effective large (20000-33333 ha)	Effective medium (667-20000 ha)	Small effective (< 667 ha)	Total effective irrigation	Small other irrigation 2	Total area equipped for irrigation
[2]	[3]	[4]	[5]	[6]	[7]=[3+4+5+6]	[8]	[9]=[7+8]
North							
Songhua	88 000	97 000	769 000	3 547 860	4 501 860	57 130	4 558 990
Liao	264 000	207 000	433 000	1 788 640	2 692 640	470 910	3 163 550
Huai	1 547 000	730 000	2 161 000	6 491 480	10 929 480	558 970	11 488 450
Huang (Yellow)	1 946 000	300 000	1 186 000	1 790 310	5 222 310	631 190	5 853 500
Hai-Luan	1 626 000	575 000	1 059 000	4 259 310	7 519 310	715 480	8 234 790
Northwest rivers	2 369 000	969 000	662 000	202 220	4 202 220	1 779 680	5 981 900
Sub-total North	**7 840 000**	**2 878 000**	**6 270 000**	**18 079 820**	**35 067 820**	**4 213 360**	**39 281 180**
South							
Chang (Yangtze)	2 247 000	854 000	3 937 000	7 886 050	14 924 050	554 710	15 478 760
Zhu (Pearl)	254 000	145 000	1 430 000	2 348 580	4 177 580	399 740	4 577 320
Southwest		47 000	244 000	578 080	869 080	156 790	1 025 870
Southeast	180 000	167 000	727 000	965 870	2 039 870	156 130	2 196 000
Sub-total South	**2 681 000**	**1 213 000**	**6 338 000**	**11 778 580**	**22 010 580**	**1 267 370**	**23 277 950**
Total 2006	**10 521 000**	**4 091 000**	**12 608 000**	**29 858 400**	**57 078 400**	**5 480 730**	**62 559 130**
Total 2005	10 232 000	4 080 000	12 106 000	26 418 000	56 562 360	5 335 580	61 897 940

1. Very large: > 500 000 mu or 33 333 ha; Large: 300 000 - 500 000 mu or 20 000 - 33 333 ha; Medium: 10 000 - 300 000 mu or 667 - 20 000 ha; Small: < 10 000 mu or 667 ha.
2. This is equal to the area equipped for irrigation of pasture, forests, orchards and other. According to the Chinese, this is all small irrigation.

FIGURE 5

Type of full control irrigation irrigation schemes

Total 62 938 226 ha in 2006



irrigated. According to a nationwide survey in the early 1980s, the average paddy rice yield of irrigated farmland was 7.3 tonnes/ha and the average yield of non-irrigated paddy rice was 2.1 tonnes/ha. In 1995, the International Rice Commission estimated an average yield of 6 tonnes/ha for irrigated paddy rice.

There is no available figure on total harvested irrigated crop area in Taiwan, where rice is the main crop. Other crops are also irrigated, such as sugarcane, vegetables, sweet potato, wheat, maize, sorghum, tobacco, rape seed, beans, melons, citrus, banana, pineapple, tea, cassava, peanuts and jute.

Status and evolution of drainage systems

In 1996, the area subject to waterlogging was 24.6 million ha, of which 20.3 million ha were controlled by drainage. In 1995, the power drained area was 4.2 million ha, while in 2006 it was an estimated 4.5 million ha (Table 11).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

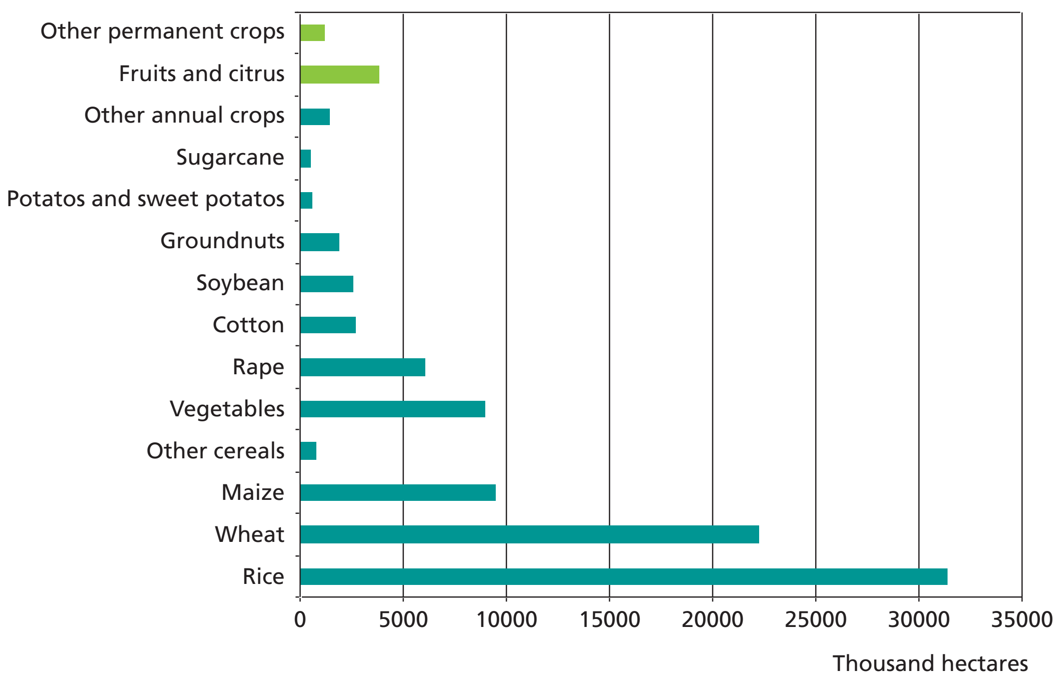
The main institutions involved in water resources management are (World Bank, 2009a):

- the Ministry of Water Resources (MWR): integrated water resource management, water resource protection planning, water function zoning, monitoring water quantity and quality in rivers and lakes; issues water resource extraction permits, proposes water pricing policy;
- Ministry of Environmental Protection (MEP): water pollution laws, regulations/standards, supervision/enforcement, water environmental function zoning, water pollution mapping in key rivers and lakes, monitors water quality;
- Ministry of Housing and Urban and Rural Construction (MHURC): urban water supply, urban wastewater treatment;
- Ministry of Agriculture (MOA): on-farm water management and agricultural non-point pollution;
- Ministry of Land and Resources (ML&R): water as a resource, land-use planning;
- State Forest Administration: forests for conserving water sources;
- Ministry of Transportation: ship transportation water pollution control;
- National Development and Reform Commission: pollution levy policy, wastewater treatment pricing policy, water pricing policy, industrial policies that affect wastewater discharge and its treatment;
- Ministry of Finance: Pollution levy proceeds management, manages wastewater treatment charges and water resource fee policy, State Office of Comprehensive Agricultural Development;
- The State Council: Implementation regulation, administrative regulation and order, lead, and coordination;
- National People's Congress: legislation, law, and supervision;
- Local Water Resources Management Department, responsible for water administration at provincial level. Each province has a Water Resource Bureau responsible for planning,

FIGURE 6

Irrigated crops on area equipped for full control irrigation (Mainland China)

Total harvested area: 93 382 000 ha in 2006 (cropping intensity on area actually irrigated: 172%)



survey, design, construction, operation and management of irrigation, drainage, flood control works, and rural hydro-electricity. Water resources bureaux at the prefecture and county levels are directly responsible for the construction and maintenance of main and secondary canals, associated irrigation and flood control structures, and medium-sized reservoirs. Townships and villages share responsibility for constructing and maintaining branch canals, ancillary works, and small reservoirs;

Ø River Basin Management Commissions (RBMC): subordinate organization of the MWR for its seven large river/lake basins (six river basin management commissions and the Lake Tai Basin Management Agency). Responsible for preparing basin-wide water allocation plans and providing technical direction and guidance to local governments within the basin.

Water management

The following developments have taken place over the past years:

Water management: China adopted the integrated water resources management (IWRM) approach, as shown in the amended new Water Law. Water productivity, water pollution protection, demand management, environmental concern are highlighted in policies and mainstreamed into planning and procedures, such as specific water allocation for environmental use. Attention is being given to zoning of water function bodies, formulation of macro water allocations and micro water quotas, basin level resources management to protect the Huang river from drying up, special water diversion projects for ecosystems, and establishment of water-saving societies.

Water development: This has shifted from expansion to improvement. There are limited new water resource development projects, and highest priority is given to improving water use efficiency, productivity and quality.

Water environment: China implemented the largest ecosystem improvement programme in its history, costing US$43 billion, on restoring water bodies from farmland, restoring forestry from cultivation, restoring grazing from farming. Large numbers of small high pollution plants along the rivers have been closed. Also, the largest drinking water improvement programme in China's history has been implemented, where millions of people now gain access to safe drinking water. The programme has lasted 10 years, with an average annual investment of US$2 billion.

Water system management: China issued new management policy and rules, grouping water infrastructures and management agencies into three categories – public services, semi-public services and commercial services – and implemented different management and financing policies for different systems. Environmental services are recognized and covered by government funds.

Irrigation development: Over ten years, China has implemented large-scale irrigation improvement programmes to improve water-use efficiency and productivity, with an annual investment of around US$2 billion. In the past 10 years, nationwide agricultural water-use efficiency has increased by 10 percent and food production has increased, while the water withdrawal amount has been reduced. The government target is to produce enough food for the 2030 population, while keeping the total water allocation for agriculture within the current scope.

In recent years, water user associations (WUA) have become a very popular form of public participation in water management in rural China. In October 2005, MWR, the National Development Reform Commission (NDRC), and the Ministry of Civil Affairs jointly promulgated the "Guidance for facilitating establishment of farmer water users associations", specifying principles and procedures for establishing such associations and their role and responsibilities in relation to governmental organizations and water supply enterprises. According to MWR, by mid 2007 water users' participation in irrigation water management had taken place in 30 provinces/municipalities across China. More than 20 000 organizations of farmer water users, mostly as WUAs, have been established, involving more than 60 million farmers participating in water management on behalf of end-users of water (World Bank, 2009a).

Policies and legislation

China's Water Law was enacted in 1988 and establishes principles, general guidelines, and technical standards for water resources management. In 2002, the Chinese government amended the Water Law to establish a legal foundation for integrated water resources management and demand management. The amended Water Law enshrines the principles that everybody should have access to safe water, and that water conservation and protection are a priority. It focuses on five areas of water resources management:

1. water allocation,
2. water rights and water withdrawal permits,
3. river basin management,
4. water-use efficiency and conservation, and
5. protecting water resources from pollution.

According to this law, all water resources, except those in ponds and reservoirs belonging to rural collectives, are owned by the state and the State Council exercises the right of ownership on behalf of the state. In reality, the State Council has delegated water ownership rights to local governments under the supervision of MWR.

The 1991 Water and Soil Conservation Law recognized the inter-relationship between water resources and soil (land) conditions. The primary purpose of this law is: prevention and control of soil erosion, protection and rational utilization of water and soil resources, mitigation of disasters from floods, droughts and sandstorms, and improvement of the ecological environment and development of production (Wang *et al.,* 1999).

The 1997 Flood Control Law is the first law for the prevention and control of natural disasters, although there have been previous administrative regulations promulgated under the water and other laws, and thus filled a gap in the water legislation system. The importance of this law is to address the specific nature of causes and remediation measures to be taken to prevent and control floods. The law introduces the important mechanism of designating "planned reserve zones or areas" in which special rules may apply to the use and activities within the area. It further provides specific requirements for the operation of reservoirs and other hydraulic works, for multiple use considerations in river course realignments and lake embankments, and for preparing a flood impact assessment for any projects in flood-prone areas (Wang *et al.,* 1999).

The first Law for Water Pollution Control came into force in 1984. This law soon became inadequate to meet the needs of economic development and environmental protection for several reasons: water pollution continued to increase, the targets of water pollution control changed greatly, and the legal measures for the control of point sources were unable to stop the decline of water quality (Wang *et al.,* 1999). Thus, the Law was amended in 1996. Adopted in 2008, the newly amended version provides more detailed measures for the prevention and control of water pollution from various sources, makes clearer specifications for the responsibilities of different stakeholders, and strengthens the legal liabilities for water pollution (World Bank, 2009a).

Finances

In 1985, the Government issued a new rule requiring water charges to be collected according to the cost of water delivery. The water charge has, in principle, been calculated based on the cost of the water supply. The water charge for agriculture is usually lower than that for industry. It is calculated either according to the quantity of water supplied, the beneficial area, or a mixture of basic water charge plus a metered water charge. Where shortages occur, a rational water allocation system is practised and dissuasive charges are applied to extra volumes of water. On average, water charges for irrigation varied between 150 and 300 Yuan/ha (US$18 and 36/ha) in 1995. The average cost for sprinkler irrigation development was 6 000 Yuan/ha (US$720/ha), and that for localized irrigation 18 000 Yuan/ha (US$2 200/ha). Even so, repeated studies have shown that water and sewerage prices in China are still below the requirements for financial cost recovery and take little account of environmental and depletion costs (World Bank, 2009a).

In 2006, the planned total investment of fixed assets in the water sector was 93 270 million Yuan (US$11 680 million) of which 30 840 million Yuan from the Central Government, 44 150 million Yuan from the local governments, 1 160 million Yuan from foreign investments, 11 200 million Yuan from domestic loans, 2 890 million Yuan from enterprises and the private sector, and 3 030 million Yuan from other financial sources. In the total investment plans 93 270 million Yuan, 45 percent, was allocated to flood control, 38 percent to water resources projects (including 8 460 million Yuan invested in the South-to-North water transfer project), 5 percent for soil and water conservation and ecological projects, and 12 percent for hydropower and other special projects (MWR, 2007b).

Outside investments and technology are very important in order for China to cope with its environmental challenges. It is hard to calculate how much external funding China has received for water issues. The World Bank has been active in loans for tackling water shortages. This started as early as the mid 1980s with emphasis on irrigation facilities rehabilitation, modernization, promotion of water saving and water resources management, and water supply and pollution control. For example, it invested US$210 million in 1995 in the Yangtze water resources development programme, US$153 million in 1987 and US$250 million in 1996 in two projects to improve sewerage in Shanghai, and US$100 million in the Guanzhong irrigation improvement project in 1999 (Burke, 2000).

ENVIRONMENT AND HEALTH

In China, serious pollution occurs widely in every river system and no single river is clean. More than half of the groundwater resources have been severely contaminated. According to FAO, 80 percent of the 50 000 km of major rivers in China are so degraded that they no longer support fish. Around urban areas 90 percent of rivers are seriously polluted, especially in the north where heavy industry is concentrated. Looking at their total river length, 69 percent of the Hai river, 73 percent of the Huai river and 71 percent of the Huang river are classified as polluted by Chinese standards (Burke, 2000).

In 2004, of all 745 monitored river sections, 28 percent were unsafe for any use and only 32 percent were safe for industrial and irrigation uses only. Of the 27 major monitored lakes and reservoirs, 48 percent were unsafe for any use, 23 percent were safe for industrial and irrigation uses only, and only 29 percent were safe for human consumption after treatment (World Bank, 2009a).

The extent of pollution aggravates water scarcity. Currently, approximately 25 km^3 of polluted water are held back from consumption, contributing to unmet demand and groundwater depletion. As much as 47 km^3 of water that does not meet quality standards are however supplied to households, industry, and agriculture, with the attendant costs related to damage. A further 24 km^3 of water beyond rechargeable quantities are extracted from the ground, which results in groundwater depletion (World Bank, 2009a).

There are a number of complex factors behind this pollution crisis. The fundamental one is that economic growth is the number one goal of the country. Also, there has been a long period of ignorance and neglect at all government levels and lack of effective policy mechanisms to address those issues. Much of the pollution results from inadequate treatment of municipal and industrial wastewater (Burke, 2000).

Total wastewater discharges have steadily risen to 53 700 million tonnes in 2006 of which only 56 percent had some form of treatment (this rate reflects the installed wastewater treatment capacity rather than the actual treatment, which is likely to be lower because of the lack of sewage networks and funds for operation and maintenance in many cities). Since 2000, domestic wastewater discharges have surpassed industrial discharges, and have become the most important source of pollution. It was not until 2007 that the rising trend of water pollution began to show a sign of reverse, as total emissions of chemical oxygen demand (COD) dropped by 3.14 percent over the 2006 level. However, the water pollution situation is still very serious. A major element is that only 56 percent of municipal sewage receives some form of treatment, versus 92 percent of industrial discharges (World Bank, 2009a).The most challenging drinking water pollutant is fecal coliform from sewage.

Rural areas have also witnessed an increase in pollution caused by the inappropriate use of chemical pesticides and fertilizers: several groundwater sites were examined in northern China where nitrate levels exceeded the limits allowed for drinking water. Further, farmers have traditionally used sewage to irrigate crops but now they are also using industrial wastewater laced with all sorts of toxic and persistent chemicals (Burke, 2000).

The World Bank estimates that the water crisis is already costing China about 2.3 percent of the GDP, of which 1.3 percent is attributable to the scarcity of water, and 1 percent to the direct impacts of water pollution. These estimates do not include the cost of impacts for which estimates are unavailable, such as the ecological impacts associated with eutrophication and the drying up of lakes, wetlands, and rivers, and the amenity loss from the extensive pollution in most of China's water bodies. Thus, total costs are undoubtedly higher.

The economic cost of disease and premature deaths associated with the excessive incidence of diarrhoea and cancer in rural China has been estimated, based on 2003 data, at 66 200 million Yuan, or 0.49 percent of the GDP (World Bank, 2009a). Above the Huang river, for example, abnormally high rates of mental retardation, stunting, and development diseases have been linked to naturally present arsenic and lead in water. In Shanxi province around the Huang river, high levels of lead and chromium were found in rice, and cadmium in cabbages (Burke, 2000).

In 2005, the area subject to waterlogging was 21.3 million ha. In northern China in particular, waterlogging, salinization and alkalization have been the main constraints to agricultural production. In 2005, 6.03 million ha of saline-alkaline cultivated areas have been improved or reclaimed and the total cultivated area protected from floods is about 44.1 million ha (MWR, 2006). More than 100 million ha of China's land has become salinized over the past several decades. The area salinized by irrigation was an estimated 6.7 million ha in 1999 (Mashali, 2005). The majority of the most serious problems have occurred in the northeast, the northwest and in some places on the north China plain. In recent years, the area affected by salinization has somewhat fallen. Ironically, it may be that the same forces diverting surface water away from agriculture and forcing producers to rely increasingly on groundwater may be the primary cause of such improvements (Wang *et al.,* 2005).

The depletion of groundwater resources is contributing to the drying up of lakes and wetlands and an increase in groundwater salinity, which occurs when seawater intrudes or when declining groundwater resources are substituted by brackish water that often lies between the shallow and deep groundwater tables. In some locations, intrusion of brackish water has been monitored at a rate of 0.5 to 2 mper year for the past 20 years. Sea water intrusion has occurred in 72 locations along coastal provinces, covering an area of 142 km^2 (World Bank 2009a).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The further development of irrigation in China faces a number of problems (Yuanhua Li, 2006):

- Water scarcity: The country level data hide massive regional differences in water scarcity behind the average figures. In 2030, the deficit at the national level would be around 13 km^3, but the water shortage on the North China Plain would be as high as 25-46 km^3.
- Shortage of funds for the rehabilitation and modernization of irrigation systems: Most of the irrigation systems were constructed in the 1950s and 1960s, and low design standards, aged structures and imperfect field works lead to low irrigation water-use efficiency, poor irrigation service, low irrigation reliability.
- Farm size: Farm size is small, and farmer's income is quite low.
- Institutional frictions: These remain among various administrative levels concerning planning, financing, constructing, and maintaining irrigation facilities.

The strategies for coping with water scarcity in China are (Yuanhua Li, 2006):

Strategy 1: Research and development

- Research and implementation of water-saving irrigation (WSI). WSI refers to any measure leading to reducing irrigation water or increasing irrigation water productivity without distinct reduction in crop yields, as:

- reducing conveyance losses;
- capturing return flow;
- alternative wet and dry irrigation (AWDI) for paddy;
- non-full irrigation;
- improving irrigation water management; and
- increasing application efficiency, etc.

Strategy 2: Modernization of irrigation systems

- Ø The large and medium-size schemes claim top priority for state investment, the improvement of which is extremely important both for water saving and food security.
- Ø The 'melons-on-the vine' irrigation system in south China and 'well-canal' system in north China have been recommended to improve the reliability of irrigation water supply and irrigation water efficiency.

Strategy 3: Institutional development

- Ø Improve irrigation water management to increase irrigation efficiency, water productivity and income of farmers.
- Ø Maximize the effects of irrigation systems and find incentives for farmers to protect the irrigation facilities and improve irrigation water management on-farm level.
- Ø High-level policy support to provide incentives for research and dissemination of new technologies.
- Ø Funding policy – priority is given to those with wider adoption of WSI practices.

Strategy 4: Water transfer

- Ø China needs more water savings from the irrigation sector because the total water supply is limited, hence, there is an urgent need to increase water and land productivity. The following indicators are included in the Report of the Eleventh Five-year Plan for national economic and social development by Premier Wen Jiabao on 5 March 2006 (Yuanhua Li, 2006):
  - total grain production must be increased to more than 500 million tonnes;
  - irrigation efficiency must be increased to 50 percent from around 45 percent; and
  - water productivity for industry must be increased by 30 percent.

Outside investment and technology are very important in order for China to cope with its environmental challenges (Burke, 2000).

The Water Resources Minister said in February 2009 that China will tighten water resources management and consider measures to reduce waste. This is to cope with worsening water shortages and that this water shortage has impelled China to consider overall economic and social development and the economical use of water resources to ensure sustainable economic and social development. China is planning to reduce water consumption per unit of GDP to 125 m^3 by 2020, a reduction of 60 percent from current use. At the end of 2008, water consumption averaged 229 m^3 per 10 000 Yuan worth of products, according to statistics provided by the Ministry of Water Resources (MWR). That figure was down 10 percent compared with the previous year. The Minister also expected to increase 79.5 km^3 of water resources by 2020 and secure water supplies for both urban and rural inhabitants. Finally, the Minister proposed reinforcement of laws and regulations on water allocation, consumption and preservation as a fundamental way to achieve this goal (Yao, 2009).

Note:

The expressions 'He'" and 'Jiang' that are often added to the names of rivers, mean 'river' and 'large river'. Therefore, in this English version of the country profile, these words have been removed from the *name of the river and replaced by the word 'River'. As an example, Qingjiang has been changed to Qing river and Huaihe has been changed to Huai river.*

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Democratic People´s Republic of Korea

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Located on the northern part of the Korean peninsula in the far east of Asia, the Democratic People's Republic of Korea has a total area of 120 540 km^2. It is bordered in the north by China, in the northeast by the Russian Federation, in the east by the Sea of Japan, in the south by the Republic of Korea and in the west by the Yellow Sea and the Korea Bay. There are nine provinces and two municipalities under central authority, including the capital city Pyongyang.

Some 80 percent of the total area of the country consists of mountains and uplands. The average height of the highlands in the northeast is 1 000 m above sea level. Based on topographic features and land use, the country can be divided into four zones:

- The northeast, where the high mountain area represents 21 percent of the territory, is essentially a forest area with practically no agriculture.
- The hilly areas, surrounding the high mountains in the north and the central chain of mountains with large areas under forest, representing 40 percent of the territory, are suitable for the cultivation of scattered plots of potato, wheat, barley and vegetables. They also have some pasture land.
- The east coast, representing 22 percent of the territory, is submountainous or hilly, but it also includes some lowlands where rice is cultivated. In addition to forest and pasture, there are slopes suitable for maize and vegetable cultivation.
- The western plains, mainly devoted to rice cultivation, represent 17 percent of the territory.

In 2009, the total cultivated area was about 2.9 million ha, of which 2.7 million ha were annual crops, of which almost 50 percent were cereals, and 0.2 million ha were permanent crops (Table 1).

Climate

The country has a continental climate with four distinct seasons. Long winters bring cold clear weather interspersed with snow storms as a result of north and northwest winds from Siberia with temperatures ranging from -20 to -40 °C. The average number of days with snowfall is 37. The weather is harsh in the northern mountainous regions. Spring and autumn are marked by mild temperatures and variable winds. Summer tends to be short, hot, humid and rainy because of the south and southeast monsoon winds that bring moist air from the Pacific Ocean. The average summer temperature is 25 °C.

Average annual precipitation is 1 054 mm, ranging from 810 to 1 520 mm. About 60 percent of all precipitation occurs between June and September.

DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA **FAO - AQUASTAT, 2011**

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	12 054 000	ha
Cultivated area (arable land and area under permanent crops)	2009	2 855 000	ha
• as % of the total area of the country	2009	24	%
• arable land (annual crops + temp fallow + temp meadows)	2009	2 650 000	ha
• area under permanent crops	2009	205 000	ha
Population			
Total population	2009	24 238 000	inhabitants
• of which rural	2009	40	%
Population density	2009	201	inhabitants/km^2
Economically active population	2009	12 953 000	inhabitants
• as % of total population	2009	53	%
• female	2009	45	%
• male	2009	55	%
Population economically active in agriculture	2009	3 099 000	inhabitants
• as % of total economically active population	2009	24	%
• female	2009	46	%
• male	2009	54	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2008	40 000	million US$/yr
• value added in agriculture (% of GDP)	2008	23.3	%
• GDP per capita	2008	1 658	US$/yr
Human Development Index (highest = 1)		-	
Access to improved drinking water sources			
Total population	2008	100	%
Urban population	2008	100	%
Rural population	2008	100	%

Population

In 2009, the population was an estimated 24.2 million inhabitants of whom around 40 percent lived in rural areas (Table 1). The average population density is 201 inhabitants/km^2. In 1996 population density varied from 44 inhabitants/km^2 in Yanggang-do province to 1 177 inhabitants/km^2 in Pyongyang. The annual demographic growth is an estimated around 0.7 percent for the period 1999-2009.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2008, gross domestic product (GDP) was US$40 000 million of which agriculture accounted for 23.3 percent (Table 1) (CIA, 2009).

The total population economically active in agriculture in 2009 was around 3.1 million inhabitants, amounting to 24 percent of the economically active population, of which 46 percent were women (Table 1).

In the 1980s it was estimated that the Democratic People's Republic of Korea had about 38 000 cooperative farms (*kolkhoz*) and 180 state farms (*sovkhoz*), the former cultivating more than 90 percent of the total cultivated land. However, since the mid-1990s, the Government has tended to advocate the gradual transfer of the cooperative farms to state farms.

The Democratic People's Republic of Korea continues to suffer widespread food shortages as a result of economic problems, limited arable land, lack of agricultural machinery and energy shortages. The country remains highly vulnerable to natural disasters. The most recently severe flooding in August 2007 caused widespread damage to crops and infrastructure in six southern provinces. The country has also suffered from the effects of the global commodity crisis, with rampant increases in market prices for staple foods and fuel. WFP/FAO assessments confirmed a significant deterioration in food security in 2008 (WFP, 2009).

WATER RESOURCES AND USE

Water resources

Most of the rivers run west to the Yellow Sea (Korea Bay). They rise in the mountain ranges of the north and east of the country. There are five river basin groups:

- the Yalu river flows southwest from the Changbai mountain range to the Korea Bay. It forms the border with China;
- the Tumen river flows east from the Changbai mountain range to the Sea of Japan. It forms the border with China and further downstream with the Russian Federation;
- the Taedong river basin is internal and is the largest one within the country. The Taedong river flows west to the Korea bay near Pyongyang.
- the west coast river basin comprises many small streams rising in the northern and eastern mountain ranges; and the
- east coast river basin.

The internal renewable surface water resources are approximately 66 km^3/year. In comparison with the Republic of Korea (approximately the same area and precipitation), groundwater resources are an estimated 13 km^3/year, most of which (12 km^3/year) comprise the base flow of the rivers. The internal renewable water resources are therefore about 67 km^3/year (=66+13-12) (Table 2).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 054	mm/yr
	-	127 000	million m^3/yr
Internal renewable water resources (long-term average)	-	67 000	million m^3/yr
Total actual renewable water resources	-	77 150	million m^3/yr
Dependency ratio	-	13.2	%
Total actual renewable water resources per inhabitant	2009	3 183	m^3/yr
Total dam capacity	2009	10 550	million m^3
Water withdrawal			
Total water withdrawal	2005	8 657.8	million m^3/yr
- irrigation + livestock	2005	6 610	million m^3/yr
- municipalities	2005	902.8	million m^3/yr
- industry	2005	1 145	million m^3/yr
• per inhabitant	2005	365	m^3/yr
Surface water and groundwater withdrawal	2005	8 657.8	million m^3/yr
• as % of total actual renewable water resources	2005	11.2	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

Since the Yalu river with a total flow of 4.9 km^3/year and Tumen river with a total flow of 15.4 km^3/year form the border with China, half of the total average discharge of these rivers, or 10.15 km^3/year, is considered as external resources of the Democratic People's Republic of Korea. The total renewable water resources are therefore an estimated 77.15 km^3/year.

In 2009, total dam capacity was estimated at 10.55 km^3. The West Sea Barrage (or Nampho Barrage) involving an 8 km dam across the Taedong river was completed in June 1986. It consists of a main dam, three locks and 36 sluices, and is believed to be the longest dam in the world. The barrage today provides water for irrigation, industries and municipalities. Another major dam has been built on the Yalu river. The Hwanggang dam, on the Imjin river, with an estimated capacity of 400 million m^3 of water, was completed in 2007. It is 42 km north of the border with the Republic of Korea, and provides water for hydropower and irrigation. The Imnam dam on the Bukhan river was completed in 2003 with a total capacity of 2.62 km3. The dam is 710 m wide and 121.5 m high.

International water issues

The Imjin river is a major waterway that starts in the Democratic People's Republic of Korea and ends in the Republic of Korea to the northwest of Seoul. The Democratic People's Republic of Korea has built several dams on this river including one a few kilometres north of the heavily armed border between the two countries that have yet to sign a formal peace treaty to end the 1950-1953 Korean War. In 2009, the Republic of Korea complained to the Democratic People's Republic of Korea about a sudden release of water into the river flowing across their border that left six people missing. The Democratic People's Republic of Korea has failed to notify the Republic of Korea ahead of releasing water on several previous occasions, resulting in flood damage. The Democratic People's Republic of Korea has claimed its dams on the Imjin are designed to release water automatically when they reach a certain threshold (Reuters, 2009). Cooperation between the two countries on flood control and setting up warning systems has so far not been successful.

In 2005, the Republic of Korea constructed the Peace dam on the Bukhan river, the only dam in the world constructed with no reservoir. The dam is to prevent flooding from the Imnam dam in the Democratic People's Republic of Korea.

Water use

In 2005, the total water withdrawal was estimated at about 8.66 km^3/year, of which 6.61 km^3/year (77 percent) for agriculture, 0.90 km^3/year (10 percent) for municipalities and 1.15 km^3/year (13 percent) for industry (Table 2 and Figure 1).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation development in the Democratic People's Republic of Korea has always been a major objective in the agriculture sector and more than half of the cultivated area is irrigated. In 1976, as a way of increasing the arable land area, the authorities launched a "nature re-making programme" with the following objectives to:

- complete the irrigation of non-paddy lands;
- reclaim 100 000 ha of new land;
- build 150 000-200 000 ha of terraced fields;
- reclaim tidal land; and
- conduct work on forestation and water conservation projects.

FIGURE 1
Water withdrawal by sector
Total 8.658 km³ in 2005

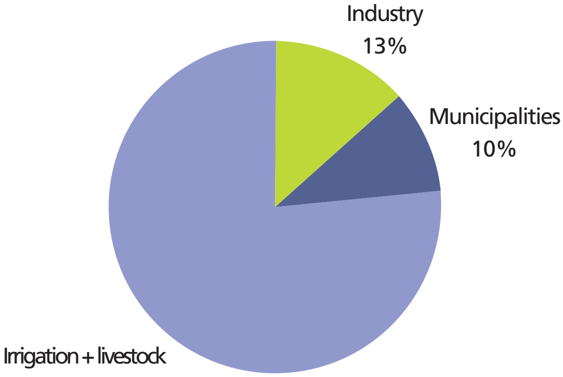
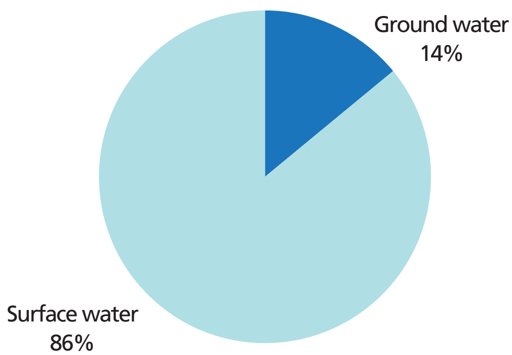


FIGURE 2
Source of irrigation water on area equipped for full control irrigation
Total 1 420 000 ha in 1990



The 1987-1993 plan target was to reclaim some 300 000 ha of tidal land. In 1989, a project was initiated to build a 400 km long canal by diverting the flow of the Taedong river along the west coast. As part of the irrigation system, the canal would provide water to rural areas and newly reclaimed tidal land in South Hwanghae and South Pyongan provinces.

By late 1990, a total of 800 km of large and small irrigation waterways had been completed. In early 1994, there were about 40 000 km of irrigation waterways together with 1 770 reservoirs and 26 000 pumping stations for irrigation purposes. In December 1995, the Kangryong Waterway (40 km) was constructed.

In 1975 the total area equipped for irrigation was an estimated 900 000 ha, in 1985 at 1 270 000 and in 1995 it accounted for 1 460 000 ha or 56 percent of the cultivated area (Table 3). Unfortunately no more recent official figures could be found. The irrigated land includes plains, terraced fields and tidal land.

In 1990, out of 1 420 000 ha of irrigation about 1 220 000 ha were irrigated from surface water and 200 000 ha were irrigated from groundwater resources (Figure 2).

Although no figures are available, the main irrigation technique is surface irrigation, while sprinkler and micro-irrigation were introduced on non-paddy fields in the late 1980s.

Role of irrigation in agricultural production, economy and society

In 2006, total harvested irrigated cropped area was an estimated 1 341 000 ha and cereals accounted for two-thirds of that area (rice accounted for 35 percent, maize 24 percent) (Table 3 and Figure 3).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

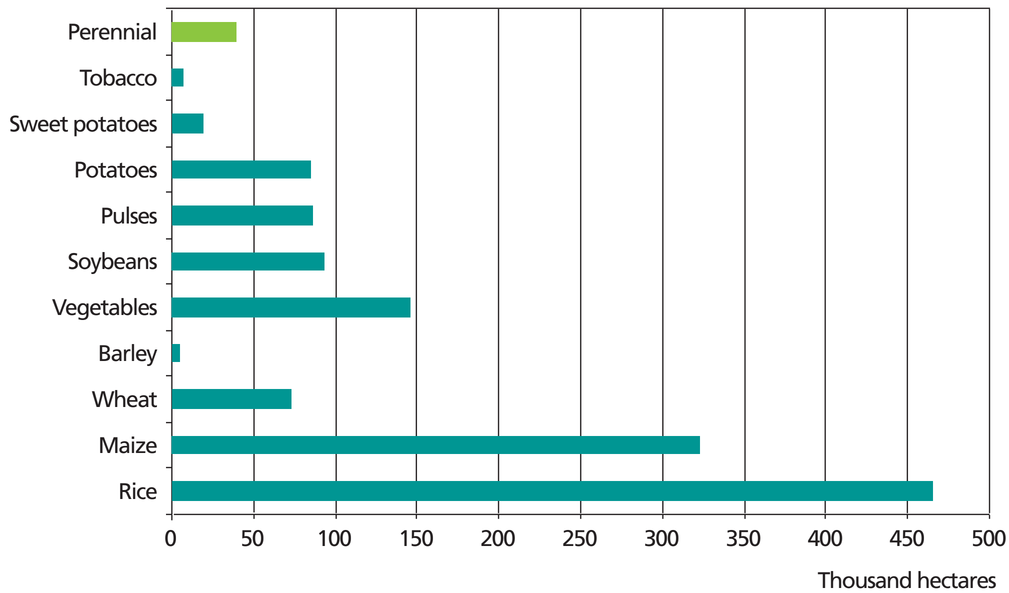
At the national level, the agriculture sector is directed by the Agriculture Commission, which is in charge of the planning, management and technical direction of production. Within the Agricultural Commission, the Department of Irrigation and Drainage has the task of providing technical assistance to farmers and of developing irrigation techniques.

At provincial level, the Agricultural Commission is represented by the Provincial Rural Economy Committee (PREC), which is directly responsible for the production and management of the

TABLE 3
Irrigation and drainage

Irrigation potential			-	ha
Irrigation				
1. Full control irrigation: equipped area		1995	1 460 000	ha
- surface irrigation		1995	1 460 000	ha
- sprinkler irrigation		1995	-	ha
- localized irrigation		1995	-	ha
• % of area irrigated from surface water		1990	86	%
• % of area irrigated from groundwater		1990	14	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**1995**	**1 460 000**	**ha**
• as % of cultivated area		1995	56	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 10 years		1985-1995	1.4	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**1995**	**1 460 000**	**ha**
• as % of cultivated area		1995	56	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production		2005	3 757 000	metric tons
• as % of total grain production		2005	80	%
Harvested crops				
Total harvested irrigated cropped area		2006	1 341 000	ha
• Annual crops: total		2006	1 302 000	ha
- Rice		2006	465 000	ha
- Maize		2006	323 000	ha
- Wheat		2006	73 000	ha
- Barley		2006	5 000	ha
- Vegetables		2006	146 000	ha
- Soybean		2006	93 000	ha
- Pulses		2006	86 000	ha
- Potatoes		2006	85 000	ha
- Sweet potatoes		2006	19 000	ha
- Tobacco		2006	7 000	ha
• Permanent crops: total		2006	39 000	ha
Irrigated cropping intensity (on full control equipped area)				%
Drainage - Environment				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

FIGURE 3
Irrigated crops on areas equipped for full control irrigation
Total harvested area 1 341 000 ha in 2006



state farms and supervises agricultural production through District/County Cooperative Farm Management Committees (CCFMCs). The country has over 200 districts and counties where the CCFMCs are entrusted with the planning, production and management of cooperative farms. The CCFMCs also directly supervise state enterprises concerned with agricultural production (i.e. farm machinery and implement factories, tractor stations and irrigation offices).

Water management

Since 60 percent of the total annual precipitation is in summer, the Democratic People's Republic of Korea has emphasized irrigation from its first development plan in 1957-1960, even extending into mountainous areas. Substantial investments were made to construct dams and reservoirs, canals and pumping stations (Woon-Keun Kim, 1999).

Challenges faced are the shortage of arable land and the increasing costs of land reclamations as well as the massive rise and fall of river/lake levels caused by heavy rainfall and drought at critical points in the crop cycle. Strategic options aiming to achieve sustainable food security by improving agricultural production systems could be based on:

1. reconstructing flood-stricken areas,
2. developing hilly mountainous land and reclaiming tidal land,
3. modernizing irrigation systems through increased investment, and
4. improving anti-flood forestation.

Policies and legislation

Agricultural policies of the Democratic People's Republic of Korea are directed towards solving the problem of food shortages through the 'four improvements' in agricultural technology: irrigation, farm mechanization, rural electrification, and agricultural chemicals. The government has also carried out a number of reclamation projects to increase the area of arable land. Priority has been given to improving the agricultural infrastructure, especially expanding irrigation facilities, and terracing and draining new arable land (Woon-Keun Kim, 1999).

The Government has adopted two strategies to meet its future cereal requirements:

- Ø increase production by using high-yielding varieties (HYVs), and through more efficient, and environmentally sound soil and crop management practices; and
- Ø increase the area of cultivated land by reclaiming tidal lands.

ENVIRONMENT AND HEALTH

The Democratic People's Republic of Korea is applying knowledge on sustainable development of upland water catchments and use of marginal agricultural land to help reduce soil erosion, protect natural resources and increase agricultural output. In a country that largely depends on agriculture for self-sufficiency, and has recently seen its agricultural production devastated by floods and droughts, an integrated and participatory approach to basin management is essential. Applying basin management throughout the country, planting trees in the uplands and developing integrated approaches to the use of natural resources will help diminish soil degradation and the dangers of downstream sedimentation. Trees help retain water in the soil, prevent water from flowing downstream all at once during heavy rains and keep moisture in the soil during low rainfall. Their roots also cling to the soil, making it more difficult for soil to erode (FAO, 2005).

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India

GEOGRAPHY, CLIMATE AND POPULATION

Geography

India is located in southern Asia and has a total area of almost 3.3 million km^2 (Table 1), making it the largest peninsula in the world and the seventh largest country. It is bordered in the northwest by Pakistan, in the north by China, Nepal and Bhutan, and in the northeast by Myanmar and Bangladesh. In the south, some 7 600 km of coastline is on the Arabian Sea, Indian Ocean and Bay of Bengal. The peninsula can be divided into three main regions: peninsular India, located south of the Vindhya and Satpura mountain ranges; the plains of the Indus (northwest) and Ganges (north and northeast) rivers; and the mountainous terrain of the Himalayas. In addition, the Lakshadweep Islands in the Arabian Sea and the Andaman Islands and Nicobar Islands in the Bay of Bengal are part of the territory of India. For administrative purposes, India is divided into 28 states and seven union territories.

The total cultivable area is approximately 183 million ha, or over 55 percent of the total area of the country. In 2009, the total cultivated area was about 170 million, of which 158 million ha were annual crops and 12 million ha were permanent crops. Between the early 1960s and the late 1980s the cultivated area increased by 5 percent, since then there has been hardly any increase in the cultivated area. Crop yields, however, have increased significantly (food grain yields have more than tripled since 1950) as well as the cropping intensity, which increased from 111 percent in 1950 to 118 in 1970, 130 in 1990 and 135 in 2006.

Climate

India has a typical monsoon climate. In this region, surface winds undergo a complete reversal from January to July, and cause two types of monsoon. In winter, dry and cold air from land in the northern latitudes flows southwest (northeast monsoon), while in summer, warm and humid air originates over the ocean and flows in the opposite direction (southwest monsoon), accounting for some 70-95 percent of the annual rainfall. For most parts of India the rainfall occurs under the influence of the southwest monsoon between June and September. However, in the southern coastal areas near the east coast (Tamil Nadu and adjoining areas) much of the rainfall is influenced by the northeast monsoon during October and November.

The average annual rainfall over the country is around 1 170 mm, but varies significantly from place-to-place. In the northwest desert of Rajasthan, the average annual rainfall is lower than 150 mm/year. In the broad belt extending from Madhya Maharashtra to Tamil Nadu, through parts of Andhra Pradesh and Karnataka, the average annual rainfall is generally lower than 500 mm/year. At the other extreme, in a short period of a few months, more than 10 000 mm of rain falls on the Khasi hills in the northeast. On the west coast, in Assam, Meghalaya, Arunachal Pradesh (states located in the northeast) and in sub-Himalayan West Bengal the average annual rainfall is about 2 500 mm.

Except in the northwest of India, the inter-annual variability of rainfall is relatively low. The main areas affected by severe droughts are Rajasthan and Gujarat.

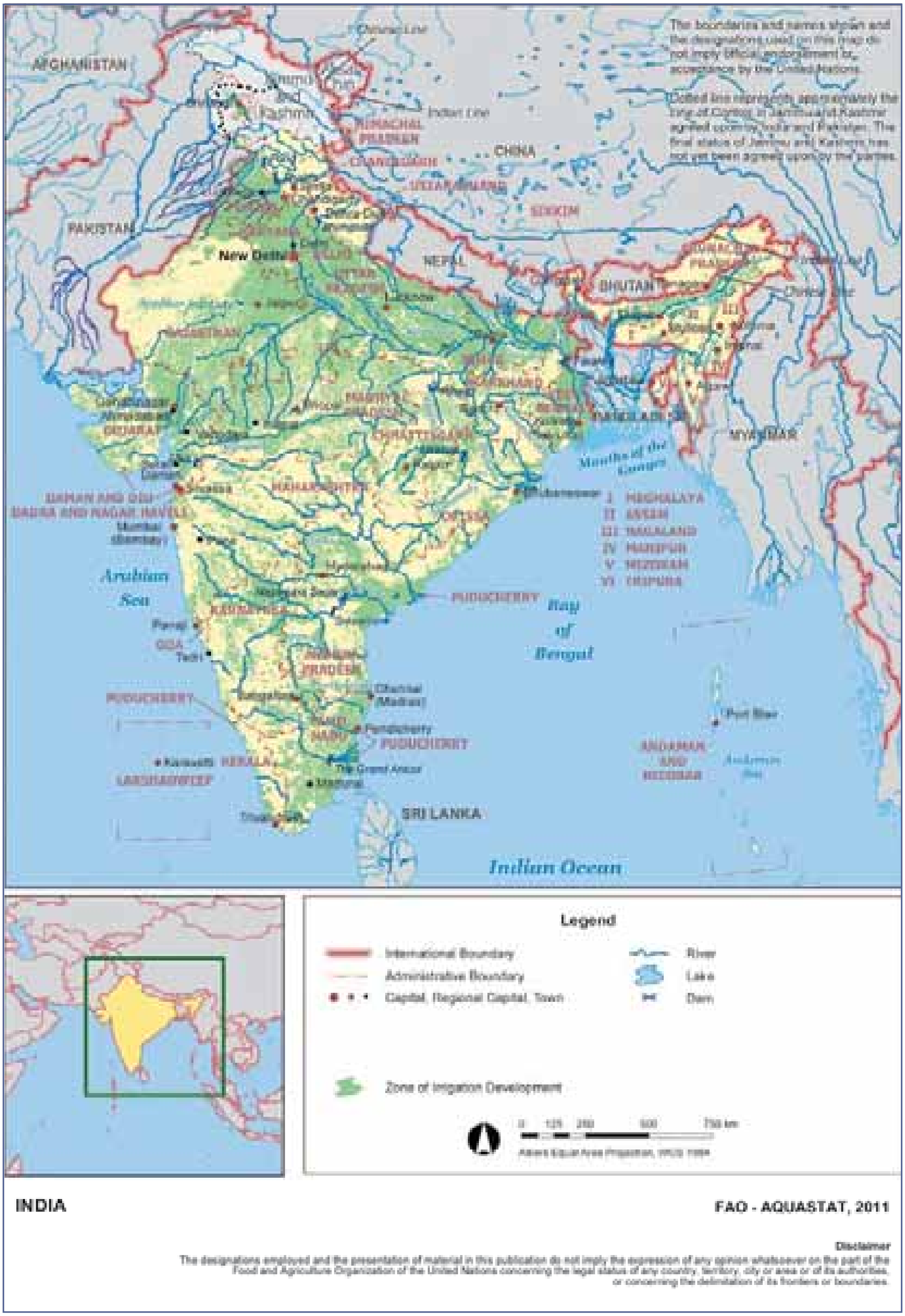
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.
AFGHANISTAN
PAKISTAN
CHINA
NEPAL
BHUTAN
MYANMAR
SRI LANKA
New Delhi
Arabian Sea
Bay of Bengal
Indian Ocean
Mouths of the Ganges
I MEGHALAYA
II ASSAM
III NAGALAND
IV MANIPUR
V MIZORAM
VI TRIPURA
PUDUCHERRY
ANDAMAN AND NICOBAR
Port Blair
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
Albers Equal Area Projection, WGS 1984
INDIA
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	328 726 000	ha
Cultivated area (arable land and area under permanent crops)	2009	169 623 000	ha
• as % of the total area of the country	2009	52	%
• arable land (annual crops + temp fallow + temp meadows)	2009	157 923 000	ha
• area under permanent crops	2009	11 700 000	ha
Population			
Total population	2009	1 207 740 000	inhabitants
• of which rural	2009	70	%
Population density	2009	367	inhabitants/km^2
Economically active population	2009	485 793 000	inhabitants
• as % of total population	2009	40	%
• female	2009	28	%
• male	2009	72	%
Population economically active in agriculture	2009	266 751 000	inhabitants
• as % of total economically active population	2009	55	%
• female	2009	32	%
• male	2009	68	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	1 310 171	million US$/yr
• value added in agriculture (% of GDP)	2009	17	%
• GDP per capita	2009	1 085	US$/yr
Human Development Index (highest = 1)	2010	0.519	
Access to improved drinking water sources			
Total population	2008	88	%
Urban population	2008	96	%
Rural population	2008	84	%

The year can be divided into four seasons, the:

- winter or northeast monsoon: January – February;
- hot season: March – May;
- summer or southwest monsoon: June – September; and
- post-monsoon season: October – December.

Temperature variations are also marked. During the post-monsoon and winter seasons, from November to February, the temperature decreases from south to north owing to the effect of continental winds over most of the country. From March to May, the temperature can increase to 40 °C in the northwest. With the advent of the southwest monsoon in June, there is a rapid fall in the maximum daily temperature, which then remains stable until November. The temperatures are suitable for year-round crop production throughout India, except at higher elevations in the Himalayas.

Population

In 2009, India was the second most populous country in the world, with an estimated total population of 1 208 million. In 2009, 849 million inhabitants (or 70 percent) were living in rural areas. The country's average population density then was an estimated 367 inhabitants/km^2, varying from fewer than 15 inhabitants/km^2 in the states of Arunachal Pradesh and

Himachal Pradesh to more than 9 300 inhabitants/km^2 in Delhi State. During the period 1999-2009 the average annual population growth rate was an estimated 1.5 percent.

In 2008, 88 percent of the population had access to improved water sources (96 and 84 percent in urban and rural areas respectively), but only 31 percent had access to improved sanitation (54 and 21 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the national gross domestic product (GDP) was US$1 310 171 million (Table 1). Agriculture accounted for 17 percent of GDP, while in 1999 it represented 25 percent. In 2009, the total economically active population was 486 million, or 40 percent of the total population. The economically active population in agriculture, then, was about 267 million, of which 32 percent were women. In 2004, about 238 million people comprising 21 percent of the total population were assessed to be below the poverty line.

The major cereals grown in India are rice, wheat, maize, bajra (spiked millet), barley, jowar (great millet), and ragi. The average yield of food grains (cereals and pulses) increased from 522 kg/ha in 1950 to 1 727 kg/ha in 2003-2004, meaning there was an average annual growth rate of 4.35 percent. Total food grain production in 2006-2007 was almost 212 million tonnes. The average operational farm size reduced from 1.57 ha in 1992 to 1.17 ha in 2002.

WATER RESOURCES AND USE

Water resources

India has an annual average precipitation of 1 170 mm and about 80 percent of the total area of the country experiences annual rainfall of 750 mm or more (Table 2). Owing to the large spatial and temporal variability in the rainfall, water resources distribution is highly skewed in space and time.

The two main sources of water in India are rainfall and glacial snowmelt in the Himalayas. Although snow and glaciers are poor producers of freshwater, they are good distributors as they yield at the time of need, in the hot season. Indeed, about 80 percent of the river flow occurs during the four to five months of the southwest monsoon season. Several important river systems originate in upstream countries and then flow to other countries: the Indus river originates in China and flows to Pakistan; the Ganges-Brahmaputra river system originates partly in China, Nepal and Bhutan, and flows to Bangladesh; some minor rivers drain into Myanmar and Bangladesh. However, no official records are available regarding the annual flows into or our of the country.

The rivers of India can be classified into four groups:

- The Himalayan rivers (Ganges, Brahmaputra, Indus) are formed by melting snow and glaciers as well as rainfall and, therefore, have a continuous flow throughout the year. As these regions receive very heavy rainfall during the monsoon period, the rivers swell and cause frequent floods.
- The rivers of the Deccan plateau (with larger rivers such as Mahanadi, Godavari, Krishna, Pennar and Cauvery draining into the bay of Bengal in the east, and Narmadi and Tapi draining into the Arabian sea in the west), making up most of the southern-central part of the country, are rainfed and fluctuate in volume, many of them being non-perennial.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 170	mm/yr
	-	3 846 000	million m^3/yr
Internal renewable water resources (long-term average)	-	1 446 000	million m^3/yr
Total actual renewable water resources	-	1 911 000	million m^3/yr
Dependency ratio	-	31	%
Total actual renewable water resources per inhabitant	2009	1 582	m^3/yr
Total dam capacity	2005	224 000	million m^3
Water withdrawal			
Total water withdrawal	2010	761 000	million m^3/yr
- irrigation + livestock	2010	688 000	million m^3/yr
- municipalities	2010	56 000	million m^3/yr
- industry	2010	17 000	million m^3/yr
• per inhabitant	2010	630	m^3/yr
Surface water and groundwater withdrawal	2010	761 000	million m^3/yr
• as % of total actual renewable water resources	2010	40	%
Non-conventional sources of water			
Produced wastewater	1996	25 410	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced	1996	0.55	million m^3/yr
Reused agricultural drainage water	2010	113 470	million m^3/yr

- Ø The coastal rivers, especially on the west coast, south of the Tapi, are short with limited catchment areas, most of them being non-perennial.
- Ø The rivers of the inland drainage basin in western Rajasthan in the northwestern part of the country, towards the border with Pakistan, are ephemeral and drain towards the salt lakes such as the Sambhar, or are lost in the sands.

For planning purposes, the country is divided into 20 river units, 14 of which are major river basins, while the remaining 99 river basins have been grouped into six river units, as presented in Table 3. The spatial imbalance of water resources distribution can be appreciated by the fact that the Ganges-Brahmaputra-Meghna basin, which covers 34 percent of the country's area, contributes about 59 percent of the water resources. The west flowing rivers towards the Indus cover 10 percent of the area and contribute 4 percent of the water resources. The remaining 56 percent of the area contributes 37 percent to the runoff.

The potential surface water resources is assessed as the natural runoff of the rivers. Looking at the Indus Water Treaty (1960) between India and Pakistan, however, these are an estimated 1 869.37 km^3, of which only 690.31 km^3 are considered usable or exploitable because of constraints related to topography, uneven distribution of the resource over space and time, geological factors and contemporary technological knowledge (Table 3).

Annual renewable groundwater resources are an estimated 432 km^3, of which around 90 percent or 390 km^3 are considered overlap between surface water and groundwater. Annual internal renewable surface water resources (IRSWR) have been estimated as 1 446.42 km^3, of which 1 404.42 km^3 surface water, 432 km^3 groundwater and 390 km^3 overlap. The IRSWR have been estimated by deducting the inflow from the total renewable surface water resources.

TABLE 3
Basin wise distribution of utilisable surface water resources (Source: Central Water Commission (1993), p 12, and Central Water Commission (1996), p 15)

	River basin unit	Location	Draining into	Catchment area (% of the country)	Average annual runoff (km^3)	Exploitable surface water (km^3)
1	Ganges	Northeast	Bangladesh	26.5	525.02	250.0
	Brahmaputra	Northeast	Bangladesh	6.0	537.24	24.0
	Meghna/Barak	Northeast	Bangladesh	1.5	48.36	
2	Minor rivers of the northeast	Extreme northeast	Myanmar	1.1	20.00	
			Bangladesh		11.00	
3	Subernarekha	Northeast	Bay of Bengal	0.9	12.37	
4	Brahmani-Baitarani	Northeast	Bay of Bengal	1.6	28.48	6.8
5	Mahanadi	Central-east	Bay of Bengal	4.4	66.88	18.3
6	Godavari	Central	Bay of Bengal	9.7	110.54	50.0
7	Krishna	Central	Bay of Bengal	8.0	78.12	76.3
8	Pennar	Southeast	Bay of Bengal	1.7	6.32	58.0
9	Cauvery (1)	South	Bay of Bengal	2.5	21.36	6.9
10	East flowing rivers between Mahanadi and Pennar	Central-east	Bay of Bengal	2.7	22.52	19.0
11	East flowing rivers between Kanyakumari and Pennar	Southeast	Bay of Bengal	3.1	16.46	13.1
12	West flowing rivers from Tadri to Kanyakumari	Southwest	Arabian Sea	1.7	113.53	16.7
13	West flowing rivers from Tapi to Tadri	Central-west	Arabian Sea	1.7	87.41	24.3
14	Tapi	Central-west	Arabian Sea	2.0	14.88	11.9
15	Narmada (2)	Central-west	Arabian Sea	3.1	45.64	14.5
16	Mahi	Northwest	Arabian Sea	1.1	11.02	34.5
17	Sabarmati	Northwest	Arabian Sea	0.7	3.81	3.1
18	West flowing rivers of kutsh and Saurashtra	Northwest	Arabian Sea	10.0	15.10	1.9
19	Rajasthan inland basin	Northeast	-	0.0	Negligible	15.0
20	Indus Eastern tributaries (3a)	Northwest	Pakistan	10.0	11.10	-
	Indus Western tributaries (3b)				62.21	46.0
	Total considering Indus Treaty			**100.0**	**1 869.37**	**690.3**

Notes: (1) The assessment for Cauvery was made by the Cauvery Fact Finding Committee in 1972 based on 38 years' flow data at Lowe Anicat on Coleroon. An area of 8000 km^2 in the delta is not accounted for in this assessment. (2) The potential of the Narmanda basin was determined on the basis of catchment area proportion from the potential assessed at Garudeshwar as given in the report on Normanda. Water disputes Tribunal Decision (1978). (3) Under the Indus Water Treaty (1960) between India and Pakistan the following is foreseen. (a) All waters of the eastern tributaries of the Indus originating in India (11.1 km^3) shall be available for unrestricted use by India (Sutlej, Beas, Ravi), except some domestic and non-consumptive use. (b) All waters of the western tributaries (Chenab, Jhelum) shall be available for unrestricted use by Pakistan, except for some domestic use, non-consumptive use, agricultural use, generation of hydroelectric power; total flow of western rivers is estimated at around 232.48 km^3 (flow from China to India is estimated at 181.62 km^3 and flow generated within India at 50.86 km^3), of which 170.27 km3 should then be reserved for Pakistan and therefore 62.21 is available for India.

Under the Indus Water Treaty (1960) between India and Pakistan, it was estimated that 73.31 km^3/year is available for India (Table 3). The following rules apply:

- *Eastern rivers:* All the waters of the eastern tributaries of the Indus river originating in India, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for unrestricted use by India. Pakistan shall be under an obligation to let flow, and shall not permit any interference with, the waters (while flowing in Pakistan) of any tributary which, in its natural course, joins the Sutlej Main or Ravi Main before these rivers have finally crossed into Pakistan. This average annual flow in India before crossing the border is an estimated 11.1 km^3. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej main or the Ravi main, after these rivers have crossed into Pakistan, shall be available for the unrestricted use of Pakistan.

- *Western rivers:* Pakistan shall receive for unrestricted use all those waters of the western rivers, i.e. Chenab and Jhelum, which India is under obligation to let flow, except for restricted uses, related to domestic use, non-consumptive use, agricultural use and generation of hydroelectric power of which the amounts are set out in the Treaty. Annual flow from China to India in the Indus basin is 181.62 km^3 and it is estimated that the flow generated within India is 50.86 km^3, resulting in a flow from India to Pakistan in this part of 232.48 km^3, of which 170.27 km^3 reserved for Pakistan and 62.21 km^3 available for India.

Besides this outflow to Pakistan from the Indus basin, 1 121.62 km^3 flows annually to Bangladesh (525.02 km^3 from the Ganges, 537.24 km^3 from the Brahmaputra, 48.36 km^3 from the Meghna and 11 km^3 from other rivers into southeast Bangladesh), and 20 km^3 flows to Myanmar.

In 1996, produced wastewater was an estimated 25.4 km^3. In 2004, wastewater production in urban centres (rural areas with larger population have not been accounted) was an estimated 10.585 km^3 and the treated wastewater was about 2.555 km^3.

No reliable statistics are available on the number or the status of desalination plants, or on their capacities or technologies adopted. Estimates indicate, however, that there are more than 1 000 membrane-based desalination plants of various capacities ranging from 20 m^3/day to 10 000 m^3/day. There are few thermal-based desalination plants. In 1996, some 550 000 m^3 of seawater were desalinated in the Lakshadweep Islands, mainly using electro dialysis and reverse osmosis (RO). Solar stills are also installed on the peninsula, as in Gujarat in the northwest. A 6 300 m^3/day desalination plant is being set up at Kalpakkam, Chennai with a capacity of 4 500 m^3 from multi stage flash (MSF) method, using low pressure steam from the Madras Atomic Power Station and 1 800 m^3/day from RO method. While the Plant using the RO method is under operation, the MSF-based plant is to be commissioned soon.

The total constructed water storage capacity, up to 2005, was 224 km^3. Another 76.26 km^3 are estimated to be possible from dams under construction and 107.54 from dams under consideration. Seven dams have a reservoir capacity that exceeds 8 km^3. They are the Nagarjuna Sagar dam on the Krishna river (11.56 km^3), the Rihand dam on the Rihand river (10.6 km^3), the Bhakra dam on the Sutlej river (9.62 km^3), the Srisailam dam on the Krishna river (8.72 km^3), the Hirakud dam on the Mahanadi river (8.1 km^3), the Pong (Beas) dam on the Beas river (8.57 km^3) and the Ukai dam on the Tapti river (8.5 km^3).

India controls the flow of the River Ganges using a dam completed in 1974 at Farraka, 18 km from the border with Bangladesh. The Farakka barrage is a low diversion structure and not classified as a large dam.

India is endowed with rich hydropower potential, ranking fifth in the world. The gross hydropower potential was an estimated 148 700 MW as installed capacity, or 84 000 MW at 60 percent power load factor, of which the Brahamaputra, Ganges and Indus basins contribute about 80 percent. Further, small, mini and micro hydropower schemes (with a capacity of less than 3 MW) have been assessed as having almost 6 782 MW of installed capacity.

International water issues

The earlier-mentioned dam at Farraka, 18 km from the border with Bangladesh, was a source of tension between the two countries, when Bangladesh asserted that the dam held back too much water during the dry season and released too much water during monsoon rains. A treaty was signed in December 1996, under which Bangladesh is ensured a fair share of the flow reaching the dam during the dry season.

The Indus Water Treaty (1960) between India and Pakistan, described earlier, helped to resolve the issues between these two countries; although during the last few years Pakistan has objected to India's development of hydropower projects on the western rivers, Chenab and Jhelum.

Similar arrangements exist between Nepal and India for the exploitation of the Kosi river (1954, 1966) and the Gandak river (1959).

Water use

It is estimated that in 2010 total water withdrawal was 761 km^3 of which 91 percent, or 688 km^3, are for irrigation. About 56 km^3 are for municipal and 17 km^3 for industrial use(Figure 1).

In 2010, primary surface water withdrawal accounted for 396 km^3, primary groundwater withdrawal accounted for 251 km^3, and reused agricultural drainage water accounted for 113 km^3. In 1996, some 550 000 m^3 of seawater were desalinated (Table 2 and Figure 2).

FIGURE 1
Water withdrawal by sector
Total 761 km^3 in 2010

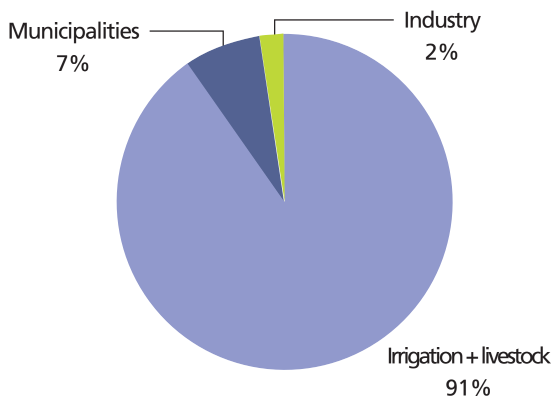
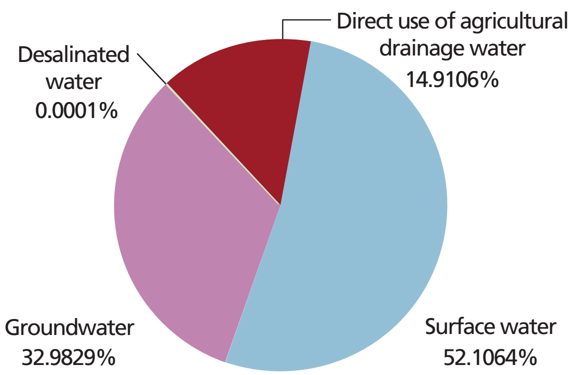


FIGURE 2
Water withdrawal by source
Total 761 km^3 in 2010



In 1990, total water withdrawal was an estimated 500 km^3, of which 92 percent was for irrigation. Primary surface water withdrawal was 362 km^3, while the amount coming from primary groundwater was an estimated 190 km^3.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The history of irrigation development in India can be traced back to prehistoric times. Ancient Indian scriptures referred to construction of wells, canals, tanks and dams and their efficient operation and maintenance. Irrigation to produce food grains is known to have been in existence for over 5 000 years (Framji, 1987). There is evidence of irrigation being practised since the establishment of settled agriculture during the Indus Valley Civilization (in 2500 Before the Common Era [BCE]). These irrigation technologies were in the form of small and minor works. Traces of irrigation structures dating back 3 700 years have been found in the state of Maharashtra. During the Mauryan era (2 600-2 200 years ago), it is reported that farmers had to pay taxes for irrigation water from neighbouring rivers.

The Grand Anicut (Canal) across the Cauvery river in Tamil Nadu was begun 1 800 years ago and its basic design is still used today. In 1800, some 800 000 ha were irrigated in India. Major irrigation canals were built following the major famines at the end of the nineteenth century and, in 1900, the Indian peninsula (including Bangladesh and Pakistan) had some 13 million ha under irrigation. In 1947, India had about 22 million ha under irrigation. High priority has been given to irrigation with nearly 10 percent of all planned outlays since 1950 being invested in irrigated agriculture. This has resulted in the development of, on average, 0.6-0.7 million ha new irrigated schemes every year.

The emphasis on irrigation development was initially on run-of-the-river schemes. Subsequently, the need was felt for storage projects for either single or multiple purposes. Irrigation schemes are grouped under three categories: major (>10 000 ha), medium (2 000-10 000 ha) and minor (<2 000 ha) schemes. Minor irrigation projects generally have both surface water and groundwater as sources, while major and medium projects exploit surface water resources. In 1993 around 65 percent were minor schemes. In new major irrigation works, social and environmental costs (resettlement of displaced people, loss of biodiversity in submerged areas, etc.) are more systematically considered than in the past.

While in 1993 the ultimate irrigation potential of India was an estimated 113.5 million ha, new estimates give a figure of 139.5 million ha, of which 58.1 million ha for major and medium irrigation schemes and 81.4 million ha for minor irrigation projects. Of the 81.4 million ha of minor irrigation potential, groundwater based potential is estimated to be 64.1 million ha and the surface water based potential is 17.3 million ha.

Total area equipped for irrigation was around 66.3 million ha in 2008 (Table 4). Irrigation is mainly concentrated in the north of the country along the Indus and Ganges rivers: Punjab, Rajasthan, Uttar Pradesh and Madhya Pradesh. A classification of irrigation by origin of water is in common use in India. It differentiates irrigation from canals (29 percent in 2001), most of which are government canals, tanks (4 percent), groundwater wells (63 percent), the majority being privately owned and managed, and other or undefined sources (4 percent) (Figure 3). In 1993 the area equipped for irrigation was about 50.1 million ha of which irrigation by canals accounted for 34 percent (97 percent are government canals), tanks 6.5 percent, groundwater 53 percent (generally privately owned and managed) and other or undefined sources (6.5 percent). This shows that the use of groundwater for irrigation has increased considerably.

Of the 19.75 million minor irrigation schemes, groundwater schemes account for 18.5 million and the rest are based on surface water resources. The surface flow schemes typically comprise tanks and storage developed by construction of check dams. Groundwater schemes are composed of dug wells, dug cum bore wells, borings, and both shallow and deep tubewells. There is considerable variation in the development of minor irrigation from state-to-state. The full potential of minor irrigation has been tapped in Uttar Pradesh, Punjab, Haryana, Rajasthan. In some of the Union Territories it is as low as 18 percent in Manipur and 20 percent in Madhya Pradesh. Minor irrigation schemes are generally in the private sector and very few (6 percent) are owned by public institutions.

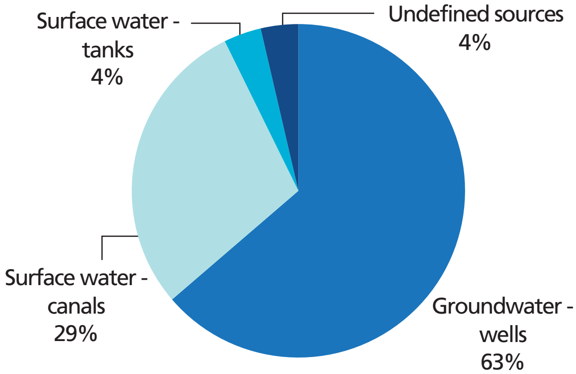
Over the past few decades, the main driving force behind the expansion of groundwater irrigation and improvement in agricultural productivity, was support to investment to provide electrical infrastructure and credit. Private groundwater irrigation, with shallow wells that serve 3-5 ha each, is considered to be the most cost-effective solution. Of the 18.50 million groundwater wells 16.43 million wells are in use (7.85 million dug wells, 8.10 million shallow tubewells and the rest deep tubewells). Development of groundwater resources varies from state-to-state. Groundwater is still available for exploitation in the eastern parts of the country, and in Madhya Pradesh, Chhattisgarh, specific pockets of Andhra Pradesh, Karnataka, Maharastra and Jammu and Kashmir. In Punjab, Haryana, Rajasthan, Gujrat and Tamil Nadu, exploitation exceeds the recharge to groundwater.

TABLE 4
Irrigation and drainage

Irrigation potential			139 500 000	ha
Irrigation				
1. Full control irrigation: equipped area		2008	66 334 000	ha
- surface irrigation		2004	61 937 988	ha
- sprinkler irrigation		2004	1 445 805	ha
- localized irrigation		2004	578 207	ha
• % of area irrigated from surface water		2001	37	%
• % of area irrigated from groundwater		2001	63	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2008	62 286 000	ha
- as % of full control area equipped		2008	94	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		2008	66 334 000	**ha**
• as % of cultivated area		2008	39	%
• % of total area equipped for irrigation actually irrigated		2008	94	%
• average increase per year over the last 7 years		2001-2008	1.0	%
• power irrigated area as % of total area equipped		2001	83	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		2008	66 334 000	**ha**
• as % of cultivated area		2008	39	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 2 000 ha	1993	33 017 000	ha
Medium-scale schemes	included in large	1993		ha
Large-scale schemes	> 10 000 ha	1993	17 084 000	ha
Total number of households in irrigation		-	-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2004	76 820 000	ha
• Annual crops: total				ha
- Rice		2004	22 428 000	ha
- Maize		2004	1 411 000	ha
- Barley		2004	472 000	ha
- Wheat		2004	23 498 000	ha
- Sorghum		2004	699 000	ha
- Cereals not specified		2004	801 000	ha
- Pulses		2004	3 326 000	ha
- Cotton		2004	2 591 000	ha
- Groundnuts		2004	1 052 000	ha
- Sugarcane		2004	4 043 000	ha
- Tobacco		2004	215 000	ha
• Permanent crops:				ha
- Oil Palm		2004	5 442 000	ha
• Annual or permanent crops:				ha
- Fruits and vegetables		2004	4 590 000	ha
- Condiments and spices		2004	1 852 000	ha
- Other crops		2004	4 400 000	ha
Irrigated cropping intensity (on area actually irrigated)		2004	130	%
Drainage - Environment				
Total drained area		1991	5 800 000	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		1991	3.4	%
Flood-protected areas				ha
Area salinized by irrigation		1998	3 300 000	ha
Population affected by water-related diseases		1998	44 000 000	inhabitants

In many states, especially in the north (Uttar Pradesh, Punjab and Haryana), the conjunctive use of surface water and groundwater has been practiced using canal systems and tubewells or dug wells to increase the yield and general efficiency of the water system. Water from the tubewells, which are installed alongside existing canals, is added into the canals for use in the canal command areas. This practice helps prevent waterlogging, but requires that farmers adopt good management techniques.

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 61 907 846 ha in 2001

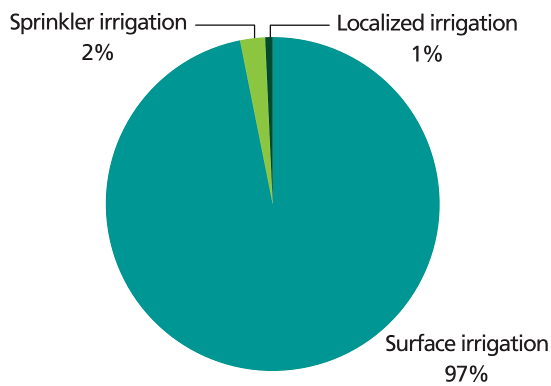


The irrigation component of the Bharat Nirman Programme of the Government of India, a business plan for rural infrastructure, started in 2005, envisages the development of an additional irrigation area of 10 million ha through various irrigation schemes. Currently, 166 major, 222 medium and 89 environmental resources management (ERM) projects are reported to be ongoing in various states. The Government of India provides support to State Governments through the Accelerated Irrigation Benefits Program (AIBP) and other schemes.

In recent years, the development of sprinkler and localized irrigation has been considerable, mainly the result of the pressing demand for water from other sectors, a fact that has encouraged governments and farmers to find water-saving techniques for agriculture. Sprinkler irrigation was not widely used in India before the 1980s; however between 1985 and 1996 more than 200 000 sprinkler sets were sold. In 2004 the area under sprinkler irrigation was an estimated 1.4 million ha, while in 1996 it was about 0.7 million ha.

Localized irrigation is also expanding rapidly in India. This can be partly explained by the subsidies offered by the Government to adopt drip systems. From about 1 000 ha in 1985, the area under drip irrigation increased to 70 860 ha in 1991, mainly in Maharashtra, Andhra Pradesh and Karnataka. In 2004 the area under localized irrigation was about 578 207 ha (Figure 4). Drip-irrigated crops are mainly used in orchards, mainly grapes, bananas, pomegranates and mangoes. Localized irrigation is also used for sugarcane and coconut. In 2004 surface irrigation covered approximately 61.9 million ha. The approximate capital cost of sprinkler systems (excluding pump cost) ranges from US$345-450/ha. The approximate cost of localized irrigation is US$1 780-6 240/ha.

FIGURE 4
Irrigation techniques on area equipped for full control irrigation
Total 63 962 000 ha in 2004

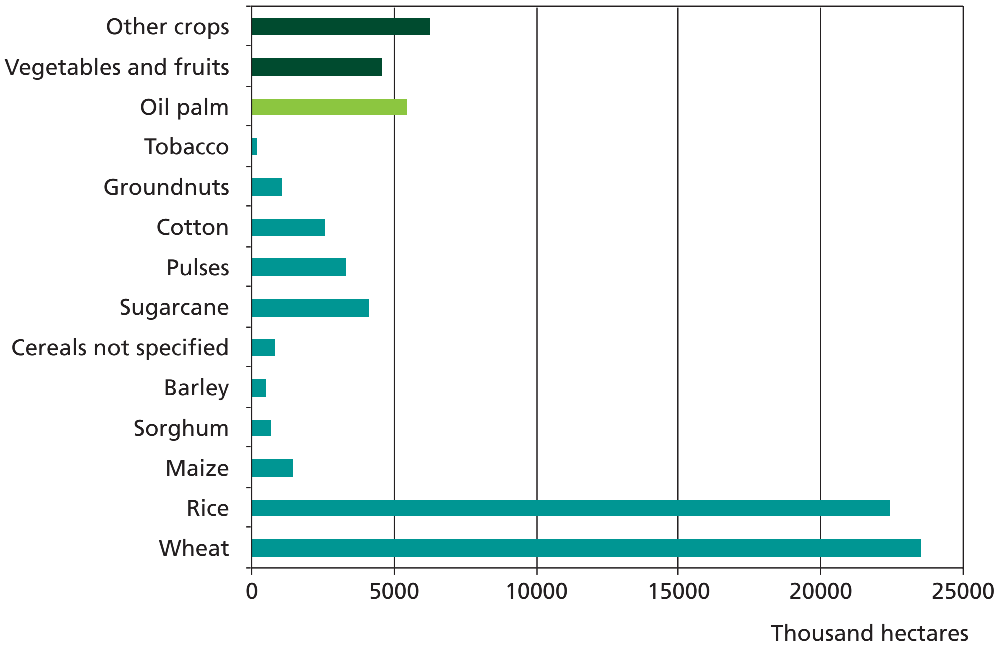


Water-harvesting systems, comprising tanks and other water conservation works, are devised to capture, store and distribute water for irrigation, besides meeting the municipal needs of the population. According to the third minor irrigation census carried out in 2001 the number of tanks, storage and other water conservation works is 0.457 million.

FIGURE 5

Irrigated crops on area equipped for full control irrigation

Total harvested area 76 820 000 ha in 2004 (cropping intensity on actually irrigated area: 130%)



Role of irrigation in agricultural production, economy and society

Irrigation development has enabled diversification of cropping patterns with crops grown all year round. The expansion of irrigation has not only directly enabled yield increases, it has also facilitated high input, high-yielding agriculture involving the use of chemical fertilizers and high-yielding varieties of wheat rice and maize. The food grain production has increased from about 50 million tonnes in 1951 to 213 million tonnes in 2004. Although irrigated crop yields have increased considerably, they are still low compared to those of other countries. This is mainly because of poor water management in many surface irrigation schemes.

In 2004, the harvested irrigated crop area covered around 76.8 million ha, of which 31 percent wheat, 29 percent rice, 2 percent maize, 7 percent oil palm, 6 percent vegetables and fruits and 5 percent sugarcane (Table 4 and Figure 5). In 1993, the total harvested area was an estimated 66.1 million ha.

Status and evolution of drainage systems

In 1991, drainage works had been undertaken on about 5.8 million ha, which was 12 percent of the irrigated area. Investment in drainage has been widely neglected and, where such investment has been made, poor maintenance has caused many drainage systems to become silted up. On the eastern Ganges plain, investment in surface drainage would probably have a larger productive impact, and at a lower cost, than investment in surface irrigation. In 2010, only some irrigation systems, predominantly of south and western India, have well laid out drainage systems.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

Under the Indian Constitution, the states are responsible for water. Thus the federal states are primarily responsible for the planning, implementation, funding and management of water resources development. The responsibility in each state is borne by the Irrigation and Water Supply Department. The Inter-State Water Disputes Act of 1956 provides a framework for the resolution of possible conflicts.

At central level, which is responsible for water management in the union territories and in charge of developing guidelines and policy for all the states, three main institutions are involved in water resources management:

- The Ministry of Water Resources (MWR) is responsible for laying down policy guidelines and programmes for the development and regulation of the country's water resources. The ministry's technical arm, the Central Water Commission (CWC), provides general infrastructural, technical and research support for water resources development at state level. The CWC is also responsible for the assessment of water resources.
- The Planning Commission is responsible for the allocation of financial resources required for various programmes and schemes of water resources development to the states as well as to the MWR. It is also actively involved in policy formulation related to water resources development at the national level.
- The Ministry of Agriculture promotes irrigated agriculture through its Department of Agriculture and Cooperation.

Further, the Indian National Committee of Irrigation and Drainage (INCID) coordinates with the International Commission on Irrigation and Drainage (ICID) and promotes research in the relevant areas. The Central Pollution Control Board (CPCB) is in charge of water quality monitoring, and the preparation and implementation of action plans to solve pollution problems.

In 1996, the Central Groundwater Authority was established to regulate and control groundwater development to preserve and protect the resource.

Water management

Water resources planning and management should be seen in a context of food grain availability. From the mid-1960s onwards, food grain production increased in the 1950s and 1960s as a result of increases in the cultivated area, expansion in irrigated area and the use of high-yielding varieties (HYVs). Irrigation also helped reduce inter-annual fluctuations in agricultural output and India's vulnerability to drought. One of the goals of Indian policy is to find ways to maintain the level of food grain availability per inhabitant in a context of population increase. Total water demand is expected to equal water availability by 2025, but industrial and municipal water demand are expected to rise drastically at the expense of the agricultural sector, which will have to produce more with less water.

The centrally sponsored Command Area Development (CAD) Programme was launched in 1974-1975. The main objectives of the programme are to improve use of the area equipped for irrigation and optimize agricultural production and productivity from irrigated agriculture. The Programme involves the implementation of on-farm development works such as construction of field channels and field drains, reclamation of waterlogged areas, renovation and rehabilitation of minor irrigation tanks, correction of irrigation water distribution system deficiencies.

The programme also involves ‘software’ activities such as adaptive trials, demonstrations, training of farmers, evaluation studies, etc. One component of the programme is *Warabandi*, which is a rotation system for the distribution of irrigation water to ensure equitable and timely supply of water to all farm holdings in the command. An amount of Rs 35 280 million has been released to the states as central assistance under the programme from inception until the end of March 2008. Since the programme’s inception, and up to the end of March 2007, 18.07 million ha had been covered. The CAD Programme was restructured in April 2004, the and renamed as the ‘Command Area Development and Water Management (CADWM)’ Programme.

The main systems of irrigation water management (distribution) schemes practised are:

- The *warabandi* system in semi-arid and arid northwest India, where irrigation water is strictly rationed in proportion to farm area and supplied on a predetermined rotational schedule. The distribution system is equipped with field channels and watercourses. Primarily designed to adapt to shortage in water supplies, farmers decide on crops according to the expected water supply.
- The *shejpali* system of western and parts of central and southern India, where farmers obtain official sanction for proposed cropping patterns and are then entitled to irrigation supplies according to crop needs. The distribution system is equipped with field channels and watercourses. These systems were designed when irrigation water was plentiful relative to demand.
- The localization system, in parts of southern India, focusses on locational control of cropping patterns. Low-lying areas are zoned for ‘wet’ crops (primarily rice and sugarcane), while higher areas are limited to ‘irrigated dry’ (ID) crops with restricted water supplies. The distribution system is equipped with watercourses and field channels. Such systems break down as head-end farmers in ID zones take up cultivation of high water requiring crops and draw more water than their allowed allocation quantity.
- The traditional field-to-field irrigation system is used mainly for rice in some areas of eastern India and some parts of south India. Continuous irrigation flows are provided, passing from field-to-field, generally without watercourses or field channels. Operating rules have often evolved and been agreed based on local tradition, and where water is abundant, yields can be good. However, crop choice and cropping patterns are limited.

A broad distinction can be made between supply-based systems (such as *warabandi*) that distribute water according to predetermined procedures and require farmers to respond accordingly for cropping patterns and areas, and demand-based systems (such as *shejpali*) that attempt to meet crop–water needs. In supply-based systems, the role of the irrigation department tends to be simpler than under demand-based systems, which require that the department responds to the changing needs of farmers with more complex and flexible infrastructure and more intensive management. The average overall water-use efficiency in canal irrigation systems is an estimated 38-40 percent.

The National Water Policy 2002 emphasises a participatory approach for water resources management. It has been recognized that participation of beneficiaries will help optimize the upkeep of the irrigation system and promote the efficient use of irrigation water. The participation of farmers in irrigation management is formulated based on the creation of water user associations (WUAs), which aim to:

1. promote and secure distribution of water among users;
2. ensure adequate maintenance of the irrigation systems;
3. improve efficiency and economic use of water;
4. optimize agricultural production;
5. protect the environment; and

6. ensure ecological balance by involving the farmers and inculcating a sense of ownership of the irrigation systems in accordance with the water budget and operational plan.

The WUAs are formed and work guided by the executive instructions and guidelines laid down by each state government. There is no central legislation or legal instrument in this regard. However, Andhra Pradesh is the only state that has passed legislation exclusively covering farmer participation in the management of irrigation systems. A total of 55 500 WUAs were constituted in India covering 10.23 million ha.

The National Groundwater Recharge Master Plan (NGRMP) provides a nationwide assessment of the groundwater recharge potential and outlines the guiding principles for an artificial groundwater recharge programme. The plan estimates that by using dedicated recharge structures in rural areas and rooftop water harvesting structures in urban areas a total of 36 km^3 can be added to groundwater recharge annually. The master plan follows two criteria for identifying recharge: availability of surplus water and availability of storage space in aquifers. Investments in the programme would, therefore, be driven by the potential available for groundwater recharge, and not by the need for recharge. Thus, the three states of Andhra Pradesh, Rajasthan, and Tamil Nadu, which together account for over half of India's threatened groundwater blocks, receive only 21 percent of funds, whereas the states of the Ganges-Brahmaputra basin, which face no groundwater over development problems, receive 43 percent of the funds. If implemented successfully, this recharge programme will be able to add a significant quantity of water to India's groundwater storage, but it will not provide much help in the areas that are most in need of help.

Finances

Currently, there is no uniform set of principles to fix the water rates. The water charges vary from state-to-state, project-to-project and crop-to-crop. The rates vary widely for the same crop in the same state depending on irrigation season, type of system, etc.

Water rates, being abysmally low, do not generate sufficient funds for the proper maintenance of irrigation systems, leading to poor quality of service. The state governments need to evolve a policy for periodical rationalization and revision of water rates, so that the revenue generated by the irrigation sector is able to meet the cost of O&M. However, in view of unreliable and poor quality of services, farmers are reluctant to pay increased water charges. They may not be averse to paying increased water charges if the quality of services is first improved.

It is imperative that the tariff structure is reviewed, and revised with simultaneous improvement in the quality of services provided, to restore efficiencies. Rationalization of water rates will also act as a deterrent to excessive and wasteful use of water. Shifting towards fixing the water rates based volume is desirable. This will encourage farmers to avoid over-irrigation and wasteful use of water, thereby increasing water-use efficiencies. A uniform formula of water pricing for the entire country would have no practical value. A recommendation may be considered of setting up an independent State Regulatory Authority to rationalize water rates in each state.

Policies and legislation

India adopted a National Water Policy in 1987, which was revised in 2002, for the planning and development of water resources to be governed at the national level. It emphasizes the need for river basin based planning of water use. Water allocation priority has been given to drinking water, followed by irrigation, hydropower, navigation and industrial or other uses. As water resources development is a state responsibility, all the states are required to develop their state water policy within the framework of the national water policy and, accordingly, set up a master plan for water resources development.

ENVIRONMENT AND HEALTH

Water quality is a major issue in India. Although in their upper reaches most rivers are of good quality, the importance of water use for cities, agriculture and industries, and the lack of wastewater treatment plants in the middle and lower reaches of most rivers cause a major degradation of surface water quality. Groundwater is also affected by municipal, industrial and agricultural pollutants. The over exploitation of groundwater can also lead to seawater intrusion. For example, there is an inland advance of the saline-freshwater interface in the Chingelput district of Tamil Nadu, where a well field along the Korttalaiyar River supplies water to the city of Madras.

In 1992, the Central Pollution Control Board completed water quality studies in all major river basins. The pollution control action plan of the Ganges River basin was formulated in 1984 and has been enforced by the Ganges Project Directorate, under the Central Ganges Authority, to oversee pollution control and the consequent cleaning of the Ganges River. The water quality in the middle stretch of the Ganges River, which had deteriorated to class C and D (the worst class is E, the best A), was restored to class B in 1990 after the implementation of the action plan. Similar programmes for other rivers have been developed, as well as a national river action plan to clean the heavily polluted stretches of the major rivers.

According to the National Commission on Floods, the area subject to flooding is an estimated 40 million ha (about 12 percent of the area of the country). About 80 percent of this area, or 32 million ha, could be provided with reasonable protection. Bihar is the worst flood hit state. Hardly a year passes without severe flood damages. With the onset of the monsoon, rivers come down from the Himalayan hills in Nepal with enormous force, leading the following rivers the Ghagra, Kamla, Kosi, Bagmati, Gandak, Ganges, Falgu, Karmnasa, Mahanadi to rise above the danger level. This results in severe floods in North Bihar.The Kosi River, popularly known as "the sorrow of Bihar", has not yet matured enough to settle on a course, and has changed its course 15-16 times, the last time as recently as August 2008. About 2.8 million people were said to have been marooned by these floods in Bihar.

The total area subject to waterlogging was an estimated 8.5 million ha in 1985, including both rainfed and irrigated areas. This is thought to be a substantial underestimate as precise data are lacking. It is estimated that about 24 percent irrigated command areas of major and medium irrigation projects is subject to waterlogging. Measures to counter waterlogging and salinity are being taken by constructing field channels and drains, and by encouraging the combined use of surface water and groundwater. Furthermore, it is estimated that out of the total irrigated area about 3.3 million ha are affected by salinity.

Water-borne diseases have continued to increase over the years in spite of government efforts to combat them. States such as Punjab, Haryana, Andhra Pradesh and Uttar Pradesh are endemic for malaria as a result of the high water table, waterlogging and seepage in the canal catchment area. There are also numerous cases of filariasis. In 1998 the population affected by water-related diseases was 44 million inhabitants.

Climate change may alter the distribution and quality of India's water resources. Some of the impacts include occurrence of more intense rains, changed spatial and temporal distribution of rainfall, higher runoff generation, low groundwater recharge, melting of glaciers, changes in evaporative demands and water use patterns in agricultural, domestic and industrial sectors, etc. These impacts lead to severe influences on the agricultural production and food security, ecology, biodiversity, river flows, floods, and droughts, water security, human and animal health and sea level rise.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Water resource availability is replete with severe uncertainties. Frequent severe droughts and floods are not uncommon. There is a need to produce as much as 325-350 million tonnes of food grains by 2025 to meet the food, feed, fodder and fibre requirements of India. To meet this estimate of food grain requirement it is assumed that the overall irrigation efficiencies will be 50 percent for surface water systems and 72 percent for groundwater systems, compared to the present level of 35-40 percent, and that the national average food grain production yields are expected to increase to 3.5 tonnes/ha for irrigated areas and 1.25 tonnes/ha for rainfed areas, compared to the present levels of 2 tonnes/ha in irrigated areas and 1 tonne/ha in rainfed areas. In the wake of the development of large-scale irrigation facilities, there were several serious problems related to the degradation of soil, water, and environment, which threatened the sustainability of agricultural production. These include:

- Ø land availability for agriculture is extremely limited;
- Ø a total of 8.53 million ha is subject to waterlogging;
- Ø land degradation of over 22.5 million ha is caused by floods, water and wind erosion;
- Ø the per capita availability of water resource is expected to reduce to 1 335 m^3/year by 2025;
- Ø no irrigation development has taken place in the Brahmaputra basin, which has 60 percent of India's water resources;
- Ø agriculture in India will face stiff competition for water from other sectors. By 2025, agricultural water withdrawal is expected to fall to 70 percent of total withdrawal, against 90 percent at present;
- Ø irrigation tanks have been neglected and most have become non-operational; and
- Ø continued extensive pollution of water bodies, both from point and non-point sources, has deteriorated the quality of available water resources, further depleting usable water

The important issues that need to be addressed immediately, to overcome these constraints, and to achieve sustainable development and use of water resources to ensure the targeted food grain production of 325-350 million tonnes by 2025 the include:

- considering precipitation as the primary renewable water resource;
- undertaking effective steps for the speedy completion of ongoing major and medium irrigation projects where large investments have already been made without appreciable physical achievement. Rehabilitation and modernization of old irrigation works is of utmost priority;
- reorienting irrigated agriculture to produce more with less water;
- providing incentives to farmers that adopt water-saving devices and scientific irrigation scheduling;
- combatting waterlogging and salinity build up in irrigation command areas;
- combatting unsustainable use of groundwater;
- inducing scientific management of water resources in drought prone areas;
- directing all efforts towards ensuring access to safe drinking water for all;
- pricing irrigation water in a way that will cover at least the O&M charges of providing the service. The water rates shall be linked directly to the quality of service provided;
- increasing participatory irrigation management and transfer of the management of water distribution system to stakeholders, spreading water use literacy among stakeholders through training programmes, and providing water at cheaper bulk rates to WUAs;

- ensuring environmental protection of water resources by meeting environmental flow requirements, environmental management of river systems, and prevention of pollution to groundwater bodies and conservation of wetlands.

To intensify research and development (R&D) efforts to seek ways to improve water-use efficiency, both location specific field studies and analytical studies should be implemented to develop systematic decision support systems for planning and implementing real time operations in the irrigation systems. These measures would allow growing multiple crops under limited water supply, using modern tools such as medium range weather forecasts, and modern irrigation methods.

Efficient water management in agriculture could fulfil the future food needs of India because of several comparative advantages. The most common strengths and opportunities for increasing food grain production, through improved water management include:

- high average annual rainfall as compared to many other countries;
- irrigation infrastructure is the largest in the world;
- total cropped area is the second largest in the world;
- widely varied climatic zones –from temperate regions suitable for horticultural crops, flowers, to tropical regions suitable for cereals, oilseeds and pulses, with ample sunshine for over 11 months of the year;
- vast alluvial tracts of the entire Gangetic plains, the fertile deltaic regions of major rivers such as the Mahanadi, Godavari, Krishna, and Kaveri, which are endowed with rich water resources, possess excellent potential for food production;
- India has the world's third largest fertilizer industry;
- the large National Agricultural Research System (NARS) comprises 87 national institutes and research centres, 81 all-India coordinated research projects and 29 agricultural universities; and
- there is ample scope for realizing the full yield potentials for most crops.

Uncommon opportunities, which are high technology innovations that are likely to be developed in the future are:

- membrane technology for wastewater treatment and desalinization at low cost, thus increasing water availability to agriculture;
- biotechnology: low water requiring crops, high yielding plant varieties that are most environmental friendly, plants that are salt tolerant or drought tolerant, plants with pest resistance (reduces pesticide pollution), hyper toxin accumulating plants to remove soil toxins;
- microbial technologies for wastewater treatment for agricultural reuse;
- increase in yields of rainfed agriculture; and
- separating heavy metals and other toxins from soil and water.

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Indonesia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Indonesia is a tropical archipelago composed of 17 504 islands. It extends over about 1.9 million km^2 and the coastline exceeds 54 000 km, which is more than the circumference of the globe making it the country with the second longest coastline after Canada. The major islands are Sumatra, Java, Nusa Tenggara (including Bali), Kalimantan, Sulawesi, Maluku, and Papua (previously Irian Jaya). Most of the major islands have a mountain range running their entire length. The mountains are of volcanic origin and some are still active. The elevations on the islands range from 0 to 5 030 m above sea level. Since 2005 the country has been divided administratively into 33 provinces. In 2006, the provinces were subdivided into 349 regencies (*kabupaten*) and 91 cities (*kota*), 5 656 subdistricts (*kecamatan*), and 71 563 villages (*desa/kelurahan*). Jakarta is the capital city of the country, located on the island of Java.

The total cultivated area in 2009 was 42.6 million ha, which is around 22 percent of the total area of the country. Arable land was an estimated 23.6 million ha and the area under permanent crops 19.0 million ha (Table 1). Farm holdings in Indonesia are relatively small: 34 percent are less than 0.25 ha and a further 25 percent are between 0.25 and 0.50 ha.

Climate

Indonesia is located in a wet tropical region with an average annual rainfall of about 2 700 mm, varying from 1 300 mm in East Nusa Tenggara to 4 300 mm in parts of Papua (Table 2) (Bappenas, 2004).

There are two seasons: the dry and the wet. The dry season is influenced by the Australia continental air masses and lasts from March to August. The wet season is influenced by the Asia Continental and Pacific air masses passing over the oceans and lasts from September to March. The heaviest rainfall is usually from November to February.

Temperatures range from 21 °C to 33 °C, but at higher altitudes the climate is cooler. Humidity is between 60 and 80 percent.

Population

In 2009, the total population was almost 237 million, of which 56 percent was rural (Table 1). There are four people in an average household. Population growth rate decreased sharply, from 2.1 percent per year during the period 1979-1989 to 1.2 percent per year from 1999 to 2009. Over time, Indonesia's population has been concentrated on Java Island, which contains 59 percent of the total population, while its land area is only 7 percent of the total land area of the country. Therefore, population density in Java was 1 019 people/km2 in 2009, while population density at the national level was 125 inhabitants per km^2.

In 2006, 80 percent had access to improved drinking water sources (89 and 71 percent for urban and rural population respectively) and sanitation coverage reached 52 percent (67 and

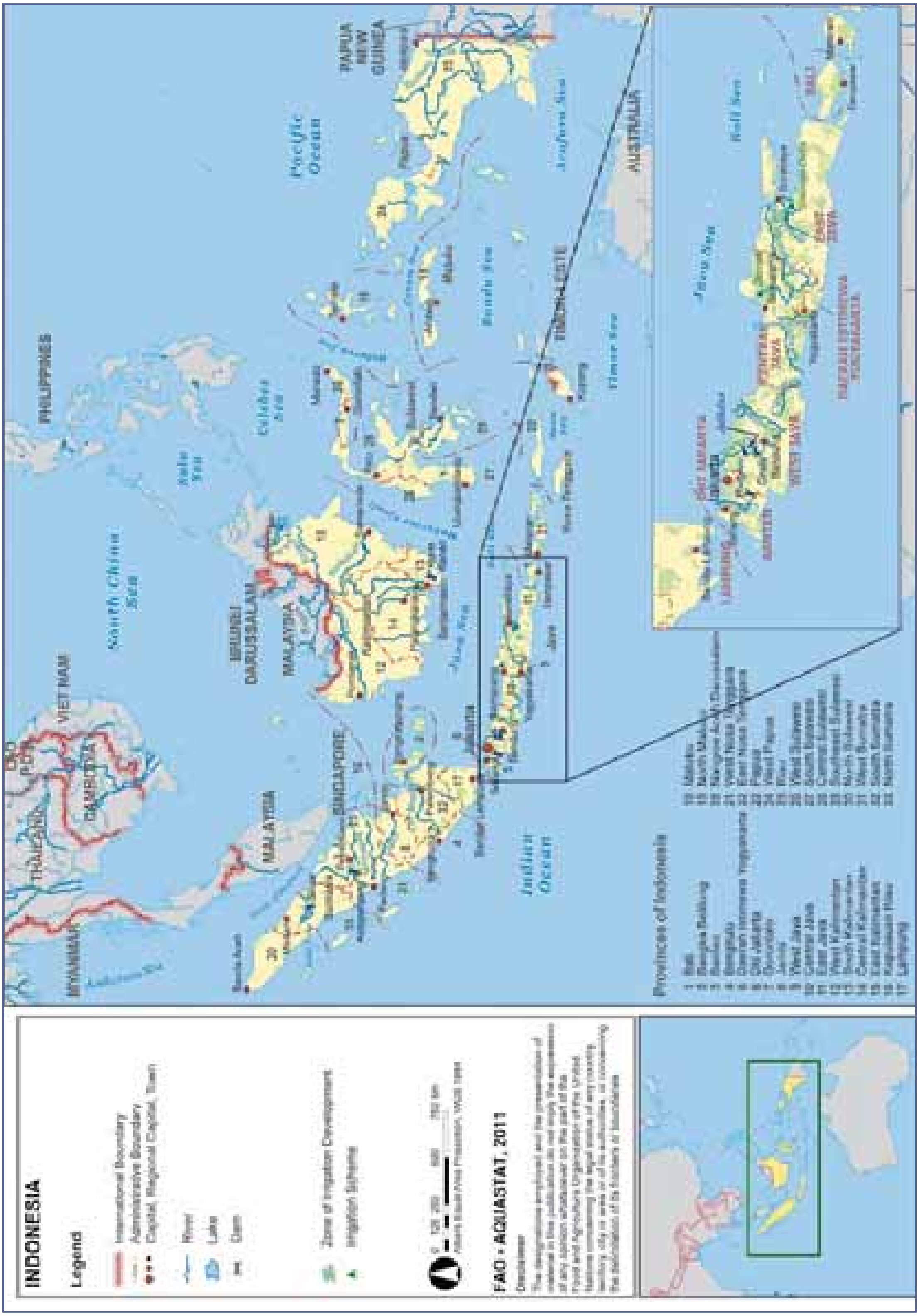

INDONESIA
Legend
FAO - AQUASTAT, 2011
Provinces of Indonesia
PHILIPPINES
VIET NAM
CAMBODIA
THAILAND
MYANMAR
MALAYSIA
SINGAPORE
BRUNEI DARUSSALAM
PAPUA NEW GUINEA
AUSTRALIA
TIMOR-LESTE
South China Sea
Pacific Ocean
Indian Ocean

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	190 457 000	ha
Cultivated area (arable land and area under permanent crops)	2009	42 600 000	ha
• as % of the total area of the country	2009	22	%
• arable land (annual crops + temp fallow + temp meadows)	2009	23 600 000	ha
• area under permanent crops	2009	19 000 000	ha
Population			
Total population	2009	237 414 000	inhabitants
• of which rural	2009	56	%
Population density	2009	125	inhabitants/km^2
Economically active population	2009	117 635 000	inhabitants
• as % of total population	2009	50	%
• female	2009	37	%
• male	2009	63	%
Population economically active in agriculture	2009	49 513 000	inhabitants
• as % of total economically active population	2009	42	%
• female	2009	39	%
• male	2009	61	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	540 274	million US$/yr
• value added in agriculture (% of GDP)	2009	16	%
• GDP per capita	2009	2 276	US$/yr
Human Development Index (highest = 1)	2010	0.600	
Access to improved drinking water sources			
Total population	2008	80	%
Urban population	2008	89	%
Rural population	2008	71	%

37 percent for urban and rural population respectively). About 60 percent of households have their own toilet facilities. In 2006, there were about 30 million poor, which is equal to 18 percent of the total population. The level of urban poverty (13 percent) is lower than that of rural areas (22 percent).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total economically active population in 2009 was 118 million, of which 37 percent were women. The population that is economically active in agriculture is an estimated 50 million, approximately 42 percent of the economically active population. Of the population economically active in agriculture, 39 percent are women and 61 percent are men. In 2009, the gross domestic product (GDP) was US$540 274 million, with a value added in agriculture that was 16 percent of the GDP (Table 1).

Wetlands play a very important role in food production, including rice and secondary crops (maize, cassava, soybean, sweet potatoes, peanut). Total harvested area of paddy in 2005 was 11.8 million ha, composed of 10.7 million ha wetland rice (91 percent) and 1.1 million ha dryland rice (9 percent). Total paddy production was 54.1 million tonnes, of which 51.3 million tonnes were wetland paddy (95 percent) and 2.8 million tonnes dryland paddy (5 percent).

TABLE 2
Average rainfall and renewable water resources (Source: Adapted from Bakosurtanal, 2001)

Island	Area	Precipitation		Internal renewable surface water and groundwater resources (km^3/year)	
	1000 km^2	mm/year	km^3/year	IRSWR	IRGWR
Sumatra	464	2 600	1 206.4	481.4	85.8
Java	132	2 600	343.2	125.6	25.6
Nusa Tenggara	73	1 500	109.5	37.1	1.5
Kalimantan	572	2 800	1 601.6	594.2	125.1
Sulawesi	168	2 100	352.8	177.1	16.6
Maluku	75	2 200	165.0	63.5	5.9
Papua	421	3 200	1 347.2	493.7	196.9
Total	**1 905**	**2 700**	**5 125.7**	**1 972.6**	**457.4**
Overlap between IRSWR and IRGWR				**411.7**	
Total IRWR				**2 018.3**	

Productivity of dryland (rainfed) rice is just a little bit more than half of the productivity of wetland rice: 2.56 tonnes/ha against 4.78 tonnes/ha.

Though Indonesia produces a large quantity of rice, it is still a rice importer. In the past, it was the largest rice importer, reaching 1.8 million tonnes of rice in 2002. However, in 2006 import rates reduced significantly, to as little as 438 000 tonnes. Besides food crops, Indonesia is also producing a large number of perennial crops, including rubber, coconut, palm oil, coffee, cocoa, and tea, which are currently exported.

In terms of food security, national rice production is relatively safe and stable. In 2000, surprisingly, Indonesia had a rice surplus of more than 2 million tonnes (Suprapto, 2001). This surplus resulted from favourable weather, increased cropping intensity and rice planting area, and from a decline in the national per capita rice consumption. The domestic food availability has fulfilled the needs of the population; the average available calories are 2 200 kcal per capita per day.

WATER RESOURCES AND USE

Water resources

Total internal natural renewable water resources are around 2 018.3 km^3/year (Table 2). Surface water resources are an estimated 1 972.6 km^3/year and groundwater resources 457.4 km^3/year. Most of the groundwater, an estimated 90 percent or 411.7 km^3/year, returns as baseflow to the rivers. It is assumed that only 30 percent of groundwater resources, or 137.2 km^3/year, are consumable, called ‘safe yield’ (Table 3) (Bakosurtanal, 2001). Over-abstraction of groundwater in Jakarta has caused saline groundwater to reach about 10 km inland from the coastline and has led to land subsidence at a rate of 2-34 cm/year in east Jakarta.

TABLE 3
Safe yield of groundwater by Island (Source: Bakosurtanal, 2001)

Island	Groundwater (km^3/year)	
	Potential	Safe Yield
Sumatra	85.8	25.7
Java	25.6	7.7
Bali and Nusa Tenggara	1.5	0.4
Kalimantan	125.1	37.5
Sulawesi	16.6	5.0
Maluku	5.9	1.8
Papua	196.9	59.1
Total	**457.4**	**137.2**

Although water resources are abundant, the seasonal and spatial variation in the rainfall pattern and lack of adequate storage create competition and conflicts among users. Municipal and industrial wastewater is discharged virtually untreated into the waterways causing rapid deterioration in the quality of river water.

Most of the lakes in Indonesia are of volcanic origin. Lake Toba is the largest volcanic lake in the world with an average surface area of 1 100 km^2 and an average volume of 1 258 km^3.

In 2006, total dam capacity reported was 22.49 km^3, but total capacity is higher because the capacity was unknown for some dams. In 1995 total dam capacity was an estimated 15.83 km^3. The dams with a capacity of over 1 km^3 are Jatiluhur (2.89 km^3), Siruar (2.82 km^3), Cirata (2.17 km^3), Pongkor (1.95 km^3), Batu Bokah (1.67 km^3), Kotopanjang (1.55 km^3) and Riam Kanan (1.20 km^3).

By developing large dams, Indonesia has progressively been able to extend its water resources utilization to support 2 200 MW of hydropower generation, representing 20 percent of the national generating capacity.

International water issues

Based on a recent river territory inventory, Indonesia has 14 rivers that exceed state boundaries: five rivers with Malaysia in Kalimantan island (Baram, Lupar, Sebuku, Sembakung, and Serundong), three rivers with Timor Lorosae in Timor island (Loes, Nitibe, and Wini), and six rivers with Papua New Guinea in Papua island (Bewani, Fly, Merauke, Sepik, Tami, and Tari) (Witoelar, undated). There are no records of major issues related to these transboundary rivers.

Water use

In 2000, total water withdrawal was 113 km^3 (Table 4 and Table 5). Water withdrawal for agriculture accounted for 93 km^3, or 82 percent, municipalities and industries accounted for

TABLE 4
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	2 702	mm/yr
	-	5 146 500	million m^3/yr
Internal renewable water resources (long-term average)	-	2 018 000	million m^3/yr
Total actual renewable water resources	-	2 018 000	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	8 500	m^3/yr
Total dam capacity	2006	22 492	million m^3
Water withdrawal			
Total water withdrawal	2000	113 290	million m^3/yr
- irrigation + livestock	2000	92 763	million m^3/yr
- municipalities	2000	13 129	million m^3/yr
- industry	2000	7 398	million m^3/yr
• per inhabitant	2000	531	m^3/yr
Surface water and groundwater withdrawal	2000	113 271	million m^3/yr
• as % of total actual renewable water resources	2000	5.6	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced	1990	19	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

TABLE 5
Total water withdrawal by Island in 2000 (km^3/year)

Island	Municipalities	Irrigation	Industry	Total
Sumatera	2.6	14.6	2.6	19.8
Java	7.9	54.1	2.9	64.9
Bali and Nusa Tenggara	0.3	5.5	0.8	6.6
Kalimantan	1.0	3.4	0.7	5.1
Sulawesi	0.9	15.0	0.4	16.3
Maluku	0.1	0.1	0.0	0.2
Papua	0.3	0.1	0.0	0.4
Total	**13.1**	**92.8**	**7.4**	**113.3**
Percentage of total	**12**	**82**	**6**	**100**

FIGURE 1
Water withdrawal by sector
Total 113.29 km^3 in 2000

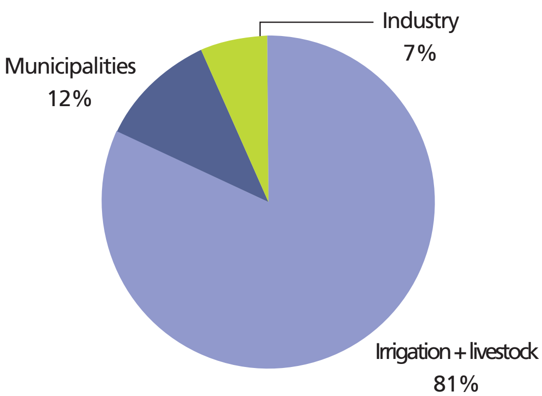
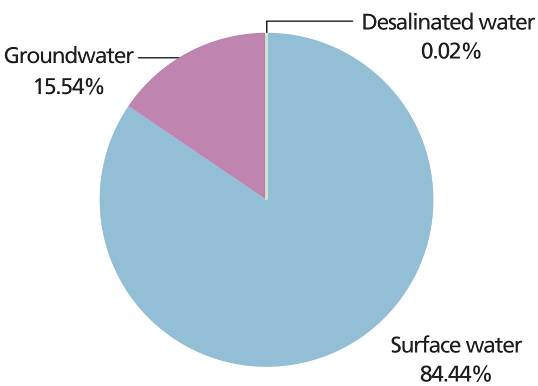


FIGURE 2
Water withdrawal by source
Total 113.29 km^3 in 2000



13 km^3 (12 percent) and 7 km^3 (6 percent) respectively (Figure 1). In 1990, total water withdrawal was about 74 km^3, of which 93 percent for agriculture, 6 percent for municipalities and 1 percent for industrial use.

In 2000 surface water and groundwater withdrawal was 84.4 percent and 15.5 percent respectively of total water withdrawal (Figure 2). In 1990 desalinated water was an estimated 19 million m^3.

Groundwater is used by 74 percent of households for their clean water sources, while the rest use river water (3.4 percent), piped surface water (21.2 percent), and other water sources (1.4 percent).

Industrial water demand has gradually increased over time. Since piped and open surface water supplies are relatively limited, where the industries are located, most use groundwater for their water source, particularly in the large cities of Java.

Both national and island-by-island water balances are positive, meaning that water availability is higher than consumption level. However, in Java and Nusa Tenggara a water deficit occurs during the dry season (July to October, varying by the province). Even some significantly large river areas in Java, including Bengawan Solo, Brantas, Ciliwung, Cimanuk, Citanduy, and Ciujung, are estimated to face water deficit problems during the dry season.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The development of community irrigation systems started more than two thousand years ago. Modern irrigation systems were introduced in the middle of the nineteenth century. Small irrigation systems developed by the communities in Java covered a total of 1.1 million ha in 1880. This asset was very significant at that time since the total population of Java was only 19.5 million. The development of irrigation systems grew at a rate of 1.21 percent per year in the period 1880-1915, covering 1.62 million ha in 1915. The Dutch colonial government developed the first large irrigation system, 34 000 ha, in Sidorajo delta in East Java by using the Brantas river water flows.

A full-technological irrigation and drainage system was first developed during the 1880s in Demak, Central Java, on 33 800 ha. This system was developed to address the famine caused by drought and floods in the area. The *Burgerlijke Openbare Werken,* which later became the Department of Public Works, was developed in 1885, among other tasks, it was to develop irrigation systems. The *Departement van Landbouw,* which later became the Department of Agriculture,)was developed in 1905 in Bogor, West Java.

The development of irrigation systems became one of the priorities of the newly created Republic of Indonesia after the Second World War. The first multi-sector project was proposed in 1948 to develop Jatiluhur dam at Citarum river in West Java to allocate water for irrigation, hydropower, and domestic use. In 1969, Indonesia launched its first five-year development programme (Repelita I). Since then, there have been other rice intensification programmes, their main objective is to achieve self-sufficiency in rice. This includes supply of irrigation water, use of high-yield varieties, fertilizers, and pesticides, and is supported by agricultural extension programmes. The irrigation development programme includes rehabilitation of existing irrigation works, expansion of service areas in existing schemes, construction of new irrigation systems, upgrading of the existing irrigation systems, implementation of efficient operation and management programmes, strengthening of water user associations (WUAs), and many other initiatives.

In the first 25 years of development, spanning five Repelitas (1969-1993) termed ‘Pembangunan Jangka Panjang I’ (PJP I) or first phase of long-term development, water resources policies were directed to supporting the development of different sectors with the primary emphasis being on agriculture. About 1.44 million ha were provided with new irrigation systems and 3.36 million ha of existing irrigation systems were either rehabilitated or upgraded through special maintenance.

The second 25-year development period (1994-2019), termed PJP II, started in April 1993 with Repelita VI. The emphasis was on sustainable development and management of water resources. Water resources have been elevated to a full sector level and policies are directed to promoting a more effective and efficient management of water resources in an integrated manner. Greater emphasis is placed on sustaining self-sufficiency in rice and on the operation and maintenance of water resources infrastructure. In addition, the Government is implementing a crash programme in Repelita VI to improve one million ha of village irrigation systems and to develop a 600 000 ha rice estate by swamp reclamation in central Kalimantan.

The irrigation potential of the country is an estimated 10.9 million ha. In 1996, the total area equipped for full control irrigation was 4.43 million ha. In addition, there were 0.70 million ha of ‘simple’ irrigation and 1.96 million ha of village managed schemes. It should be noted, however, that large discrepancies are observed between sources of information, leading to significant uncertainties about the areas under irrigation. It was reported that, in 1995, 638 reservoirs, 10 770 weirs, 1 017 barrages, 1 192 pumping stations and 6 792 intakes were used to supply water to 4 600 000 ha. In 1995, irrigation from groundwater reportedly covered 44 209 ha, of which 36 784 ha were served by 834 deep tubewells, 4 204 ha by 363 intermediate tubewells and 14 807 ha by 471 shallow tubewells. In 2005 it was estimated that 99 percent of the total equipped area was irrigated by surface water and 1 percent by groundwater (Figure 3).

Total water managed area covered 9 855 616 ha in 2005 (Table 6). Full control irrigation areas covered 6 722 299 ha (68 percent), comprising technical, semi-technical, and simple irrigation, while non-equipped cultivated wetlands covered 3 133 317 ha (32 percent), of which 2 088 622 ha were village managed and 1 044 695 cultivated by the state. Of the total equipped area for irrigation 100 percent is irrigated using surface irrigation techniques.

Fields under water management are classed under five types: technical, semi-technical, and simple irrigation, and village-managed wetlands and cultivated swamps (Table 7). Usually the first three types belong to the public works system.

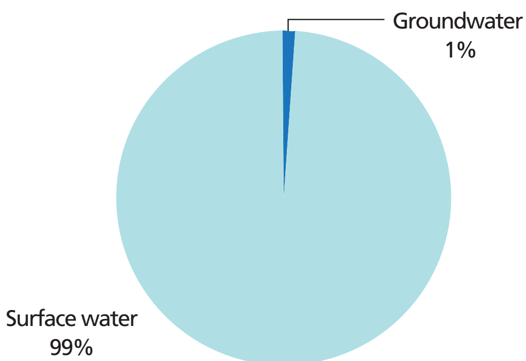
Technical irrigation is an irrigation system in which distribution of water can be fully controlled from the source to the field. It is characterized by permanent canals, control structures, and measuring devices. This irrigation system consists of primary, secondary, and tertiary canals, which are fully controlled by the government. In 2005 they served 4 781 860 ha while in 1996 they served 3 328 016 ha.

Semi-technical irrigation systems are characterized by permanent canals and few control or measuring devices. The government usually controls the primary canals, which are equipped with measuring devices, while the distribution systems next to those canals are not equipped with measuring devices. This system served 1 257 987 ha in 2005 and 1 099 906 ha in 1996.

Simple irrigation systems are characterized by only a few permanent control or distribution structures and may be managed by farmers. The government may provide a part of the system, for example building the required dam. Simple irrigations systems were serving 683 242 ha in 2005 and 697 194 ha in 1996.

Village-managed wetland cultivation is a basic wetland water control system, developed and managed spontaneously by farmers. This system served 2 088 622 ha in 2005 and 1 961 496 ha in 1996.

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 6 722 299 ha in 2005



Cultivated swampland is wetland where its watering mechanisms depend on river water, which is affected by seawater tides. Indonesia has an estimated 39 million ha of coastal and inland swamps. The extent of arable swampland has not been assessed in detail but is estimated to be 7.5 million ha. In 2005, the tidal and non-tidal swamp area mainly used for rice was about 1 044 695 ha and in 1996 1 182 760 ha in 1996.

In 2006, the average cost of developing a public scheme was US$1 630/ha, while the average operation and maintenance cost of a public irrigation system was US$390/ha per year.

TABLE 6
Irrigation and drainage

Irrigation potential			10 886 000	ha
Irrigation				
1. Full control irrigation: equipped area		2005	6 722 299	ha
- surface irrigation		2005	6 722 299	ha
- sprinkler irrigation			-	ha
- localized irrigation			-	ha
• % of area irrigated from surface water		2005	99	%
• % of area irrigated from groundwater		2005	1	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2005**	**6 722 299**	**ha**
• as % of cultivated area		2005	18	%
• % of total area equipped for irrigation actually irrigated		-	-	%
• average increase per year over the last 10 years		1996-2005	4.3	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		2005	3 133 317	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2005**	**9 855 616**	**ha**
• as % of cultivated area		2005	26	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes	> ha and < ha		-	ha
Large-scale schemes	< ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2005	13 388 358	ha
• Annual crops: total		2005	13 388 358	ha
- Rice		2005	10 733 600	ha
- *Rice-one*		2005	4 541 200	ha
- *Rice-two*		2005	3 869 200	ha
- *Rice-three*		2005	2 323 200	ha
- Maize		2005	1 269 100	ha
- Soyabeans		2005	279 900	ha
- Vegetables		2005	244 388	ha
- Tobacco		2005	198 200	ha
- Potatoes		2005	65 420	ha
- Sweet Potatoes		2005	178 300	ha
- Groundnuts		2005	324 000	ha
- Sugarcane		2005	95 450	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on full control irrigation equipped area)		2005	199	%
Drainage - Environment				
Total drained area		1990	3 350 000	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		1999	400 000	ha
Population affected by water-related diseases		2005	5 111 472	inhabitants

TABLE 7
Distribution of water managed areas by types, 2005 (ha)

Irrigation		**6 722 299**
- Technical	4 781 860	
- Semi technical	1 257 197	
- Simple irrigation	683 242	
Cultivated wetland		**3 133 317**
- Village management	2 088 622	
- Cultivated swamps	1 044 695	
Total		**9 855 616**

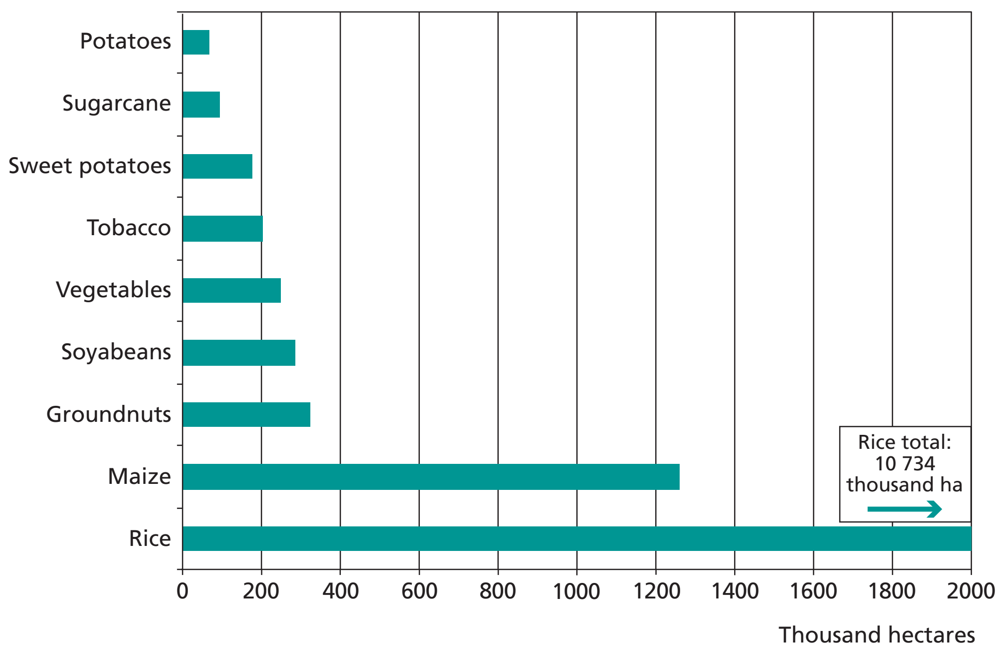
Role of irrigation in agricultural production, economy and society

One of the main objectives of irrigation development in Indonesia is to achieve food self-sufficiency, particularly rice; since 1969 rice cultivation has been expanding. By promoting this kind of rice production, combined with land development, irrigation rehabilitation and crop intensification programmes, the country achieved rice self-sufficiency in 1984. However, because of the rapid rate of fertile agricultural land conversion to non-agricultural use (at an average rate of 50 000 ha/year), a prolonged period of drought and flood, precipitous environmental degradation, reduced subsidies for agricultural inputs and extension activities, rice self-sufficiency became unstable.

Since 1994, Indonesia has been importing rice to meet demand or to maintain a national buffer stock, which is managed by the Bureau of Logistic (BULOG) for market operation, if there is a rice scarcity, especially during the dry season. However, as a result of continuous efforts to increase food production, Indonesia could achieve almost 100 percent of its rice requirements. The import level is significantly lower (about 2 percent of total national rice production) compared to the past records.

Water resources and related infrastructure development have contributed to agricultural, local and national development through their contribution to increasing farmers' average income and consequent alleviating poverty.

FIGURE 4
Irrigated crops on area equipped for full control irrigation
Total harvested area 13 388 358 ha in 2005 (cropping intensity on equipped area: 199% in 2005)



In 2005, the total harvested area of paddy was 11.84 million ha (90.7 percent irrigated and 9.3 percent rainfed) which produced 54.15 tonnes of paddy.

In 2005 the total harvested irrigated cropped area was 13.39 million ha (Table 6 and Figure 4). The major crops cultivated under full control irrigation are paddy, which account for 10.73 million ha, followed by maize, groundnuts and soybeans, which account for 1.3 million ha, 0.32 million ha and 0.28 million ha respectively.

Most irrigated areas are planted with rice twice a year and are left fallow or planted with secondary crops (such as maize or other) in the third season. Typical cropping patterns are rice-rice-fallow or rice-rice-secondary crop. In other areas, particularly those close to irrigation channels, rice can be planted up to three times. In general, rice is always available in the field, but in a smaller area in the third season.

Status and evolution of drainage systems

In 1990 the total drained area was an estimated 3 350 000 ha.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO AGRICULTURAL WATER USE

Institutions

The Constitution of the Republic of Indonesia (Undang-Undang Dasar 1945) Article 33 states that, "production branches which are important to the country and which provide for the needs of the people must be controlled by the State. Earth and water and all natural resources contained in their bodies are managed under authority of the State and utilized in the interests of the welfare of the nation". This enshrines the concept that Indonesia's natural resources belong to the state and are to be used for the welfare of the Indonesian people. Operational policy of this basic rule is explained in Law (Undang-Undang) number 7 of 2004.

This law reiterates the constitutional principle that water resources have a social function: water exploitation should be used for the highest prosperity of the people and should be controlled by the state. This law promulgates the institution of two departments in association with water resources. The Department of Public Works is authorized to coordinate all efforts and activities for the planning, detailed engineering, supervision, business development, maintenance, as well as legislation and utilization of surface water resources, which also includes water springs. The Department of Mining and Energy is authorized to manage groundwater resources, which also includes thermal spring waters. The institutional framework is, in fact, relatively complex, because it involves many agencies and each agency might produce individual regulations (including Government Regulation, Presidential Decrees and Decisions, Ministerial Regulations, Directorate Regulations, Governor and District Regulations) to control water resources (Syaukat, 2000).

Water management

Issues of water resources management, both quantitative and qualitative, are increasingly important on Java and on other islands, including Kalimantan, Sumatra, Sulawesi, Papua, but with different types of problems and hence different approaches to be undertaken. Problems in Java are characterized by overpopulation, as well as water and other natural resources degradation and depletion. The other islands are mainly characterized by water and other natural resources degradation because of widespread deforestation and improper open mining practices and new plantations.

Overexploitation of groundwater has resulted in some critical problems, including contamination by pollutants entering groundwater, salinization of aquifers and land subsidence. Land subsidence is mainly the result of a strong decrease in the levels of deep groundwater in areas with high groundwater extraction. Over-extraction of groundwater results in external costs including those related to the lowering of the shallow groundwater table and the table in deep wells, and costs related to land subsidence and pollution of shallow groundwater (Syaukat, 2000).

These conditions require an improvement in water resources management in Indonesia. There should be an integrated management and treatment of both surface water and groundwater. With this approach, a better water resources planning, development and management could be attained.

Finances

From the end of the 1960s, the government made large investments in land and water resources development to achieve food self-sufficiency. However, as Indonesia gained confidence in securing its national food supply, attention gradually began to include the industrial sector, to support export promotion and import substitution. Therefore, since the beginning of 1990, government investments in land and water resources have gradually decreased. In this period, investments in land and water resources focused on improved operation and maintenance of irrigation infrastructure and facilities.

Funding for the development of this sector came from national budgets and international donors. These includied the International Bank for Reconstruction and Development (IBRD), Japan International Cooperation Agency (JICA), Japan Bank for International Cooperation (JBIC), and the Asian Development Bank (ADB). For example, IBRD financed groundwater development projects in 11 provinces from 1993 to 1999, and integrated tidal swamp development in three provinces from 1994 to 2000. The ADB financed irrigation sector projects in four provinces in Sulawesi from 1994 to 2000. The main objective of all these projects is to increase land productivity and food crop production.

Policies and legislation

During the government period 2004-2009, the following five strategic policies on water resources management were determined:

- Water resource conservation: This policy is designed to conserve and maintain the availability and functions of water resources in order to meet the water needs not only for current generation, but also for the future generations. The efforts are directed towards increasing water availability, to improving water quality, as well as to recovering and improving the capacity of the environment.
- Optimal use of water resources: This policy includes various efforts in the provision, use, development and management of water resources to meet the various water demands: household, agriculture, municipalities, industries, electricity, tourism and environment.
- Control of potential water-destructive capacity: This policy aims to reduce and copw with the potential impacts of flood, drought, erosion and abrasion on the area of agricultural and industrial production, human settlement and other infrastructure. The efforts include preventive measures to protect production and settlement areas, and public infrastructure from floods, to recover environmental conditions, and to improve community alertness on the issues of floods and other potential damage caused by water.
- Empowerment and improvement of community, private and government participation: This policy includes increasing the cooperation and participation of all stakeholders, including government, private sector and community to achieve a productive, effective, efficient and equitable water resources management system, without sacrificing public interests, and to prepare effective and efficient government institutions in association with decentralization, democratization, synergy privatization, and conflict resolution in water resources management.

- Increasing transparency and availability of data and information on water resources management: This policy intends to push democratization in water resource management. Transparency in the processes of water resource management should be improved to provide more access to all stakeholders to participate in the implementation of water resources development programmes.

The laws and regulations concerning water resources and their management are as follows:

- Ø Indonesian Law Number 7, year 2004: water resources laws
- Ø Government Regulation Number 77, year 2001: irrigation
- Ø Government Regulation Number 82, year 2001: water quality management and water pollution control
- Ø Government Regulation on water resource management
- Ø Government Regulation on management of water resources in river system
- Ø Government Regulation on financing water resource development
- Ø Government Regulation on rivers
- Ø Government Regulation on groundwater
- Ø Government Regulation on drinking water
- Ø Government Regulation on Perum Jasa Tirta I
- Ø Government Regulation on Perum Jasa Tirta II
- Ø Presidential Instruction Number 3, year 1999: policy reformation on irrigation management
- Ø Presidential Decree Number 9, year 1999: coordination team on river water use and development policies
- Ø Presidential Decree Number 123, year 2001 (renewed by President Decree Number 83, year 2002): coordination team on water resources management
- Ø Decision of the Coordinator Ministry on Economy, Finance, and Industry
- Ø Decision of the Coordinator Ministry on Economy
- Ø Decision of the Ministry of Settlements and Regional Infrastructures (Dept of Public Works)
- Ø Decision of the Ministry of Internal Affairs
- Ø Decision of the Ministry of Environment
- Ø Provincial Regulations on formation of the agencies for water resources development (8 provinces)
- Ø Provincial Regulations on water pollution control (4 provinces)
- Ø Governor Decisions on development of the Coordination Teams for Provincial Water Resources Management (8 provinces)
- Ø District and Municipality Regulation concerning water resources for domestic, agricultural and industrial use.

ENVIRONMENT AND HEALTH

The strategic geographical location, accompanied by high rainfall, mountainous geography, as well as large forest resources, have led Indonesia to be rich in water resources. However, environmental changes are influencing the water cycle, which causes uneven distribution of water supply. The imbalanced water supply is a serious problem, since it might lead to a number of natural disasters. Flooding occurs during the rainy season, while drought is frequent in the dry season.

Massive deforestation and environmental degradation have been caused by these extreme conditions. Massive deforestation in the upper parts of the watershed has caused the rainfall to runoff more freely, and to concentrate more rapidly into the waterways, thus causing flash floods. Owing to the high level of municipal and industrial waste, many rivers are significantly or seriously polluted. It has not been possible to quantify the costs of pollution to the economy, but major costs have been identified in sickness and the resulting loss of work; pollution is so severe in major cities, such as Jakarta and Surabaya, that industries have been forced to close during dry years because of raw water shortages. Costs have also been accounted by calculating the losses in fisheries and aquaculture, and by the damage suffered by mangroves and fragile coastal areas.

Water pollution poses an immediate threat to human welfare and industrial growth. This problem is exacerbated by water shortage in the dry season, which prevents waste from being flushed away from the inhabited centers. The most excessive pollutant in Indonesian rivers is faecal coliform from human waste. This element exceeds the recommended standards in key cities by a thousand-fold or more. Water-borne diseases such as cholera, dysentery, gastroenteritis, typhoid, paratyphoid, hepatitis A, and parasitic intestinal infection, are transmitted by the ingestion of water contaminated with human feces. The transmission of these diseases is frequently related to lack of available safe water. Improvement of water and sanitation can be expected to reduce diarrheal mortality and morbidity.

The number of people with AIDS and HIV infection is reported to have increased over time. In 2004, the number of people with AIDS was 2 682, of these 700 people have died. This showed that the AIDS rate was about 1.33 cases per 100 000 people. In 2005, there were 5 560 people infected with HIV/AIDS.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Issues of water resources management will be increasingly important in the years ahead, especially in Java, which covers only 7 percent of the total area of the country, but has 59 percent of the population, 70 percent of irrigated agriculture, and 75 percent of the industry. Issues of water quantity include emerging conflicts between competing uses (agricultural, industrial and municipal), and between surface water and groundwater in rapidly growing urban areas. While Java is endowed with rainfall, it is highly seasonal. Dry season flows in the main rivers are only 20 percent of the annual flows. River basins on Java are relatively steep and short, and most of the wet season water runs unused into the sea. Reservoirs hold less than 5 percent of total river flows.

During the wet season, river flows bring high rates of sedimentation resulting from excessive erosion in the upstream part of the basin. This causes very fast sedimentation rates in reservoirs and lakes, making the lifetime of reservoirs shorter than planned, as well as reducing storage capacities. Most of the reservoircapacity of major river basins in Java (Bengawan Solo, Brantas, Citarum, Serayu-Bogowonto) was planned to meet the water demand for various uses up to 2010. While additional sites have been identified for future dams, implementation will be constrained by high population densities and the social and economic costs of resettlement.

Though industrial and municipal water use is still relatively low, it will increase over time. Meeting this demand will require a transfer of water in dry season from agriculture to municipal and industrial use. Minimizing the social and economic costs for farmers and potential disruption to agricultural output will require that water resources will be managed according to the integrated river basin principle. The challenge of meeting the water demand during the dry season is becoming even more complex if the pollution from growing urban and industrial waste is considered.

Based on the above conditions, an integrated action is needed to reverse the present trends of over-consumption, pollution, and increasing threat of drought and floods. To support water resources development and management, the government has proposed an Integrated Water Resources Management Policy framework to support and guide development and conservation effort. The policy is addressing water quantity and quality for both surface water and groundwater in the context of river basins, including the upper parts of the basins and estuarine areas. A specific component of the policy is dealing with environmentally and socially sensitive swampland development issues.

The future of irrigation should be considered as an integral framework to increase human welfare, to provide social justice, and to maintain ecosystem sustainability. Along with overcoming water and land resources problems, some national action should be taken, including: improving agricultural infrastructure, increasing the quality of intensification, improving the institutions, conducting reforestation and re-greening programmes.

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Lao People´s Democratic Republic

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Lao People's Democratic Republic is a landlocked country in the mainland Southeast Asia with a total area of 236 800 km^2. The country is bordered by China to the north, Viet Nam to the east, Cambodia to the south, Thailand to the west and Myanmar to the northwest. The country stretches more than 1 700 km along a north-south axis. Some 80 percent of the country's area is composed of hills and mountains. The highest point is the Phu Bia at 2 820 m above sea level. Administratively, the country is divided into 16 provinces (*khoueng*) which are: Attapu, Bokeo, Bolikhamxai, Champasak, Houaphan, Khammouan, Louangnamtha, Louangphrabang, Oudomxai, Phongsali, Salavan, Savannakhet, Vientiane (Viangchan) province, Xaignabouli, Xekong and Xiangkhoang and one capital city (*nakhon luang*) which is Vientiane (Viangchan).

The cultivable area is an estimated 2 million ha, composed of narrow valleys and the flood-prone plain of the Mekong river and its tributaries. In 2009 the total cultivated area accounted for 1 468 000 ha, around 6 percent of the total area of the country. Arable land was an estimated 1 360 000 ha and the area under permanent crops was 108 000 ha (Table 1).

Climate

The climate is typically tropical with a rainy season from mid-April to mid-October dominated by the humid southwest monsoon. The average annual rainfall is 1 834 mm but ranges from 1 300 mm in the northern valleys to over 3 700 mm at high elevations in the south (Table 2). About 75 percent of the rainfall occurs during the rainy season. The water level in the Mekong river may fluctuate by up to 20 m between wet and dry seasons.

Population

In 2009, the total population was an estimated 6.1 million inhabitants of whom around 68 percent lived in rural areas (Table 1). During the period 1999-2009 the average annual growth rate was 1.6 percent. The average population density is 26 inhabitants/km^2, which is amongst the lowest in the region. The lowest population density is in the southern provinces of Attapu and Xekong near the Vietnamese border and the highest in Savannakhet or Champasack provinces.

In 2008, access to improved drinking water sources reached 57 percent (72 and 51 percent for urban and rural population respectively) and 53 percent had sanitation coverage (86 and 38 percent for urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the gross domestic product (GDP) was about US$5 939 million, with a value added in agriculture in 2008 accounting for 35 percent of the GDP. In 2009, the total economically

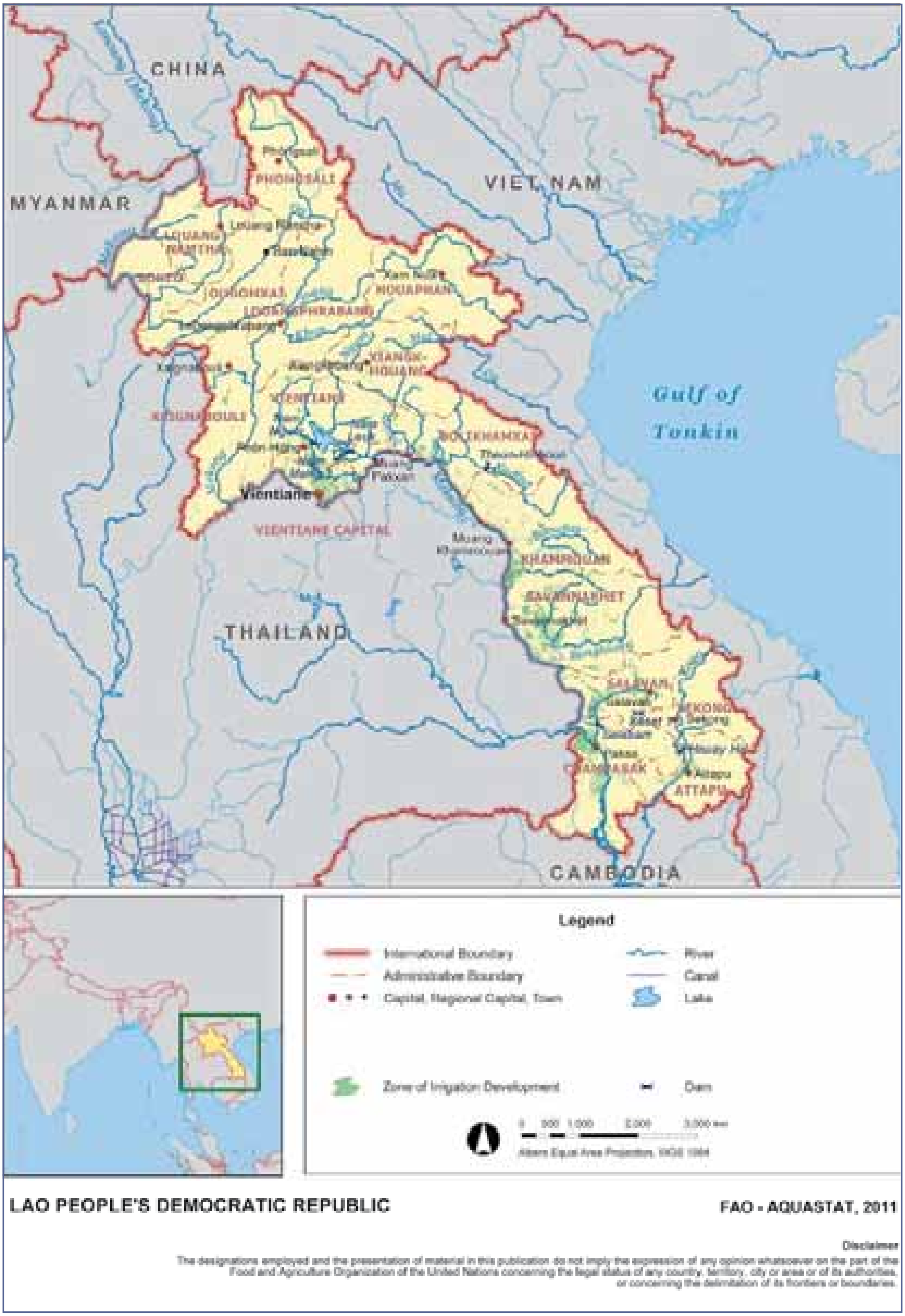
CHINA
MYANMAR
VIET NAM
THAILAND
CAMBODIA
Gulf of
Tonkin
PHONGSALI
HOUAPHAN
VIENTIANE
Vientiane
VIENTIANE CAPITAL
KHAMMOUAN
SAVANNAKHET
SALAVAN
SEKONG
CHAMPASAK
ATTAPU
Attapu
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Canal
Lake
Zone of Irrigation Development
Dam
LAO PEOPLE'S DEMOCRATIC REPUBLIC
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	23 680 000	ha
Cultivated area (arable land and area under permanent crops)	2009	1 468 000	ha
• as % of the total area of the country	2009	6	%
• arable land (annual crops + temp fallow + temp meadows)	2009	1 360 000	ha
• area under permanent crops	2009	108 000	ha
Population			
Total population	2009	6 112 000	inhabitants
• of which rural	2009	68	%
Population density	2009	26	inhabitants/km^2
Economically active population	2009	3 077 000	inhabitants
• as % of total population	2009	50	%
• female	2009	50	%
• male	2009	50	%
Population economically active in agriculture	2009	2 311 000	inhabitants
• as % of total economically active population	2009	75	%
• female	2009	52	%
• male	2009	48	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	5 939	million US$/yr
• value added in agriculture (% of GDP)	2008	35	%
• GDP per capita	2009	972	US$/yr
Human Development Index (highest = 1)	2010	0.497	
Access to improved drinking water sources			
Total population	2008	57	%
Urban population	2008	72	%
Rural population	2008	51	%

active population was almost 3.1 million, of which 50 percent were women. The population economically active in agriculture was around 2.3 million inhabitants, approximately 75 percent of the economically active population. Of the population economically active in agriculture, 52 percent are women.

Women are major contributors to agricultural production. They do most of the farm work (planting, weeding and harvesting crops), tend livestock, and spend long hours performing off-farm and household chores such as collecting firewood, preparing meals and caring for children. Traditionally, men plough, make bunds and prepare seedbeds. In some areas the traditional task division is changing because of the lack of male labour.

Women are often unpaid, but their contributions are crucial for household food security and the rural economy. Nevertheless, their activities are often excluded from economic accounts and their contributions remain invisible and therefore greatly undervalued as a result of lack of sex-disaggregated data. The Government has enacted conducive policies to promote gender equality. In the agricultural sector, gender concerns are being integrated into specific programmes and projects through a number of measures (FAO, 2010).

Food security still is and will be the highest priority strategy to stabilise economic development and sociopolitical security. As rice is the staple for the population, its production must be stabilised at a high level. Increased paddy production is to be achieved through intensified

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 834	mm/yr
	-	434 290	million m^3/yr
Internal renewable water resources (long-term average)	-	190 420	million m^3/yr
Total actual renewable water resources	-	333 550	million m^3/yr
Dependency ratio	-	42.9	%
Total actual renewable water resources per inhabitant	2009	54 565	m^3/yr
Total dam capacity	2005	7 811	million m^3
Water withdrawal			
Total water withdrawal	2005	4 260	million m^3/yr
- irrigation + livestock	2005	3 960	million m^3/yr
- municipalities	2003	130	million m^3/yr
- industry	2003	170	million m^3/yr
• per inhabitant	2005	740	m^3/yr
Surface water and groundwater withdrawal	2005	4 260	million m^3/yr
• as % of total actual renewable water resources	2005	1.3	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

production in the six major plains and expansion of cultivated areas for paddy in mountain valleys with adequate water. Rice production reached 2.2 million tonnes in 2000 compared to 1.4 million tonnes in 1995. This remarkable increase was mainly the result of the rapid development of irrigation systems for dry season rice production since 1997.

Average production of rice per capita has increased from 310 kg in 1995 to 430 kg in 2000. During these five years the annual growth of rice production was 9.2 percent and other foodstuffs such as maize, roots and tuber crop, soybean, vegetables, eggs, poultry and meat products also increased. These annual growth rates exceeded the annual population growth rate of about 2.5 percent. However, production of food and foodstuffs is still insufficient and unevenly distributed. Foodstuff production is not very stable because of frequent natural events, such as calamitous floods and drought, and limited agricultural infrastructure. There is also a wide variation in food production between provinces. The main food producing areas are concentrated in the main plains along the Mekong river and account for 60-70 percent of food output. In the mountains, where over half the population lives, food output in 2002 was only 30-40 percent of total output (FAO, 2002).

WATER RESOURCES AND USE

Water resources

The Lao People's Democratic Republic has abundant water resources. The Mekong river is the main river and 90 percent of the country is located in the Mekong river basin. It forms the border with Thailand over a very large distance and almost every part is navigable. In the south, near Pakse, it enters the country with an estimated 280 km^3/year at the confluence with the Chi/Mun river coming from Thailand. About 25 percent of the Mekong river basin is located in the Lao People's Democratic Republic, which contributes 35 percent of the Mekong's total flow. There are about 39 main tributaries in the Mekong river basin and the main ones that have their largest catchment area in the Lao People's Democratic Republic are from north to south: Ou, Suang and Khan in the northern region; Ngum and Nhiep in the northern-central region; San, Theun-Kading and Bangfay in the central region, Banghiang in the Savannakhet plain in the central-southern region; Done in the southern region; and Kong in the southeastern region (Table 3). For planning purposes, the Lao part of the Mekong river basin is divided into 32 sub-basins.

Rivers that are not part of the Mekong river basin, such as the Tale, Ma, Mat and Xa rivers, drain from the Lao People's Democratic Republic towards Viet Nam, and the Luang and Mô rivers join in Viet Nam before reaching the sea.

A significant part of the water resources of the country (143.13 km^3/year) comes from neighbouring countries: 73.63 km^3/year enters from China (after first becoming the border between Myanmar and Lao People's Democratic Republic and then over a short distance the border between Thailand and Lao People's Democratic Republic before entering the country), 17.6 km^3/year from Myanmar (contribution of Myanmar to the Mekong in the border reach), and 51.9 km^3/year from Thailand (contribution of Thailand to Mekong in the border reach). The outflow from Lao People's Democratic Republic to other countries (333.55 km^3/year) consists mainly of the Mekong river to Cambodia with 324.45 km^3/year and small rivers, the Ca and Ma rivers, with 9.1 km^3/year to Viet Nam.

The internal renewable surface water resources have been estimated as the difference between the outflow and the inflow to the country, which is 190.42 km^3/year, while groundwater resources are an estimated 38 km^3/year, all forming the base flow of the rivers, thus being considered the overlap between surface water and groundwater resources. The total renewable water resources are therefore an estimated 333.55 km^3/year, which is equal to the total flow out of the country (Table 2).

Groundwater is emerging as a large and generally untapped resource. However, there is very little monitoring of groundwater quality in the country, even though it is the main source of rural water supply. A study made by the Interim Mekong Committee (1986) observed that the country is divided into two geological areas: the Annamian Strata occupying most of northern and eastern part and the Indosinian sediments mainly along the Mekong. There are three different aquifer systems:

- Ø The Annamian aquifers, which occur randomly, discharge locally to the river or its tributaries. As such, they are not part of the regional flow system and will not carry pollution into the regional groundwater system. The water should be of reasonably good

TABLE 3
Major River Basin (tributaries of Mekong river) in Lao PDR (Source: WEPA, 2010)

	Name of River basin	Basin area (km^2)	Annual discharge (million m^3)	Length of main stream (km)
1	Ou	19 700	12 277	390
2	Suang	5 800	3 654	150
3	Khan	6 100	29 455	250
4	Ngum	16 500	23 021	1 403
5	Nhiep	4 270	5 885	156
6	San	2 230	4 271	120
7	Theun/Cading	3 370	7 027	138
8	Bangfay	8 560	13 624	190
9	Banghieng	19 400	15 673	370
10	Done	6 170	5 065	1 574
11	Kong	10 500	16 146	170

quality and for the most part potable but rich in iron. Yields up to 5 litres/s can generally be anticipated.

- Ø The Indosinian aquifers, which have regional flows, include rock of the Indonisian Moyennes and Superieures and are relatively young. They are mostly freshwater sediments; although there are horizons of brackish water, and one major zone of saline water. Yields of 12-24 litres/s can be developed.
- Ø The alluvial aquifers, which are associated with the sedimentary deposits of the Mekong river, are not highly rated as aquifers.

In 2009, total dam capacity was estimated at 7.811 km^3. The country has great potential for hydropower development, estimated as 30 000 MW (WEPA, 2010). All existing and potential dams are on tributaries of the Mekong. The earliest major hydropower plant, Nam Ngum dam located north of Vientiane, has a storage capacity of 7.01 km^3 and a total power generation capacity of 150 MW. Two other dams in the south, Xeset 1 and Selabam, have a total storage capacity of 0.3 km^3 and can generate 50 MW. Since its commissioning in 1991, the 45 MW Xeset 1 dam has been generating electricity for domestic consumption and for export to Thailand. However, the Xeset 1 dam has a small reservoir, and low dry-season flow volumes of the Set river (Xeset) have resulted in correlated low volumes of electricity generation by Xeset 1.

Two more hydroelectric projects, the Xeset 2 and Xeset 3, are being proposed for construction in the Set river basin, which are also being promoted to increase rainy season water storage on the upper Set river to increase flow volumes for Xeset 1 (AKHA, 2006). In 1998, the 80 m high Houay-Ho dam was constructed in the south of the country, it produces 150 MW, which is exported to Thailand. In 2000, the Nam Leuk dam was constructed with a total power generation capacity of 60 MW, and in 2004, Nam Mang 3 was constructed producing 40 MW.

The Theun-Hinboun Power Company (THPC) developed the first independent power project in the country. The project, which was completed in 1998, is a trans-basin run-of-the-river project, located near the border of Bolikhamxay and Khammouan provinces. With a relatively small dam and reservoir, it transfers most of the Theun-Kading river to the neighbouring (and lower) Hinboun river to the west by tunnel. The generating capacity is 220 MW, of which 210 MW is used to export energy to Thailand and 10 MW to supply local power demands in the two provinces. THPC is now expanding the project to increase the total generating capacity to 500 MW. The capacity for export will rise to 440 MW and 60 MW will be available for Électricité du Laos (EdL). The expansion project will enable growth of the new Lao power transmission system by extending the 115 kV transmission grid to the area, increasing electricity supply to the grid, and improving reliability and quality of the EdL system (THPC, 2009).

Feasibility studies for 21 other hydropower projects throughout the country, all located on tributaries of the Mekong river, have been undertaken or are planned. Projects on the main stream of the Mekong have been planned for many years, more than 40 years in the case of the Pa Mong dam, but have not yet been implemented.

In 1999, it was estimated that 35 percent of liquid effluent disposal to inland surface waters from all sources was treated, while the quantity was unknown (WEPA, undated).

International water issues

The Mekong River Commission (MRC) came into existence on 5 April 1995 on agreement between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. These four countries signed the "Agreement on the cooperation for the sustainable development of the Mekong River Basin" and agreed on joint management of their shared water resources and development of the economic potential of the river. The MRC has been built on a foundation of nearly 50 years of knowledge and experience in the region, starting in 1957 as the

United Nations-founded Mekong Committee. In 1996, China and Myanmar became Dialogue Partners of the MRC and the countries now work together within a cooperation framework.

The Asian Development Bank (ADB) and the World Bank have collaborated since 2004 on the preparation of the Mekong Water Resources Assistance Strategy (MWRAS), which was developed after analytical work and strategic workshops were carried out in 2004 and early 2005 with the national governments of the four countries. The MWRAS preparation work confirmed that there is a need for extensive capacity-building in all aspects of integrated water resources management (IWRM) in the region to support the further investments required in water management (ADB, 2007).

Water use

In 2005, total water withdrawal was an estimated 4.26 km^3, which is only 1 percent of the total actual renewable water resources (Table 2). Water withdrawal for agriculture was approximately 3.96 km^3, while for municipalities and industries it was an estimated 0.13 km^3 and 0.17 km^3 respectively (Figure 1).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

A rough estimate of the irrigation potential for Lao People's Democratic Republic is 600 000 ha (Table 4). The history of irrigation can be traced back several centuries in the northern mountains, where irrigation systems are based on primitive water intake made by logs, soil and/or stone, and have been managed well by communities. From the 1960s, 'modern' irrigation systems with concrete weirs and well-designed canals have been built with technical and financial assistance from foreign donors. Irrigation is classified by region into three types: (i) community-managed gravity irrigation in the northern mountains, with a range of service area from 1 ha to over 300 ha; (ii) pump irrigation in the Vientiane plain; (iii) recently introduced pump irrigation along the Mekong river where most of the plain is flood-prone (FAO, 2002).

In 2005, the total area equipped for irrigation was 310 000 ha (Pheddara, 2007). Irrigation by groundwater covers only 200 ha (Figure 2). In 1995, river diversion was the main source of water for irrigation schemes, particularly the smaller ones, accounting for 83 percent of the total equipped area. Pumping from rivers, which is concentrated in the southern region, accounted for 15 percent, and reservoirs 2 percent. All areas use surface irrigation techniques. In 2000 there were 19 170 irrigation schemes.

The actually irrigated area in the wet season has increased from 138 077 ha in 1995 to 270 742 ha

FIGURE 1
Water withdrawal by sector
Total 4.26 km^3 in 2005

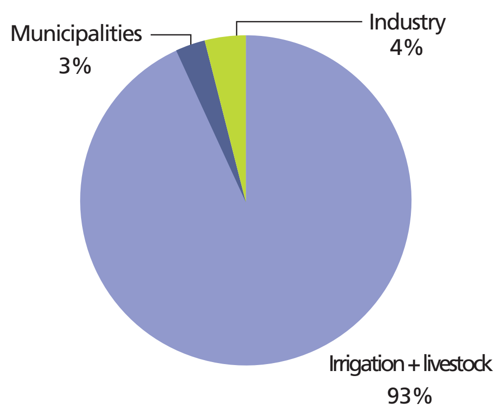


FIGURE 2
Source of irrigation water on area equipped for full control irrigation
Total 310 000 ha in 2005

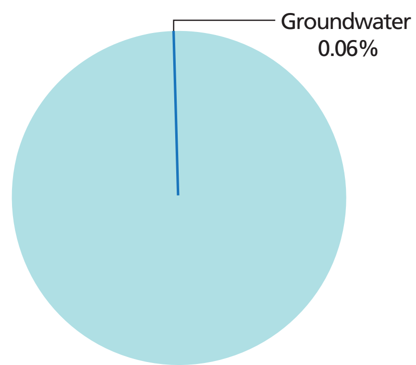


TABLE 4
Irrigation and drainage

Irrigation potential			600 000	ha
Irrigation				
1. Full control irrigation: equipped area		2005	310 000	ha
- surface irrigation		2005	310 000	ha
- sprinkler irrigation		2005	0	ha
- localized irrigation		2005	0	ha
• % of area irrigated from surface water		2005	99.94	%
• % of area irrigated from groundwater		2005	0.06	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2005	270 742	ha
- as % of full control area equipped		2005	87.3	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2005**	**310 000**	**ha**
• as % of cultivated area		2005	27	%
• % of total area equipped for irrigation actually irrigated		2005	87	%
• average increase per year over the last 10 years		2000-2005	0.96	%
• power irrigated area as % of total area equipped		1995	15	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area		1995	231 500	ha
Total water-managed area (1+2+3+4+5)		**2005**	**541 500**	**ha**
• as % of cultivated area		2005	48	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes	> ha and < ha		-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2005	371 676	ha
• Annual crops: total		2005	356 676	ha
- rice		2005	310 676	ha
- Vegetables		2005	33 000	ha
- Cotton		2005	8 000	ha
- Sugarcane		2005	5 000	ha
• Permanent crops: total		2005	15 000	ha
- Citrus		2005	15 000	ha
Irrigated cropping intensity (on actually irrigated area)		2005	137	%
Drainage - Environment:				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

TABLE 5
Typology of irrigation schemes (1999)

Size	Type of water control	Description	Location	Population involved
Small schemes < 100 ha	Weir schemes	Traditional wet season supplementary irrigation systems. Most of them are < 50 ha	Mountainous provinces	1-2 villages, up to 50 households
	Pump schemes	Designed for dry and wet season irrigation	Along the Mekong and its tributaries	
Medium schemes 100-500 ha	Weir schemes	Wet season supplementary irrigation. Most built with external assistance	In the floodplains	Up to 8 villages, up to 500 households
	Pump schemes	Designed for dry and wet season irrigation	Near Vientiane and Pakse	
	Reservoir schemes	Gravity irrigation in dry and wet season. Built by provincial irrigation services on behalf of communities	Near Savannakhet	
Large schemes > 500 ha	Reservoir schemes	Gravity irrigation in dry and wet season	2 reservoirs: Nam Houm and Nam Souang near Vientiane	
	Pump schemes	Dry and wet season irrigation	Near Vientiane using water from the Mekong and Ngun rivers	

in 2005, while in the dry season the area has increased from 36 282 ha in 1995 to 100 934 ha in 2005 (FAO, 2008). While wet season irrigation is common throughout the country, dry season irrigation is mainly concentrated near major cities. It has been noted that after poor yields during rainy seasons, the irrigated area in the dry season are higher than the average to compensate for the low production of the previous season. In 1995, non-equipped flood recession cropping area was an estimated 231 500 ha.

A typology of irrigation schemes is presented in Table 5. The large-scale and several medium-scale schemes are generally underexploited and face operation and maintenance difficulties. Government policy is to transfer management responsibilities to users, but farmers lack management skills as they have never been involved in scheme and water management.

Another classification of irrigated schemes is by type of management. Some schemes are wholly managed by the farmers themselves, while others receive the assistance of irrigation department services. Pump schemes belong to the latter. More than 80 percent of the gravity irrigated schemes are managed by the farmers themselves.

A major irrigation scheme is the community-managed irrigation sector project (CMISP), funded by the ADB, which is to improve more than 40 existing irrigation schemes in the central and northern regions. The communities are responsible for managing the improved facilities by organizing water user associations (WUAs). Other similar schemes are the decentralized irrigation development and management sector project (DIDMP), funded by ADB and France, and the agricultural development project (ADP), funded by the World Bank. DIDMP is a pilot project exercising the irrigation management transfer process, focusing on pump irrigation schemes in six selected provinces. ADP, covering four southern provinces, is a rural development project including not only improvement of irrigation systems but also market oriented community development using village investment funds.

Role of irrigation in agricultural production, economy and society

In 2005, total harvested irrigated cropped area was an estimated 371 676 ha, of which 270 742 ha in the wet season and 100 934 ha in the dry season. The major irrigated crops are rice, which account for 310 676 ha (245 676 ha in the wet season and 65 000 ha in the dry season), vegetables 33 000 ha, cotton 8 000 ha, citrus 15 000 ha and sugarcane 5 000 ha (Table 4 and Figure 3).

The country also has a large area of non-irrigated rice cultivation (estimated as 450 000 ha in 1994), of which about half is estimated to be upland rice (shifting cultivation), and the other half lowland flooded rice on the alluvial plains (Table 4).

In 1999, the average cost of small-scale weir scheme development was about US$200-400/ha. Large schemes implemented by the government, sometimes with external aid, cost between US$3 500 and 7 000/ha.

Status and evolution of drainage systems

Drainage and flood protection structures have generally been considered in the irrigated schemes design plan but have often not been implemented because of budget restrictions.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO AGRICULTURAL WATER USE

Institutions

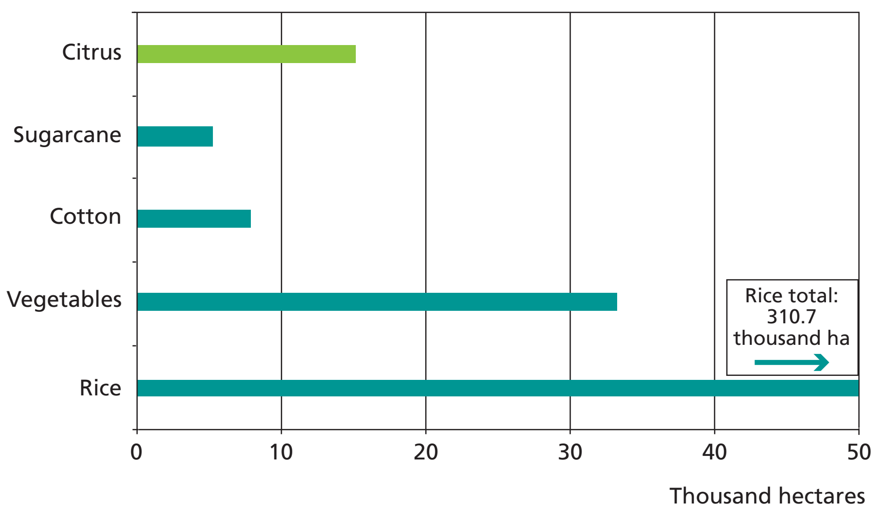
The Prime Minister's Office is responsible for:

- Ø The Water Resources Coordination Committee (WRCC), which provides advice to the government on matters related to water resources. It coordinates the planning, management, follow-up, inspection and protection of water resources for their sustainable development and utilization in line with the government policy of socio-economic development. It was established in 1997.
- Ø The Lao National Mekong Committee (LNMC), which formulates policy, strategic plans, projects and programmes related to water resources development in the Mekong Basin to protect the environment, ecological balance, and to ensure community

FIGURE 3

Irrigated crops on area equipped for full control irrigation

Total harvested area 371 676 ha in 2005 (cropping intensity on actually irrigated area: 137%)



participation and development, cooperation with other Mekong riparian countries, other countries and donors.

- The Science, Technology and Environment Agency (STEA), which monitors and inspects environmental parameters, such as: water, soil, air, radiation, noise, colour, etc. concerning development activities for adherence to environmental standards.

The Ministry of Agriculture and Forestry (MAF) is responsible for:

- The Integrated Watershed Management Unit (IWMU), which assists MAF in watershed management and rural development planning on a subwatershed (sub-basin) area.
- The Department of Irrigation (DoI), which carries out the testing and analyses of water quality based on MRC standard, and develops irrigated agriculture and drainage, flooding and drought prevention plans.

The Ministry of Industry and Handicraft is responsible for:

- The Industrial Environment Division (IED), which is responsible for industrial environment management, occupational health and safety, industrial waste, mineral resource management, hydropower and regulations to protect and control pollution from industrial factories (wastewater, smoke, odour, radiation, vibration, noise, etc.).

The Ministry of Communication, Transportation, Post and Construction is responsible for:

- The Waterway Administration Division (WAD), which is responsible for data collection (water quality sampling at some hydrological stations such as Luangphrabang, Savannakhet and Pakse), then forwarding it to Water Quality Laboratory, Irrigation Survey Design Center under Department of Irrigation, MAF.
- The Water Supply Authority (WASA), mainly develops regulations concerning urban water supply, and provides technical assistance to water supply operations for the whole country.

The Ministry of Public Health is responsible for:

- The National Center for Environment Health and Water Supply (NCEHWS), which regulates control of solid waste and waste water; defines disposal methods for solid and liquid waste, and supplies water and sanitation services to non-urban locations.
- The Food Management Division (FMD), which sets and monitors standards for drinking water supplies.

Water management

In 1984, about 23 percent of the cultivated area was managed by cooperatives. However, following the New Economic Mechanism implemented in 1986, the cooperatives were dissolved, and all the cultivated area is now privately managed.

The government's long-term objective for domestic water supply is to provide 80 percent coverage to the population by 2015. Although each province has benefited from an urban water supply programme financed by international aid (from Japan, Germany, ADB, WB and EU), rural water supply programmes have not been numerous.

The Water and Water Resources Law states that water and water resources are the property of the national community, which the State represents in managing as well as thoroughly and reasonably allocating its use to various parties. Individuals, juristic entities, or organizations shall have the right to control and use any natural water and water resource in any activity only so long as they have received approval from relevant authorised agencies, except in the case of small-scale use as provided by this Law. The management instrument of the Water and Water Resources Law is the National Water Sector Strategy and Action Plan.

During the 1990s, the Government recognized the problems facing the country, and the strategy in the irrigation sector was redefined. The water law is based on:

- Improving the planning of new irrigation projects so that they are based on the needs of farmers and driven and managed by them. Water user groups (WUGs) are being set up, and the water law should provide a legal framework for these associations. The objectives of DoI are: (i) to develop irrigation for all lowland rice fields in the wet season as long as farmers are interested and group themselves into WUGs; (ii) to develop dry season irrigation.
- Making the existing schemes economically viable and self-sustaining, by: (i) helping farmers to establish WUGs; (ii) training farmers in irrigation management; (iii) encouraging farmers to introduce operation and maintenance cost recovery systems; (iv) developing marketing infrastructure.

Being a least-developed country rich in water resources, the most important challenges for WRCC in carrying out its coordinating role include: (1) strengthening of the legal framework for an effective and harmonious integration of water resources management, development and protection activities into the socio-economic development process, in particular to meet national priorities; (2) to enhance and consolidate the existing systems and foundation to operate, maintain and rehabilitate facilities safely, reliably and efficiently to protect the investment for public benefits; (3) to prioritize the capacity-building needs so as to enhance organizational capacity and effectiveness of the water resources coordination system (WEPA, 2010).

The objectives written in the Master Plan for integrated agricultural development are: to formulate an action plan and an implementation programme that contribute to more effective agricultural development promotion, based on the strategic vision framework in the agricultural development strategy and vision 2020; and to identify priority programmes and projects. 'Towards the Year 2020', an integrated agricultural development action plan, covers ten subsectors: land and water resources development, institution and organization, human resources development, field crop, livestock and fisheries, stabilising shifting cultivation, marketing and agro-processing, rural finance, rural development, and irrigation.

Finances

Under the New Economic Mechanism, formulated in the 1990s, policy for irrigated agriculture emphasizes the role of markets and prices as allocation mechanisms and a shift to cost recovery for services and facilities provided by government to farmers. Electricity and operating costs have been paid directly by farmers since 1992. Secondary and tertiary canals are the responsibility of farmers for all maintenance matters. Until 1994, the Irrigation Department was responsible for the operation and maintenance of weirs, dams, pumps and primary canals, after which it was supposed to be handed over to WUGs or WUAs. However, in many cases, operation and maintenance are still carried out by the Irrigation Department or its provincial services. A pragmatic approach has been adopted for a transitional period, where the establishment of WUGs is encouraged and farmers are trained in irrigation management, irrigation scheduling, and operation and maintenance. It is expected that, eventually, each WUG will be able to define the water charge needed to sustain the irrigation scheme.

Policies and legislation

In 1996, the Water and Water Resources Law was enacted and implemented. It determines necessary principles, rules, and measures relative to the administration, exploitation, use and development of water and water resources to preserve sustainable water and water resources and to ensure volume and quality providing for people's living requirements, promoting agriculture, forestry, and industry, developing the national social-economy and ensuring that no damage is caused to the environment (WEPA, 2010).

In 2001, a Decree was enacted on the Implementation of the Water and Water Resources Law to implement the Law on Water and Water Resources and to establish the responsibilities of different ministries, agencies and local authorities regarding the management, exploitation, development and use of water and water resources. The Decree also ensures efficient development and use, conformity with the socio-economic development planning, an increase in production, an improvement of the living conditions of the people and sustainable use of water resources.

ENVIRONMENT AND HEALTH

In general, the water quality of rivers within the country and the Mekong is considered to be good, based on international standards. The level of oxygen is high and the nutrient concentration is low. Sediment is the primary pollutant source affecting rivers. Sedimentation loads in tributaries vary considerably, from 41 to 345 tonnes/km^2 per year. Tributaries and river reaches with high sedimentation are the Banghiang, Done, Ou, and the upper and lower stretches of the Mekong.

With the pressure of rapid demographic growth, socio-economic development and urbanization, however, the water quality is increasingly exposed to deterioration. Currently there are some problems related to waste and polluted water in major urban areas from varied community use (residential density, hotels, hospitals and entertainment centres). In addition there is water pollution from agricultural and industrial sectors, including mineral exploitation. This is not yet a major problem, but it could become one (WEPA, 2010).

A study on wastewater management and building in Vientiane (2004) reported that, with a rapidly growing population in the urban area of Vientiane Capital City, sewerage is becoming a serious problem because of the lack of a sufficient drainage system and lack of sewerage systems, while on-site sewerage disposal or septic tanks are often poorly designed. Further contributing to the problem in urban area is stagnant untreated wastewater from households and some small industries with open road-side drains, flowing directly into marsh or natural channels. This mixing of sewerage in the storm drainage system will continue to have a detrimental impact on public health (WEPA, 2010).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Management of the Mekong will increasingly require riparian countries to address cross-border issues, which in turn will demand strong national capacities to deal with complex water use and resource protection issues. The future may require tradeoffs that have been avoided so far as a result of the relatively limited development of water resources in the basin. The projected challenges highlight the need for each country in the basin to have appropriate polices and capacities for water resource management (ADB, 2007).

In 2006, the ADB and World Bank undertook further studies to define the scope of an IWRM strengthening programme in the country. The study identified ten major groups of activities necessary for the effective facilitation of IWRM, which would take about 5 years to implement, at a cost of about US$9 million (ADB, 2007).

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Malaysia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Malaysia is situated in southeast Asia. It is composed of two regions: peninsular Malaysia in the west, lying between Thailand and Singapore, and the states of Sabah and Sarawak, located in the east of the island shared with Indonesian Borneo. The two regions are separated by the South China Sea. The total land area is 330 800 km^2 (Table 1). Malaysia is a federal country, divided into 13 states and one federal territory (*wilayah persekutuan*), which includes the city of Kuala Lumpur (legislative capital), Labuan and Putrajaya (administrative capital).

In peninsular Malaysia, a mountainous spine known as Banjaran Titiwangsa separates the east of the peninsula from the west. About 61 percent of the peninsula is less than 100 m above sea level and the land is generally suitable for cultivation. The interior of Sabah is criss-crossed by a series of mountain ranges and hills, the most prominent is the Crocker range, with the highest point at Gunung Kinabalu (4 101 m). Sarawak is generally mountainous with the highest range forming the border with Indonesia.

Total cultivable area is an estimated 14.2 million ha, or 43 percent of the total land area. In 2009, about 7.6 million ha of the cultivable area, or 53 percent was cultivated. Permanent crops represented 76 percent of this cultivated area (5.8 million ha), while the remaining 24 percent (1.8 million ha) was under annual crops, mainly rice.

Climate

Malaysia lies entirely in the equatorial zone. The climate is governed by the northeast and southwest monsoons. The northeast monsoon from October to March is responsible for the heavy rains that hit the east coast of the peninsula and frequently cause widespread floods. It also causes the wettest season in Sabah and Sarawak. The southwest monsoon period occurs between May and September, and is a drier period for the whole country. The period between these two monsoons, April, is marked by heavy rainfall.

The average temperature throughout the year is very stable, 26 °C, and mean annual rainfall is 2 875 mm. Regional variations of temperature and rainfall are linked to altitude. For example the Cameron Highlands have a mean temperature of 18 °C and an annual rainfall of over 2 500 mm, compared to the mean temperature in Kuala Lumpur, which is 27 °C and 2 400 mm of annual rainfall. In general, Sabah and Sarawak experience more rainfall (3 000-4 000 mm/year) than the peninsula. The humidity is high (80 percent) as a result of the high evaporation rate. About 60 percent of the rain falls in the months of November and January.

Population

The population in 2009 was an estimated 28 million, 29 percent lived in rural areas (Table 1). The population is concentrated along the west coast of peninsular Malaysia and in the capital Kuala Lumpur. Average population density is 84 inhabitants/km^2. The annual demographic growth for 1999-2009 was around 2.0 percent.

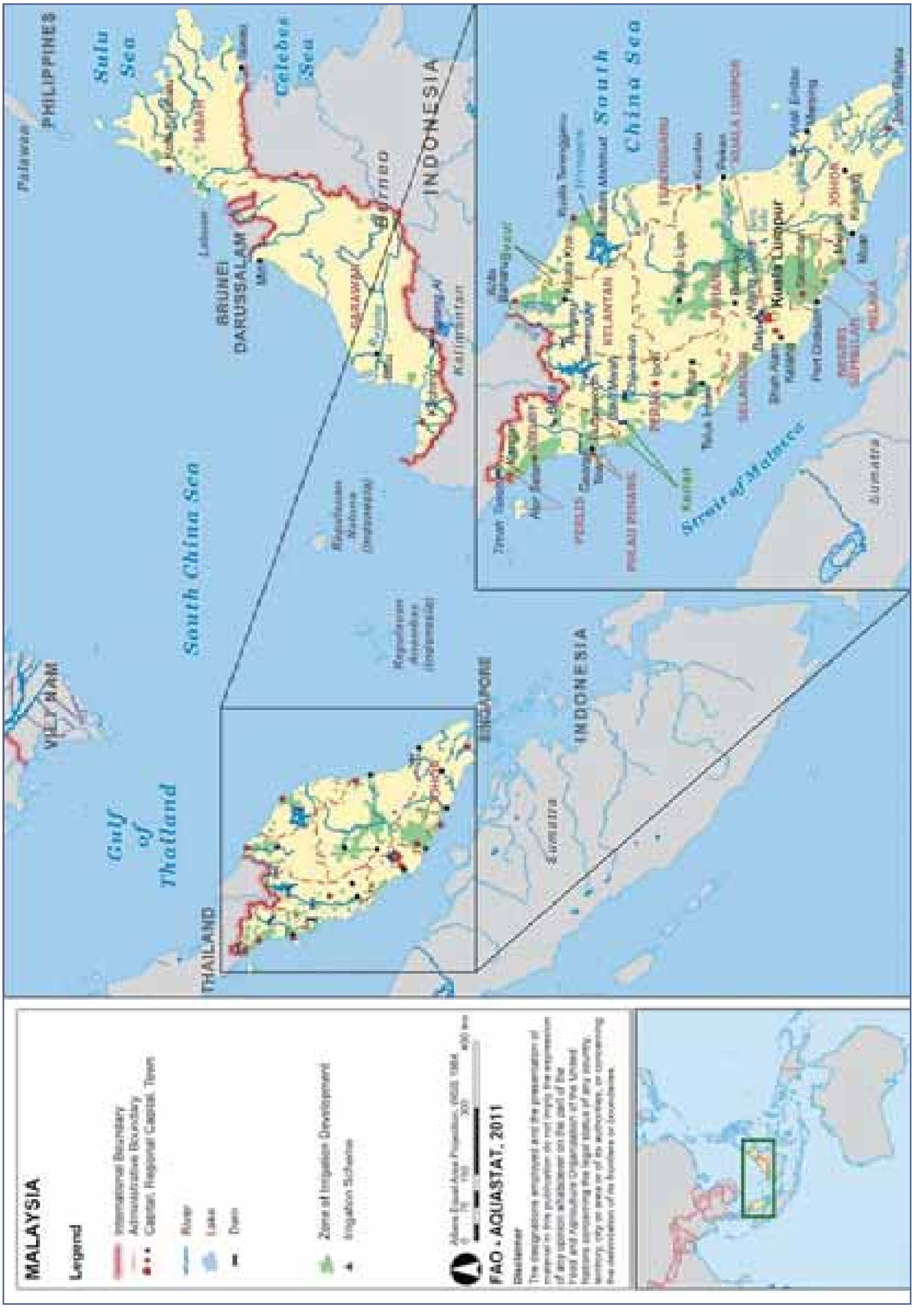

MALAYSIA
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
Irrigation Scheme
FAO - AQUASTAT, 2011
Disclaimer
PHILIPPINES
Sulu Sea
Celebes Sea
BRUNEI DARUSSALAM
Borneo
INDONESIA
Kalimantan
South China Sea
Gulf of Thailand
VIET NAM
THAILAND
SINGAPORE
Sumatra
Kuala Lumpur
Strait of Malacca

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	33 080 000	ha
Cultivated area (arable land and area under permanent crops)	2009	7 585 000	ha
• as % of the total area of the country	2009	23	%
• arable land (annual crops + temp fallow + temp meadows)	2009	1 800 000	ha
• area under permanent crops	2009	5 785 000	ha
Population			
Total population	2009	27 949 000	inhabitants
• of which rural	2009	29	%
Population density	2009	84	inhabitants/km^2
Economically active population	2009	12 366 000	inhabitants
• as % of total population	2009	44	%
• female	2009	36	%
• male	2009	64	%
Population economically active in agriculture	2009	1 640 000	inhabitants
• as % of total economically active population	2009	13	%
• female	2009	21	%
• male	2009	79	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	193 093	million US$/yr
• value added in agriculture (% of GDP)	2009	10	%
• GDP per capita	2009	6 909	US$/yr
Human Development Index (highest = 1)	2010	0.744	
Access to improved drinking water sources			
Total population	2008	100	%
Urban population	2008	100	%
Rural population	2008	99	%

In 2008, there was almost 100 percent access to improved drinking water sources; 100 and 99 percent for the urban and rural population respectively.

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture in 2009 was an estimated 1.64 million, amounting to 13 percent of the economically active population, of which 21 percent were women. Gross domestic product in 2009 was US$193 093 million (Table 1) and agriculture accounted for 10 percent of GDP, compared with 15 percent in 1990.

The agriculture sector is divided into large-scale plantations concentrating on three crops – rubber, oil palm and cocoa and most of the farming population are smallholders. In 1995, palm oil, rubber and saw logs accounted for more than 58 percent of total agricultural exports.

WATER RESOURCES AND USE

Water resources

Peninsular Malaysia is drained by a dense network of rivers and streams (there are about 150 major river basins), the longest being the Pahang river, which follows a course of 434 km before reaching the South China Sea. It drains a catchment area of 29 000 km^2. Other major rivers that drain into the South China Sea are the Kelantan, Terengganu, Dungun, Endau and Sedili rivers. Major river basins in the east of Malaysia tend to be larger than those in peninsular Malaysia. Malaysia's longest river is the Rajang (563 km) in Sarawak.

Out of an annual rainfall volume of 950 km^3, 39 percent or 370 km^3 are lost to evapotranspiration. The total annual surface runoff is 566 km^3 and about 64 km^3 contribute to groundwater recharge. However, about 78 percent of the groundwater flow, or 50 km^3, returns to the rivers and is therefore not considered an additional resource (overlap). The total internal water resources of Malaysia are thus an estimated 580 km^3/year.

The Kolok river originates in Thailand and then forms the border between Thailand and Malaysia. This river is very short with a total length of just over 100 km and, while no information on flows is available, the amount is negligible compared to the total internal renewable water resources (IRWR).

Major floods occurred in 1967, 1971, 1973 and 1983. Some 29 000 km^2 are considered as flood-prone areas, affecting about 2.7 million people. The average annual economic damage caused by floods was evaluated as US$40 million in 1980.

On the west coast of peninsular Malaysia, the low gradient has resulted in large extensions of tidal flats and swamps. One of the swamp lakes is Lake Bera in Pahang state, with an area of 61.5 km^2.

In 1999, Malaysia had a total of 56 dams, of which 32 were more than 15 m high. In 2009, total dam capacity is an estimated 23.72 km^3.

In 2009, the Department of Irrigation and Drainage, at the Ministry of Natural Resources and Environment, managed 16 dams having a total capacity of 460 million m^3. Located in various states, these dams fulfill the department's role in providing adequate irrigation water, flood mitigation and silt retention. Beris dam (2004) has the largest capacity with 122 million m^3, followed by Bukit Merah dam (1906) with 75 million m^3, Pontian dam (1985) and Timah Tasoh dam (1992) each with a capacity of 40 million m^3, Anak Endau dam (1985) with 38 million m^3 and Batu dam (1985) with 37 million m^3. More dams are scheduled for construction to meet the ever increasing demands and social expectations of the public.

The Klang Gates dam, with a capacity of 25 million m^3, was completed in 1958 and is a major supplier of drinking water to residents of the Klang valley, Kuala Lumpur.

In 1995, the gross theoretical hydropower potential of peninsular Malaysia was 123 000 GWh/year, and that of Sabah and Sarawak together 107 000 GWh/year. In 1995, total hydropower generation was about 5 800 GWh, or 30 percent of all power production in Malaysia. The most important hydropower dams are Chenderoh dam, the oldest hydropower dam in Malaysia (1920) with a capacity of 95 million m^3, Batang Ai dam (1985) with a capacity of 750 million m^3, Pergau dam (2000), Sultan Mahmud dam (1972), Temenggor dam (1972) with a capacity of 6 050 million m^3 and Tenom Pangi dam (1984).

In 1995 total produced wastewater was 2.69 km^3 and treated wastewater was an estimated 0.40 km^3. In 1990 desalinated water produced accounted for 4.3 million m^3 (Table 2).

International water issues

Two water agreements signed between Malaysia and Singapore in 1961 and 1962 are in force up to 2011 and 2061 respectively. The Tebrau and Skudai Water Agreement was signed in

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	2 875	mm/yr
	-	951 000	million m^3/yr
Internal renewable water resources (long-term average)	-	580 000	million m^3/yr
Total actual renewable water resources	-	580 000	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	20 752	m^3/yr
Total dam capacity	2009	23 720	million m^3
Water withdrawal			
Total water withdrawal	2005	13 210	million m^3/yr
- irrigation + livestock	2005	4 520	million m^3/yr
- municipalities	2005	3 902	million m^3/yr
- industry	2005	4 788	million m^3/yr
• per inhabitant	2005	506	m^3/yr
Surface water and groundwater withdrawal	2005	13 205.7	million m^3/yr
• as % of total actual renewable water resources	2005	2.28	%
Non-conventional sources of water			
Produced wastewater	1995	2 690	million m^3/yr
Treated wastewater	1995	398	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced	1990	4.3	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

1961, while the Johor River Water Agreement was signed in 1962. The 1961 agreement allows Singapore to draw up to 0.40 million m^3 (86 million gallons) of water daily from the Pontian and Gunung Pulai reservoirs as well as the Tebrau and Skudai rivers, while the 1962 agreement allows up to 1.15 million m^3 (250 million gallons – 1 gallon = 4.5 litres) of water per day to be drawn from the Johor river. In total, these agreements allow Singapore to draw up to 1.55 million m^3 (250.4 million gallons) per day.

Both agreements are honoured under the 1965 Separation Act between Singapore and Malaysia, and lodged with the United Nations. Singapore pays Malaysia (the Johor Government) 3 cents (RM 0.03) for every 1 000 gallons drawn from these rivers. In turn, the Johor Government pays Singapore 50 cents (RM 0.50) for every 1 000 gallons of treated water. Both also contain a provision that allows for a review of water prices in 25 years, and arbitration if there is a disagreement. Prices can be revised in line with the purchasing power of money, labour costs, and cost of power and materials used to supply water. Malaysia did not revise water rates in 1986 and 1987 because of financial considerations. If the Johor government raises the price of raw water, it would concurrently have to pay dearer prices for the treated water it buys from Singapore (Lee Poh Onn, 2003).

In June 1988, a Memorandum of Understanding on water and gas was signed between Singapore and Malaysia that gave Singapore the right to construct more reservoirs and to draw more than what has been presently set for an additional one hundred years.

Water use

In 2005, total water withdrawal was an estimated 13.210 km^3, of which 4.520 km^3 (34 percent) for agriculture, 3.902 km^3 (30 percent) for municipalities and 4.788 km^3 (36 percent) for industries (Table 2 and Figure 1).

FIGURE 1
Water withdrawal by sector
Total 13.210 km³ in 2005

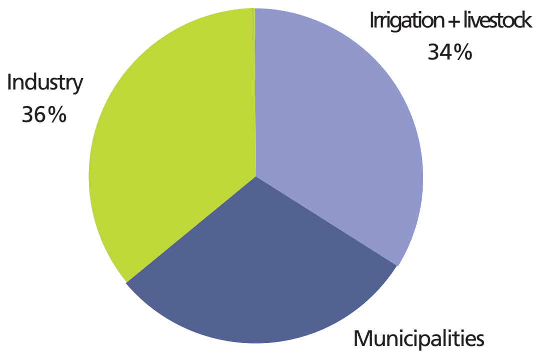
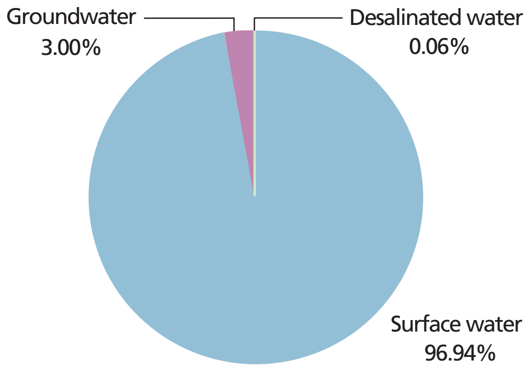


FIGURE 2
Water withdrawal by source
Total 7.503 km³ in 1995



Surface water is readily available throughout the year and is abstracted mainly for irrigation and domestic uses. The groundwater potential is limited to some pockets of the coastal region and is generally exploited by rural people to supplement their piped water supply. In 1995, surface water represented approximately 97 percent of the total water withdrawal, while groundwater represented 3 percent (Figure 2). About 60-65 percent of groundwater used is for municipal purposes, 5 percent for irrigation and 30-35 percent for industry.

In 1995, about one third of the water withdrawal of the municipal and industrial sectors is lost in the distribution system owing to several factors such as pipe leakage, under-metering, and other unaccounted water losses. Water supply is undertaken by government agencies and privatized water companies.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential is about 413 700 ha. Irrigation development dates back to the end of the eighteenth century. The Kerian irrigation schemes were the first large schemes to be constructed, in 1892. Since the formation of the Department of Irrigation and Drainage in 1932, irrigated areas for rice cultivation have progressively increased. By 1960, about 200 000 ha had been developed, the emphasis then being on supplementing rainfall for single crop cultivation.

During the 1960s and early 1970s, the introduction of double cropping of rice cultivation required the development of adequate water resources for the second cropping season. During the 1980s, the priority for irrigation took on a new dimension with the need to rationalize rice cultivation and increase its productivity. The Government developed a policy to concentrate efforts on irrigation development in eight large irrigation areas, designated as granary areas and totalling 210 552 ha. They are the irrigated areas of Kada, Seberang Muda Perai, Trans Perak, Northwest Selangor, Kerian-Sungai Manik, Besut and Kemasin-Semarak.

In 1994, Malaysia had over 932 irrigation schemes covering 340 717 ha, comprising the above eight granary schemes (210 552 ha), 74 mini-granary schemes (29 507 ha) and 850 non-granary schemes (100 658 ha) (Table 3 and Figure 3). The non-granary schemes are scattered throughout the country and their size varies between 50 and 200 ha. In 1994, 92 percent of the full control equipped area was irrigated by surface water and 8 percent by groundwater (Figure 4). Surface irrigation and localized irrigation accounted for 340 600 ha and 117 ha respectively (Figure 5).

TABLE 3
Irrigation and drainage

Irrigation potential			413 700	ha
Irrigation				
1. Full control irrigation: equipped area		1994	340 717	ha
- surface irrigation		1994	340 600	ha
- sprinkler irrigation		1994	0	ha
- localized irrigation		1994	117	ha
• % of area irrigated from surface water		1994	92	%
• % of area irrigated from groundwater		1994	8	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		1994	21 970	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**1994**	**362 687**	**ha**
• as % of cultivated area		1994	4.8	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 4 years		1990-1994	1.48	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**1994**	**362 687**	**ha**
• as % of cultivated area		1994	4.8	%
Full control irrigation schemes	**Criteria**			
Non-granary schemes (850 schemes)	(50-200 ha)	1994	100 658	ha
Mini-granary schemes (74 schemes)		1994	29 507	ha
Granary schemes (8 large schemes)		1994	210 552	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production		2005	1 434 000	metric tons
• as % of total grain production		2005	63	%
Harvested crops				
Total harvested irrigated cropped area		2006	382 000	ha
• Annual crops: total		2006	382 000	ha
- Rice		2006	363 000	ha
- Vegetables		2006	6 000	ha
- Groundnuts		2006	1 000	ha
- Sugarcane		2006	12 000	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on full control equipped area)				%
Drainage - Environment				
Total drained area		1994	940 600	ha
- part of the area equipped for irrigation drained		1994	340 600	ha
- other drained area (non-irrigated)		1994	600 000	ha
• drained area as % of cultivated area		1994	12	%
Flood-protected areas		1994	840 000	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases		1992	7 000	inhabitants

FIGURE 3
Type of full control irrigation schemes
Total 340 717 ha in 1994

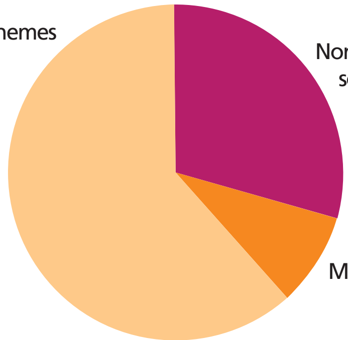
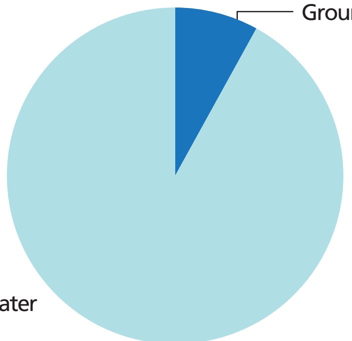


FIGURE 4
Source of irrigation water on area equipped for full control irrigation
Total 340 717 ha in 1994



In addition, there are 21 970 ha, which are inundation and control drainage schemes. The total irrigation area was an estimated 362 687 ha in 1994.

In the major irrigation schemes, flooding or basin irrigation is practiced on rice fields, and the water depth is controlled individually by farmers. Major irrigation schemes are designed with proper farm roads to cater for farm mechanization especially for ploughing and harvesting.

Role of irrigation in agricultural production, economy and society

Irrigation is predominately for rice cultivation and, to a minor extent, for vegetables and cash crops. Rice cultivation is mostly carried out by individual farmers working on small plots of about 1-1.5 ha. In 2006, the total harvested irrigated cropped area on the full control irrigation area was about 382 000, of which 95 percent was rice, 3.1 percent sugarcane, 1.6 percent vegetables and 0.3 percent groundnuts (Table 3 and Figure 6).

In 1999 irrigation efficiency was around 35-45 percent with a water productivity index for rice of about 0.2 kg/m^3. The average yield for irrigated rice was 4 tonnes/ ha in 1995.

Status and evolution of drainage systems

In 1994, the total drained area was 940 600 ha. About 600 000 ha were drained for oil palm cultivation, using public funding for smallholders. Most of the irrigation schemes (340 600 ha) are provided with separate drainage facilities.

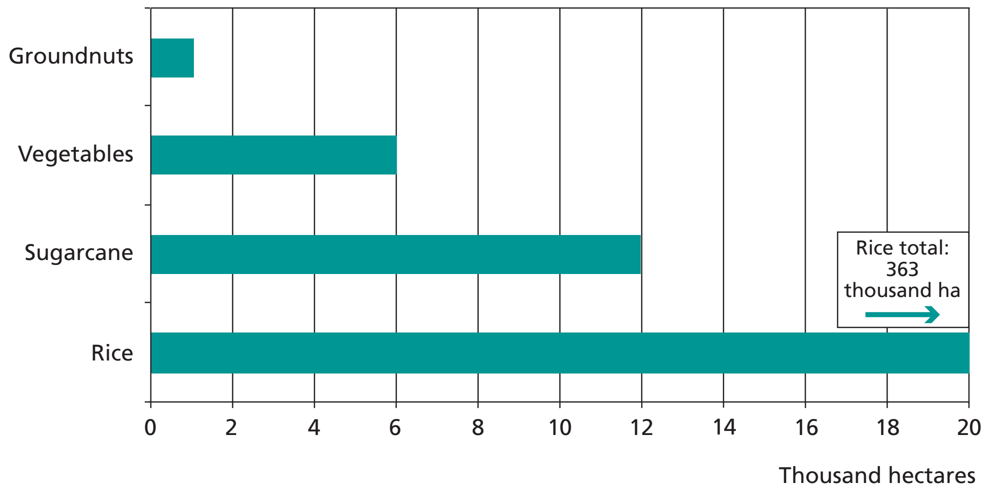
WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The responsibility for water resources planning and development is shared by various government agencies. Malaysia has no single water resources authority, which might provide an overall coordinated approach to planning and integrated river management.

The Ministry of Agriculture and Agro-based Industries (MoA) has the mandate to transform the agriculture and agro-based industry into a modern, dynamic and competitive sector, to position Malaysia as a major world food exporter and to develop the agriculture sector as the country's engine of growth.

FIGURE 6
Irrigated crops on area equipped for full control irrigated
Total harvested area 382 000 ha in 2006



MoA's Division of Irrigation and Agricultural Drainage (BPSP) is responsible for the planning, implemention and operation of irrigation, drainage and flood control projects throughout the country, notably:

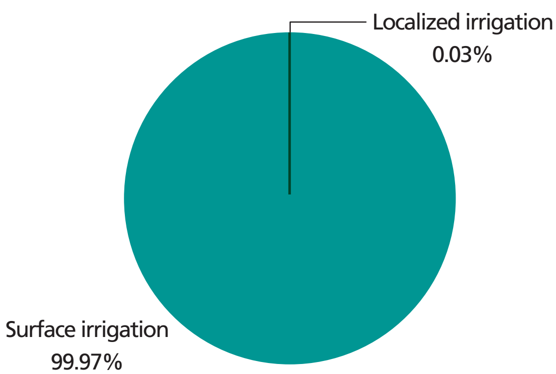
- preparing the criteria and standard policy for the implementation of agricultural infrastructure;
- planning, implementing and assessing agricultural infrastructure and agricultural drainage development programmes;
- providing technical services to departments under the ministry; and
- providing and developing an inventory system as well as irrigation and drainage infrastructure database.

The Ministry of Natural Resources and Environment (MoNRE), which has been assigned the task of formulating, managing and enforcing policies, strategies and programmes related to natural resources. There is no dedicated department within the ministry that could provide the full scope of technical support to carry out this function with regard to water (Hanapi, 2011).

The Department of Irrigation and Drainage at the Ministry of Natural Resources and Environment is in charge of flood mitigation, river and coastal management, hydrology, urban drainage and dams.

In the water supply sector, the Public Works Department (PWD), under the Ministry of Public Works, is responsible for the planning, implementation and operation of urban water supply projects. However, in line with the

FIGURE 5
Irrigation techniques on area equipped for full control irrigation
Total area 340 717 ha in 1994



Government's privatization policy, many water supply projects have been taken over by water supply companies or privatized.

The Ministry of Health (MOH) provides untreated but drinkable water to rural communities not served by the local water authorities. The MOH also monitors water quality at water treatment plant intakes as well as the quality of water within the distribution system for compliance with national drinking water standards.

The control of water pollution is the responsibility of the Department of Environment (DOE), which is empowered to enforce compliance with effluent standards for point sources of pollution. The Ministry of Housing and Local Government is responsible for compliance with regulations and standards on sewerage works which have been privatized to a national sewerage company.

The Muda Agricultural Development Authority (MADA) is a semi-autonomous agency, which came into effect in 1969 and was formally established in 1970. Statutorily responsible to the MoA, and under the budgetary control of the Ministry of Finance, MADA is responsible for operating and improving the irrigation system and its area and supplying extension, credit and other services to farmers. It also has been innovative and active in the planning of improvements, project socio-economic evaluation, and so on.

Water management

Malaysia has recently decided to improve its strategic target of rice self-sufficiency to 100 percent. This has important implications for water allocation to agriculture. At the same time, the Division of Irrigation and Agricultural Drainage (BPSP) of the MoA has received significant budgets to support this new policy and, therefore, has an opportunity to address problems related to managing demand or improving efficiency by modernizing the systems. One approach suggested by BPSP is to develop new irrigation schemes (as commercial plantations) in areas with low population pressure, such as eastern Malaysia.

As far as existing systems are concerned, the hotspot for water allocation is the MADA irrigation system, which produces 40 percent of national rice production. MADA has been a priority national project since the First National Plan. As the largest national granary area, concentrating over 40 percent of rice production, it has national strategic significance. The main objective of water resources development in the northern basins has been to supply water to MADA. Increasingly the Muda and Kedah basins have been interconnected and now serve three states as well as other water users.

Kedah State is an agricultural state and thus poor almost by definition. With the announced creation of a 'State Water Resource Authority' in Kedah State in 2010, tensions around the allocation of water to MADA are bound to increase between state and federal level on the economic objectives of water resources management (supply to industries, potential hydropower generation, water supply). In spite of new plans for further water resources management, water supply to irrigation and the performance of MADA are bound to come under closer scrutiny at national and local levels.

Finances

In 1999, it was estimated that fees collected from farmers cover only 10-12 percent of the actual operational cost. The Government does not seek full cost recovery because the farming community is considered a low-income group. A total of US$917 million have been spent on irrigation development by the Government during the period 1970-2000.

Policies and legislation

In line with the Third National Agricultural Policy, as well as the vision of the country's leadership, an objective of the Ninth Malaysia Plan (2006-2010) is to activate the industrialization of the country's agriculture sector. This would reactivate the development of the agricultural sector and thus transform it into one of the nation's engines of growth. The plan supports agricultural irrigation projects.

Although, either directly or indirectly, much legislation touches on water resources, most of the existing laws are considered outdated. The Water Act of 1920 is inadequate for dealing with the current complex issues related to water abstraction, pollution and river basin management.

ENVIRONMENT AND HEALTH

The main sources of organic water pollution are domestic and industrial sewage, effluent from palm oil mills, rubber factories and animal husbandry. Mining operations, housing and road development, logging and clearing of forests are major causes of high concentration of suspended sediments in the rivers. In several urban and industrial areas, organic pollution of water has resulted in environmental problems and has adversely affected aquatic life. Besides organic waste, rivers remain a convenient means of solid waste disposal. A major portion of household refuse, which is not collected, burned or buried, finds its way into drains and rivers. In the Klang valley, an estimated 80 tonnes of waste ends up in the river system every day. River water quality and pollution control need to be addressed urgently since 98 percent of the total water used originates from rivers. Almost all the investments in water-related infrastructure depend on reasonable river water quality (Le Huu Ti and Facon, 2001).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Malaysia vision for water in the twenty-first century is to conserve and manage its water resources to ensure adequate and safe water for all (including the environment). The key objectives of the vision are as follows:

- *Water for people:* all have access to safe, adequate and affordable water supply, hygiene and sanitation.
- *Water for food and rural development:* provision of sufficient water that will ensure national food security and promote rural development.
- *Water for economic development:* provision of sufficient water to spur and sustain economic growth within the context of a knowledge-based economy and e-commerce.
- *Water for the environment:* protection of the water environment to preserve water resources (both surface water and groundwater) and natural flow regimes, bio-diversity and the cultural heritage, along with mitigation of water-related hazards.

The set of initiatives that need to take place to achieve the vision's key objectives is evaluated based on the four challenges of creating a better water future, which are:

1. managing the water resources efficiently and effectively (addressing both quantity and quality aspects),
2. moving towards integrated river basin management,
3. translating awareness into political will and capacity and
4. moving towards adequate, safe and affordable water services, as will befit a developed-nation status by 2020.

The actions for a better water future are also determined based on milestones and targets and they have to do with: (a) institutional and legal aspects; (b) participatory approach in the decision-making process; (c) development of innovative technologies; (d) efficient use of water resources; (e) extensive research and development; (f) shift from water-supply to water-demand management; (g) establishment of river basin organizations; (h) integrated water resources management; (i) promotion of water awareness and water education; (j) promotion of networking in the water sector; (k) good databases and dissemination; (l) resource assessment, monitoring and protection; (m) water ecosystems protection; (n) flood and drought contingency plans; (o) water-quality management; (p) frequent dialogues with the stakeholders; (q) a Water Sector Master Plan and (r) formation of a National Water Institute (Le Huu Ti and Facon, 2001).

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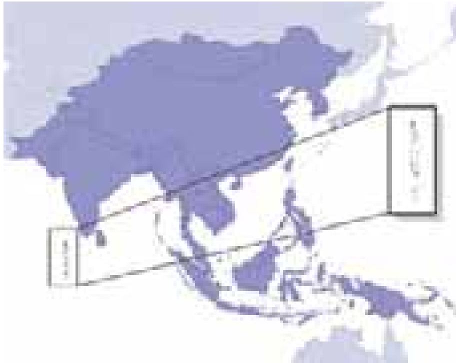
Maldives



GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Maldives are composed of 1 190 low-lying islands, spreading along a north-south axis over a distance of some 1 000 km, about 600 km southwest of Sri Lanka in the Indian Ocean, of which 198 are inhabited.

The total land area of the Maldives is 300 km^2 (Table 1). The islands form 26 natural atolls, which for administration purposes are grouped into 19 atolls (*atholhu*, singular and plural): Alifu, Baa, Dhaalu, Faafu, Gaafu Alifu, Gaafu Dhaalu, Gnaviyani, Haa Alifu, Haa Dhaalu, Kaafu, Laamu, Lhaviyani, Meemu, Noonu, Raa, Seenu, Shaviyani, Thaa, Vaavu; and the capital city: Male (Maale). Most of the islands are very small, few have a land area of more than 1 km^2, with elevations of not more than 2 m above sea level. All the main islands lie around the rim of the atolls, he lagoons are shallow, containing sandbars and cays with deep passages between the atolls.

In 2009 the total cultivated area was an estimated 7 000 ha, of which 3 000 ha were under permanent crops such as coconut and arecanut. Annual crops such as maize, sorghum, cassava, onion and chilies were grown on the other 4 000 ha.

Climate

The islands have a tropical climate with two monsoons, the:

- southwest monsoon from May to September; and
- northeast monsoon from November to March.

There are many thunderstorms during the months of April and October, which is in between the two monsoons. Precipitation is uniformly distributed throughout the year, except for a dry period of about 90 days from January to March. The long-term mean annual rainfall is 1 972 mm.

The daily temperature varies little throughout the year. The annual mean temperature is 28 °C, ranging from 26.2 to 30.6 °C.

Population

The total population in 2009 was 312 000 inhabitants, of which around 61 percent lived in rural areas (Table 1). The annual average growth rate during the period 1999-2009 was an estimated 1.5 percent. The population is concentrated on Male Island, while many of the other islands remain sparsely populated. Only 198 islands out of 1 190 are inhabited. Considering all islands together, in 2009 the average population density was 1 040 inhabitants/km^2, but it is much higher if taking only those islands where the majority of the people live.

Access to improved drinking water sources in 2008 reached 91 percent (99 and 86 percent for the urban and rural population respectively) and 98 percent of the population had access

MALDIVES

FAO - AQUASTAT, 2011

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	30 000	ha
Cultivated area (arable land and area under permanent crops)	2009	7 000	ha
• as % of the total area of the country	2009	23	%
• arable land (annual crops + temp fallow + temp meadows)	2009	4 000	ha
• area under permanent crops	2009	3 000	ha
Population			
Total population	2009	312 000	inhabitants
• of which rural	2009	61	%
Population density	2009	1 040	inhabitants/km^2
Economically active population	2009	146 000	inhabitants
• as % of total population	2009	47	%
• female	2009	42	%
• male	2009	58	%
Population economically active in agriculture	2009	23 000	inhabitants
• as % of total economically active population	2009	16	%
• female	2009	39	%
• male	2009	61	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	1 473	million US$/yr
• value added in agriculture (% of GDP)	2009	5	%
• GDP per capita	2009	4 721	US$/yr
Human Development Index (highest = 1)	2010	0.602	
Access to improved drinking water sources			
Total population	2008	91	%
Urban population	2008	99	%
Rural population	2008	86	%

to improved sanitation (100 and 96 percent for urban and rural populations respectively). Following the 2004 tsunami, 79 islands had no safe drinking water and 15 percent of the water systems were destroyed or contaminated.

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture was around 23 000 inhabitants (2009), amounting to 16 percent of the economically active population. Of the total population economically active in agriculture 39 percent were women. In 2009, the gross domestic product (GDP) was US$1 473 million of which agriculture accounted for 5 percent (Table 1).

Maldivians rely on natural rainfall for agriculture. The main crops are maize, sweet potatoes, millet, almonds, sugarcane, pineapples, taro, cassava, and a number of tropical fruits and vegetables. Fruits, such as sweet bananas, papaya, mangoes, limes, star-apples and guavas are grown within the compounds of each family's property together with a few vegetables.

The Maldives depend on imports for most food requirements and income that is generated by the two main activities, fisheries and tourism, is used to meet import requirements (Shabau, 2008). Fish is the main export product, followed by that coir and copra that are produced from the coconut palms. Recently, attempts have been made to encourage people to return to farming rather than depending on imported goods such as rice, which is the staple food, and wheat. Uninhabited islands, especially those next to the inhabited, are often leased to individuals, or villages, who become responsible for the maintenance of the island's vegetation, coconut trees and imeber. Coconut production is the dominant agricultural activity and a large variety of local timber is grown for domestic use. Watermelons are grown mainly on Thoddoo Island in the Alifu atoll. Some villagers keep goats and chickens although space is limited (Lamberti, 2007).

The impact of the tsunami in December 2004 was felt across the country, rather than in certain parts or regions. About 100 000 people, or one-third of the population, were severely affected. While loss of life, fortunately, was low, damage on many islands was great, especially hitting tourism on which the economy depends heavily. Of the 198 inhabited islands, 53 suffered severe damage and 10 percent of the islands were destroyed. Schools, clinics and pharmacies were destroyed on some 50 islands. According to the National Disaster Management Centre 64 schools, 30 health centres, and 60 island administrative facilities needed to be reconstructed or rehabilitated. In total, more than 5 000 buildings were damaged (ADB, 2006).

WATER RESOURCES AND USE

Water resources

There are no permanent rivers or streams on any of the islands, but small brackish ponds or freshwater lakes known as *kulhis* are found on some islands. Rainwater is collected on a small scale and used for drinking.

The Maldives finds it extremely difficult to obtain suitable drinkable water. Groundwater is found in freshwater lenses underlying the atolls and floating on top of the saline water, but heavy abstraction for municipal use has depleted them, especially in the capital city of Male, causing saltwater intrusion. Groundwater is recharged by rainfall but becomes contaminated while percolating through the soil, which is generally polluted with organic and human waste.

A rough estimate of the groundwater resources, based on an assumed 0.1 m/year recharge throughout the country (300 km^2), is 0.03 km^3/year, may be the Maldives' only renewable water resource. This is hardly exploitable because of seawater intrusion and pollution (Table 2).

Where the quality of water has been degraded (by high salinity and/or polluted water), and where there is insufficient space available for rainwater collection and storage, desalination has become the only alternative means of providing a safe water supply. This is the case in the capital Male and in what was the most densely populated island Kandholhudhoo in Raa Atoll. The size of this latter island is only 0.044 km^2, meaning roughly 210 m by 210 m. It was home to over 3 000 people, but it was one of the islands most affected by the tsunami and all inhabitants were left homeless and had to evacuate.

The first desalination plant in Male was installed in 1988 with a capacity of 200 m^3/day. In line with increases in population and water consumption, the capacity has been increased steadily and is now 5 800 m^3/day. The quantity of desalinated water used in Male has increased from 323 300 m^3 in 1996 to 1 206 900 m^3 in 2001, equal to about 900 and 3 300 m^3/day respectively (Ibrahim *et al.,* 2002). The desalination plant in Kandholhudhoo, constructed in 1999, has a production capacity of 50 m^3/day (18 262 m^3/year), and is a reverse osmosis plant.

When the population of Kandholhudhoo was served by desalinated water in May 1999, about 28 percent of the population of the Maldives had access to desalinated water and over 20 percent of the population almost entirely depended on desalinated water, besides the tourists on the resort islands. Desalination plants have been used in the Maldives' tourist resorts since the late

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 972	mm/yr
	-	590	million m^3/yr
Internal renewable water resources (long-term average)	-	30	million m^3/yr
Total actual renewable water resources	-	30	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	96	m^3/yr
Total dam capacity	-	-	million m^3
Water withdrawal			
Total water withdrawal	2008	5.9	million m^3/yr
- irrigation + livestock	2008	-	million m^3/yr
- municipalities	2008	5.6	million m^3/yr
- industry	2008	0.3	million m^3/yr
• per inhabitant	2008	19	m^3/yr
Surface water and groundwater withdrawal	2008	4.675	million m^3/yr
• as % of total actual renewable water resources	2008	15.6	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced	2001	1.225	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

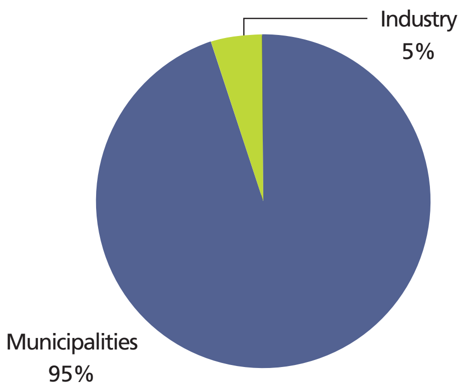
1970s. Currently each resort island has its own desalination plant, which is usually operated and maintained by a technician appointed for that purpose.

A large international company signed a US$42 million water purchase agreement in 2010 with Southern Utilities Limited to provide potable water to the Southern Province of the Maldives, which includes the Seenu and Gnaviyani atolls. The current population of around 26 000 is projected to increase to around 37 000 over the life of the contract. The company will construct six seawater reverse osmosis desalination plants with a total production of 3 000 m^3/day and will design and construct the distribution system to enable storage and delivery of potable water to over 4 500 households. After the commissioning period, it will operate and maintain the desalination plants for 20 years. In addition, it will design and construct four new sewage treatment plants as well as a new sewer collection system to transport wastewater from households to the new treatment plants and it will operate and maintain the sewage treatment system for the same 20 year period (IRC, 2010).

Water use

No recent figures are available on water withdrawal in the Maldives. It is, therefore, estimated that in 2008 the total municipal water withdrawal was 5.6 million m^3 against 3.3 million m^3 in 1987 (Table 2 and Figure 1). The industrial withdrawal was around 0.3 million m^3 against 0.1 million m^3 in 1987. No information is available on water withdrawal for irrigation. If, however, there is irrigation it will mostly rely on collected rainwater. This gives a total water withdrawal of 5.9 million m^3, of which 1.225 million m^3 is provided by desalinated water. The above amounts do not include water used by tourists. An estimated 500 000 tourists visit the Maldives per year and all tourist resorts have their own desalination plants. In addition, many people collect and store rainwater for their use, which is not included in the above amounts.

FIGURE 1
Water withdrawal by sector
Total 0.0059 km³ in 2008



Rainwater is tapped from roofs and collected and stored in various types of tanks. All the islands have individual household as well as community tanks. The situation is different on the island Male, which is the capital and where everyone has access to desalinated water distributed through a piped network. In Male it is common for people to use desalinated water for drinking and cooking, bathing and other domestic purposes because the groundwater is highly contaminated. Groundwater is mainly used to flush toilets s. Those who can, however, often prefer to collect rainwater for drinking to save money. Those who cannot afford to have house connections can collect limited quantities of water for free from tap bays located in 15 places around the island (Ibrahim *et al.,* 2002).

As in Male, many islands are now facing groundwater problems caused by human activities such as over-abstraction and sewage pollution. The island of Kandholhudhoo, the most densely populated island before the tsunami, had experienced problems similar to Male. A freshwater lens polluted by poor sanitation facilities and depleted by over-extraction, coupled with insufficient space to collect enough rainwater for the island's population, has left little alternative but desalination.

In the tourist resorts, the desalinated water produced is generally used for cooking and bathing only, as guests are encouraged to buy bottled water for drinking. Rainwater is sometimes collected for staff to drink, and groundwater is sometimes used for irrigation of tiny areas, though neither resource is used to its full extent. On a few resorts treated wastewater is used for irrigation of food crops and some landscaping, but no data are available, though the amount must be very small (Ibrahim *et al.,* 2002).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

No information is available on irrigation areas (Table 3). There is usually no irrigation because crops are rainfed, but some irrigated areas may exist around tourist resorts for some crops, such as vegetables and for landscaping.

Currently, some agricultural activities in the Maldives may rely on sunken wells and manual watering for crop irrigation. That procedure, while labour intensive, ensures sustainable use of water as a small plot of land, or a number of plots close together, may be adequately served by one or two wells (Zuhair, undated). On some islands, such as Thoddoo Island in the Alifu Atoll, mechanized irrigation systems are used. Pumps are used to draw water from a number of sunken wells through large hoses. Water is applied over the entire soil surface, but most of it will not reach the roots and will be lost through evaporation, making it a crude and wasteful form of irrigation. Localized irrigation aimed directly at the roots would be more feasible. Some new methods are being tested by the Ministry of Fisheries and Agriculture.

TABLE 3
Irrigation and drainage

Irrigation potential		-	ha
Irrigation			
1. Full control irrigation: equipped area		-	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- localized irrigation		-	ha
• % of area irrigated from surface water		-	%
• % of area irrigated from groundwater		-	%
• % of area irrigated from mixed surface water and groundwater		-	%
• % of area irrigated from mixed non-conventional sources of water		-	%
• area equipped for full control irrigation actually irrigated		-	ha
- as % of full control area equipped		-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)		**-**	**ha**
• as % of cultivated area		-	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year		-	%
• power irrigated area as % of total area equipped		-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)		**-**	**ha**
• as % of cultivated area		-	%
Full control irrigation schemes	**Criteria**		
Small-scale schemes	< ha	-	ha
Medium-scale schemes		-	ha
Large-scale schemes	> ha	-	ha
Total number of households in irrigation		-	
Irrigated crops in full control irrigation schemes			
Total irrigated grain production		-	metric tons
• as % of total grain production		-	%
Harvested crops			
Total harvested irrigated cropped area		-	ha
• Annual crops: total		-	ha
- Other annual crops		-	ha
• Permanent crops: total		-	ha
- Other perennial crops		-	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)		-	%
Drainage - Environment			
Total drained area		-	ha
- part of the area equipped for irrigation drained		-	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-related diseases		-	inhabitants

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The most important institutions concerned with water management are:

- Environmental Protection Agency (EPA): In 2009, the President of the Maldives abolished the Maldives Water and Sanitation Authority (MWSA), established in 1973, and the Environment Research Centre and transferred all activities to the newly established EPA. Following this change, the EPA was linked to the Ministry of Housing, Transport and Environment. It operates as a regulatory authority administered under a governing board (WASH, 2009).
- Male Water and Sewerage Company (MWSC): This was established in 1995 and is responsible for the operation and management of water supply and sewerage services in Male.
- Ministry of Housing, Transport and Environment.
- Ministry of Fisheries and Agriculture (MOFA): Has the overall mandate for the sustainable management and development of the nation's fisheries, agriculture and marine resources.

Water management

The development of sustainable water supplies should rely on a combination of developing groundwater resources and rainwater harvesting. Desalination is considered an expensive alternative in the Maldives, but one that is necessary on some islands. Desalination is widely used in the 87 tourist resorts. These are islands set aside solely for tourists, and each island has its own small desalination plant. It is an affordable option, because the islands are generating substantial revenue from the tourists.

Groundwater resources management requires improved land-use planning, assessment of groundwater conditions before development, and the designation of groundwater protection zones. The need for groundwater quality protection through improved sewage treatment and disposal of wastewater is recognized. Trials are to begin on use of gravel bed hydroponics (GBH) or constructed wetlands for sewage treatment to protect the groundwater from pollution. The *kulhis* (freshwater ponds) could be developed as a water resource, though studies have yet to be undertaken to explore this feasibility (Ibrahim *et al.,* 2002).

Training is required for the following (Ibrahim *et al.,* 2002):

- water quality monitoring and groundwater assessment, processing and interpretation of data and selection and use of equipment;
- developing geographical information systems (GIS) and groundwater modelling techniques, hydrology, hydrogeology and surveying;
- water balance studies to assess groundwater recharge and sustainable yield using climate and other data;
- design of appropriate groundwater pumping systems including infiltration galleries; and
- appropriate methods and techniques for determining marine water quality.

The government's policy is to ensure that all inhabited islands have water supplies that meet basic requirements. Except for Male, current investment on the islands is for rainwater collection to develop a consistent supply of safe water for drinking and cooking. The Government's objective, according to the Health Master Plan 1996–2005, is to provide access to 10 litres/person per day of safe water for drinking and cooking for the entire population and, on islands where groundwater is not potable, to provide 40 litres/person per day.

In 2006, MWSA presented the five-year activity plan, with the following activities: water resources assessment and monitoring, water supply and sanitation guidance and regulation development, and water and wastewater quality compliance monitoring (MWSA, 2006).

Finances

The cost of water varies, depending on whether it is used for domestically or commercially. The domestic tariff is stepped to provide a minimum quantity of water per day at an affordable rate. Table 4 gives the details of water tariffs in Male (Ibrahim *et al.,* 2002). Male's desalinated water is expensive. The average household spends between US$40-60 per month on water, while earning something like US$668 dollars per month, so people can spend about 6–9 percent of their income on their water bill (MPND/UNDP, 1998). Wastewater charges are also included in the water charge. The advantage of the present arrangement is that the public has the choice of using groundwater, rainwater or desalinated water according to the customer's needs and their income. The application of charges has made the public aware and willing to conserve and use water judiciously (Ibrahim *et al.,* 2002).

The associated costs of desalinated plants on resort islands are covered by revenue accrued by the resorts, of which they are a relatively small percentage.

The total cost of purchase, transport and installation of the desalination plant in Kandholhudhoo was US$102 000 and the cost per m^3 of water around US$7.84. This tariff covers the cost of operation and routine maintenance, but does not provide any additional funds to cover the cost of replacing the filter membranes or other spare parts, which can be expensive and difficult to obtain. The government met the capital cost of the plant and no attempt is being made to recover this cost through the tariff being collected. The responsibility for operation and maintenance of the plant on Kandholhudhoo is held by the Island Office, equivalent to a local government office.

Policies and legislation

The following policies for the sustainable development of water resources were set out in the context of the Health Master Plan 1996–2005 and the Second National Environmental Action Plan 1999:

- Ø To increase collection and storage of rainwater at household level. This will include the sizing of rainwater tanks at the household level to have sufficient capacity to store rainwater to last the whole year through.
- Ø To improve community collection and storage by increasing the storage capacity, renovating existing tanks, increasing catchment areas and conducting information, education and communication (IEC) activities to ensure rainwater is collected safely. This will include the building of underground rainwater tanks during construction of community buildings, and will encourage directing rainwater into household wells where rainwater tanks are not available.
- Ø To pilot new schemes such as community groundwater systems (infiltration galleries) in areas of low salinity with a low risk of pollution, as a means of supplementing rainwater supplies where necessary.

TABLE 4
Water tariffs in Male (2002)

Consumer group	Thresholds for fixing rates	Price to consumer, per m3
Domestic household	Up to 90 litres/day	MRf 25.32, equivalent to US$1.99 (band A)
	90–270 litres/day	MRf 75.95, equivalent to US$5.96 (band B)
	270 litres/day and above	MRf 101.26, equivalent to US$7.94 (band C)
Institutions	Metered flat rate	MRf 75.95, equivalent to US$5.96
Commercial	Metered flat rate	MRf 101.26, equivalent to US$7.94

- Ø In order to protect groundwater resources from becoming saline, to discourage the use of electric pumps.

ENVIRONMENT AND HEALTH

During the 1970s, the quantity of water drawn from Male's aquifer increased tremendously together with the amount of sewage disposed into the ground made it more susceptible to groundwater pollution. Water-borne diseases such as diarrhoea, cholera, shigella and typhoid started spreading because of the poor sanitary conditions. In response to this problem, a special office was established in 1973, the Maldives Water and Sanitation Authority (MWSA). A study carried out by MWSA in Male revealed about 1.3 million litres of water were being used from the aquifer daily, the thickness of the freshwater lens had reduced to about 12 m and there was rapid deterioration of tgroundwater quality. This was because of a larger population and poor sanitary conditions.

Outbreaks of cholera in 1978 and shigella in 1982 claimed many lives. As a result, the Male Water Supply and Sewerage project was conceived (Ibrahim *et al.,* 2002). Detailed surveys were carried out in 1980/1981. Subsequently, with assistance from West German Aid, the Saudi Fund for Development and the European Commission, the Government implemented the Male Water Supply and Sewerage Project in 1985. Under the project, the following work was carried out in Male between 1985 and 1988:

- Ø eight boreholes were drilled to investigate the aquifer and for subsequent monitoring;
- Ø large steel tanks were installed for storage of rainwater, with a total capacity of 9 900 m^3;
- Ø water from these tanks was pumped into a holding tank (600 m^3) and later distributed from a water tower (95 m^3) by gravity and distributed at 30 tap bays free of charge during selected hours;
- Ø 1 154 household tanks were built, with a total capacity of 4 157 m^3;
- Ø new wells were sunk in mosques and disinfected well water was fed to tap bays located at these locations, and distributed to the public free of charge throughout the day; and
- Ø a sewerage scheme was built for the whole island of Male. Sewage flows by gravity to sumps located in nine areas and is pumped from pumping stations into the deep sea without treatment through six outfalls located at four different places (Ibrahim *et al.,* 2002).

In the 1990s, the population of Male continued to grow and increasing pressure was placed upon the island's freshwater lens. Though the new sewerage scheme, using septic tanks and soakaways, helped to alleviate the pollution of the lens, it contributed to another problem. The increased volume of groundwater being used to flush toilets was no longer returning to the aquifer but was being discharged into the sea. As a result, the salinity of the aquifer increased sharply, limiting its usefulness as a resource. Because the available roof catchment area and the space available for rainwater storage was too limited to provide for Male's increasing population, desalination became one of the few options available for providing sufficient safe water to Male.

In 1988 the first desalination plant was installed, a reverse osmosis plant with a capacity of 200 m^3/day. Since then, more plants have been installed to satisfy demand, currently 5 000 m^3 of desalinated water can be produced per day. In 1995 a joint venture company, Male Water and Sewerage Company (MWSC) was formed and the responsibility was transferred for the operation and management of water supply and sewerage services in Male. The Maldives Water and Sanitation Authority became responsible for regulating this company, though it retains responsibility for providing services to the other inhabited islands (Ibrahim *et al.,* 2002).

Outside the capital, the major source of groundwater pollution is poor household sanitation. Fortunately, there are relatively few heavy industries and intensive agriculture is practiced on only a couple of islands. The majority of households have septic tanks and soakaways. The tanks are often poorly built or have suffered from hydrogen sulphide corrosion and are prone to leakage. As a result, tanks are often full or nearly full of sludge and have very short retention times. Soakaways are usually deep pits, not shallow trenches. Rather than use the unsaturated soil above the water table to remove at least some of the pollutants from the septic tank effluent, they effectively create a shortcut for septic tank effluent to reach the groundwater below. These factors combine to cause the contamination of groundwater resources by septic tank effluent (Ibrahim *et al.,* 2002).

When the December 2004 tsunami hit the Maldives, waves swept over many islands, affecting nearly one-third of the country's inhabitants. The saltwater from the tsunami completely flooded the sewage systems, contaminating groundwater with raw sewage and creating unsanitary conditions and increasing the risk of disease. The powerful waves also destroyed much of the infrastructure by overflowing sewage catch-pits, bursting pipes and filling the air with a foul stench. The islands' residents rely on groundwater as their main source of water for domestic activities such as cooking, cleaning and washing (ARC, 2006). An Asian Development Bank (ADB) grant for environmental management focuses predominantly on environmental health and awareness. It designed a strategy for reconstructing the water and sanitation sector following the tsunami and improving the country's environmental assessment capability. It also tests innovative environmental public awareness programmes and promotes community management of sanitation and solid waste systems (ADB, 2006).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The Maldives, ranks fifth amongst the countries with the highest population density, the most important preoccupation remains water availability and accessibility. Ways are sought continuously fto improve availability by desalinating water, treating wastewater, collecting and storing rainwater and responsibly using and conserving the little groundwater available.

Following the tsunami, it was estimated that the Maldives would need about US$304 million to effectively implement a recovery and reconstruction strategy, according to the joint needs assessment *Tsunami: Impact and Recovery* carried out by the ADB, the United Nations system, and the World Bank (ADB, 2006).

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Mongolia

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Mongolia is located in the north of the central Asian plateau and has an area of about 1.56 million km^2 (Table 1). It is a landlocked country bordered in the north by the Siberian Russian Federation, and in the east, south and west by China. Administratively the country is divided into 21 provinces *(aimags)*, each with a provincial capital and a local government headed by an *aimag* governor, and the capital city Ulaanbaatar.

The country consists principally of inter-mountain plateaux. About 80 percent of the territory lies above 1 000 m above sea level. The main mountain ranges are the Mongolian Altai in the west and the Khangai and Khentii mountains in the north and centre, with the large depression of the Great Lakes located between the two ranges, while to the east there are elevated plains. Geographically, Mongolia can be divided into four regions: Khangai forest region, the eastern steppe region, Gobi (*Govi* in Mongolian) desert region and the semi-desert region.

The total cultivable area is an estimated 1.8 million ha, which is about 1 percent of the total area. Some 80 percent of the total land area can be used for pastoral activities. The main crop growing areas are in the central-northern part of the country and include portions of Selenge, Tov and Bulgan provinces, which contain about 67 percent of all cultivated land. These areas comprise a broad basin draining to the north. Only valley bottom land and the lower slopes of hills with sufficiently deep soils are cultivated. In 2009, the total cultivated area was estimated at 962 000 ha, of which 960 000 was arable land and 2 000 ha permanent crops. Only 10 percent of the country is forested (FAO, 2003).

Climate

The country has severe climatic conditions with long cold winters. The average annual precipitation is 241 mm, ranging from 400 mm in the north to less than 100 mm in the southern Gobi region. The mean monthly temperature is below 0 °C throughout the country between November and March. Late spring and early autumn (even late summer) frosts reduce the vegetation period to 80-100 days in the north and 120-140 days in the south. Summer precipitation occurs between June and August, representing 80-90 percent of the total annual rainfall. Other climatic factors affecting agricultural production include low soil moisture and air humidity in spring and early summer, and strong winds in spring, resulting in high evaporation and soil erosion.

Population

The total population in 2009 was 2.7 million, of which around 39 percent lived in rural areas (Table 1). Mongolia is sparsely populated with the lowest average population density in the world, 2 inhabitants/km^2, but there are 180 inhabitants/km^2 in the capital city Ulaanbaatar. The annual population growth rate during the period 1999-2009 was 1.3 percent.

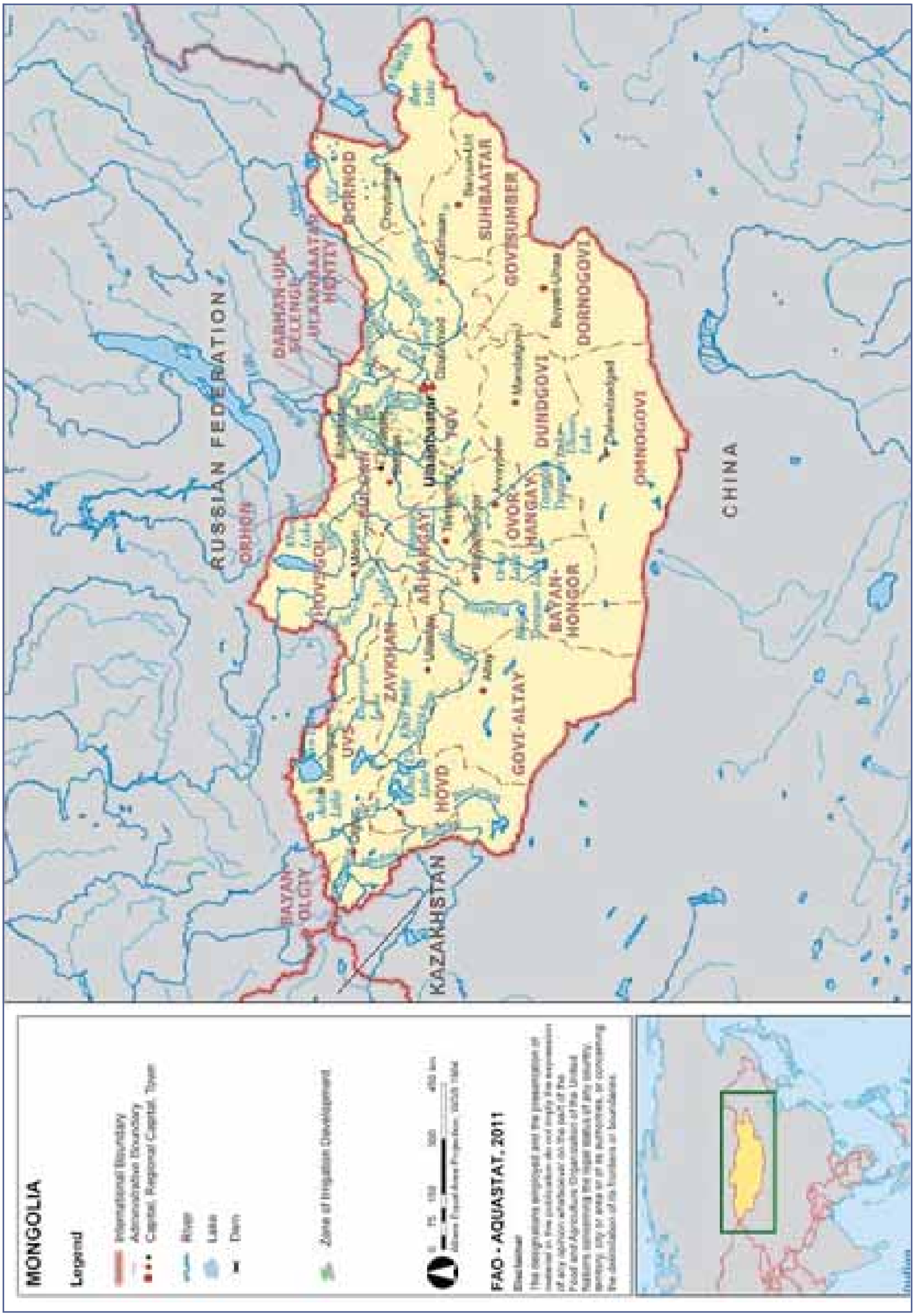

MONGOLIA
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
FAO - AQUASTAT, 2011
Disclaimer
RUSSIAN FEDERATION
CHINA
KAZAKHSTAN
BAYAN-OLGIY
UVS
HOVD
ZAVHAN
HOVSGOL
ARHANGAY
BULGAN
ORHON
SELENGE
DARHAN-UUL
TOV
GOVI-ALTAY
BAYAN-HONGOR
OVORHANGAY
DUNDGOVI
OMNOGOVI
DORNOGOVI
GOVISUMBER
SUHBAATAR
HENTIY
DORNOD
Ulaanbaatar

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	156 412 000	ha
Cultivated area (arable land and area under permanent crops)	2009	962 000	ha
• as % of the total area of the country	2009	0.6	%
• arable land (annual crops + temp fallow + temp meadows)	2009	960 000	ha
• area under permanent crops	2009	2 000	ha
Population			
Total population	2009	2 712 000	inhabitants
• of which rural	2009	39	%
Population density	2009	2	inhabitants/km^2
Economically active population	2009	1 200 000	inhabitants
• as % of total population	2009	44	%
• female	2009	50	%
• male	2009	50	%
Population economically active in agriculture	2009	221 000	inhabitants
• as % of total economically active population	2009	18	%
• female	2009	52	%
• male	2009	48	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	4 202	million US$/yr
• value added in agriculture (% of GDP)	2009	24	%
• GDP per capita	2009	1 550	US$/yr
Human Development Index (highest = 1)	2010	0.622	
Access to improved drinking water sources			
Total population	2008	76	%
Urban population	2008	97	%
Rural population	2008	49	%

In 2008, access to improved drinking water sources reached 76 percent (97 and 49 percent for the urban and rural population respectively). Sanitation coverage accounts for 50 percent (64 and 32 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total population economically active in agriculture was an estimated 221 000, amounting to 18 percent of the economically active population. About 52 percent of the population economically active in agriculture are women. In 2009, the gross domestic product (GDP) was US$4 202 million of which agriculture accounted for 24 percent (Table 1).

The Mongolian agriculture sector is divided into four subsectors:

- extensive livestock, which is the traditional semi-nomadic pastoral system, where camels, horses, cattle, sheep and goats are grazed together;
- mechanized large-area crop production of cereals and fodder crops;
- intensive farming, producing potatoes and other vegetables, with both mechanized and simple production methods; and
- intensive livestock, with housed dairy cattle, pigs and poultry.

The livestock sector dominates, contributing almost 85 percent of total agricultural production (FAO, 2001).

The country adopted a free-market economy in 1990. The privatization of crop production has partly failed and is still incomplete. Under liberalization policies, the original, very large production units were to be privatised, reduced in size and organized into various types of companies. In the beginning the number of these companies increased rapidly, then many disappeared during the break up of the Union of Soviet Socialist Republics (USSR), because of inadequate access to credit, inflation and mismanagement in the new free market conditions. By 1997, only 300 large wheat farms (between 1 000 and 30 000 ha each) remained operational (FAO, 2001).

In 1992, cereals occupied nearly 90 percent of the total cropped area, but declined as a result of the reduced availability and increased cost of production inputs and lack of working capital. About 8 percent of the total arable area was devoted to fodder crops. Potatoes and vegetables together accounted for 1.5 percent of the area planted, while fruit trees covered 0.5 percent of the total area.

WATER RESOURCES AND USE

Water resources

Mongolia is situated on three international river basins (Mongolian River Resources, 2010):

- The Arctic Ocean Basin in northern and central Mongolia, also known as the Yenisei river basin, drains in a northerly direction through the Russian Federation into the Arctic Ocean and covers 20 percent of the country. The many lakes and rivers are fed by water from the northern Khangai mountains and the western slopes of the Khentii mountains. The total length of the rivers in the basin is 35 000 km, which is about 50 percent of the total length of all Mongolia's rivers. The basin's flow accounts for 51.4 percent of the country's total annual runoff. Major rivers in the basin are the Selenge and its tributary the Orkhon, the Ider and the Delgermurun.
- The Pacific Ocean Basin in eastern Mongolia, also known as the Amur River Basin, drains in an easterly direction through China, the Russian Federation and the Democratic People's Republic of Korea into the Pacific Ocean and covers 12 percent of the country. This Basin encompasses rivers in the eastern part of Mongolia, which originate in the Khentii and Khyangan mountains. The basin's flow accounts for about 15 percent of the country's total annual runoff. Major rivers in this basin are the Onon, Ulz, Khalkh and Kherlen.
- The Central Asian Internal Drainage Basin in southern and western Mongolia covers 68 percent of the country, does not drain into an ocean, occupies much of the arid Gobi Desert and hence has few rivers (Hovd, Zavkhan, Bulgan, Uyench, Bodonch and Buyant) and limited groundwater resources. It has a series of internal drainage systems: the Khar-Us Nuur, the Uvs Nuur, and the Pu-Lun-To. It is home to 78 percent of Mongolia's wetlands.

Located within these international basins are eight major regional basins, determined by their economic and environmental significance (Mongolian River Resources, 2010):

- Arctic Ocean Basin:
  - the Selenge river basin, located in semi-arid northern Mongolia, is the country's largest basin. It is composed of two main rivers, Selenge and its tributary Orkhon. Its major sub-basins are the Egiin, Ider, Orkhon and Tuul river basins;
  - the Tuul river basin covers almost 3.2 percent of the country and is home to more than half of Mongolia's population. It has a catchment area of 49 840 km^2.

- the Khuvsgul lake basin in northern Mongolia is the location of the second biggest freshwater lake in the world.

Ø Pacific Ocean Basin:
- the Kherlen river basin covers 116 455 km^2 in semi-arid eastern Mongolia;
- the rivers of the Onon, Ulz, and Khalkh basins are among the largest in eastern Mongolia and originate in the upper reaches of the Khentii and Khyangan mountains; They account for about 11 percent of the country's total surface water runoff.

Ø Central Asia Internal Drainage Basin:
- the Great Lakes basin in western Mongolia contains Central Asia's most important wetlands. The basin is divided into four parts: the Uvs, Khyargas, Khar-Us and Sharga depressions. It features a series of large lakes: the Uvs, Khyargas, Khar-Us, Khar, Airag and Shargiin Tsagaan;
- the Northern Gobi river basins; and
- the Southern Gobi river basins.

There are about 4 113 rivers in Mongolia, with a total length of 67 000 km. Large rivers originate in the mountainous areas in the north and west of the country – primarily in the Mongol Altai, Khangai-Khuvsgul and Khentii mountain ranges – where small rivers and mountain streams merge to create well-developed water networks. In contrast, the southern, central and southeastern parts of the country have few rivers or other water resources. In the interior drainage basins, in the western and southern areas of Mongolia, seasonal or intermittent streams end in salt lakes or disappear into the desert. The rivers' main water sources are rainfall, groundwater, snow and glaciers, with melting snow accounting for 15-20 percent of the annual runoff. From November to May, the rivers in the north are frozen. Waterways in the Gobi Desert are fed almost exclusively by groundwater. Sixty percent of Mongolia's river runoff drains into the Russian Federation and China, while the remaining 40 percent flows into the lakes of the Gobi Desert. The longest rivers within the Mongolian territory are (Mongolian River Resources, 2010):

Ø The Orkhon river (1 124 km) originates in the Khangai mountains. It initially flows eastward, before heading north and joining the Selenge river as its major tributary, which then continues northwards into the Russian Federation and Lake Baikal, by volume this is the world's largest freshwater lake. It has a drainage area of 132 855 km^2 and occupies 47 percent of the Selenge river basin. The Tuul and Kharaa rivers drain into the Orkhon river.

Ø The Selenge river (1 024 km) is Mongolia's principal waterway, accepting 30.6 percent of the flow of all the rivers in Mongolia. It is formed by the confluence of the Delgermurun and Ider rivers. It flows north into the Russian Federation, eventually draining into Lake Baikal, of which it is the most substantial source of water. Its main tributaries are the Egiin, Orkhon and Uda rivers. It is also the headwater of the Yenisei-Angara river.

Ø The source of the Kherlen river (1 090 km) is in the Khentii mountains. It flows to China, where it subsequently empties into Lake Hulun. Its main tributaries are the Iluur, Burkh, Baidrag, Terelj and Tenuun rivers.

Ø The Zavkhan river (808 km) starts at the confluence of the Buyant and Shar Us rivers in the Khangai mountains. It empties into Lake Airag in the Great Lakes basin, which then connects with Lake Khyargas. The river provides most of Lake Khyargas' tributary flow.

Ø The Tuul river (704 km) originates at the confluence of the Namiya and Nergui streams. It flows in a southwesterly direction, passing through the southern part of the Mongolian capital, Ulaanbaatar, before joining the Orkhon river.

Ø The source of the Hovd river (593 km), is on the northern side of the Mongol Altai mountains, rises from the permanent snows of Tavan Bogd mountain. It flows into Lake Khar-Us in Hovd province in western Mongolia. Its main tributaries are the Tsagaan and Sagsai rivers.

- The Eruu river (323 km) starts in the Khentii mountains at the confluence of the Khongiin and Sharluun rivers. It flows into the Orkhon river and has a drainage area of 11 860 km^2.
- The Onon river (298 km) originates in the Khentii mountains, from where it flows in a northeasterly direction, eventually converging with the Ingoda river in the Russian Federation to produce the Shilka river. At the border with China, the Shilka joins the Argun river to form the Amur river, which eventually drains into the Pacific Ocean. The Onon river has a drainage area of 94 010 km^2. Its main tributaries are the Barkh, Balzh and Khurkh rivers.
- The Kharaa river (291 km) originates in the mountains north of Ulaanbaatar and passes through Selenge and Darkhan-Uul provinces before flowing into the Orkhon river.

Mongolia's long-term average annual renewable water resources include 32.7 km^3 of surface water and 6.1 km^3 of groundwater. Part of the groundwater flow, estimated at 4 km^3/year, returns to the river system as base flow and is called overlap (Table 2). This gives a total of 34.8 km^3/year (32.7+6.1-4.0) for internal renewable water resources (IRWR). It is estimated that no water enters the country from neighbouring countries, but that 25 km^3/year flows into the Russian Federation and 1.401 km^3/year into China.

There are some 3 060 natural lakes with surface area larger than 100 ha or 0.1 km^2. The lake with the largest surface area is Lake Uvs (3 518 km^2), which is a saline lake without an outlet (Table 3). Lake Khuvsgul has the greatest volume (384 km^3) and depth (139 m). It contains 74 percent of the total freshwater resources of Mongolia, and is fed by 46 rivers and other large lakes. In the higher mountainous regions the potential evaporation is lower than the annual precipitation and, therefore, the lakes never dry up and persist against periods of drought. In areas such as the Valley of Lakes, however, it is the opposite and therefore the lakes there can become quite shallow in very dry areas. Most of the medium lakes such as Orog, Taatsyin

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	241	mm/yr
	-	377 000	million m^3/yr
Internal renewable water resources (long-term average)	-	34 800	million m^3/yr
Total actual renewable water resources	-	34 800	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	12 832	m^3/yr
Total dam capacity		-	million m^3
Water withdrawal			
Total water withdrawal	2005	511.2	million m^3/yr
- irrigation + livestock	2005	227	million m^3/yr
- municipalities	2005	121.8	million m^3/yr
- industry	2005	162.4	million m^3/yr
• per inhabitant	2005	201	m^3/yr
Surface water and groundwater withdrawal	2005	511.2	million m^3/yr
• as % of total actual renewable water resources	2005	1.47	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

TABLE 3
Characteristics of some natural lakes (Source: Davaa, Oyunbaatar and Sugita, 2007)

Lake	Water level (m)	Surface area (km^2)	Volume (km^3)	Average depth (m)	Area/depth (km^2/m)	Location
Khuvsgul	1 647.6	2 770.0	383.7	138.5	200	Khuvsgul
Uvs	760.0	3 518.3	35.7	10.1	986	Great Lakes' Hollow
Khyargas	1 035.3	1 481.1	75.2	50.7	197	Great Lakes' Hollow
Khar-Us	1 160.1	1 495.6	3.1	2.1	4794	Great Lakes' Hollow
Khar	1 134.1	565.2	2.3	4.1	1378	Great Lakes' Hollow
Terkhiin Tsagaan	2 059.2	54.9	0.3	6.1	90	Khangai Mountain
Buir	583.0	615.0	3.8	6.1	1008	Eastern Mongolian Plain Land
Boon Tsagaan	1 312.0	252.0	2.4	10.0	252	Valley of Lakes
Adgiin Tsagaan	1 285.0	11.5	0.01	0.8	144	Valley of Lakes
Orog	1 217.0	140.0	0.4	3.0	467	Valley of Lakes
Ulaan	1 008.0	175.0	Dried up	-	-	Valley of Lakes

Tsagaan, Adgiin Tsagaan and Ulaan in the Valley of Lakes dry up once or twice every 11-12years, which can lead to an ecological crisis when millions of fish, aquatic plants and animals die in isolated spots of concentrated saline mud left by the drying lake (Davaa *et al.,* 2007).

In 1999, about 27 earth dams were constructed to store water for sprinkler irrigation systems. A small part (55 km^2) of the catchment drained by the Boroo river is intercepted by the Shariin Am dam and storage reservoir facility. The Shariin river is a narrow and shallow river with a small dam about 4 m high, capable of impounding a small storage reservoir with a regulating capacity of about 250 000 m^3.

The theoretical hydropower potential in 1999 was an estimated 5 500-6 000 MW. There is a 528 kW mini-hydroplant in operation (the Kharakhoum scheme) on an irrigation canal that diverts water from the Orkhon river.

International water issues

There are about 210 rivers flowing through Mongolia into the Russian Federation and China. The first international agreement on transboundary water resources was between the governments of Mongolia and the USSR in 1974. This stipulated the use of water and protection of the Selenge river basin, which plays an important role in the economic and industrial development of both countries. The agreement made between the governments of Mongolia and the Russian Federation in 1995 on the protection of transboundary water resources focuses on over 100 small rivers and streams located in the western part of the country.

The drainage basins of the transboundary rivers between Mongolia and the Russian Federation cover almost one-third of Mongolia's territory. In 1994, an agreement was signed between China and Mongolia on the protection of transboundary water resources concerning Lake Buir, the Kherlen, Bulgan, Khalkh rivers, and 87 small lakes and rivers located near the border. Transboundary water resources shared with China include surface water bodies in Dornod, Hovd, and Bayan-Olgiy provinces and groundwater resources in Govi-Altay, Omnogovi, Bayanhongor, Suhbaatar and Dornogovi provinces (UN, 2006b).

Water use

In 1996, total water withdrawal from groundwater (80 percent) and surface water (20 percent) was equal to 400 million m^3, of which 138 million m^3 (34.6 percent) for livestock, including irrigated fodder production, 32 million m^3 (7.9 percent) for irrigation of other crops, 101 million m^3 (25.2 percent) for municipalities, 103 million m^3 (25.8 percent) for industry and 26 million m^3 (6.5 percent) for other needs (Myagmarjav and Davaa, 1999).

In 2005, total water withdrawal was about 511 million m^3, of which around 227 million m^3 (44 percent) for agriculture, 122 million m^3 (24 percent) for municipalities and 162 million m^3 (32 percent) for industries (Table 2 and Figure 1). About 82 percent, or 419 million m^3, was contributed by groundwater resources (Figure 2).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation in Mongolia was probably developed under the Huns in the first century. Irrigation development appears to have peaked at about 140 000 ha during the seventeenth and eighteenth century.

Traditional irrigation methods had been largely abandoned by the end of the nineteenth century. Chinese ‘migrants’ developed comparatively small-scale schemes on the larger rivers. ‘Modern’ irrigation development started in the 1950s, and the first modern irrigation scheme was designed in 1955.

FIGURE 1
Water withdrawal by sector
Total 0.5112 km³ in 2005

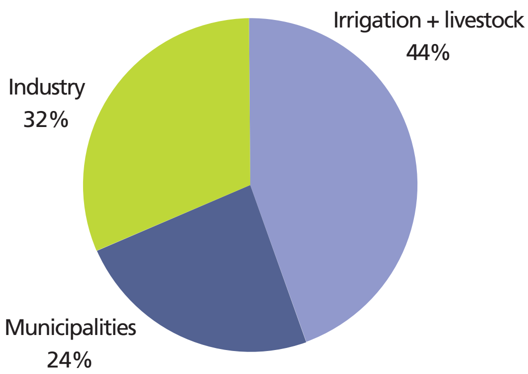
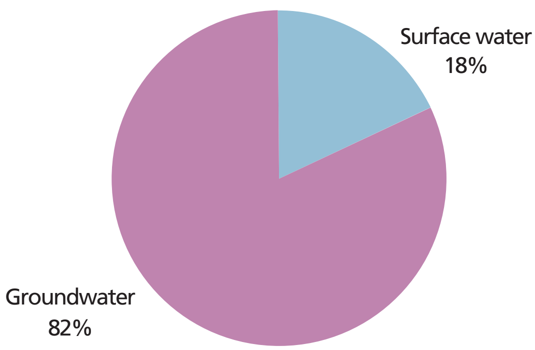


FIGURE 2
Water withdrawal by source
Total 0.5112 km³ in 2005



About 518 000 ha with irrigation potential were identified at reconnaissance level in the early 1970s, of which 117 000 ha have been studied in more detail for potential development. Starting in 1971, some small irrigation schemes were built in the western *aimags*. A government campaign began in 1975 to produce irrigated fodder in the western and Gobi regions. The construction of further irrigation schemes, large and small, continued until 1988.

In the 1980s, irrigation schemes were characterized by sprinkler systems, generally serving from 400 to 500 ha or more, primarily for fodder and cereal production and, to a lesser extent, for vegetables and potato production.

In 1993, the total area equipped for irrigation was an estimated 84 300 ha. The total area equipped for full control irrigation amounted to 57 300 ha, of which 43 400 ha under sprinkler systems (registered schemes) and 13 900 ha of systems using surface irrigation methods (unregistered schemes) (Table 4 and Figure 3). In addition, an estimated 27 000 ha of pasture benefited from traditional floodwater diversion (spate irrigation). The area equipped for full control irrigation that is actually irrigated was estimated as 35 000 ha (61 percent), while 62 900 ha (75 percent) of the total area equipped for irrigation was actually irrigated.

TABLE 4
Irrigation and drainage

Irrigation potential		518 000	ha
Irrigation			
1. Full control irrigation: equipped area	1993	57 300	ha
- surface irrigation	1993	13 900	ha
- sprinkler irrigation	1993	43 400	ha
- localized irrigation	1993	0	ha
• % of area irrigated from surface water	1993	37	%
• % of area irrigated from groundwater	1993	63	%
• % of area irrigated from mixed surface water and groundwater		-	%
• % of area irrigated from mixed non-conventional sources of water		-	%
• area equipped for full control irrigation actually irrigated	1993	35 000	ha
- as % of full control area equipped	1993	61.1	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation	1993	27 000	ha
Total area equipped for irrigation (1+2+3)	**1993**	**84 300**	**ha**
• as % of cultivated area	1993	6.2	%
• % of total area equipped for irrigation actually irrigated	1993	74.6	%
• average increase per year over the last -- years		-	%
• power irrigated area as % of total area equipped		-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		-	ha
5. Non-equipped flood recession cropping area		-	ha
Total water-managed area (1+2+3+4+5)	**1993**	**84 300**	**ha**
• as % of cultivated area	1993	6.2	%
Full control irrigation schemes	**Criteria**		
Small-scale schemes	< ha	-	ha
Medium-scale schemes		-	ha
Large-scale schemes	> ha	-	ha
Total number of households in irrigation		-	
Irrigated crops in full control irrigation schemes			
Total irrigated grain production		-	metric tons
• as % of total grain production		-	%
Harvested crops			
Total harvested irrigated cropped area		-	ha
• Annual crops: total		-	ha
• Permanent crops: total		-	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)		-	%
Drainage - Environment			
Total drained area		-	ha
- part of the area equipped for irrigation drained		-	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area		-	%
Flood-protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-related diseases		-	inhabitants

An inventory of 156 registered schemes exists, covering a total of 43 400 ha and varying in size between 5 and 3 300 ha, two-thirds of them being smaller than 50 ha. Most schemes have

FIGURE 3
Irrigation techniques on area equipped for full control irrigation
Total 57 300 ha in 1993

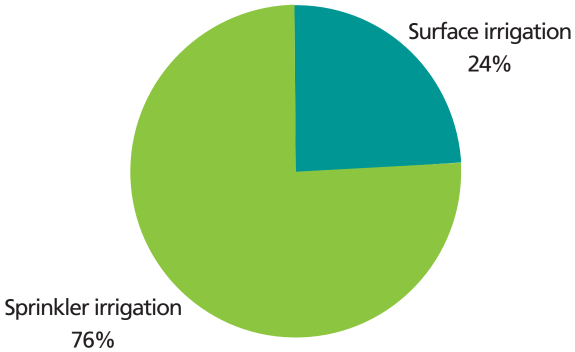
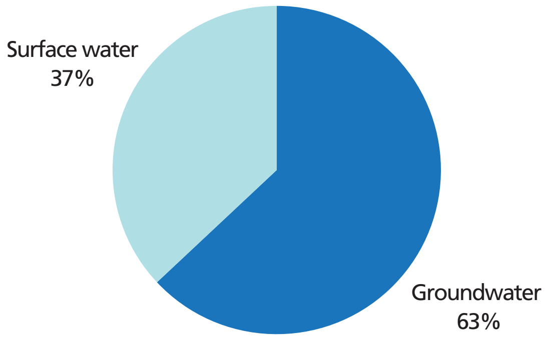


FIGURE 4
Source of irrigation water on area equipped for full control irrigation
Total 57 300 ha in 1993



been developed in the north (48 percent) and west (47 percent). Unregistered schemes, an estimated 80 percent, are concentrated in the west of the country, are smaller (1-100 ha) and are the result of spontaneous efforts by local people, or are state schemes taken over by companies and private individuals after being abandoned.

Of the sprinkler irrigated area, side-roll systems account for 43 percent, tractor-mounted water guns or sprinkler booms for 28 percent, centre pivots for 25 percent and movable laterals for 4 percent. About 46 percent of the total irrigated area is served by gravity canals and the remaining 54 percent by buried steel pipes. In 1993, 36 099 ha or 37 percent of the total area equipped for full control irrigation was irrigated by surface water and 21 201 ha or 63 percent by groundwater (Figure 4).

The total sprinkler irrigated area has been in steady decline with the privatization of the state farms operating the systems and the subsequent lack of finance. Producers growing crops on irrigated areas experienced high operation costs, huge energy consumption and shortage of skilled and trained labour on the farms. It was not possible to fully exploit the production potential of the irrigated areas.

Sprinkler irrigation was difficult to operate and sometimes this method leached the soil. It also had high operation and maintenance costs, and produced overcapacity, which sometimes could not be harvested (FAO, 2003). In 1992, only 52 percent of the total area under sprinkler systems, or 22 000 ha, was operational. Of the remaining area, 11 000 ha are classified as abandoned for irrigation purposes, while the other 10 000 ha are defined as non-functional owing to failed or missing equipment. Individual irrigators have established plots on schemes as the farming companies have withdrawn from irrigation.

Role of irrigation in agricultural production, economy and society

Because of the dry character of the country, especially in the Gobi and steppe zones, a reliable harvest vegetables or other crops is possible only using irrigation; rainfed crop production is limited. As most precipitation falls in summer little humidity is kept in the soil (FAO, 2003).

During the 1980s, fodder crops accounted for approximately 50 percent of the area irrigated under sprinkler systems, annual cereal crops (mainly wheat) for 20-40 percent, potatoes for 5-10 percent, vegetables (mainly cabbage, onions, carrots and turnips) for 5-10 percent, and fruit (seabuckthorn, blackcurrant and Siberian apples) for less than 2 percent. Unregistered irrigation schemes have focused primarily on potatoes, vegetables and fruit production, with significant areas of fodder production in the west and south. Fodder, cereals and potatoes have suffered from the reduction in irrigation extension. Vegetables, some fruits and early potatoes are the main crops currently grown on irrigation schemes.

In 1986, total crops harvested amounted to 869 300 tonnes with 15 700 tonnes (2 percent) from irrigated areas. In 1999, the total harvest was 171 200 tonnes with 2 500 tonnes (1.4 percent) from irrigated areas. In other words, over a period of 15 years there was a steady decline to only one-fifth of the original production (by tonnage). Comparing 1999 with 1986, the production of wheat declined 3.9 times, potatoes 1.1 times, vegetables 1.1 times, and planted fodder crops 40 times. In the past Mongolia was self-sufficient in crop produce. In 1999, because of the hot weather, there was a poor harvest (FAO, 2003).

According to cost estimates provided by the Ministry of Food and Agriculture in 1993, registered irrigation investment averaged US$1 300/ha at 1993 prices, with infrastructure representing 87 percent of this amount. In 1995, an FAO mission estimated new irrigation establishment costs at approximately US$2 000/ha and rehabilitation costs at approximately US$700-1 000/ha.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The main institutions dealing with agriculture and water resources development are the Ministry of Food, Agriculture and Light Industry (MOFALI) and the Ministry of Environment (MOE). MOFALI is responsible for rural water supply and contains the Department of strategic planning and Policy, which is the Water Policy and Regulation Unit (Batnasan, 2003). MOE is responsible for water conservation. Under this ministry is the Agency of Meteorology, Hydrology and Environment Monitoring and the Agency for Nature, Forest and Water resources, which contains the Center for Water Research.

Currently, Mongolia has no fully developed integrated institutional infrastructure on river basin management issues.

In 2000, the National Water Committee (NWC) was established to coordinate and monitor the implementation of the National Water Programme (Batsukh *et al.,* after 2005). In addition to the MOFALI and the MOE other ministries are involved in the NWC, such as the Ministry of Industry and Trade, the Ministry of Defense, the Ministry of Health and the Ministry of Infrastructure (Batnasan, 2003).

Water management

The management of the country's water resources is detailed in the Law on Water, enacted in 1995 to regulate the protection, effective use and restoration of water. It also focuses on capacity-building in the water sector and the decentralization of water management (Asia Foundation, 2010).

Dutch engineering companies, in close collaboration with UNESCO-IHE, plan to support the Mongolian Ministry of Environment in its mission to modernize water management in Mongolia. The project entitled 'Strengthening integrated water resources management (IWRM) in Mongolia' aims to introduce IWRM into the country as well as expand the knowledge and skills in the Mongolian water sector. The project initiators aim to transfer their know-how to the local community by providing training for the project partners. Meanwhile, two university courses on water management will be set up in Mongolia. The Mongolian water sector is currently facing a variety of challenges. There is a lack of safe drinking water and insufficient sanitation for the entire population (MDGs). The project started in January 2009 and is set to finish in four years. The total budget estimated for the project is €6.5 million (UNESCO-IHE, 2009).

Finances

Mongolia's pricing policy is decentralized and local authorities are entitled to set up and revise the water tariffs (UN, 2006a). Mongolia's Law on Water covers pricing policies intended to ensure cost recovery and the equitable allocation of water resources. In 2008, however, only 65 percent of water costs were recovered through pricing, partly because of the country's present economic conditions. For example, although the regulation states that all water used by industry will be charged, industries are not making enough profit to pay for the real costs of water. Water use for agriculture is free, although every user must establish a contract for the use of water, while household users pay small fees for their use (ADB, 2008).

Policies and legislation

A Water Law has been in force since June 1995 and was amended in 2004 to integrate river basin management practices with the goal of better use of water resources while protecting ecosystems. The Water Law also recognizes the economic value of water, requires capacity-building in the water sector, focuses on the decentralization of water management, puts forward the need for environmental impact assessments and sets new penalties for violating water legislation (Batsukh *et al.,* after 2005).

In 1995, the Law on Water and Mineral Water Use Fees was also enacted, establishing fees for the use of water by citizens, companies and other organizations. Other laws related to water are the Environmental Protection Law, enacted in 1995, and the Environmental Impact Assessment Law, enacted in 1998 (Asia Foundation, 2010).

The Mongolian Action Programme for the twenty-first century, the National Water Programme and the National Action Programme on climate change were approved on 1998, 1999 and 2000 respectively (Batnasan, 2003).

The United Nations Framework Convention on Climate Change (UNFCCC) and the Ramsar Convention on Wetlands were ratified by the Mongolian parliament in 1993 and 1997 respectively, and entered into force in 1994 and 1997 (Batnasan, 2003).

ENVIRONMENT AND HEALTH

Freshwater ecosystems of Mongolia are subject to increasing and multiplying threats, including overgrazing, dams and irrigation systems, growing urbanization, mining and gravel extraction, climate change impact and lack of water management policies and institutional framework (Batnasan, 2003).

The Asia Foundation's Securing Our Future (SOF) programme is a three-year initiative designed to promote the sustainable use of Mongolia's natural resources that is focused on responsible mining and land-use practices. It is being jointly implemented by The Asia Foundation, The Netherlands, and a coalition of non-governmental, public and private sector partners. The overall purpose of the programme is to ensure that future mining activities in Mongolia generate long-term benefits for the people of Mongolia without compromising the nation's ecological and social heritage.

SOF involves seven programme areas. Maximum community participation is sought in the decision-making process, in long-term collective management and use of the country's vast natural resources. One of the seven areas focusses on the development of a Mongolian river water quality monitoring network. This will enlist citizens and students to work in partnership with Mongolian and expatriate scientific experts in the collection and dissemination of data on the quality of river water across the nation. It will lead to the compilation of a complete ecological inventory of Mongolian waterways (Asia Foundation, 2010).

Overuse of groundwater resources and climate change has led to lowering of the groundwater table, which has consequently caused some springs, lakes and their associated ecosystems to dry up.

Since the systematic observation period, from 1940 onwards, serious floods have been observed at Mongolia rivers, which have caused severe property damage and loss of life. About 18 flood events have been observed from 1996 to 1999 and have resulted in 54 lives lost and much property damages (Davaa *et al.,* 2007).

Out of 10 000 cases of diarrhoea every year, almost 70 percent have occurred in the capital Ulaanbaatar. Dysentery and hepatitis are also common. These infections stem from a lack of access to safe water and sanitation infrastructure (UN, 2006a).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Solving the stressed present freshwater situation in Mongolia would require a coordinated approach of governmental institutions, donors, NGOs and key stakeholder groups on river basin level. Currently, however, there is no fully developed integrated institutional or legal infrastructure handling Integrated River Basin Management (IRBM) issues. Thus, there is an urgent need to consider implementing the IRBM principles for sustainable water management (Batnasan, 2003).

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Myanmar

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Myanmar has a total area of 676 590 km^2 (Table 1). The country's southern coastline lies on the Andaman Sea and to the southwest the Bay of Bengal, it is bordered by Bangladesh to the west, India to the northwest, China to the northeast and Lao People's Democratic Republic and Thailand to the east. The country is divided into seven states (*pyi ne-myar,* singular: *pyi ne*), mainly covering the hill regions: Chin, Kachin, Kayah, Kayin, Mon, Rakhine (former Arakan) and Shan; and seven divisions (*taing-myar,* singular: *taing*), covering the plains: Ayeyarwady, Bago, Magway, Mandalay, Sagaing, Tanintharyi and Yangon.

Topographically, the country can be divided into five regions. They are the northern and western mountains, the eastern plateau (Shan plateau), the central basin and coastal strip. The country is mountainous, rising to more than 5 800 m above sea level in the far north, and reaching an elevation of well over 2 000 m over much of Shan state in the northeast, and in Rakhine and Chin states in the west.

The total cultivable area is almost 18.3 million ha. Total cultivated area in 2009 was around 12.1 million ha of which 11.0 million ha or 91 percent was for annual crops and 1.1 million ha or 9 percent for permanent crops. The cultivated areas are concentrated in the Ayeyarwady river basin, while potential for further expansion lies mainly in upper Myanmar, in the Chin, Kachin and Shan states.

Climate

Myanmar's climate is tropical monsoon. Rainfall is highly seasonal, being concentrated in the hot humid months of the southwest monsoon (May-October). In contrast, the northwest monsoon (December-March) is relatively cool and almost entirely dry.

The mean annual rainfall is around 2 341 mm. The most significant regional variations are those associated with the intensity of the southwest monsoon rains. Annual rainfall ranges from as high as 4 000-6 000 mm along the coastal reaches and in the mountains of Rakhine and Tanintharyi to as low as 500-1 000 mm in the central dry zone. Intermediate levels of rainfall are found across the Ayeyarwady delta areas (2 000-3 000 mm), the Shan plateau (1 000-2 000 mm) and the transitional areas. As with the rainfall, 90 percent of the discharge flows between May and October.

Population

The total population in 2009 was 47.6 million, of which around 67 percent lived in rural areas (Table 1). With a population density of 70 inhabitants/km^2, Myanmar is well below the density level of other countries in South and Southeast Asia. The annual population growth rate during the period 1999-2009 was around 0.7 percent.

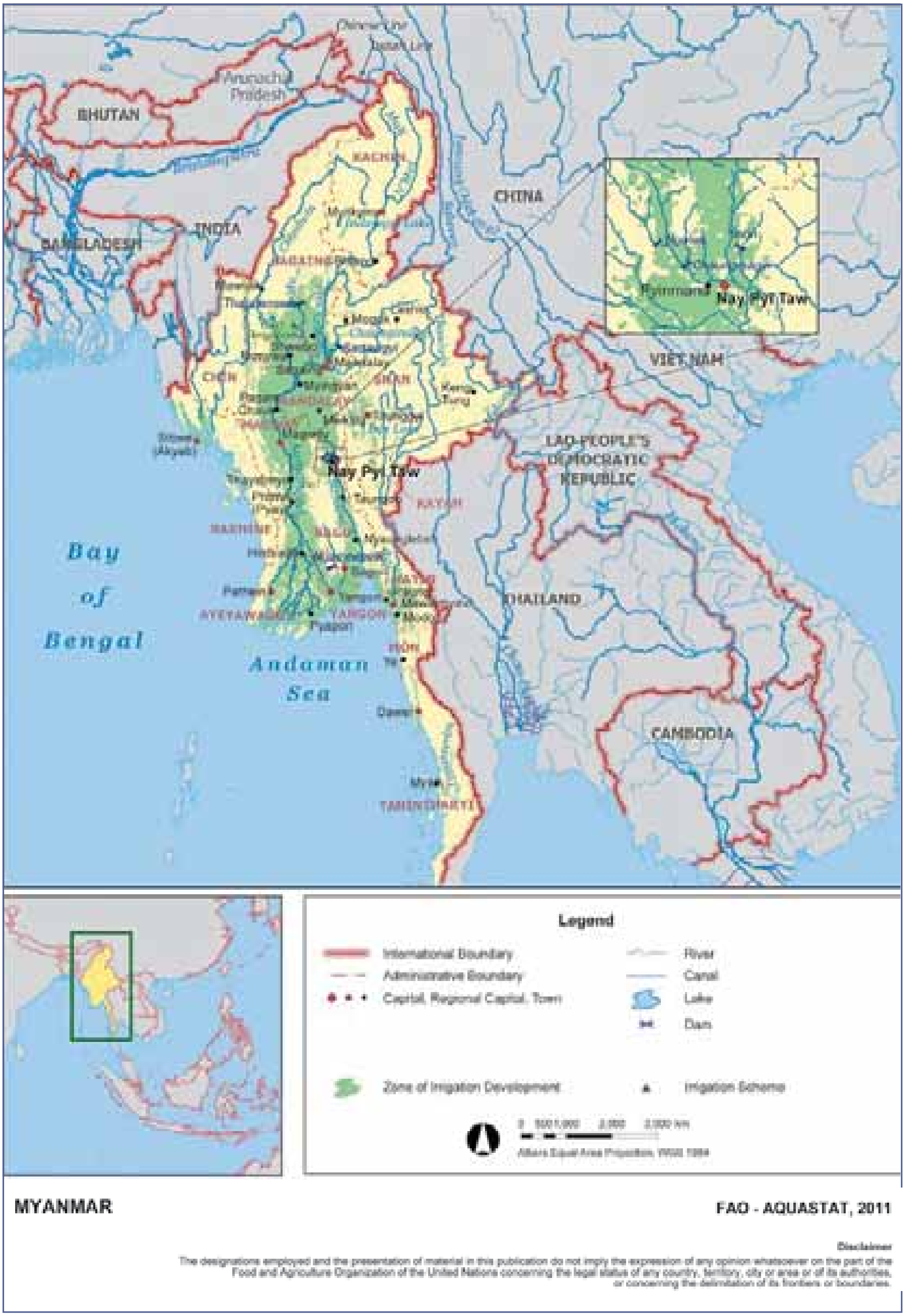
BHUTAN
BANGLADESH
INDIA
CHINA
VIET NAM
LAO PEOPLE'S DEMOCRATIC REPUBLIC
THAILAND
CAMBODIA
Bay of Bengal
Andaman Sea
KACHIN
SAGAING
CHIN
SHAN
MANDALAY
MAGWAY
RAKHINE
KAYAH
BAGO
AYEYAWADY
YANGON
MON
TANINTHARYI
Nay Pyi Taw
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Canal
Lake
Dam
Zone of Irrigation Development
Irrigation Scheme
MYANMAR
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	67 659 000	ha
Cultivated area (arable land and area under permanent crops)	2009	12 135 000	ha
• as % of the total area of the country	2009	18	%
• arable land (annual crops + temp fallow + temp meadows)	2009	11 035 000	ha
• area under permanent crops	2009	1 100 000	ha
Population			
Total population	2009	47 601 000	inhabitants
• of which rural	2009	67	%
Population density	2009	70	inhabitants/km^2
Economically active population	2009	27 612 000	inhabitants
• as % of total population	2009	58	%
• female	2009	46	%
• male	2009	54	%
Population economically active in agriculture	2009	18 613 000	inhabitants
• as % of total economically active population	2009	67	%
• female	2009	48	%
• male	2009	52	%
Economy and development			
Gross Domestic Product (GDP) (current US$)		-	million US$/yr
• value added in agriculture (% of GDP)	2004	48.35	%
• GDP per capita		-	US$/yr
Human Development Index (highest = 1)	2010	0.451	
Access to improved drinking water sources			
Total population	2008	71	%
Urban population	2008	75	%
Rural population	2008	69	%

Access to improved drinking water sources in 2008 was 71 percent (75 and 69 percent for the urban and rural population respectively). Access to improved sanitation reached 81 percent (86 and 79 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture in 2009 was around 18.6 million, which was 67 percent of the economically active population. Of the population economically active in agriculture 48 percent are women. In 2004, agriculture accounted for 48 percent of the gross domestic product (GDP) (Table 1).

Rice is by far the main agricultural crop and has great significance for the national economy. The total harvested area in 2004 was an estimated 16 721 000 ha, of which 6 543 000 ha was rice, 2 492 000 ha peas and beans, 1 465 000 ha sesame, 655 000 ha groundnut and 511 000 sunflowers (MOAI, 2010).

WATER RESOURCES AND USE

Water resources

Myanmar is endowed with abundant water resources, but here are problems,related to their uneven spatial and temporal distribution. The monthly distribution of river flows closely follows the pattern of rainfall, which means that about 80 percent flows during the monsoon season (May-October) and 20 percent in the dry season (November-April).

The north-south direction of Myanmar's mountain ranges is reflected in the flow of its major rivers, of which two are international. There are six river basins:

- Ayeyarwady (Irrawaddy)-Chindwin river basin, which is almost entirely located in Myanmar, drains 58 percent of the territory. It can be divided into three sub-basins: Upper Ayeyarwady, Lower Ayeyarwady and Chindwin.
- Sittaung river basin, which is also entirely located in Myanmar to the east of the downstream part of the Ayeyarwady, drains 5.4 percent of the territory.
- Thanlwin (Salween in Thailand, Nu in China) river basin drains 18.4 percent of the territory, mainly the Shan plateau in the east. The source of the river is inChina and, after entering the country, forms the border with Thailand for about 110 km.
- Mekong (Lankang in China) river basin drains 4.2 percent of the territory in the far east and forms the border with Lao People's Democratic Republic. Myanmar is not a member of the Mekong River Commission.
- Rakhine (Arakan) coastal basin in the west drains into the Bay of Bengal.
- Tanintharyi (Tenasserim) coastal basin in the south drains into the Andaman Sea.

Total surface water produced internally is an estimated 992.1 km^3/year. Groundwater resources have been estimated as 453.7 km^3/year; but a large part of this water (about 443 km^3/year) comprises the base flow of the rivers and is also accounted for as surface runoff. This gives a total internal renewable water resources (IRWR) of 1002.8 km^3/year (992.1+453.7-443).

The annual inflow from other countries is about 128.186 km^3: with 20 km^3 coming from India, 68.74 km^3 (Nu to Thanlwin) and 31.3 km^3 (rivers in west Yunan) from China, and 8.156 km^3 from Thailand. The Mekong river forms the over 170 km border with Lao People's Democratic Republic. The source of the river is in China, the total annual flow is 73.63 km^3, half of which or 36.815 km^3 can theoretically be considered as an additional external resource. The total natural renewable water resources (including flow from incoming or border rivers) are therefore an estimated 1 167.8 km^3/year (Table 2).

There are two major natural lakes. The largest is tInle lake in Shan state which runs some 24 km from north to south and 13 km from east to west, covering an area of 155 km^2. The Indawgyi lake in Kachin state stretches about 22 km from north to south and 11 km from east to west.

The Irrigation Department, which was established to coordinate the development and management of water resources for irrigation, has constructed about 200 irrigation projects, which receive water t from constructed dams, weirs and sluices. A surface water runoff of about 15.46 km^3 has been stored in the constructed reservoirs and can irrigate about 1 million ha (Naing, 2005).

The implementation of the Ngamoeyeik Dam Project started in 1992-1993 and the dam opened in 1995. It is an earth embankment measuring 4 724 m by 23 m with a reservoir capacity of 0.222 km^3 (MIC, 2006). The dam was built to facilitate double cropping to supply additional water to farmlands in the rainy season if necessary, to take flood prevention measures on the Ngamoeyeik creek, and to supply around 600 000 m^3 of water to Yangon City daily. Arrangements are being made to supply water to Ngamoeyeik dam by building the Mahuya dam and Paunglin dam to ensure that the Ngamoeyeik dam is able to work at full capacity. Measures have been taken to generate electricity from Ngamoeyeik dam (The new light of Myanmar, 2003a).

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	2 091	mm/yr
	-	1 415 000	million m^3/yr
Internal renewable water resources (long-term average)	-	1 002 800	million m^3/yr
Total actual renewable water resources	-	1 167 800	million m^3/yr
Dependency ratio	-	14.1	%
Total actual renewable water resources per inhabitant	2009	24 537	m^3/yr
Total dam capacity	2005	15 460	million m^3
Water withdrawal			
Total water withdrawal	2000	33 230	million m^3/yr
- irrigation + livestock	2000	29 575	million m^3/yr
- municipalities	2000	3 323	million m^3/yr
- industry	2000	332	million m^3/yr
• per inhabitant	2000	739	m^3/yr
Surface water and groundwater withdrawal	2000	33 230	million m^3/yr
• as % of total actual renewable water resources	2000	2.8	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

The Thaphanseik dam on the Mu river in Sagaing division, completed in 2001 is, 6 km long making it one of the largest dams in Southeast Asia. It is a multi-purpose dam, providing water for irrigation and for power for the nation's developmental needs. The dam enables year-round irrigation of over 200 000 ha with feeder canals extending to eight townships (Earth Snapshot, 2009).

The Sedawgyi dam, used for hydropower, is on the right bank of the Chaunginagyi river and has a capacity of 25 MW; it became commercially operational in 1989. The Ngalaik dam in Pyinmana township was completed in 1987, with a full capacity of 0.093 km^3. The Chaungmagyi dam for irrigation, also in Pyinmana township, was completed in 2003 and is able to store 0.05 km^3 (The new light of Myanmar, 2003b). Another important dam for irrigation is the Yezin dam with a total capacity of 0.074 km^3, which is able to irrigate 6 400 ha of agricultural land.

The Kataik dam, is 71 m high with a total capacity of 0.07 km^3, was constructed in 2007 in Paung township. It is able to supply water to 4 050 ha of farmland and contributes much to regional development, since local people are able to engage in double cropping cropping (The new light of Myanmar, 2007).

According to studies by the United Nations and other sources, the hydropower potential of Myanmar is estimated to be as much as 40 000 MW. By 2002, 35 hydropower stations (including 15 medium-scale projects) had been completed with a total capacity of 390 MW, which is just 1 percent of the potential.

The government signed an agreement with China Power Investment Corporation in 2007 for the construction of seven large dams along the Ayeyarwady, Mali, and N'Mai rivers in Kachin state. The largest one, the Myitsone dam, will be located at the confluence of the Mali and N'Mai rivers, which then become the Ayeyarwady river and will be 152 m high with an installed capacity of 6 000 MW. The reservoir will flood an area larger than Singapore in one of the world's most disputed biodiversity 'hotspots'. An estimated 10 000 people will have to be displaced (BRN, 2010).

Two important hydropower dams, the Hatgyi and Tasang dams, are proposed to be constructed on the Thanlwin river (BRN, 2009).

Yangon wastewater treatment plant has been operational since 2005 and is designed to treat 12 300 m^3/day (Than, 2010).

Water use

The total water withdrawal in 2000 was about 33.23 km^3, of which around 29.58 km^3 (89 percent) for agriculture, 3.32 km^3 (10 percent) for municipalities and 0.33 km^3 (1 percent) for industries (Table 2 and Figure 1).

Approximately 30.24 km^3, or 91 percent of the total water withdrawal, comes from surface water and 2.99 km^3, or 9 percent, from groundwater (Figure 2). Groundwater is mostly used for domestic purposes.

FIGURE 1
Water withdrawal by sector
Total 33.230 km^3 in 2000

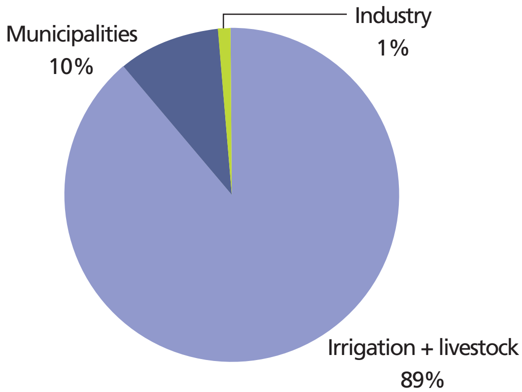
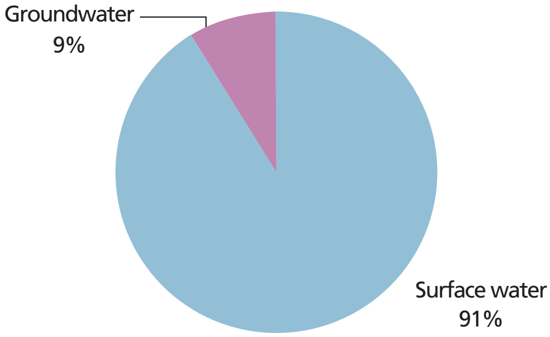


FIGURE 2
Water withdrawal by source
Total 33.230 km^3 in 2000



International water issues

The Mekong River Commission (MRC) came into existence on 5 April 1995 on agreement between the governments of Cambodia, Lao People's Democratic Republic, Thailand and Viet Nam. These four countries signed the "Agreement on the cooperation for the sustainable development of the Mekong River Basin" and agreed on joint management of their shared water resources and development of the economic potential of the river. The MRC was established on the foundation of nearly 50 years of knowledge and experience in the region, starting in 1957 as the United Nations-founded Mekong Committee. In 1996, China and Myanmar became Dialogue Partners of the MRC and the countries now work together within a cooperation framework.

The proposed Hatgyi and Tasang dams would generate electricity that would mostly be bought by Thailand, and Thai and Chinese companies are involved in the construction. The construction of the dams in Myanmar on the Thanlwin river could displace thousands of ethnic minorities (Karen), which might have to flee into neighbouring Thailand. Damming the Thanlwin has also raised environmental concerns, both in Myanmar and in upstream China. It is said that the projects would threaten one-third of the 75 fish species in the river. In 2004, China announced the suspension of all projects on the upstream Nu river pending further scientific study.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Because of the rainfall and hydrological patterns, the need for irrigation is highest in the central dry zone, while in the delta there is more concern aboutt drainage and flood protection.

It is thus logical that the first irrigation works should have been undertaken near Bagan (Pagan) in the central region in the eleventh and twelfth centuries. They were typically composed of diversion systems on tributaries of the middle Ayeyarwady, and were designed to provide security to the main season rice crop. Storage reservoirs were also constructed for the same purpose. The ancient systems were subsequently modernized, extended and operated in the traditional manner, with a greater emphasis on the upgrading and development of the existing flood protection and drainage facilities in the Ayeyarwady delta. This enabled the development of rice cultivation and made Myanmar a major rice-exporting country before the Second World War. Dam construction and irrigation network implementation were significantly accelerated in the 1960s, 1970s and after 1990. The irrigation potential, considering both water and soil resources, is about 10.5 million ha .

In 1986 the Ye-U irrigation rehabilitation and modernization project was approved. The main objective of the project was to rehabilitate and modernize the Ye-U irrigation and drainage system commanding 49 370 ha in the Mu river basin, located in the central dry zone, mainly to increase the production of rice in the area (World Bank, 1995).

The total area equipped for irrigation in 2004 was an estimated 2 110 000 ha (MOAI, 2010). In 2000 and 1995 was around 1 841 000 ha and 1 555 000 ha respectively.

Irrigated areas were traditionally supplied by water from weirs used to divert rivers or dams and tanks. Since the 1980s, however, there has been substantial development of wells and water is pumped from rivers. Other types of irrigation water supply include windmills, watermills, watering with buckets, ponds, etc. In 2000, out of the total irrigated area of 1 841 000 ha, 31 percent was supplied by canals (57 percent managed by the government and 43 percent by farmers), 11 percent was supplied by tanks (93 percent managed by the government and 7 percent by farmers), 4 percent by tubewells, 46 percent by pumps and 8 percent by other types of irrigation water supply (Fujita and Okamoto, 2006). Water resources for pump lift irrigation are mainly based on the flow of three major rivers, the Ayeyarwady, Chindwin, and Sittaung. Further expansion of electric pumping, however, still remains constrained, owing to limited supply of electricity (MOAI, 2010).

All irrigation in Myanmar is surface irrigation. Sprinkler and localized irrigation have been developed only on pilot farms, and altogether do not exceed 50 ha.

There are two types of irrigation management in Myanmar: public and private schemes. Government schemes account for 53 percent of weir schemes and 81 percent of the dams and tanks (all dams of and above 6.1 m). Wells and pump irrigation, although possibly originally implemented by the services of the former Ministry of Agriculture, are mainly private.

Although farmers are responsible for implementation, management, operation and maintenance of the private schemes, both the Irrigation Department and the Water Resources Utilization Department provide technical and financial assistance.

There are important groundwater aquifers in Myanmar. Their exploitation, however, has been limited to municipal water supply and to the intensive irrigation of vegetables and other high-value crops from hand-dug wells. In the central dry zone, where most of the potential for economical run-of-the-river diversion schemes has been used, dams for surface water irrigation projects, as well as groundwater irrigation projects, were started in the 1980s. Irrigation from groundwater was practised on 55 175 ha in 1995, mainly for cotton, wheat, beans and pulses (Table 3 and Figure 3). Groundwater is drawn using diesel pumps (77 percent of the area), followed by electric pumps (15 percent) and artesian wells (8 percent). Generally, one tubewell allows supplementary irrigation on 4 ha. The groundwater irrigation area increased to 81 000 ha in 2000 and 100 000 ha in 2003 (Irrigation Department, 2004).

In the Myanmar classification of cultivated areas, inland valley bottoms that are equipped for irrigation are generally known as *maye* land, and, in 1995, were estimated at around 27 000 ha. To generate increased rice production, a combination of rice and fish farming, on plots of 1-2 ha protected by embankments, has been introduced into *maye* land areas, where rice yields were uncertain. Another type of water management is called *kaing* land in the Myanmar classification (flood recession cropping). This land, which is mainly in the Ayeyarwady delta are mostly cultivated with vegetables.

Role of irrigation in agricultural production, economy and society

Jute used to be the second most widely cultivated crop (after rice), but it has now been replaced by cash crops such as beans, pulses, sunflowers, chilies and vegetables. In 2006, total harvested irrigated cropped area was an estimated 2 722 000 ha, of which the most important crops are rice accounting for 1 861 000 ha (68 percent), pulses 284 000 ha (10 percent), wheat 89 000 ha (3 percent), cotton 85 000 ha (3 percent) and sugarcane 79 000 ha (3 percent) (Table 3 and Figure 4).

Rice is currently cultivated on 6.54 million ha (of which 1.25 million ha irrigated), comprising 4.90 million ha in the rainy season and 1.64 million ha in the dry season. Rice is mostly found in the delta and central dry zone areas. Supplemental irrigation is supplied for the rainy season rice cultivation mainly in the Mandalay, Sagaing and Magway regions, which are located in the central dry zone of Myanmar, where the rainfall is insufficient for the crop-water requirement. Other upland crops are cultivated there in the dry season using irrigation.

About 60 percent of the delta region, including the Ayeyarwady, Bago and Yangon region of Lower Myanmar, is cultivated with rainfed rice. Dry season rice is mostly cultivated in Lower Myanmar using irrigation. Rice cultivation has increased from 4.78 million ha in 1988 to 6.54 million ha in 2003, and production from 12.96 million tonnes to 22.79 million tonnes. Rice exports increased to 1 million tonnes in 2004. According to national planning targets, the sown area of rice will be expanded to 7.29 million ha (Naing, 2005).

Among other major upland crops are pulses and oilseeds. Pulses are cultivated for export and the cost of cultivation is relatively inexpensive. As a result of the increasing demand for both domestic consumption and export, the cultivation of pulses has increased from 0.73 million ha in 1988 to 3.31 million ha in 2003, of which 0.28 million ha are irrigated, production has increased from 0.5 million tonnes to 3 million tonnes. Around 1 million tonnes of pulses are now being exported. The major oilseed crops are groundnut, sesame and sunflower and cultivation of these crops increased to 2.78 million ha in 2003 (Naing, 2005).

In 1999, average irrigation development costs varied from US$2 000-8 000/ha (12 300-49 100 kyatts/ha).

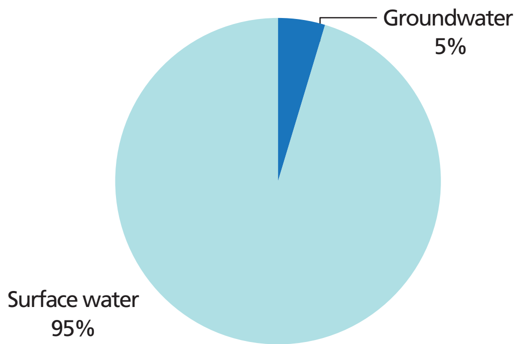
Status and evolution of drainage systems

In the Ayeyarwady delta, drainage, salt intrusion and flood protection are major concerns. Embankments have been developed to protect large areas from both floods and salt intrusion. These embankments may have drainage facilities. Around 1995, there were a total of 318 flood protection works, both government (88 percent) and private (12 percent), protecting a total

TABLE 3
Irrigation and drainage

Irrigation potential			10 500 000	ha
Irrigation				
1. Full control irrigation: equipped area		2004	2 083 000	ha
- surface irrigation		2004	2 083 000	ha
- sprinkler irrigation		2000	0	ha
- localized irrigation		2000	0	ha
• % of area irrigated from surface water		2004	95.2	%
• % of area irrigated from groundwater		2004	4.8	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2004	2 083 000	ha
- as % of full control area equipped		2004	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2004	27 000	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2004**	**2 110 000**	**ha**
• as % of cultivated area		2004	20	%
• % of total area equipped for irrigation actually irrigated		2004	100	%
• average increase per year over the last 9 years		1995-2004	3.45	%
• power irrigated area as % of total area equipped		1995	3.5	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2004**	**2 110 000**	**ha**
• as % of cultivated area		2004	20	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2006	2 722 000	ha
• Annual crops: total		2006	2 691 000	ha
- Rice		2006	1 861 000	ha
- Wheat		2006	89 000	ha
- Maize		2006	34 000	ha
- Pulses		2006	284 000	ha
- Cotton		2006	85 000	ha
- Sugarcane		2006	79 000	ha
- Vegetables		2006	47 000	ha
- Potatoes		2006	9 000	ha
- Sweet Potatoes		2006	2 000	ha
- Tobacco		2006	1 000	ha
- Other annual crops		2006	200 000	ha
• Permanent crops: total		2006	31 000	ha
- Fruit trees		2006	31 000	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)		2006	131	%
Drainage - Environment				
Total drained area		1994	193 400	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			2	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases		2005	-	inhabitants

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 1 983 000 ha in 2004



of 1.2 million ha of cultivable land. A small portion of this area (less than 10 percent) is also irrigated by small lift pumps.

In 1995, 193 363 ha were reported as being equipped with surface drainage networks. Drainage works are also considered a form of flood protection. In 1999, drainage and embankment development cost around US$1 200/ha (7 400 kyatts/ha).

Salinization caused by irrigation is mainly found in the central dry zone, near Meiktila in Mandalay Division, where groundwater is used for irrigation.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

No institution is responsible for the overall management of national water resources in the public and private sectors. A proposal for establishing a Myanmar Water Commission (MWC) had been submitted to the Ministry of Agriculture and Irrigation (MOAI) for official approval.

Currently, MOAI is the main ministry involved in water resources, with the mandate to develop agriculture and irrigation. The Ministry of Agriculture was renamed the Ministry of Agriculture and Irrigation in 1996 to acknowledge the importance of irrigation for agriculture. The following departments are involved in water resources:

- Water Resources Utilization Department: is responsible for groundwater use (for both irrigation and rural water supply), irrigation by pumping in rivers, and the development of sprinkler and localized irrigation.
- Irrigation Department: is responsible for the operation and maintenance of irrigation works, construction of new projects, and investigation, design and implementation of proposed projects, as long as surface water is used.
- Settlement and Land Records Department: is responsible for collecting agricultural statistics and land administration.
- Agricultural Planning Department: is in charge of planning, monitoring and evaluation of all agricultural projects, including irrigation and drainage projects.

The Meteorology and Hydrology Department of the Ministry of Communication, Posts and Telegraphs is in charge of collecting hydrological and meteorological data, while the Irrigation Department has its own hydrological network. Hydropower generation is supervised by the Myanmar Electric Power Enterprise, within the Ministry of Electric Power.

Water user associations (WUAs) and water user groups (WUGs) play an important role in water management. However, the functional associations and groups are more useful for implementing irrigation works (Naing, 2005).

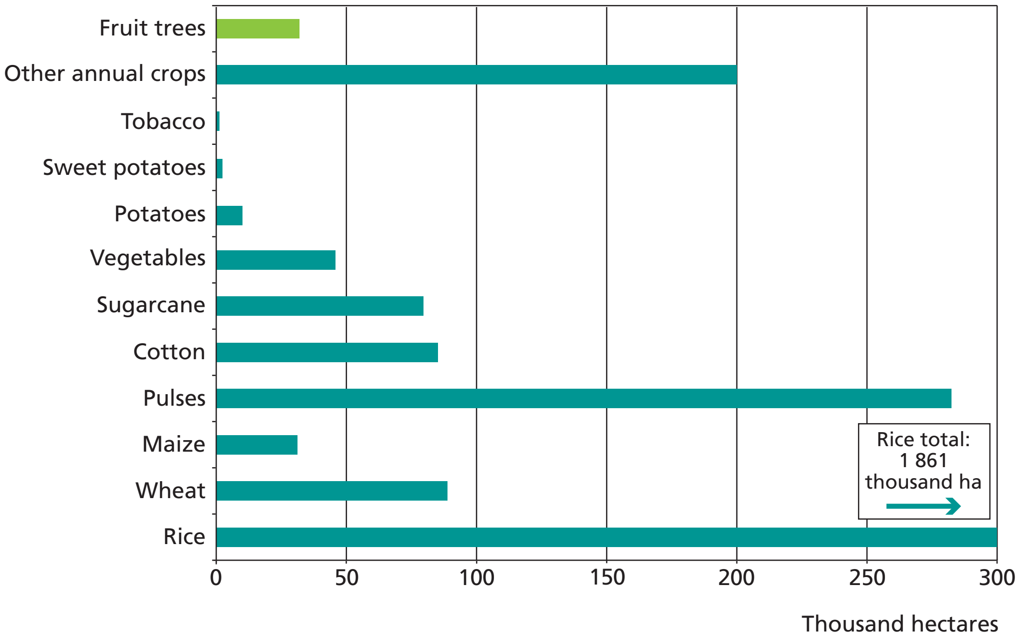
Water management

The Irrigation Department maintains and operates major facilities such as main dams, headworks, main canals and secondary units. Farmers maintain and operate the terminal units such as field ditches and watercourses (Naing, 2005).

FIGURE 4

Irrigated crops on area equipped for full control irrigation

Total harvested area 2 722 000 ha in 2006 (cropping intensity on full/control equipped area: 131%)



The availability of adequate water for agriculture is a critical factor and is crucial for enhancing yields. MOAI has accordingly adopted five measures to raise irrigation coverage from around 20 to 25 percent of the net sown area. Emphasis is placed on the five following measures in the provision of adequate water for agricultural purposes (MOAI, 2010):

- construction of new reservoirs and dams;
- renovation of existing reservoirs to raise storage capacity and facilitate the efficient delivery of irrigation water;
- diversion of water from streams and rivulets during high water levels into adjacent ponds or depressions and for storage with sluice gates;
- lifting water from rivers and streams using pump irrigation; and
- efficient use of groundwater.

Since 1990-1991, the government has focussed on the above five strategies and the implementation of new irrigation coverage, the development of border and rural areas and greening of the dry zone. MOAI carried out appropriate works in the various states and divisions and, as a result, 170 irrigation projects were completed from 1991 to 2005 (Table 4).

Furthermore, 72 electric pump stations and 42 medium electric-pump stations were established as an alternative to irrigation provision from reservoirs. Similarly, 36 groundwater resources were tapped and made available in various locations.

No target has been fixed by the government to address concerns in the flood-protected areas; although some 400 000 ha in the delta are in need of reclamation.

TABLE 4
Government irrigation projects

State/Division	Government irrigation projects	Beneficial Area (ha)
Kayah	2	1 275
Kayin	1	40
Chin	1	202
Sagaing	18	149 714
Tanintharyi	1	Water Supply
Bago	40	253 731
Magway	31	118 712
Mandalay	42	135 392
Mon	7	25 820
Rakhine	4	182
Yangon	14	90 449
Shan	2	44 858
Ayeyarwady	7	108 224
Total	**170**	**928 599**

Starting 10-15 years ago, all new projects involving dam construction are multipurpose projects and include flood control, town water supply, hydroelectricity and irrigation. The priority for multipurpose projects with hydropower is an indicator of the expanding demand for energy.

In 2003, with the cooperation of the United Nations Economic and Social Commission for Asia and the Pacific (UNESCAP) and FAO, the Irrigation Department launched a programme to develop the Myanmar Water Vision and to coordinate the establishment of a national water coordination agency (NWCA) as the principle body responsible for overall management of water resources in cooperation with both the public and private sectors.

A national level Myanmar Water Resources Committee (MWRC) is planned together with the formulation of a strategic management plan (SMP) to enhance the application of integrated water resources management (IWRM) in the country. Recently, the MOAI Inter-Ministry Task Force on Water Resources (IMTFWR) presented the Strategic Plan for IWRM, the main objective is to enhance IWRM application. The IWRM components studied when formulating the Strategic Plan were:

- principles of water resources development and management;
- operation and management;
- water allocation among competing uses and users;
- water productivity at farm, system and basin levels;
- financial resources for water source development and management;
- conjunctive use of surface water and groundwater;
- interactions between irrigation, human health and environment;
- public involvement; and
- capacity-building and human resources development.

Finances

The Irrigation Department water tariff is very low for the gravity irrigation systems, getting water from dams, and does not recover the cost of maintenance work. The annual budget for the maintenance and repair of the facilities is mostly paid for by the government. The water tariff for the river pumping systems under the Water Resources Utilization Department is higher than that of the dam systems. The water prices for rice cultivation in the dam systems are 150 and 300 times less than those of the electric and diesel type river pumping systems. As a result of the lower water price, farmers use water without caring about water shortages or water losses (Naing, 2005).

Policies and legislation

There is no single law that covers all aspects of water resources. The laws of Myanmar, however, cover many issues related to water. In particular, the roles and responsibilities of various agencies need to be developed for specific activities such as water allocation. Formulation of further legislation or decrees for proper water management is needed. All existing laws, legislation, rules and regulations should be reviewed with the objective of enacting a unified water resources law that would allow the adoption of a more effective legal framework for coordination and management of water resources (IMTFWR, after 2004).

Since the promulgation of the Land Nationalization Act (1953), all land officially belongs to the State. However, farm households benefit from a customary usufruct right to the land.

ENVIRONMENT AND HEALTH

Sedimentation is one of the major adverse effects of storage dams and in the lower courses of rivers. Mining and deforestation along the upper reaches of river basins cause serious erosion problems. Transported sediment is reducing the storage capacity of reservoirs and the bed levels are rising in the lower reaches. Consequently, flooding occurs and navigation is problematic. Although some nutrients and some sediment are needed to support the aquatic environment, the Government is emphasizing the implementation of the terrace farming system to reduce shifting cultivation.

The development of industry and increasing population density will cause increasing river pollution and health risks for people living close to the rivers. Careful management of groundwater extraction is also required to avoid pollution (IMTFWR, after 2004).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The population of Myanmar is estimated to reach 86 million by 2025, against 50 million at present. Increasingly food will be necessary for the country's growing population. Rice is the main food crop, and is one of the most important crops grown. The MOAI has the objective of achieving a surplus in rice production. Other objectives are to achieve self-sufficiency in edible oil and to set up the production of exportable pulses and industrial crops. Irrigation will have to play a major role in the development of Myanmar's agriculture sector.

The Irrigation Department plans to implement a project on "Strengthening farmers' irrigation management", together with the Myanmar Agriculture Services, the Water Resources Utilization Department and the Settlement and Land Records Department with the technical assistance of the Japanese Government. The Project objective is to reduce government administrative and maintenance costs for new irrigation projects as well as those of the existing irrigation system. The resources made available from these adjustments could be used to improve the system losses, expand the area under irrigation, and to update farm-level facilities. Farmers will voluntarily form water user associations, irrigation system management will be enforced and maintenance and repairs of irrigation facilities will be carried out. Rules, regulations and principles should be improved to ensure equitable and efficient water use and allocation (Naing, 2005).

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Nepal

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Nepal is located entirely in the Ganges basin and is bordered by India in the east, south and west and by China in the north. With fifteen peaks higher than 7 000 m, including the world's highest peak Mount Everest at 8 848 m, Nepal is one of the highest countries in the world. The total land area is 147 180 km^2. Physiographically, the country can be divided into three parts: the high Himalayas in the north (24 percent of the country's total area); the hill and mountain slopes in the centre (56 percent), which include the lower hills called *siwalik* where elevations vary between 300 and 700 m; and the plain called *terai* in the south at elevations below 300 m (20 percent). For administrative purposes, the country is divided into five development regions and 75 districts.

The cultivable area is about 4 million ha, of which 34 percent in the *terai*, 8 percent in the *siwalik*, 48 percent in the mountain and hill region and 10 percent in the high Himalayas. In 2009, the total cultivated area was around 2 520 000 ha, of which 95 percent (2 400 000 ha) were for annual crops and 5 percent (120 000 ha) for permanent crops (Table 1).

Climate

Extremely varied topography within a small width ranging from 145 to 241 km influences the weather and climate. The country experiences tropical, meso-thermal, micro-thermal, taiga and tundra types of climate. The mean annual rainfall is 1 500 mm, with a maximum annual rainfall record of 5 581 mm in 1990 at Lumle in Kaski district (elevation 1 740 m) in the mountain region; and a minimum record of 116 mm in 1988 at Jomsom in Mustang district located at 2 744 m in the Kaligandi river valley near the Annapurna Himalayan range.

There are two rainy seasons: one in the summer (June to September), when the southwest monsoon brings more than 75 percent of the total rainfall, and the other in winter (December to February), accounting for less than 25 percent of the total. With the summer monsoon, rain first falls in the southeast and gradually moves west with diminishing intensity. Thus, more rain naturally occurs in the east. On the other hand, during winter, rain occurs as a result of westerly disturbances. This rain first enters Nepal in the west and gradually moves east with diminishing intensity.

The temperature decreases from the lowland *terai* (northern part of the Ganges plain) to the high Himalayan region. The extreme temperatures recorded show that in Lomangtang (Mustang district) located at an elevation of 3 705 m the minimum temperature was -14.6 °C in 1987, while in Dhangadhi (Kailali district) located at an elevation of 170 m the maximum temperature was 44 °C in 1987. Precipitation falls as snow at elevations above 5 100 m in summer and 3 000 m in winter. Temperature is a constraint on crop production in the Himalayas and the mountain region where only a single crop per year can be grown. On the other hand, in the *terai* three crops a year are common where the water supply is adequate. Single rice cropping is possible up to elevations of 2 300 m while double rice cropping is limited to areas below 800 m.

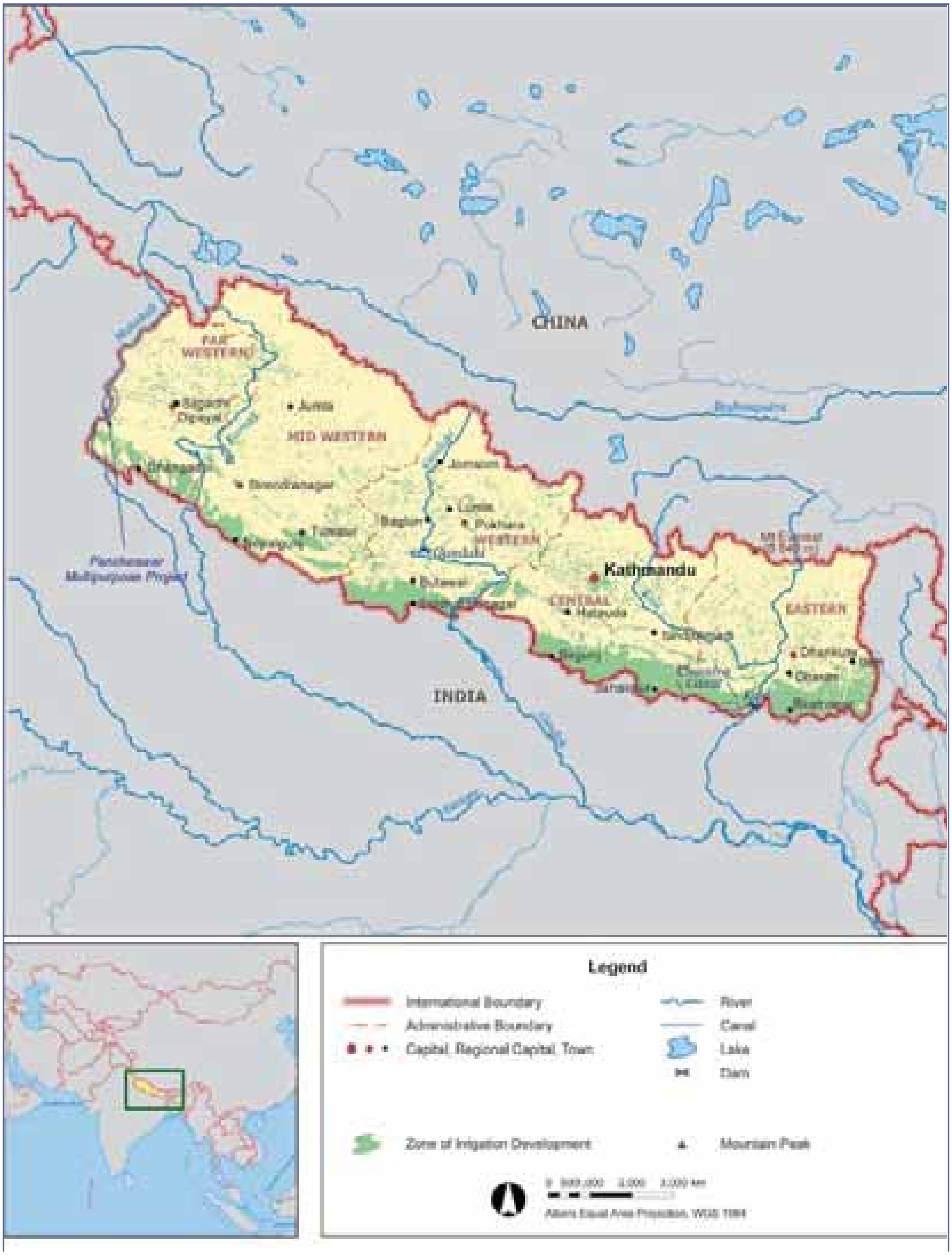

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	14 718 000	ha
Cultivated area (arable land and area under permanent crops)	2009	2 520 000	ha
• as % of the total area of the country	2009	17	%
• arable land (annual crops + temp fallow + temp meadows)	2009	2 400 000	ha
• area under permanent crops	2009	120 000	ha
Population			
Total population	2009	29 433 000	inhabitants
• of which rural	2009	82	%
Population density	2009	200	inhabitants/km^2
Economically active population	2009	12 605 000	inhabitants
• as % of total population	2009	43	%
• female	2009	45	%
• male	2009	55	%
Population economically active in agriculture	2009	11 721 000	inhabitants
• as % of total economically active population	2009	93	%
• female	2009	48	%
• male	2009	52	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	12 531	million US$/yr
• value added in agriculture (% of GDP)	2009	34	%
• GDP per capita	2009	426	US$/yr
Human Development Index (highest = 1)	2010	0.429	
Access to improved drinking water sources			
Total population	2008	88	%
Urban population	2008	93	%
Rural population	2008	87	%

Population

In 2009, the total population was 29.4 million, of which almost 83 percent were rural (Table 1). In 1998, the total population was about 23.3 million (82 percent rural), meaning an average annual demographic growth rate of 2.1 percent for the period 1999-2009. In 2009, population density was 200 inhabitants/km^2. In 1991, highest population density was in the capital district Kathmandu, 1 710 inhabitants/km^2, and in Bhaktapur district near the capital, 1 454 inhabitants/km^2. Lowest density was in Manang district (a Himalayan valley) with 2.4 inhabitants/km^2. In 1991, 8 percent of the total population was living in the mountain region, 45 percent in the hill region and 47 percent in the *terai* region.

In 2008, access to improved drinking water sources reached 88 percent (93 and 87 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total population economically active in agriculture was around 11 721 000 inhabitants (93 percent of economically active population), of which 48 percent were women. In 2009, gross domestic product (GDP) was US$12 531 million and agriculture accounted for 34 percent of GDP (Table 1).

In 1996, agriculture contributed 42 percent of GDP and employed 93 percent of the economically active population. The main agricultural exports were pulses, jute and rice.

WATER RESOURCES AND USE

Water resources

Average annual precipitation is an estimated 1 500 mm (Table 2). Nepal has more than 6 000 rivers, which provide a dense network with steep topographic conditions. All rivers in Nepal drain into the Ganges river. The country is divided into five river basins, which are from west to east:

- Mahakali river basin, which is shared with India, with an average flow from the Indian tributaries into the border river, of arounds 15 km^3/year and some 3.4 km^3/year from the Nepalese tributaries.
- Karnali river basin, with an average outflow of about 43.9 km^3/year.
- Gandaki river basin, with an average outflow of roughlys 50.7 km^3/year;
- Kosi river basin, with an average outflow estimated as 47.2 km^3/year, which receives a contribution of some 12 km^3/year from the upper catchment area located in China; and the
- southern river basins, which produce some 65 km^3/year of water flowing into India.

The seasonal distribution of flow is extremely variable. It might be as low as 1.5-2.4 percent of the total runoff in January, February and March, and as high as 20-27 percent in July and August for snowfed rivers, while the corresponding figures for purely rainfed rivers are 0.5-3 percent from March to May and 19-30 percent in July and August.

The surface water resources produced internally are estimated as 198.2 km^3/year. The groundwater resources have not been fully assessed. Ongoing studies show that a good potential for groundwater extraction exists, especially in the southern *terai* lowland plains and inner valleys of the hilly and mountainous regions. Much of the *terai* physiographic region and some parts of *siwalik* valleys are underlain by deep or shallow aquifers, many of which are suitable for exploitation as sources of irrigation water. A rough estimate can be made by assuming a groundwater resource equivalent to 10 percent of surface water, i.e. approximately 20 km^3/year, which corresponds to the base flow of the rivers. The total internal water resources would therefore amount to 198.2 km^3/year. Chinese statistics mention an average outflow to Nepal of 12 km^3/year, which brings the total renewable water resources of Nepal to 210.2 km^3/year. It is assumed that all the renewable water resources of Nepal flow out of the country to India.

In 2009, the total dam capacity was 85 million m^3, although the potential exists for at least 138 km^3. Hydroelectricity accounted for more than 96 percent of total electricity generation. The two main diversion barrages are the Kosi and Gandaki reservoirs.

International water issues

No agreements have been established with China for the sharing of water resources. A joint commission for the exploitation of the Kosi river was set up with India in 1954 and 1966, and another for the exploitation of the Gandak river in 1959. In 1996 a treaty on the Mahakali river was ratified by parliament. The treaty makes provision for equal entitlement in the utilization of water from the Mahakali river without prejudice to respective existing consumptive uses.

In September 2008, the third meeting of the Nepal-India Joint Committee on Water Resources (JCWR) took place, to resolve pending issues and facilitate the mitigation of flood problems along the Nepal-India border and to enhance bilateral cooperation in the water sector. The Pancheshwar Multipurpose Project was identified as a priority and JCWR reviewed the current status of discussions on issues related to location of the regulating dam, unit size and installed capacity

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 500	mm/yr
	-	220 770	million m^3/yr
Internal renewable water resources (long-term average)	-	198 200	million m^3/yr
Total actual renewable water resources	-	210 200	million m^3/yr
Dependency ratio	-	5.71	%
Total actual renewable water resources per inhabitant	2009	7 142	m^3/yr
Total dam capacity	2009	85.3	million m^3
Water withdrawal			
Total water withdrawal	2005	9 787.1	million m^3/yr
- irrigation + livestock	2005	9 610	million m^3/yr
- municipalities	2005	147.6	million m^3/yr
- industry	2005	29.5	million m^3/yr
• per inhabitant	2005	359	m^3/yr
Surface water and groundwater withdrawal	2005	9 787.1	million m^3/yr
• as % of total actual renewable water resources	2005	4.7	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

of the power plants, assessment of project benefits in terms of irrigation and power to India and Nepal and sharing of the project cost by the two sides. JCWR is setting up a Pancheshwar Development Authority (PDA) at the earliest, in accordance with Article 10 of the Mahakali Treaty for the development, execution and operation of the Pancheshwar Multipurpose Project.

In December 2008, the first meeting of the India-Nepal Joint Standing Technical Committee (JSTC) was held. During the above-mentioned third meeting of JCWR a three-tier joint mechanism was decided upon to expedite the decision-making process and implementation of decisions undertaken at the institutional interactions. Whereas a Joint Ministerial Commission on Water Resources would be headed by the Ministers of Water Resources of India and Nepal, a Joint Standing Technical Committee was formed to rationalize technical committees and subcommittees in India and Nepal that work on flood management, inundation problems and flood forecasting activities besides project specific committees on hydropower. The JSTC will be coordinating all technical committees and subcommittees under JCWR.

The fourth meeting of JCWR was held in March 2009 to discuss the issues of water resources development projects, further strengthening the ties between the two countries. India and Nepal hoped that the works on the breach closure of the Kosi barrage would be completed in time with the cooperation of the two governments. Nepal informed on the demands of local people for the maintenance and rehabilitation of Main Gandak Western Canal and flood control structures. To date, no noticeable progress has been made concerning these demands. India informed that short-term measures have already been implemented.

Water use

In 2005, total water withdrawal was an estimated 9 787 million m^3, all freshwater withdrawal, of which 98.2 percent for agricultural purposes, 1.5 percent for municipalities and 0.3 percent for industry (Table 2 and Figure 1).

Water withdrawal for the domestic sector is from different types of sources such as springs, open wells, tubewells, rivers or streams, traditional stone taps and modern piped systems.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation development in Nepal has a long history. Numerous small *raj kulos* (canals) in the government sector first appeared in and around Kathmandu valley in the seventeenth and eighteenth centuries. The first large public sector irrigation canal system (the Chandra Canal System) with a net command area of 10 000 ha was constructed in 1922 and is still in operation.

The irrigation potential of the country is an estimated 2 177 800 ha (Table 3). This potential is mainly for irrigation using surface water, but some 352 050 ha are potentially irrigable from groundwater in the *terai* region; 292 600 ha from shallow tubewells (83 percent) and 59 450 ha from deep tubewells (17 percent).

In 2002, the area equipped for irrigation was an estimated 1 168 300 ha, of which 79.5 percent was irrigated by surface water, 19.2 percent by groundwater and 1.3 percent by mixed surface water and groundwater (Figure 2). Seasonal canals accounted for 58 percent of the area irrigated by surface water, permanent canals accounted for 39 percent, and ponds for 3 percent. In 1992, the area equipped for irrigation accounted for 882 400 ha and in 1982 for 583 900 ha.

In 1994, 73.9 percent of the area equipped for irrigation was irrigated by surface water, 12.4 percent by groundwater and 13.8 percent by not fully identified irrigation systems. Almost all areas using surface water are dependent on transit flow availability at the sources. Therefore, the irrigated area varies from season to season and from region to region. As far as the public schemes are concerned, 91 percent were dependent on surface water in 1994 and 9 percent on groundwater. Only 67.7 percent of the public schemes was irrigated in summer, 31.1 percent in spring and 1.2 percent in winter.

Many irrigation systems use surface irrigation (basin, furrow). Some areas in the hills and mountains use sprinkler irrigation, but no figures are available.

Irrigated areas are often classified as public irrigation systems and farmer-managed irrigation systems (FMIS). Non-formal associations have existed for a long time in almost all FMIS. Water user associations (WUAs) received legal status after the promulgation of the 1992 Water Resources Act. The WUA has now become a prerequisite for the transfer of public schemes to users. In 2008, 70 percent of the country's irrigated area fell under FMIS. In the remaining areas, some systems are being transferred completely to the WUAs for management, whereas some are being jointly managed by the government and WUAs. Farmer- and community-managed systems are found to be more efficiently managed than government-managed systems. However, the government plays a crucial role in research and development, extension services and other regulatory fiscal and non-fiscal mechanisms. At the same time, essential and emergency assistance from the government

FIGURE 1
Water withdrawal by sector
Total 9.787 km^3 in 2005

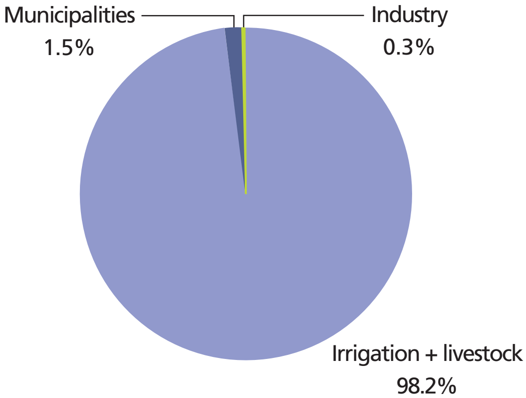
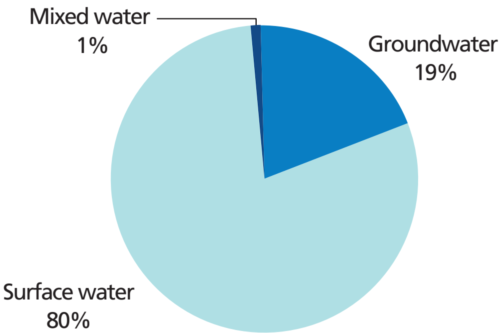


TABLE 3

Irrigation and drainage

Irrigation potential		-	2 178 000	ha
Irrigation				
1. Full control irrigation: equipped area		2002	1 168 300	ha
- surface irrigation			-	ha
- sprinkler irrigation			-	ha
- localized irrigation			-	ha
• % of area irrigated from surface water		2002	79.5	%
• % of area irrigated from groundwater		2002	19.2	%
• % of area irrigated from mixed surface water and groundwater		2002	1.3	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2002**	**1 168 300**	**ha**
• as % of cultivated area		2002	47	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 10 years		1992-2002	2.85	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2002**	**1 168 300**	**ha**
• as % of cultivated area		2002	47	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes	> ha and < ha		-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation		2002	1 997 600	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2006	1 926 000	ha
• Annual crops: total		2006	1 926 000	ha
- Wheat		2006	629 000	ha
- Rice		2006	710 000	ha
- Maize		2006	415 000	ha
- Vegetables		2006	39 000	ha
- Sugarcane		2006	39 000	ha
- Oil crops		2006	36 000	ha
- Other annual crop		2006	58 000	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on actually irrigated area)		2006	165	%
Drainage - Environment:				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

FIGURE 2
Source of irrigation water on area equipped for full control irrigation
Total 1 168 300 ha in 2002



to the communities in the rehabilitation and repair of irrigation systems has to be continued to sustain the farmer-managed systems (MOIR, 2005).

FMIS can be either entirely managed by farmers or assisted by specialized agencies. In FMIS, most diversion structures are constructed from brushwood and boulders and are, therefore, temporary and often washed away during monsoon season. The canals are generally unlined and prone to damage. There is, typically, a large expenditure of labour every year to restore the systems or to maintain them. In spite of these physical limitations, FMIS have demonstrated managerial skills (at community level) that have kept them functioning and contributing significantly to Nepal's food supply.

Modernization of irrigation systems and improved water management practices could lead to a reduction in irrigation water withdrawal. On the other hand, a higher cropping intensity on the irrigated areas, which would be desirable because of the increasing need for food supply, could result in increased agricultural water withdrawal.

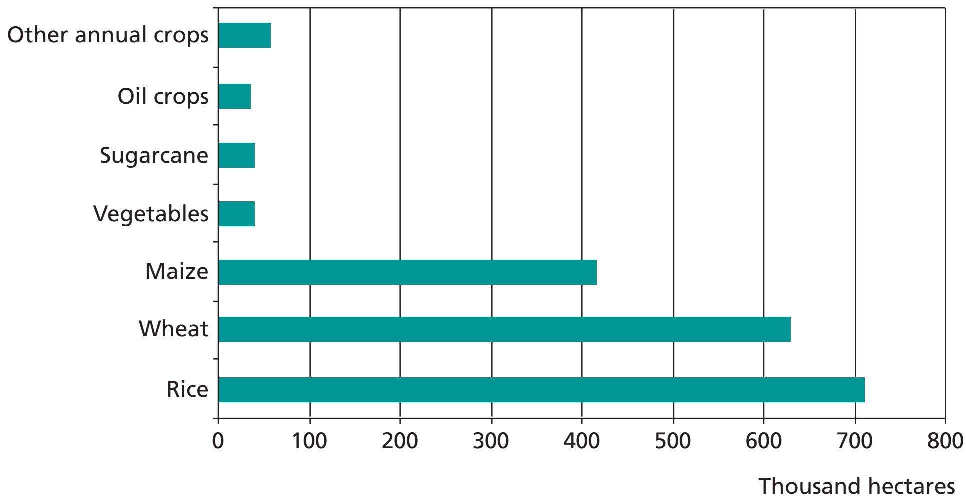
The Sunari Morang Irrigation Project (SMIP) was implemented in the *terai* of southeastern Nepal in the 1990s. It has about 65 000 ha under command of the Chatra Main Canal (CMC), which is fed from the Kosi river. The CMC, which runs from west to east, gives a gross water delivery of about 0.9 litres/s/ha, or rather less than 0.5 litres/s/ha at the plant root. This is because it was designed for supplementary irrigation, i.e. to supply enough water to supplement (by 80 percent) the monsoon rainfall, thus guaranteeing one crop of rice a year over the entire area. A series of secondary canals, running north-to-south, take the water from the CMC into the command area, which extends almost to the Nepal-India border some 20 km to the south. There is considerable conjunctive use of groundwater (STWs) and low lift pumping from drainage lines to supplement supplies from the CMC, particularly towards the tail end of the system.

The Sikta Irrigation Project is situated in the Banke district of the mid-western development region. The project, with a command area of 33 766 ha, including the rehabilitation of the Dunduwa irrigation system constructed by Indian Cooperation Mission in 1964, would irrigate almost all the lowlands of the Banke district and its economic impact could be significant for this development region. The irrigated area can be further extended by 9 000 ha. Based on the Feasibility Study Report 2004, the Government of Nepal decided to implement the project in three phases: Phase I - Construction of headworks and desilting basin; Phase II - Construction of main canal and branch canals; and Phase III - Command area development.

The Community Managed Irrigated Agriculture Sector Project (CMIASP) is the follow-up programme to the Irrigation Sector Project (ISP) and the Second Irrigation Sector Project (SISP) in 35 districts of the eastern and central development regions. The overall goal of the project is to promote inclusive economic growth while reducing poverty in the rural areas. Its specific objective is to improve agricultural productivity and sustainability of existing small- and medium-size FMIS suffering from low productivity and incidence of high poverty. To achieve the objective, the project will

1. provide improved means to empower WUAs, for irrigation facilities, agricultural extension, and targeted livelihood enhancement to build the human capital of the poor, including women and traditionally neglected disadvantaged groups; and

FIGURE 3
Irrigated crops on area equipped for full control irrigation
Total harvested area 1 926 000 ha in 2006 (cropping intensity on full control equipped area 165%)



2. strengthen policies, plans, and institutions for more responsive service delivery and sustained impacts.

The irrigation facilities will be provided in about 210 FMIS covering the total command area of 34 000 ha (including 8 500 ha expanded command area).

In 1999, the average cost of irrigation development varied from US$2 900 to 3 700/ha for the large schemes, and from US$850 to 4 300/ha for small hill schemes. The average cost of irrigation rehabilitation varies from US$1 000 to 1 800/ha. The average cost of operation and maintenance (O&M) was about US$42/ha in the smaller schemes, and US$8-14/ha in the larger schemes.

In 2002, there were 1 997 600 households that practiced irrigation, while in 1992 there were 1 377 500.

Role of irrigation in agricultural production, economy and society

In 2006, the harvested irrigated crop area covered around 1 926 000 ha, of which 37 percent was for rice, 33 percent wheat, 22 percent maize, 2 percent vegetables, 2 percent oil crops, 2 percent sugarcane and 3 percent other annual crops (Table 3 and Figure 3).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The major government institution currently involved in the water resources and irrigation sectors is the Ministry of Irrigation (MOIR), which is responsible for the utilization and management of water resources. It prepares plans and policies and their implementation regarding irrigation development. The MOIR includes the Department of Water Induced Disaster Prevention and the Department of Irrigation.

Other institutions with direct links to the irrigation sector are:

- Ø Ministry of Agriculture and Cooperatives (MOAC): responsible for the formulation and implementation of agricultural and cooperative development policies and plans, agricultural research, training of farmers, transfer of modern technology, and activities to develop youth and women farmers;
- Ø National Planning Commission (NPC): prepares plans for all sectors including irrigation;
- Ø Water and Energy Commission Secretariat (WECS): is a Government consultative body;
- Ø Agriculture Development Bank of Nepal (ADB/N): provides concessional loans and channels government subsidies for rural projects; and the
- Ø Department of Hydrology and Metrology of the Ministry of Environment.

The FMIS may also be classed as institutions because they are voluntary associations of farmers who organize themselves for the building and management of irrigation infrastructure, in accordance with formal or informal rules and procedures.

Water management

Traditional water resources management is focused on the supply side where only technical solutions were considered to meet the growing demand for water. Isolated projects for irrigation, drinking water supply and sanitation, hydropower, flood control and other uses were developed. Evaluation was mainly based on economic criteria, while the environmental and social impacts were hardly considered. Independent sector authorities mostly controlled these projects on the basis of command and control. The results, so far, have not been satisfactory, resulting in inter-sectoral, inter-regional and riparian conflicts.

The formulation of the Water Resources Strategy (WRS) is based on certain identified policy principles involving integrated water resources management (IWRM). Two of the stated policy principles relevant to river basin management (RBM) are: (a) Development and management of water resources shall be undertaken in a holistic and systematic manner, relying on IWRM; (b) Water utilization shall be sustainable to ensure conservation of resources and protection of the environment. Each river basin system shall be managed holistically.

The 20-year Agricultural Perspective Plan (APP), which was adopted in 1995, focuses on ways to reduce food deficits by increasing food production. The APP gave top priority to groundwater development policy mainly by installing shallow tubewells in the *terai.* However, the farmers' requests for shallow tubewells unexpectedly declined owing to the removal of the subsidy and the weakening trend of government investment in repair and maintenance of irrigation infrastructure.

In the current Tenth Five-year Plan period (2003-2008), irrigated agriculture has been given priority by high-ranking government officials. In this plan, great emphasis is placed upon the expansion of irrigation using groundwater and small irrigation development using surface water. The plan encourages the use of shallow tubewells in *terai* and localized irrigation and rainwater harvesting for irrigation. The baseline planning document also gives priority to the empowerment of local WUAs for participatory and effective irrigation management.

Finances

Nepal is mainly a rural society, and there is a traditional belief that water is a God-given free commodity. In 1999, there was a water charge only for water used by volume in urban areas for domestic use. Irrigation water is levied as a service charge. This charge is levied only for the public irrigation systems. It varies from US$1.3 to 8/ha depending upon the type and source of supply.

Policies and legislation

Irrigation Policy No. 2060 was signed in 2003 with the purpose of: obtaining year-round irrigation through the effective use of the country's current water resources; developing institutional capacity of water users for the sustainable management of existing systems; and enhancing the knowledge, skills and institutional capacity of technicians, water users and non-governmental organizations working for the development of the irrigation sector.

The National Water Plan (NWP), approved in 2005, was prepared to implement the Water Resources Strategy (WRS), which was approved in 2002. The broad objective of the NWP is to contribute to the overall national goals of economic development, poverty alleviation, food security, public health and safety, decent standards of living for the people and protection of the natural environment. The NWP provides a framework to guide, in an integrated and comprehensive manner, all stakeholders in developing and managing water resources and water services. A set of specific short-, medium- and long-term action plans have been developed for the water sector, including for programme and project activities, investments and institutional aspects.

The Water Resources Act No. 2049 of 1992 specifies the ownership, use and priority order for the utilization of water resources, WUA constitutions, provisions of licenses and the use of water resources for hydroelectricity.

ENVIRONMENT AND HEALTH

The 1994 Environmental Action Plan provided guidelines for both IWRM and maintaining water quality at the river basin level. Since 1996/1997 the Environment Protection/Conservation Act (EPA) has been revised, however, the task of formulating working rules and defining accountability at various levels of governance and line agencies for the implementation of the Act has not yet been completed.

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Pakistan

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Pakistan, with a total area of 796 100 km^2, is located in Southern Asia (Table 1). It is bordered by India in the east, China in the northeast, Afghanistan in the north and northwest, the Islamic Republic of Iran in the southwest and the Arabian Sea to the south. Pakistan is divided into four provinces, namely the Punjab, Sindh, Khyber Pakhtunkhwa and Balochistan.

The geography of Pakistan is a profound blend of landscapes varying from plains to deserts, forests, hills and plateaus and ranging from coastal areas of the Arabian Sea in the south to the mountains of the Karakoram range in the north. Pakistan geologically overlaps both with the Indian and the Eurasian tectonic plates, where its Sindh and Punjab provinces lie on the northwestern corner of the Indian plate, while Balochistan and most of Khyber Pakhtunkhwa lie within the Eurasian plate, which mainly comprises the Iranian plateau, some parts of the Near East and Central Asia. Pakistan is divided into four broad geographic areas:

- The Northern Highlands include parts of Hindu Kush, Karakoram and the Himalaya's ranges. Mount Godwin Austen, at 8 611 m in the Himalaya's range, is the second highest peak in the world. The Tirichmir, 7 690 m, is the highest peak in the Hindu Kush range. More than one-half of the summits are over 4 500 m, and more than 50 peaks are over 6 500 m.
- The Pothwar Plateau is bounded on the west by the Indus river, on the north by the Kala Chitta range and the Margalla hills, on the east by the Jhelum river and on the south by the Salt range. The terrain is undulating. The Kala Chitta range rises to an average height of 450-900 m and extends for about 72 km.
- The Indus plain is the valley of the River Indus, a large geographical subdivision of Pakistan. It is bordered on the west by the Iranian plateau (the Sulaiman mountains and the Kirthar range), on the north by the Salt range, and on the east by the Thar desert. The length of the valley along the course of the Indus is about 1 000 km, in Punjab it is about 350 km wide and in lower Sindh it is 200 km. It is subdivided into the trans-Indus plain, the right bank of the Indus, the Thal desert in between the water beds of the Indus and the Jhelum, the Punjab plain, and the Sindh lowlands.
- The Balochistan plateau in the southwest has an average altitude of 600 m and is located at the eastern edge of the Iranian plateau. Dry hills run across the plateau from northeast to southwest. A large part of the northwest is desert. It is geographically the largest of the four provinces having area of 347 190 km^2 comprising 48 percent of the area of Pakistan. The southern region is Makran and the central is Kalat. The Sulaiman mountains dominate the northeast corner with the Bolan pass, which is a natural route into Afghanistan going towards Kandahar. Much of the province south of the Quetta region is sparse desert terrain with pockets of inhabitable towns, mostly near rivers and streams.

The land is mostly used for agriculture and rangelands. In 2009, the total cultivated area was an estimated 21.3 million ha, of which 20.4 million ha (96 percent) for annual crops and 0.9 million ha (4 percent) for permanent crops.

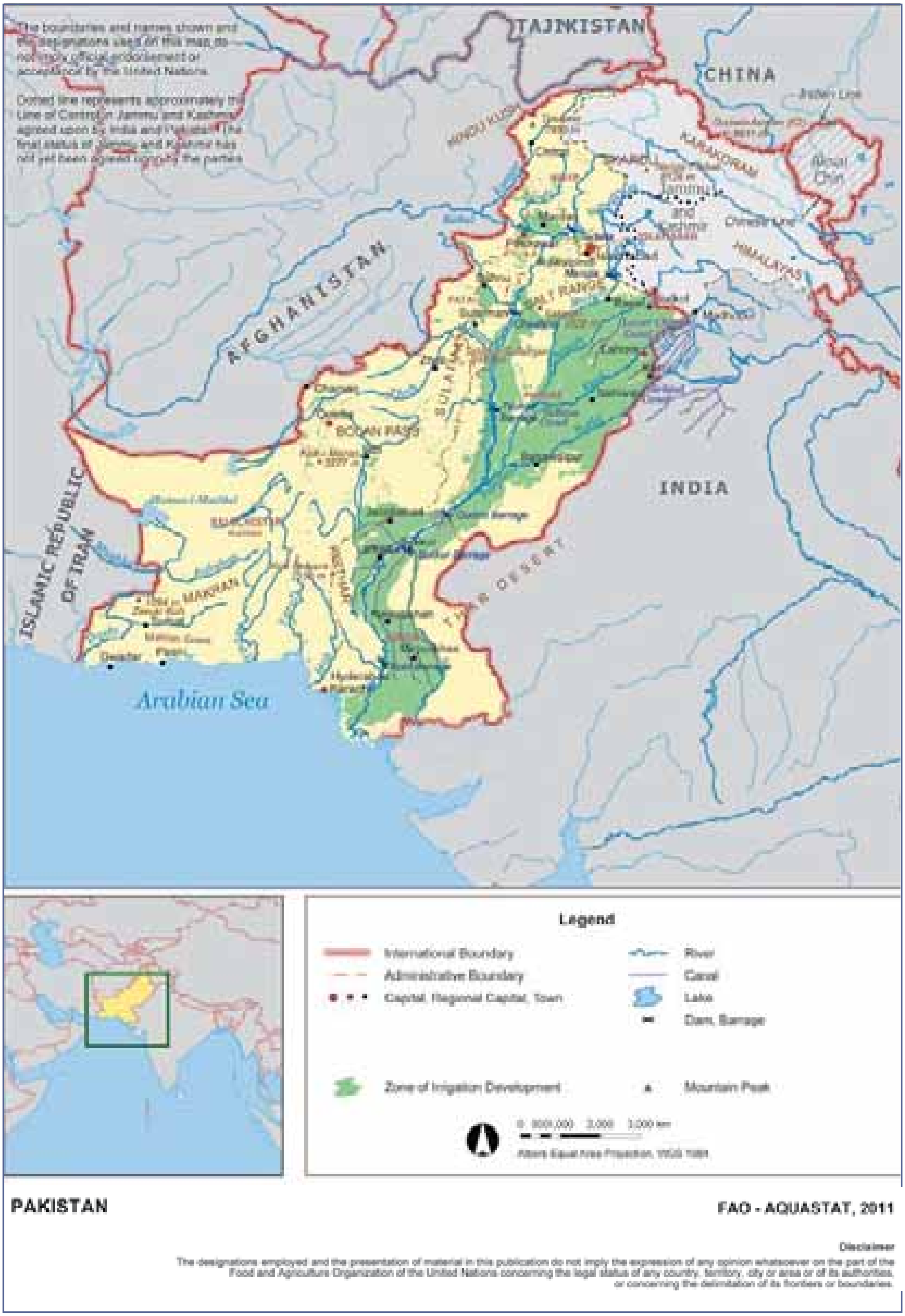
The boundaries and names shown and the designations used on this map do not imply official endorsement or acceptance by the United Nations.
Dotted line represents approximately the Line of Control in Jammu and Kashmir agreed upon by India and Pakistan. The final status of Jammu and Kashmir has not yet been agreed upon by the parties.
TAJIKISTAN
CHINA
AFGHANISTAN
INDIA
ISLAMIC REPUBLIC OF IRAN
Arabian Sea
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Canal
Lake
Dam, Barrage
Zone of Irrigation Development
Mountain Peak
PAKISTAN
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	79 610 000	ha
Cultivated area (arable land and area under permanent crops)	2009	21 280 000	ha
• as % of the total area of the country	2009	27	%
• arable land (annual crops + temp fallow + temp meadows)	2009	20 430 000	ha
• area under permanent crops	2009	850 000	ha
Population			
Total population	2009	170 494 000	inhabitants
• of which rural	2009	64	%
Population density	2009	214	inhabitants/km^2
Economically active population	2009	60 692 000	inhabitants
• as % of total population	2009	36	%
• female	2009	20	%
• male	2009	80	%
Population economically active in agriculture	2009	23 994 000	inhabitants
• as % of total economically active population	2009	40	%
• female	2009	71	%
• male	2009	29	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	161 990	million US$/yr
• value added in agriculture (% of GDP)	2009	22	%
• GDP per capita	2008	926	US$/yr
Human Development Index (highest = 1)	2010	0.490	
Access to improved drinking water sources			
Total population	2008	90	%
Urban population	2008	95	%
Rural population	2008	87	%

Climate

Pakistan lies in the subtropical arid zone and most of the country is subjected to a semi-arid climate. Based on physiographic factors and causes of diversity in climate, the country has been classified into four major climatic regions:

1. the marine tropical coastland;
2. the subtropical continental lowlands;
3. the subtropical continental highlands; and
4. the subtropical continental plateau (ADB, 2003).

Water is a critical and limiting resource for the country's sustained economic development. Linked to water, and based on physiography, in 1980 Pakistan was divided into the following agro-ecological zones:

1. Indus delta;
2. southern irrigated plain;
3. sandy desert;
4. northern irrigated plains;
5. Barani (rainfed) areas;
6. wet mountains;

7. western dry mountains;
8. dry western plateau; and
9. Sulaiman Piedmont (Ahmad, 2004a).

June is the hottest month on the plains and July in the mountainous areas, with temperatures over 38 °C, while the mean monthly minimum is only 4 °C in December/January. The average annual precipitation is around 494 mm, but is unevenly distributed. It varies from less than 100 mm in parts of Balochistan and Sindh provinces to more than 1 500 mm in the foothills and northern mountains of Punjab and Khyber Pakhtunkhwa. The mean Rabi season rainfall (October to March) varies from less than 50 mm in parts of Sindh province to more than 500 mm in Khyber Pakhtunkhwa. The mean Kharif season rainfall (April to September) varies from less than 50 mm in parts of Balochistan to more than 800 mm in the northern Punjab and Khyber Pakhtunkhwa.

About 60 percent of the rainfall in the monsoonal climate is received from July to September. The extreme variability in seasonal rainfall directly affects river flows, which vary considerably during the Rabi and the Kharif seasons. In the northern areas, at altitudes of more than 5 000 m, snowfall exceeds 5 000 mm/year and provides the largest resource of water in the glaciated zone. Around 92 percent of the country's area is classified as semi-arid to arid, facing extreme shortage of precipitation. Most of the irrigated area is classified as semi-arid to arid. The reference crop evapotranspiration varies from 1 150 to 1 800 mm/year (Ahmad, 2008a).

Population

In 2009, the total population was 170 million, of which around 64 percent lived in rural areas (Table 1). The average population density is 214 inhabitants per km^2, with the population being concentrated on the Indus plain. The population density in the Balochistan plateau is extremely low because of the mountainous terrain and scarcity of water. Average annual population growth during the period 1999-2009 was an estimated 1.9 percent.

In 2008, access to improved drinking water sources reached 90 percent (95 and 87 percent for the urban and rural population respectively). Sanitation coverage was 45 percent (72 and 29 percent for urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture was an estimated 24.0 million, which was 40 percent of the economically active population. About 29 percent of the population economically active in agriculture are women. In 2009, GDP was US$161 990 million of which agriculture accounted for 22 percent (Table 1).

The roles of men and women are sharply defined, but women are actively involved in farming. Women are largely responsible for livestock production and maintenance, picking cotton, transplanting rice, harvesting and threshing other crops.

In 2007, the overall unemployment rate was 5.2 percent of the total labour force, out of which 4.7 percent of rural labour and 6.3 percent of urban labour is unemployed. There is an increase in the number of severely food-insecure people, from 23 percent in 2005-2006 to 28 percent in 2008. Food security in 2007-2008 had significantly worsened as a result of food price hikes. The total number of households falling into this category in 2008 was around 7 million; equal to about 45 million people. In relative terms, the increase is more pronounced in rural areas, where food expenditure rose by 10 percent and total expenditure by 4 percent (GoP, 2008b).

Food exports account for 13.2 percent of total exports, or US$2 050 million, contributing 26.1 percent to overall export growth. Rice accounting for 60 percent, has registered an impressive growth of 28.5 percent. Pakistan clearly benefited from the unprecedented rise in the international price of rice. Since Pakistan is a net exporter of rice, it is likely to benefit from the elevated international price of rice in coming years. This will encourage farmers in Pakistan to grow more rice and benefit from the higher prices on the international market. Other important foods registered impressive growth, such as fruits, oilseeds, nuts and kernels, meat and fish. More than a 67 percent increase in imports is attributed to wheat, followed by 47 percent for edible oil (GoP, 2008a; GoP, 2008b).

WATER RESOURCES AND USE

Water resources

Pakistan can be divided into three hydrological units:

- The Indus basin covers more than 520 000 km^2, or 65 percent of the territory, comprising all the provinces of Punjab, Sindh and Khyber Pakhtunkhwa and the eastern part of Balochistan. The Indus river has two main tributaries, the Kabul on the right bank and the Panjnad on the left bank. The flow of the Panjnad results from five main rivers (literally Punjab means 'five waters'): the Jhelum and Chenab, known as the western rivers, and the Ravi, Beas and Sutlej, known as the eastern rivers.
- The Karan desert in the west of Balochistan, western Pakistan, is an endorheic basin covering 18 percent of the territory. The Mashkel and Marjen rivers are the principal source of water in the basin. The Marjen is a minor tributary to the Mashkel. The water is discharged into the Hamun-i-Mashkel lake in the southwest, on the border with the Islamic Republic of Iran.
- The arid Makran coast, along the Arabian Sea, covers17 percent of the territory in its southwestern part (Balochistan province). The Hob, Porali, Hingol and Dasht are the principal rivers in this coastal zone.

The flows in the river basins outside the Indus Basin Irrigation System (IBIS), the Makran coast and the Karan closed basin, are flashy in nature and do not have a perennial supply. They account for a total flow inferior to 5 km^3 per year.

The long-term average annual precipitation for Pakistan is 494 mm, representing 393.3 km^3 (Table 2). Precipitation in 2008 was 278 mm. Internally produced surface water is 47.4 km^3/year, whereas internally generated groundwater is 55.0 km^3/year. Some of the groundwater drains directly into the sea, while the rest feeds the base flow of the river system, which is an estimated 47.4 km^3/year. Taking into account this overlap of 47.4 km^3/year between surface water and groundwater, the internal renewable water resources (IRWR) are an estimated 55 km^3/year.

River flows are composed of glacier melt, snowmelt, rainfall and runoff. The Indus basin has a total drainage area of 1.1 million km^2, of which 47 percent lies in Pakistan, and the other 53 percent in China, Afghanistan and India. Because of the importance of irrigation on the Indus plain, the water balance of the Indus basin has been carefully studied, which is not the case for the other basins. Most results found, therefore, refer only to the Indus basin. The mean annual inflow into the country through the Indus river system is an estimated 265.08 km^3, of which 21.5 km^3 is from the Kabul river and other tributaries of the Indus river flowing from Afghanistan, 11.1 km^3 from the eastern rivers of the Indus basin and 232.48 km^3 from the western rivers, both flowing from India.

Under the Indus Water Treaty (1960) between India and Pakistan, it is estimated that 170.27 km^3/year is reserved for inflow from India into Pakistan. The following rules apply:

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	494	mm/yr
	-	393 300	million m^3/yr
Internal renewable water resources (long-term average)	-	55 000	million m^3/yr
Total actual renewable water resources	-	246 800	million m^3/yr
Dependency ratio	-	78	%
Total actual renewable water resources per inhabitant	2009	1 474	m^3/yr
Total dam capacity	2005	23 360	million m^3
Water withdrawal			
Total water withdrawal	2008	183 421	million m^3/yr
- irrigation + livestock	2008	172 371	million m^3/yr
- municipalities	2008	9 650	million m^3/yr
- industry	2008	1 400	million m^3/yr
• per inhabitant	2008	1 096	m^3/yr
Surface water and groundwater withdrawal	2008	183 421	million m^3/yr
• as % of total actual renewable water resources	2008	74	%
Non-conventional sources of water			
Produced wastewater	2000	12 330	million m^3/yr
Treated wastewater	2000	145	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

- Ø *Eastern Rivers:* All the waters of the eastern tributaries of the Indus river originating in India, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for unrestricted use by India. Pakistan shall be under an obligation to let flow, and shall not permit any interference with, the waters (while flowing in Pakistan) of any tributary which in its natural course joins the Sutlej main or Ravi main before these rivers have finally crossed into Pakistan. This average annual flow in India before crossing the border is an estimated 11.1 km^3. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan shall be available for the unrestricted use of Pakistan.
- Ø *Western Rivers:* Pakistan shall receive for unrestricted use all those waters of the western rivers, i.e. Chenab and Jhelum, which India is under obligation to let flow, except for restricted uses, related to domestic use, non-consumptive use, agricultures use and generation of hydroelectric power of which the amounts are set out in the Treaty. Annual flow from China to India in the Indus basin is 181.62 km^3 and it is estimated that the flow generated within India is 50.86 km^3, resulting in a flow from India to Pakistan in this part of 232.48 km^3, of which 170.27 km^3 reserved for Pakistan and 62.21 km^3 available for India.

Given the seasonal nature of the Himalayan runoff, roughly 85 percent of the annual flows are in the *Kharif* season (summer), and only 15 percent in the *Rabi* season (winter).

The Indus basin has a large groundwater aquifer covering a gross command area of 16.2 million ha.

In 2005, the total dam capacity was an estimated 23.36 km^3 (Table 2). Currently, there are three large hydropower dams and 50 smaller dams (no more than 15 m high), while 11 smaller dams are under construction.

The designed live storage capacity of the three large hydropower dams in the Indus basin is 22.98 km^3 (Tarbela 11.96 km^3, Raised Mangla 10.15 km^3, which includes recent raising of 3.58 km^3, and Chashma 0.87 km^3). The current live storage capacity of these three large hydropower dams is 17.89 km^3, representing an overall loss of storage of 22 percent (World Bank, 2005). Pakistan can barely store 30 days of water in the IBIS. Each km^3 of storage capacity lost means 1 km^3/year less water that can be supplied with a given level of reliability. There is an urgent need for storage just to replace capacity that has been lost as a result of sedimentation. Given the high silt loads from the young Himalayas, two large reservoirs are silting rapidly. In 2008, because of the raising of the Mangla dam, the loss owing to sedimentation was recovered (WB, 2005).

The designed live storage capacity of 50 small dams is 0.383 km^3. The information related to sedimentation and loss of live storage of small dams is not available. It was assumed, therefore, that on average 25 percent of the live storage in these small dams has been lost as a result of sedimentation.This has lead to the current live storage capacity of these small dams of 0.287 km^3. There are more than 1 600 mini dams (less than 15 m high), which were constructed for small-scale irrigation, but the capacity of these mini dams is low because they are usually constructed for an individual farmer. The information on the live storage capacity of mini dams is not available. Storage of mini dams is negligible compared to that of small dams. According to certain estimates, the total designed capacity of these mini dams would be around 0.036 km^3.

Pakistan has a hydroelectric potential of about 50 000 MW, when the whole of Chitral as well as Skardu gorges are comprehensively assessed. The Indus river and its tributaries are the main source of water. Its main gorge, between the Skardu and Tarbela, has a potential of almost 30 000 MW. These include Bashan (4 500 MW), Disso (3 700 MW), Banjo (5 200 MW), Thicket (1 043 MW), Paten (1 172 MW), Racicot (670 MW), Yuba (710 MW), Hugo (1 000 MW), Tunas (625), and Sakardu or Kithara (possibly 4 000 to 15 000 MW). Almost 20 000 MW potential is available on various sites on the rivers: Swat, Jhelum, Neelam, Punch and Kumar (Qazilbash, 2005).

In 2000, the total wastewater produced was an estimated 12.33 km^3, while treated wastewater was an estimated 0.145 km^3.

International water issues

The Indus Water Treaty (1960) between India and Pakistan, described earlier, helped to resolve the issues between these two countries and allowed Pakistan to have large investments in the Indus Basin Project (IBP) during the 1960s to construct a network of canals and barrages to divert water from the western rivers to the command of the eastern rivers as replacement works. In the last few years, however, Pakistan has objected to India's development of the of hydropower projects on the western rivers, Chenab and Jhelum.

Water use

Agriculture withdrew an estimated 172.4, or 94 percent of the total water withdrawal. Municipal and industrial water withdrawal was an estimated 9.7 km^3 and 1.4 km^3, respectively (Figure 1) (GoP, 2008a; Zakria, 2000).

Total water withdrawal in 2008 was an estimated 183.4 km^3. Surface water withdrawal accounts for 121.8 km^3 (66.4 percent) and groundwater withdrawal accounts for 61.6 km^3 (33.6 percent). This mainly refers to the IBIS, the withdrawal outside the IBIS being extremely small (GoP, 2008a) (Table 2 and Figure 2).

Most summer rains are not available for crop production or recharge to groundwater because of rapid runoff of torrential showers.

FIGURE 1
Water withdrawal by sector
Total 183.421 km³ in 2008

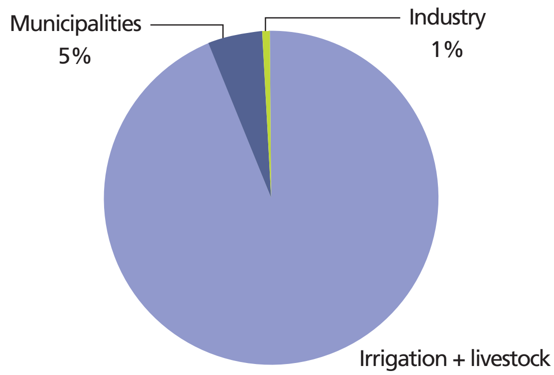
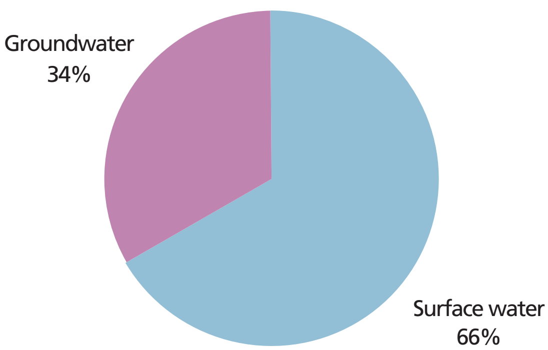


FIGURE 2
Water withdrawal by source
Total 183.421 km³ in 2008



The overall irrigation efficiency in the IBIS is 40 percent (canal efficiency 75 percent, conveyance efficiency 70 percent and field application efficiency 75 percent). The water lost during conveyance and application largely contributes towards recharging groundwater.

In some areas, development appears to have reached the point where groundwater is being mined. Most urban and rural water is supplied from groundwater. Over 50 percent of the village water supply is obtained from hand pumps, which are installed by private households. In saline groundwater areas, irrigation canals are the main source of municipal water.

Groundwater is pumped using electricity and diesel fuels. There are currently one million tubewells, of which 87 percent are operated by diesel. Power failures, extended load shedding and poor electricity supply are the main reasons for the slow growth of electric tubewells compared to diesel-operated tubewells (Ahmad, 2008b).

Information on the use of treated wastewater and desalinated water is not available, it is however a minor fraction of the total. Sewage water from urban areas is used by farmers in the peri-urban areas to irrigate fodder crops and vegetables. Farmers also reuse drainage water during periods of water scarcity to supplement canal water supplies, but data are not available.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

The irrigation potential of land and water resources is estimated to be equal to the cultivable area, or 21.3 million ha. In 2008, the area equipped for irrigation was around 19.99 million ha, compared with 15.73 million ha in 1990. The total water managed area is an estimated 21.24 million ha, compared with 16.96 million ha in 1990, and can be divided according to the following classification (Table 3):

- Full control irrigation schemes cover 19.27 million ha, of which 14.87 million ha within the IBIS and 4.40 million ha outside the IBIS. The areas outside the IBIS cover minor perennial irrigation schemes, groundwater schemes including tubwells, wells, *karezes* and springs. They are located in Khyber Pakhtunkhwa and Balochistan. In Khyber Pakhtunkhwa irrigation is carried out using pump lifts, which are maintained by the Provincial Irrigation Department (PID). In the northern parts of Khyber Pakhtunkhwa contour channels are used to irrigate, offtaking water from the locally available sources, which are often steep sided streams or springs. Most of these schemes are owned and operated directly by the beneficiaries through traditional social organizations. In Balochistan irrigation water is taken from *karezes* and perennial springs. (*Karezes* are tunnels or underground channel that tap an aquifer). Irrigation schemes are generally small, ranging between 50 and 400 ha, and operated by a group. . Some small, group-operated schemes, are irrigated from infiltration galleries or small weirs in rivers and individuals may pump water from tubewells and open wells.

- Spate irrigation in 2004 covered a total potential area of 2 million ha (1.4 million ha in 1990). This area refers to potential spate area, but actual area varies based on flood occurrence and frequency and is around 0.72 million ha in an average year. In Pakistan, these areas are known as *Rod Kohi* in Khyber Pakhtunkhwa and Punjab, or *Bandat* in Balochistan, and the irrigation method is often called flood irrigation. The streams on the Makran coast and the Karan closed basin are flashy in nature and do not have a perennial supply, thus about 25 percent of their flow, which is less than 5 km^3, is used for spate irrigation. This kind of irrigation relies on floods from hill torrents. Wherever possible, the runoff is harnessed for irrigation by weirs or temporary diversion structures. Farmers divert the spate flow onto their fields by constructing breachable earth bunds (called *gandas*) across the rivers, or by constructing stone/gravel spurs leading towards the centre of the river. Captured water flows from field-to-field and, when the soil profile is saturated, the lower bund is breached to release water into another field. Annual average cropping intensity is 20 percent.
- Flood recession cropping areas cover 1.25 million ha on 2004 (1.23 million ha in 1990). In Pakistan these areas are known as *Sailaba*, and are often called falling flood irrigation areas. Sailaba cultivation is carried out on extensive tracts of land along the rivers and hill streams subject to annual inundation. Moisture retained in the root zone is utilized after the flood subsides together with subirrigation resulting from the capillary rise of groundwater and any rain.

Apart form these water managed areas, some attempts have been made to develop water harvesting, which is known in Pakistan as *Khushkaba*, though it is not possible to quantify this area.

In 2008, out of the 19.27 million ha of full control irrigation schemes, 6.91 million ha were commanded by surface water (canals), 4.13 million ha by groundwater (wells, tubewells), whereas 7.96 million ha were commanded by both surface water and groundwater. Only 0.27 million ha were commanded by non-conventional sources of water (Figure 3). Surface irrigation is the only irrigation technique used. In 2008, the entire area equipped for full control irrigation was actually irrigated.

In 2008, small schemes (< 100 ha) covered 21.4 percent of the total area equipped for full control irrigation, medium-size schemes (100-25 000 ha) 2.3 percent and large schemes (> 25 000 ha) 76.3 percent (Figure 4).

The Indus Basin Irrigation System

Although irrigation takes place in other areas of Pakistan, information on the history and development of irrigation generally refers to the IBIS, where more than 95 percent of the irrigation is located.

The 4 000 year old Indus civilization has its roots in irrigated agriculture. Canal irrigation development began in 1859 with the completion of the Upper Bari Doab Canal (UBDC) from Madhopur headworks (now in India) on Ravi river. Until that time, irrigation was undertaken through a network of inundation canals, which were functional only during periods of high river flow. These provided water for *Kharif* (summer) crops and residual soil moisture for *Rabi* (winter) crops. The last inundation canals were connected to weir-controlled supplies in 1962 with the completion of the Guddu barrage on Indus river (barrages in the IBIS are constructed to divert river water into canals and the storage capacity is insignificant).

TABLE 3
Irrigation and drainage

Irrigation potential			21 300 000	ha
Irrigation				
1. Full control irrigation: equipped area		2008	19 270 000	ha
- surface irrigation		2008	19 270 000	ha
- sprinkler irrigation		2008	0	ha
- localized irrigation		2008	0	ha
• % of area irrigated from surface water		2008	35.9	%
• % of area irrigated from groundwater		2008	21.4	%
• % of area irrigated from mixed surface water and groundwater		2008	41.3	%
• % of area irrigated from mixed non-conventional sources of water		2008	1.4	%
• area equipped for full control irrigation actually irrigated		2008	19 270 000	ha
- as % of full control area equipped		2008	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation		2008	720 000	ha
Total area equipped for irrigation (1+2+3)		**2008**	**19 990 000**	**ha**
• as % of cultivated area		2008	94	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 7 years		2001-2008	1.66	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area		2004	1 250 000	ha
Total water-managed area (1+2+3+4+5)		**2008**	**21 240 000**	**ha**
• as % of cultivated area		2008	100	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 100 ha	2008	4 130 000	ha
Medium-scale schemes		2008	440 000	ha
Large-scale schemes	> 25 000 ha	2008	14 700 000	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2008	21 451 674	ha
• Annual crops: total		2008	20 656 701	ha
- Wheat		2008	7 334 600	ha
- Rice		2008	2 515 400	ha
- Maize		2008	946 530	ha
- Millet		2008	477 540	ha
- Sorghum		2008	253 260	ha
- Barley		2008	81 990	ha
- Potatoes		2008	154 317	ha
- Pulses		2008	1 006 441	ha
- Vegetables		2008	352 656	ha
- Tobacco		2008	51 398	ha
- Cotton		2008	3 054 300	ha
- Fodder		2008	2 459 500	ha
- Groundnuts		2008	9 012	ha
- Sunflower		2008	397 306	ha
- Sesame		2008	69 915	ha
- Rapeseed		2008	201 600	ha
- Sugarcane		2008	1 241 300	ha
- Other annual crops		2008	49 636	ha
• Permanent crops: total		2008	794 973	ha
- Citrus		2008	199 369	ha
- Bananas		2008	35 558	ha
- Other permanent crops		2008	560 046	ha
Irrigated cropping intensity (on area actually irrigated)		2008	111.3	%

TABLE 3
Irrigation and drainage (continued)

Drainage - Environment			
Total drained area	2008	15 140 000	ha
- part of the area equipped for irrigation drained	2008	15 140 000	ha
- other drained area (non-irrigated)	2008	0	ha
• drained area as % of cultivated area	2008	71	%
Flood-protected areas		-	ha
Area salinized by irrigation	2004	7 003 000	ha
Population affected by water-related diseases		-	inhabitants

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 19 270 000 ha in 2008

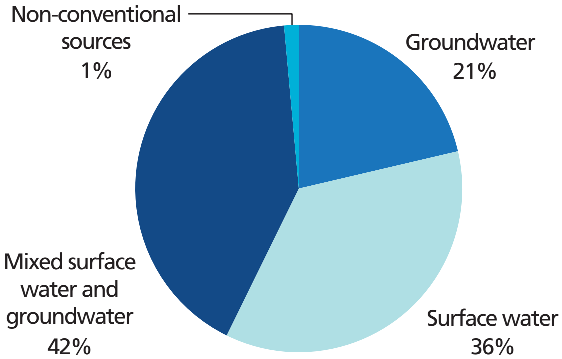
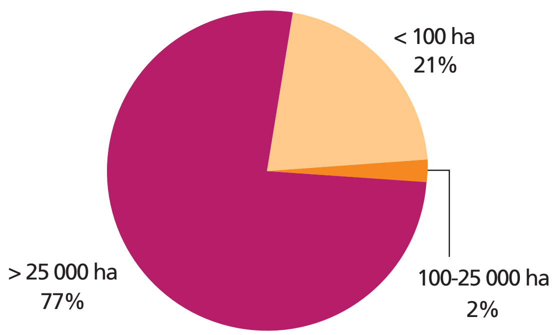


FIGURE 4
Type of full control irrigation schemes
Total 19 270 000 ha in 2008



UBDC was followed by Sirhind canal from Rupar headworks on Sutlej in 1872 (also in India) and Sidhnai canal from Sidhnai barrage on Ravi in 1886. The Lower Chenab from Khanki on Chenab in 1892, and Lower Jhelum from Rasul on Jhelum in 1901 followed. Lower and Upper Swat, Kabul river and Paharpur canals in Khyber Pakhtunkhwa were completed during 1885 to 1914.

In the beginning of the 1900s, it became apparent that the water resources of the individual rivers were not in proportion to the potential irrigable lands. Ravi river, serving a large area of Bari Doab, was low in supply while Jhelum had a surplus. An innovative solution was developed in the form of the Triple Canal Project, constructed during 1907-1915. The project linked the Jhelum, Chenab and Ravi rivers, allowing a transfer of surplus Jhelum and Chenab water to the Ravi. The Triple Canal Project was a land-mark in integrated inter-basin water resources management and provided the key concept for the resolution of the Indus waters dispute between India and Pakistan in 1960.

The Sutlej Valley Project, comprising four barrages and two canals, was completed in 1933. This resulted in the development of the unregulated flow resources of the Sutlej river and motivated planning for the Bhakra reservoir (now in India). During the same period, the Sukkur barrage and its system of seven canals, serving 2.95 million ha in the Lower Indus, were completed. These are considered to be the first modern hydraulic structures on the downstream Indus river. Haveli and Rangpur from Trimmu headworks on Chenab in 1939 and Thal canal from Kalabagh headworks on the Indus were completed in 1947. This comprised the system inherited by Pakistan at the time of its creation in 1947.

At independence, the irrigation system, conceived originally as a whole, was divided between India and Pakistan without considering the irrigated boundaries. This resulted in the creation of an international water dispute in 1948, which was finally resolved by the enforcement of the Indus Water Treaty in 1960 under the aegis of the World Bank. The Indus Basin Project (IBP) including Mangla dam, five barrages, one syphon and eight inter-river link canals, was completed during 1960-1971, while Tarbela dam started partial operation in 1975-1976.

After the partition, Kotri, Taunsa and Guddu barrages were completed on the Indus river to provide controlled irrigation to areas previously served by inundation canals. The Taunsa barrage was completed in 1958 to divert water to two large areas on the left and right banks of the river. This made irrigated agriculture possible for about 1.18 million ha of arid landscape in Punjab province. Currently rehabilitation and modernization of the barrage is in progress. Also, three additional inter-river link canals were built prior to the initiation of the IBP.

As a result of these extensive developments Pakistan now possesses the world's largest contiguous irrigation system. It commands 14.87 million ha (2008) and encompasses the Indus river and its tributaries including three large reservoirs (Tarbela, Mangla, and Chashma), 23 barrages/headworks/siphons, 12 inter-river link canals and 45 canals commands extending for 60 800 km with communal watercourses, farm channels, and field ditches covering another 1.6 million km to serve over 90 000 farmer-operated watercourses. In the Indus system, river water is diverted by barrages and weirs into main canals and subsequently branch canals, distributaries and minors.

The flow to the farm is delivered by over 107 000 watercourses, which are supplied through outlets *(moghas)* from the distributaries and minors. The *mogha* is designed to allow a discharge that self-adjusts to variations in the parent canal. Within the watercourse command (an area ranging from 80 to 280 ha), farmers receive water proportional to their land holding. The entire discharge of the watercourse is given to one farm for a specified period on a seven day rotation. The rotation schedule, called *warabandi*, is established by the Provincial Irrigation and Power Department, unless the farmers can reach a mutual agreement.

Role of irrigation in agricultural production, economy and society

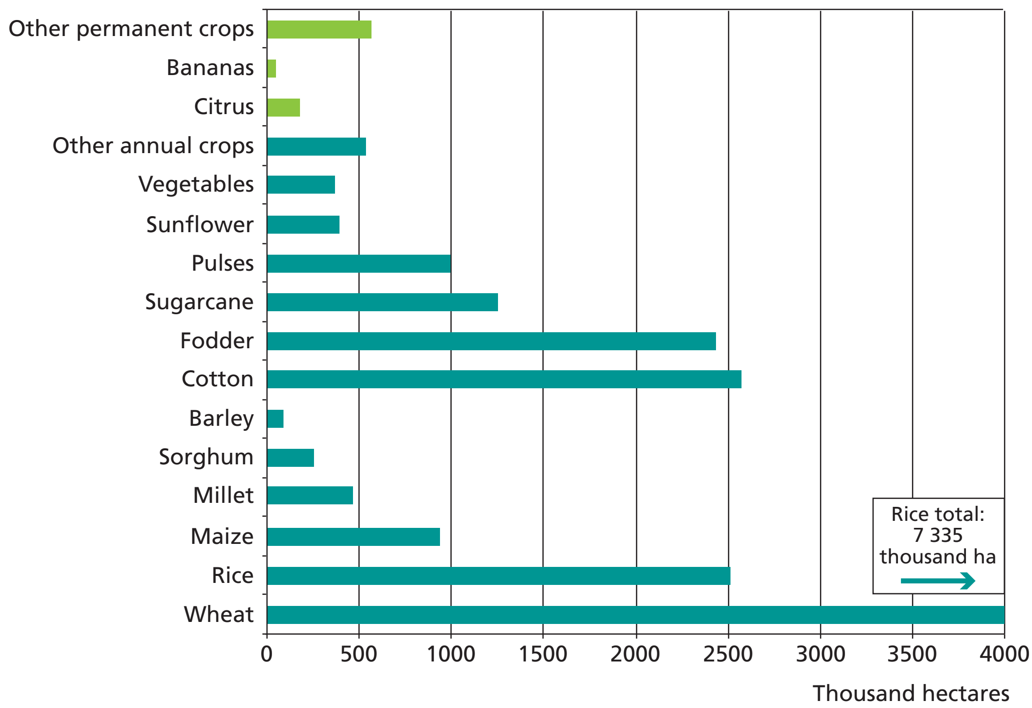
All cotton, rice, sugarcane, fodder, maize grain, fruits, vegetables, freshwater fisheries, dairy livestock are grown under irrigated conditions, and 90 percent of the wheat area is irrigated. Coarse grains, pulses, groundnut, sorghum and millets are normally rainfed or spate irrigated. Around 10 percent of the wheat area is rainfed,contributing only 5 percent of wheat production. Wheat, pulses and coarse grains are spate irrigated. Recession agriculture is also practiced around the rivers and streams during floods; after receding of floodwater the crops are grown.

In 2008, the total harvested irrigated cropped area was about 21.45 million ha (Table 3 and Figure 5). The major irrigated crops are wheat, rice, sugarcane, cotton and fodder. These crops are almost 78 percent of the total harvested area and consume 82 percent of the total available water resources. The area under these crops is 16.60 million ha, of which 7.33; 2.52; 1.24; 3.05 and 2.46 million ha for wheat, rice, sugarcane, cotton and fodder, respectively (GoP, 2008a).

Full control irrigated agriculture provides 90 percent of wheat and small grains besides nearly 100 percent of sugarcane, rice, cotton, fruits and vegetables, whereas the *Barani* (rainfed) and *Sailaba* (spate irrigation) areas contribute only 10 percent of wheat and a portion of small grains and pulses. It also provides milk, meat and fuelwood besides crops (Ahmad, 2004a; Ahmad, 2004b; Ahmad, 2008a; GoP, 2008b). The average yield of irrigated wheat, rice, sugarcane, cotton and fodder is 2.5, 2.2, 51.5, 0.65 and 22.4 tonnes/ha respectively (GoP, 2008a).

In 2008, the average cost of irrigation development in public schemes was an estimated US$1 300/ha, while the cost of drainage development was aroundUS$2 650/ha. The average cost of operation and maintenance (O&M) is US$65/ha per year. The average cost of sprinkler and irrigation for on-farm installation is US$1 500/ha and US$1 750/ha respectively.

FIGURE 5
Irrigated crops on area equipped for full control irrigation
Total harvested area 21 451 674 ha in 2008 (cropping intensity on full control equipped area: 111.3%)



Status and evolution of drainage systems

When the IBIS was developed, the drainage needs were initially minimal. Water tables were deep and irrigation water supplies were too low to generate much groundwater recharge and surface water losses. Whatever little drainage was required, could readily be accommodated by the existing natural drainage. The drainage needs, however, have increased as more irrigation water has been diverted and the water table has risen to harmful levels causing waterlogging and salinity. The drainage systems were developed over the last 30-40 years (Bhutta and Smedema, 2005).

Drainage and reclamation programmes to mitigate waterlogging and salinity, especially in areas where the water table is 0-1.5 m deep, have been assigned priority. Under the Salinity Control and Reclamation Projects (SCARPs), a disastrous area of 1.97 million ha (with a water table at 0-1.5 m) was reclaimed through rehabilitation of existing drains and investments for the new drainage schemes. Surface drains were also constructed in areas where surface runoff resulted from rainfall or excess irrigation. To encourage private sector participation in drainage, SCARP tubewells were transferred from the public to private sector. Tile drainage was given due attention. The current situation of the waterlogged area shows that the area at risk (with a water table at less than 1.5 m) comprises 12 percent of the total irrigated area. About 1.06 million ha of this area at risk has been covered under various SCARPs. During the current decade, an area of 1.21 million ha was reclaimed under drainage projects such as LBOD, RBOD-I, II and III, Drainage-IV and the National Drainage Programme with the installation of 1 260 drainage wells, transitioning of 5 000 public tubewells, construction or rehabilitation of 2 200 km of open drains, and laying of tile drainage system in 146 500 ha (MTDF 2005).

In 2008, the total drained area equipped for irrigation, was approximately 15.14 million ha.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

Water is a federal subject, for which the following federal institutions are responsible:

- The Ministry of Water and Power is responsible for the development of water projects including hydropower dams, main canals and inter-provincial works. The Ministry is supported by the Office of the Chief Engineering Advisor, the Chair of the Federal Flood Commission and the Chair of the Indus River System Authority (IRSA).
- The IRSA is responsible for the distribution of water among the provinces and assists provinces to share shortages according to the Apportionment Accord of 1991.
- The Water and Power Development Authority (WAPDA), created in 1958 as a semiautonomous body, is the functional arm of the Ministry of Water and Power and is responsible for the development of hydropower and water development projects.
- The Ministry of Food and Agriculture is responsible for water management at the watercourse command level and farm level irrigation and water productivity. The Ministry is supported by the Federal Water Management Cell, which coordinates the national projects and provides services to the provinces for planning, evaluation and monitoring of Mega projects. This Cell also provides support to the provincial Departments of Agriculture through the provincial On-Farm Water Management (OFWM) Directorate Generals. These OFWMs implement the programmes and projects related to water management for agriculture and are involved in organizing water user associations at the watercourse level and their federations at the distributary canal command level.
- The Pakistan Agricultural Research Council (PARC) is a national apex research organization responsible for research in agriculture, land, water, energy, environment and livestock.
- The Water Resources Research Institute of the National Agricultural Research Centre of PARC is a major institution dealing with research related to water for agriculture. Recently, the federal government transferred the *High Efficiency Irrigation Project,* which is a mega project, to PARC under the directive of the Prime Minister of Pakistan.
- Pakistan Council of Research in Water Resources is an organization under the federal Ministry of Science and Technology. The Council is also involved in some areas of water research related to agriculture, but has no formal link to the Department of Agriculture in the provinces. Its activities are related to water for domestic use, water quality and control of desertification.

Irrigation and drainage are handled at the provincial level. The Provincial Irrigation and Drainage Authorities (PIDAs) are the custodians of the irrigation networks in association with the Area Water Boards (AWB). These institutions carry out O&M and the distribution of water within the province and to design and develop new irrigation and drainage schemes. The PIDA experiment is still in its infancy, the Provincial Irrigation Departments (PIDs) are still active, as the responsibility and authority has not yet been transferred to the AWBs.

The Farmers' Organizations (FOs) were registered during the early twentieth century. The Institutional Reforms for the water sector, the Provincial Irrigation and Drainage Authority Acts authorized the PIDAs to form and register the FOs at the distributary canal level. At the provincial level the FOs have been established in the selected AWBs. The FOs are responsible for collecting the water fee.

Along with the FOs, the first Water User Associations (WUA) were created in 1981 under the World Bank-supported *On-Farm Water Management Programme.* These were formed at the watercourse level, with the primary objective of rehabilitating the watercourses. Currently around 80 000 WUAs have been formed that have participated in the rehabilitation and lining of the watercourses.

Environment institutions have been established within most of the organizations besides the federal and provincial Environmental Protection Agencies (EPAs) to address issues related to field level activities. The regulatory and legal aspects of pollution control are being implemented by the EPAs.

Water management

The government of Pakistan has undertaken a *National Project on the Improvement of Watercourses* to improve 88 000 watercourses costing Pakistani Rupees 66 billion (about US$0.8 billion in 2009) and cost sharing of 70:30 percent, where 70 percent is contributed jointly by the federal and provincial governments and 30 percent by farmers. Since 2007 the federal government has been funding a *National Programme for Water Conservation for Productivity Enhancement using High Efficiency Irrigation System.* A subsidy of Pakistani Rupees 90 000/ha (US$1 070/ha in 2009) is provided jointly by the federal and provincial governments and the rest by the farmer. Private sector service and supply companies have been registered in to provide 'turn-key' installation of sprinkler and drip irrigation systems. Recently, this project has been transferred to PARC owing to the extremely slow progress.

The public sector operates the irrigation systems above the *moghas* (turnout). Each season, the Water and Power Development Authority (WAPDA) of the Federal Government estimates water availability for the following season. The Provincial Irrigation Departments (PID) inform the WAPDA of provincial water demands at specific locations. The WAPDA releases water from the reservoirs to meet demands as closely as possible. The limited reservoir capacity of the systems does not allow the full regulation of rivers for irrigation.

Farmers use groundwater to irrigate their fields at peak demand owing to scarcity of water and shortages imposed resulting from fixed rotation and the continuous flow irrigation system, which is too rigid to meet crop-water demands. The water distribution system is based on a rotation schedule, called *Warabandi* (7-10 days rotation), and water is supplied equitably to farmers on a fixed rotation; inequity arises from the inefficiency of water conveyance (Ahmad, 2008a).

An agreement was reached in March 1991 between the provinces on the apportionment of the Indus water to replace a much older agreement. The new agreement has released the provincial canal systems from the need to be operating at all times so as to protect or establish future rights. Now that the supplies have been apportioned, including the formula for sharing any surplus river flows, the provincial systems are free to move toward more efficient water use.

Finances

O&M expenditure is collected by levying water charges and/or drainage taxes. In Punjab and Khyber Pakhtunkhwa, water charges are assessed by the Provincial Irrigation Departments (PIDs). In Sindh and Balochistan, they are assessed by the Provincial Revenue Department (PRD). Water and drainage charges are not linked to O&M needs. They are collected in all regions by PRD, and are deemed to be part of provincial revenues. The gap between O&M expenditures and recoveries through water charges is high (44 percent) and increasing. The difficulties faced in cost recovery have resulted in very poor O&M which, together with deliveries at less than the designed levels and illegal diversion, has led to major inequalities in the distribution of water. In reality, water often does not reach the tail-end users, which can partly explain the increasing groundwater extraction.

The FOs are responsible for collecting the water fee. They retain 40 percent for O&M at the distributary canal level and deposit 60 percent with the AWB for upstream O&M.

The IBIS is the largest infrastructural enterprise accounting for about US$300 000 million investment (at current rates).

Policies and legislation

Since 2005, the Draft National Water Policy is still in the process of being approved. The Pakistan Water Strategy was prepared during 2001, which is the basic document for water development and management. Further, there is no formal Agriculture Policy; although policy decisions have been made on a case-by-case basis. The only approved Integrated Water Resources Management Policy is for Balochistan province.

The 1967 Land Reform Act established a register of rights, which is a cadastral register for land and water rights.

ENVIRONMENT AND HEALTH

Water quality of the Indus river and its tributaries is excellent. Total dissolved solids (TDS) range between 60-374 ppm (parts per million), which is safe for multiple uses (Bhutta, 1999; PWP, 2000). TDS in the upper reaches range between 60 ppm during high-flow to about 200 ppm during low-flow. Water quality deteriorates downstream but remains well within permissible limits, with TDS in the lower reaches of the Indus (at Kotri Barrage) ranging from 150 to 374 ppm. TDS of some of the tributaries such as Gomal River at Khajuri, Touchi River at Tangi Post and Zhob River at Sharik Weir range between 400 to 1 250 ppm (IWASRI, 1997). The quality of the groundwater is marginal to brackish in 60 percent of the IBIS aquifer. The groundwater quality in the area outside the IBIS varyies, depending on recharge (Ahmad, 2008a; Ahmad, 2008b).

Indiscriminate and unplanned disposal of effluents, including agricultural drainage water, municipal and industrial wastewater, into rivers, canals and drains is causing deterioration of water quality downstream. In 1995 around 12.435 km^3/year (9 000 million gallons/day - 1 gallon = 4.5 litres) of untreated water were being discharged into water bodies (Ahmad, 2008b). It was estimated that 0.484 and 0.345 km^3/year (350 and 250 million gallons/day) of sewage was produced in Karachi and Lahore metropolitan areas and most of it was discharged untreated into water bodies. The polluted water is also being used for drinking in downstream areas causing numerous water-borne diseases.

Quality of groundwater varies widely, ranging from < 1 000 ppm to > 3 000 ppm. Around 5.75 million ha have underlying groundwater affected by salinity < 1 000 ppm, 1.84 million ha with salinity ranging from 1 000 to 3 000 ppm and 4.28 million ha with salinity > 3 000 ppm. In addition to TDS, water quality concerns are related to the sodium adsorption ratio (SAR) and residual sodium carbonate (RSC) (WAPADA 2006).

Use of pesticides and nitrogenous fertilizers seriously affects shallow groundwater and entry of effluents into rivers and canals is deteriorating the quality of freshwater. Almost all shallow freshwater is polluted with agricultural pollutants and sewage (Ahmad, 2008a; Ahmad, 2008b).

Investments in drainage have been significant during the last two decades, though waterlogging still affects large tracts of land. Soil salinity and sodicity also constrain farmers and affect agricultural production. These problems are further exacerbated by the use of poor quality groundwater (Kijne and Kuper, 1995). In fresh groundwater areas, excessive pumping by tubewells leads to mining and redistribution of groundwater quality (WRRI, MONA and IIMI, 1999).

Waterlogging in the IBIS has been high in the 1990s because of heavy floods. Early in the 2000s, droughts resulted in lowering of the water table and in reduction of the waterlogged area. The overall analysis shows that there is no change in waterlogging. Currently, waterlogged and saline areas are around 7 million ha. During the late 1990s most of the SCARP tubewells were abandoned and farmers were provided support to install shallow tubewells (Zaman and Ahmad, 2009)

Climate change is also expected to significantly affect agriculture. Potential impacts include vulnerability of crops to heat stress, possible shifts in spatial boundaries of crops, changes in productivity potentials, changes in water availability and use, and changes in land-use systems. Even a fractional rise in temperature could have serious adverse effects, such as considerable increase in growing degree days (GDD, which is a measure of heat accumulation used to predict the date that a flower will bloom or a crop will reach maturity). This could not only affect the growth, maturity and productivity of crops, but would also require additional irrigation water to compensate the heat stress (Afzal, 1997).

The quality of shallow and deep groundwater can adversely impact human and animal health. Around 25 percent of all illnesses diagnosed at public hospitals and dispensaries are gastro-enteric and 40 percent of all deaths, 60 percent of infants' deaths are related to infections and parasitic diseases, most are water-borne. The most common diseases are diarrhoea, dysentery, typhoid, hepatitis, kidney stones, skin disease and malaria.

HIV is not currently a dominant epidemic in Pakistan; however, the number of cases is growing. The World Health Organization (WHO) estimates indicated that the number of HIV/AIDS cases were around 97 000 ranging from the lowest estimate of 69 000 to the highest estimate of 150 000. The overall prevalence of HIV infection in adults aged 15 to 49 is 0.1 percent. The majority of cases go unreported because of social taboos about sex and victims' fears of discrimination. On the other hand, over 900 individuals receive free HIV medicines and tests from nine public and three private sector facilities (WHO, UNAIDS and UNICEF, 2008).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

The prospects for agricultural water management are:

- Empowerment of users' institutions with an extended role in O&M of irrigation and drainage schemes and improvement of water productivity and access to market and input services.
- Improvement of adequacy, reliability and efficiency of irrigation through improved performance of the public- and private-sector schemes that will result in sustainable irrigated agriculture with safe disposal of effluents to freshwater streams.
- Improvement of farm water productivity with efficient use of water, using higher efficiency irrigation systems, such as furrow irrigation instead of basin irrigation, localized and sprinkler irrigation and control environment agriculture.
- Investments for small-scale irrigated agriculture schemes to generate new livelihoods for the deprived and poor especially in conflict areas bordering Afghanistan.
- Formulation of water and agriculture policies, especially focusing on the policy of Water for Agriculture with the objective of extending the role of agricultural institutions, users' institutions and the private sector in provision of services to farmers.
- Country Assistance Strategies developed by donor agencies (World Bank and ADB) enhanced investments in the water and agriculture sectors. The current involvement of USAID will improve the livelihoods of farmers and the rural poor.

The population is increasing and he agriculture sector must grow at a rate of over 4 percent per year. This target will be achieved with improved performance of existing irrigation schemes and enhanced productivity. This is because new water resources are more difficult to access; the development of large dams, will require at least 10 years before they can be completed. Future growth in agriculture will directly impact groundwater and surface water streams, owing to expanded use of chemicals. As people's diet changes and they increase their consumption of dairy products, meat, fruits and vegetables, the sector will face new challenges for water use. Policy support is required to covert agriculture into a profit-oriented enterprise.

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Papua New Guinea

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Papua New Guinea lies to the north of Australia just south of the equator. Apart from the mainland, it consists of a collection of islands, atolls and coral reefs scattered around the coastline. The total area of the country is 462 840 km^2 (Table 1). For administrative purposes, the country is divided into fourteen provinces on the mainland: Central, Chimbu, Eastern Highlands, East Sepik, Enga, Gulf, Madang, Milne Bay, Morobe, Northern, West Sepik (also called Sandaun), Southern Highlands, Western, and Western Highlands; four provinces in the Bismarck Archipelago: East New Britain, Manus, New Ireland, and West New Britain; one autonomous region: North Solomons (also called Bougainville); and one district: National Capital (Port Moresby).

The principal topographical features of the mainland, the Bismarck Archipelago and the North Solomon Islands are the highly dissected mountain ranges, which reach 4 509 m on the mainland. In the western half of the mainland are the extensive lowland plains and swamps of the Sepik-Ramu and Fly rivers, lying respectively north and south of the main mountain ranges.

In 1997, the cultivable area was about 12 500 000 ha, or about 27 percent of the total area. In 2009, the total cultivated area was an estimated 960 000 ha of which 260 000 ha or 27 percent for annual crops and 700 000 ha or 73 percent of permanent crops. In 1997 some 787 000 ha were reported to be cultivated, mainly with starch food crops such as taro, sweet potato, yam, cassava, banana and sago. Export crops planted in extensive plantations and by subsistence farmers include coffee, cocoa, oil palm, coconut and minor export crops such as tea, cardamon, vanilla and rubber.

Climate

The climate is humid and rainy. Temperatures are not extreme for tropical climates and most areas, apart from the high altitudes, have a daily mean temperature of 27 °C with little variation. Humidity in the lowland areas varies around 80 percent. Varied topography and location determine localized climates. There are two principal wind directions, which strongly influence the rainfall patterns: southeast from May to October and northwest from December to March.

April and November are transition months. However, high mountain barriers across the path of these winds induce heavy orographic convective rainfall on the northern and southern slopes in the highlands themselves. Thermal convective rainfall is characteristic of the Fly and Sepik lowlands.

Average rainfall varies from one location to another. On the mainland, the mean annual rainfall ranges from less than 2 000 mm along the coast to more than 8 000 mm in some mountain areas. The island groups to the north and northeast receive an average annual rainfall between 3 000 and 7 000 mm. Areas lying southwest of the Fly River, west of Lae in the Markham valley, receive less than 2 000 mm/year. The Port Moresby coastal area receives least rain with less than 1 000 mm/year.

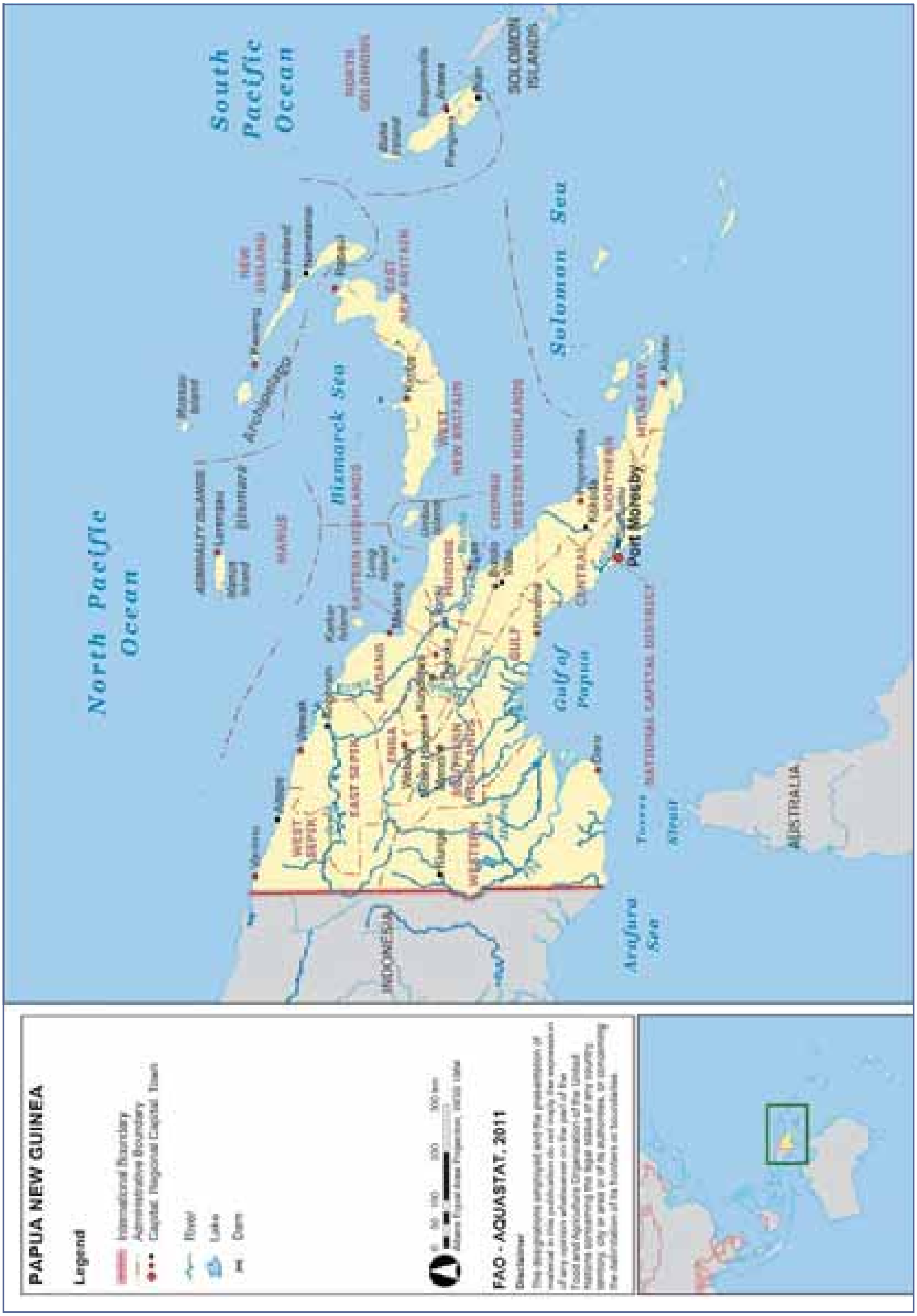

PAPUA NEW GUINEA
Legend
FAO - AQUASTAT, 2011
North Pacific Ocean
South Pacific Ocean
Bismarck Sea
Solomon Sea
Gulf of Papua
Arafura Sea
Port Moresby
AUSTRALIA
INDONESIA
SOLOMON ISLANDS

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	46 284 000	ha
Cultivated area (arable land and area under permanent crops)	2009	960 000	ha
• as % of the total area of the country	2009	2	%
• arable land (annual crops + temp fallow + temp meadows)	2009	260 000	ha
• area under permanent crops	2009	700 000	ha
Population			
Total population	2009	6 703 000	inhabitants
• of which rural	2009	88	%
Population density	2009	14	inhabitants/km^2
Economically active population	2009	2 949 000	inhabitants
• as % of total population	2009	44	%
• female	2009	49	%
• male	2009	51	%
Population economically active in agriculture	2009	2 065 000	inhabitants
• as % of total economically active population	2009	70	%
• female	2009	55	%
• male	2009	45	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	7 893	million US$/yr
• value added in agriculture (% of GDP)	2009	36	%
• GDP per capita	2009	1 177	US$/yr
Human Development Index (highest = 1)	2010	0.431	
Access to improved drinking water sources			
Total population	2008	40	%
Urban population	2008	87	%
Rural population	2008	33	%

Population

In 2009, the total population was 6.7 million, of which around 88 percent live in rural areas (Table 1). Population density is 14 inhabitants/km^2. Population densities are higher in pockets such as Chimbu, Western Highlands and Eastern Highlands province. The annual population growth rate was 2.5 during the period 1999-2009.

In 2008, access to improved drinking water sources reached 40 percent (87 and 33 percent for the urban and rural population respectively). Sanitation coverage was 45 percent (71 and 41 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total population economically active in agriculture was around 2 065 000 inhabitants, amounting to 70 percent of the economically active population. Of the total population economically active in agriculture, 55 percent are women. In 2009, the gross domestic product (GDP) was US$7 893 million of which agriculture accounted for 36 percent (Table 1).

WATER RESOURCES AND USE

Water resources

Geologically, Papua New Guinea is a young country. The presence of high mountain ranges and abundant rainfall leads to high runoff over most of the country.

There are nine hydrological drainage divisions (basins). The largest river basins are the Sepik, Fly, Purari and Markham. Even though the Sepik has the lowest annual discharge, it has the largest catchment area, 78 000 km^2, followed by the Fly River with 61 000 km^2, Purari with 33 670 km^2, and Markham with 12 000 km^2. The other catchments are less than 5 000 km^2 in area and very steep.

The internal renewable water resources are an estimated 801 km^3/year (Table 2). As the country has an abundance of surface water resources and as there are few large-scale consumers, groundwater resources have not been developed. However, there is evidence that groundwater is being used increasingly as a source of reliable high-quality water. In 1974, a surveyed 34 percent of the villages relied on groundwater from boreholes, dug-wells or springs. In the 1970s and 1980s, groundwater was developed for urban water supply schemes in seven major towns. Groundwater resources have not been assessed but it is assumed that most groundwater returns to the river systems and is therefore included in the surface water resources.

There are 5 383 mostly small natural freshwater lakes, only 22 have a surface area exceeding 1 000 ha. Lake Murray is the largest with a surface area of 64 700 ha.

In 1986, there were three dams over 15 m high. The gross theoretical hydropower potential for Papua New Guinea is 175 000 GWh/year. In 1990, the total installed capacity was 163 MW and the annual generation was 438 GWh. In 2008, of the country's total power generating capacity of 580 MW, hydropower comprises 220 MW (ADB, 2008). The Sirinumu dam,

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	3 142	mm/yr
	-	1 454 000	million m^3/yr
Internal renewable water resources (long-term average)	-	801 000	million m^3/yr
Total actual renewable water resources	-	801 000	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	119 499	m^3/yr
Total dam capacity	2009	665	million m^3
Water withdrawal			
Total water withdrawal	2005	392.1	million m^3/yr
- irrigation + livestock	2005	1	million m^3/yr
- municipalities	2005	223.5	million m^3/yr
- industry	2005	167.6	million m^3/yr
• per inhabitant	2005	64.3	m^3/yr
Surface water and groundwater withdrawal	2005	392.1	million m^3/yr
• as % of total actual renewable water resources	2005	0.05	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

which was officially opened in 1963, provides water for consumption and electricity for Port Moresby (NLA, 1963). The Yonki dam, a 60 m high dam of zoned earth-fill construction, is a hydroelectricity dam located on the Ramu river in Eastern Highlands Province. In 2009, total dam capacity has been estimated at 665 million m^3.

International water issues

In 1973, an agreement was enacted between Australia (acting on its own behalf and on behalf of Papua New Guinea) and Indonesia concerning administrative arrangements with regard to the border between Papua New Guinea and Indonesia, which involved the Sepik basin (of which 97 percent of the area lies in Papua New Guinea and 3 percent in Indonesia) and the Fly basin (of which 93 percent of the area lies in Papua New Guinea and 7 percent in Indonesia) (UNEP and FAO, 2002).

Water use

In 2005, the total water withdrawal was estimated at about 392 million m^3, of which about 1.0 million m^3 (0.3 percent) for agriculture, 223.5 million m^3 (57.0 percent) for municipalities and 167.6 million m^3 (42.7 percent) for industries (Table 2 and Figure 1).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Subsistence agriculture is the largest single economic activity. Most of the crops are rainfed and there is very little irrigation. There is evidence that simple flood irrigation techniques began in the highlands at least 450 years ago. The traditional methods of water application include:

- Simple flooding, where water is led to the upper edge of the garden and then circulates down, usually with wood or stone barriers to slow the flow. This acts to control erosion and trap sediments. In some cases, rough terraces are constructed directly in small stream beds. This is a highland practice found in Enga, Madang, Western Highlands, Eastern Highlands and Morobe provinces. Irrigated garden areas are generally small.
- The pondfield system, where the planted area is an artificial pond through which water is kept constantly flowing. The system is reported on the Mussau islands.
- Corrugated or furrow irrigation, where water is applied to the ground in small, shallow furrows so that it soaks laterally through the soil, wetting the area between the corrugations. This system is used in west New Britain and Bougainville.

A FAO study in 1986 identified a land area of 36 000 ha as agronomically suitable for irrigated rice production (Table 3). A commercial company in the Markham-Ramu valley introduced limited supplementary irrigation early in its development to establish seed cane nurseries and initial wetting of plant cane to promote germination. However, the project was later abandoned for economic reasons.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The major government institutions involved in the water resources and irrigation sector are:

- Department of Environment and Conservation (DEC), which is responsible for the management and protection of the country’s water resources, pollution control, water-related laws and regulations, and their enforcement. Its Water Resources Management

Branch is responsible for the management, conservation and control of the natural water resources. The Branch's policy states that the role of the Bureau is: "To monitor, manage and control the country's water resources in an effective and efficient manner for the benefit of the community, as stipulated in the Water Resources Act 1982". The Hydrological Services Branch maintains a network of hydrological stations around the country as well as a national hydrological data bank and carries out hydrological data collection analysis and archiving for the government and clients (IPA, 2006).

- Ø Geological Survey of the Department of Mineral Resources (GSPNG), which is responsible for providing advice on groundwater exploration, assessment, management and protection of resources.
- Ø Water Board, which is a statutory organization responsible for water supply and sewerage in 11 towns throughout the country, though not the capital city. The development and management of rural water supply and sanitation has been delegated to the Department of Health since 1987.

Water management

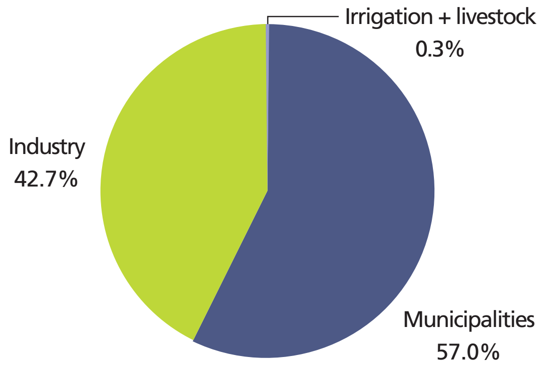
Papua New Guinea is rich in natural resources including water. However, owing to a lack of both human resources and political interest, and to underlying financial constraints, it has not been able to achieve sustainable development in the water sector. The water sector is fragmented and poorly coordinated.

The fourth directive principle of the country's national constitution is to conserve its natural resources (including water), use them for the collective benefit and ensure that they are replenished for the benefit of future generations.

Papua New Guinea is a rural country, where up to 90 percent of the population is reported to depend on subsistence or semi-subsistence agriculture. There is hardly any significant irrigation development programme or proper irrigation policy. This experience has led the Government to seriously consider irrigation development as announced by the Minister for Agriculture and Livestock in a 1997 World Food Day message. According to this message:

- Ø there is a need to develop small-scale village water supply, irrigation and water management;
- Ø the Government and policy-makers need to examine irrigation development as a component of the strategy for increased food production; and
- Ø it is important to establish an irrigation development unit within the Department of Agriculture and Livestock and to develop a national irrigation policy.

FIGURE 1
Water withdrawal by sector
Total: 392 million m³ in 2005



Irrigation was introduced for the first time in a pilot area, under FAO's Special Programme for Food Security, where subsistence farming is the norm.

The Government is aware that the natural water resources are coming under increasing pressure from the large number of resource development projects that are being implemented throughout the country in accordance with the government's overall development policies. There is an increasingly urgent need to ensure that the protection and conservation of this resource is managed in an effective, efficient and sustainable manner (IPA, 2006).

TABLE 3
Irrigation and drainage

Irrigation potential			36 000	ha
Irrigation				
1. Full control irrigation: equipped area			-	ha
- surface irrigation			-	ha
- sprinkler irrigation			-	ha
- localized irrigation			-	ha
• % of area irrigated from surface water			-	%
• % of area irrigated from groundwater			-	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from mixed non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)			**-**	**ha**
• as % of cultivated area			-	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 13 years			-	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)			**-**	**ha**
• as % of cultivated area			-	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area			-	ha
• Annual crops: total			-	ha
• Permanent crops: total			-	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)			-	%
Drainage - Environment				
Total drained area		1997	0	ha
- part of the area equipped for irrigation drained		1997	0	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		1997	0	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

The Water Resources Act (1982) is applied through the issuance of Water Use and Water Investigation Permits and through the declaration of Water Control Districts. Compliance conditions attached to the permits are designed to ensure that environmental quality is adequately protected in order to sustain the value of the resource. The establishment of Water Control Districts is a planning instrument, which is used to provide wider protection of environmental values in key or critical areas.

The Act is implemented by a Water Resources Board, which is composed of representatives from the Division and other Government departments and agencies including Health, Agriculture, Fisheries, Forests, Mining and Petroleum and the various Water Boards that are responsible for water supply and sewerage reticulation. The Water Resources Management Branch is required to provide the Water Resources Board with sound and accurate resource management advice on all water-related matters, and to implement and enforce the decisions and recommendations of the Board under the Act. A key component in the formulation of sound resource management is the availability of accurate information upon which to base reliable assessments. The integrity and efficacy of the Bureau's planning strategies and management programmes, which form the basis of the advice given to the Board, depend primarily on the quality of these assessments (IPA, 2006).

The Branch is responsible for carrying out the administrative and managerial functions of the Water Resources Act 1982. This includes water resource planning allocation, water management programmes, and impact assessment and mitigation strategies. Its functions under the Act include the processing of all Water Use Permits, the inspection and enforcement functions provided for in the Act and the provision of advice and support to the Minister, other government departments and other organizations on water-related issues (IPA, 2006).

Current budget allocations to the water and sanitation sector are relatively small, though the political climate for development in the water and sanitation sector is improving. The Government's 2001-2010 National Health Plan aims to prioritize these essential services with water quality monitoring and promotion of safe waste disposal alongside ensuring that water supplies are sustainable year-round even during droughts.

Finances

The Asian Development Bank (ADB) had made a loan for the water supply and sewerage development project in the urban cities in 1999 and 2000. In 2010, the new Port Moresby Sewerage System Upgrading Project was financed loans from the Japanese Official Development Assistance (Japanese ODA loans, 2010).

Policies and legislation

The Water Resources Act (1982) is the statutory instrument under which the allocation and management of water resources proceed (IPA, 2006).

ENVIRONMENT AND HEALTH

Land uses and waste disposal linked to population growth is affecting the capacity to supply water resources in terms of quantity and quality. Currently, there are few catchments that are directly accessible to the main urban towns and cities. The development of these sources to sustain demand is difficult when settlers are located in critical areas such as at headwaters, causing concern for pollution to the original source, etc. Land uses such as agriculture, cultivating crops that consume more water, deprive other users from benefitting from the same source. Catchments such as Laloki, Wahgi and Bumbu are overstressed with poor quality yields and high demand from various users. Further, there are no proper catchment management plans that would dictate the land-use type in the area and equally distribute water resources.

The constant increase in population has pushed communities and settlements to move into catchments that could not support different agricultural land uses, causing stress to the environment and water resources. Clearing of riverbanks are causing increasing erosion and depositing them into waterways (SOPAC, 2007).

More than 87 percent of the population is rural. Sewerage systems have been developed mainly in Port Moresby and urban cities. The sewerage systems were developed by Australia, which was governing the country, in the 1960s to the early 1970s before independence. They were constructed in the inland area of Port Moresby, and were extended in 1999 and 2000 in urban areas, Mount Hagen, Madang, etc., supported by a loan from the ADB. In Port Moresby, where the population is concentrated, three sewage treatment plants are in operation (Waigani, Gerehu, and Morata), which serve a population of 90 000 of the inland area of Port Moresby, which has a total population of 290 000. The treated wastewater quality of those sewage treatment plants is generally good.

However, some of the facilities need repair because they are ageing. On the other hand, there is no sewage treatment plant in the coastal area of Port Moresby, where 67 000 people are living. For this reason, sewage is once pre-treated in septic tanks and then discharged into the ocean through undersea discharge pipes, or discharged by underground seepage. The current quality is way above the standard tolerance value, 23-2 400 MPN/100ml of coli bacteria (environmental standard in Papua New Guinea: 200 MPN/100ml), 1.4-4.2 mg/litre of nitrogen (no standard in Papua New Guinea, 0.3 mg/litre for standard in Japan), 0.21-0.69 mg/l of phosphorus (no standard in Papua New Guinea, 0.03mg/litre for standard in Japan).

Discharge of such sewage of insufficient treatment to the ocean is causing water contamination in the coastal area, and is destroying the ocean environment including bleaching coral reefs, as well as causing deterioration of the sanitary environment of the local residents and affecting their health, especially those living on the sea. The ratio of water-borne diseases in the coastal area is higher than in the other areas. Average morbidity from diarrhoea is 31 percent in the coastal area, while 5 percent in the city (Japanese ODA loans, 2010).

The Japanese ODA loans financed a new project in 2010, called Port Moresby Sewerage System Upgrading. The objective of this project is to develop sewerage facilities in the coastal area of Port Moresby in order to provide sewerage services to the area, prevent the discharge of contaminated water to the coastal waters, thereby establishing a sanitary living environment of the area, as well as to improve the residents' living environment and activate the industries (Japanese ODA loans, 2010).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

A main concern in Papua New Guinea is to develop a policy to regulate activities within critical catchments and provide equal distribution of the resources to all users (SOPAC, 2007).

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Philippines

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Philippines is an island nation located in Southeast Asia. It is composes of 7 107 islands called the Philippine Archipelago, with an area of approximately 300 000 km^2 (Table 1). The archipelago is bounded by the Bashi Channel in the north, the Philippine Sea (Pacific Ocean) in the east, the Sulu and Celebes Seas in the south and the South China Sea in the west. Its northernmost islands are approximately 240 km south of the island of Taiwan, and the southernmost islands lie 24 km off the coast of Borneo (Malaysia). The islands are commonly divided into three island groups, which are further divided into regions, provinces, cities and municipalities and *barangays.* The islands and their respective administrative regions are:

- Ø Luzon, 142 000 km^2, composed of eight administrative regions: Ilocos (Region I), Cagayan Valley (Region II), Central Luzon (Region III), Calabarzon (Region IV-A), Mimaropa (Region IV-B), Bicol Region (Region V), National Capital Region and Cordillera Administrative Region);
- Ø Visayas, 56 000 km^2, composed of three administrative regions: Western Visayas (Region VI), Central Visayas (Region VII) and Eastern Visayas (Region VIII));
- Ø Mindanao, 102 000 km^2, composed of six administrative regions: Zamboanga Peninsula (Region IX), Northern Mindanao (Region X), Davao Region (Region XI), Soccsksargen (Region XII), Caraga (Region XIII) and Autonomous Region in Muslim Mindanao).

The Philippines has a varied topography with highlands and numerous valleys. Its four major lowland plains are the central plain and the Cagayan valley in Luzon, and the Agusan and Cotabato valleys in Mindanao. These lowlands contrast sharply with the adjacent high mountain areas of the central and east Cordilleras and the Zambales mountains. The highest peaks are almost 3 000 m above sea level at less than 30 km from the sea. There are many active volcanos such as Mayon, Mount Pinatubo, and Taal. Lying on the northwestern fringes of the Pacific Ring of Fire, the Philippines experience frequent seismic and volcanic activities.

In 2009, the total cultivated area was approximately 10.5 million ha, of which 52 percent (5.4 million ha) were for annual crops and 48 percent (5.1 million ha) for permanent crops (Table 1). In 1995, the total cultivated area was around 9.9 million ha, of which 56 percent was for annual crops.

Climate

The climate is tropical and monsoonal with uniform temperature, on average 27 °C throughout the year. Humidity is relatively high, above 70 percent everywhere all year except in southern Tagalog, where it falls to 65 percent in March/April. There is low solar radiation, diversity of rainfall and high frequency of tropical cyclones. The main air streams affecting the Philippines are the northeast monsoon, known locally as the *amihan,* from late October to March, the southwest monsoon, known locally as the *habagat,* from May to October and the North Pacific trade winds, are dominant during April and early May. Many of the larger islands of

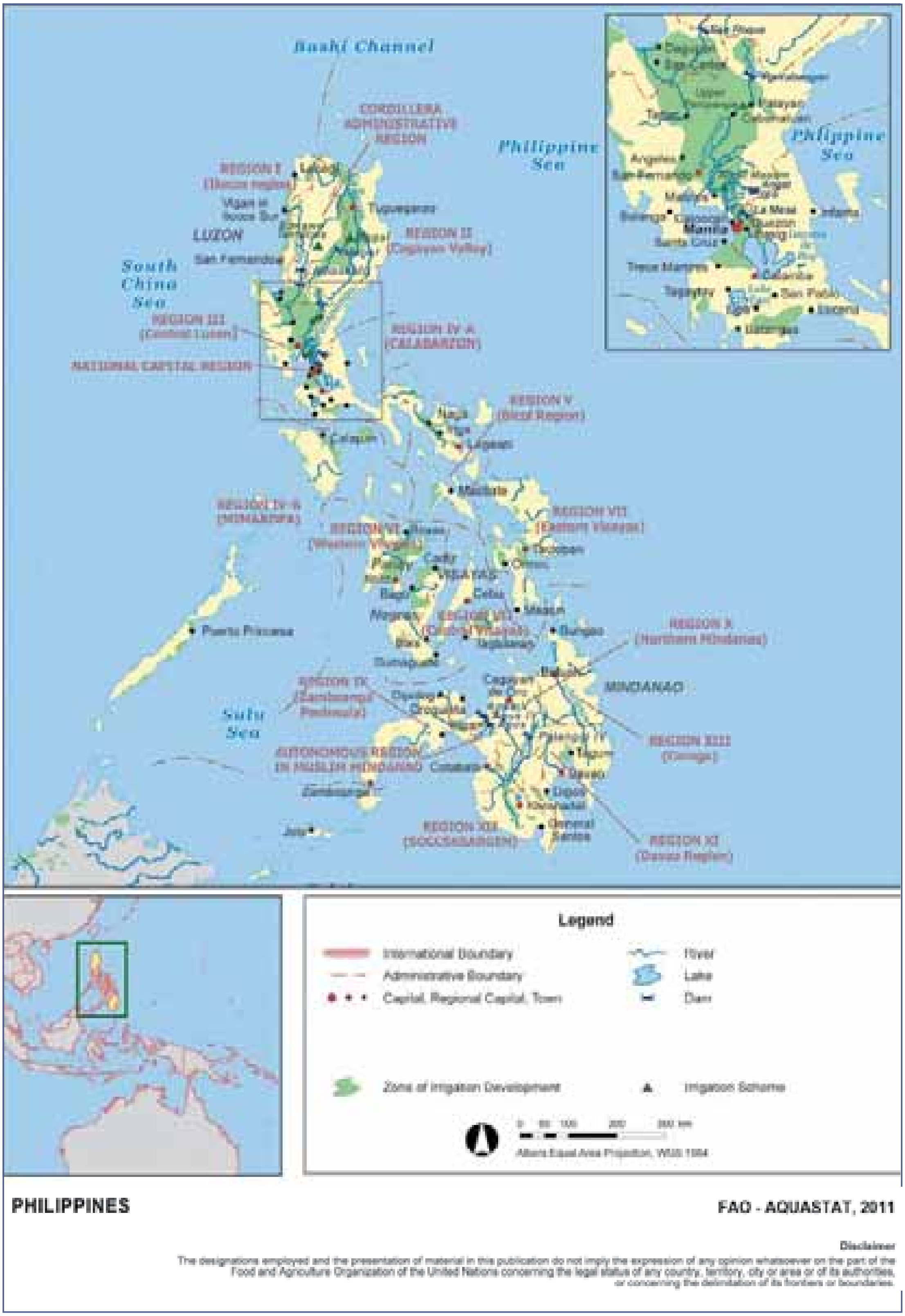
Bashi Channel
CORDILLERA ADMINISTRATIVE REGION
Philippine Sea
REGION I (Ilocos region)
Laoag
Vigan in Ilocos Sur
Tuguegarao
LUZON
REGION II (Cagayan Valley)
South China Sea
San Fernando
REGION III (Central Luzon)
REGION IV-A (CALABARZON)
NATIONAL CAPITAL REGION
REGION V (Bicol Region)
Naga
Legaspi
Calapan
Masbate
REGION IV-B (MIMAROPA)
REGION VI (Western Visayas)
REGION VIII (Eastern Visayas)
Tacloban
Roxas
Cadiz
VISAYAS
Cebu
Negros
Puerto Princesa
REGION VII (Central Visayas)
REGION X (Northern Mindanao)
MINDANAO
Sulu Sea
REGION IX (Zamboanga Peninsula)
Dipolog
Cagayan de Oro
AUTONOMOUS REGION IN MUSLIM MINDANAO
Cotabato
Zamboanga
Jolo
REGION XIII (Caraga)
Tagum
Davao
Digos
REGION XII (SOCCSKSARGEN)
General Santos
REGION XI (Davao Region)
Dagupan
San Carlos
Tarlac
Palayan
Cabanatuan
Angeles
San Fernando
Malolos
Manila
Quezon
Infanta
Santa Cruz
Trece Martires
Tagaytay
Calamba
San Pablo
Batangas
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
Irrigation Scheme
Albers Equal Area Projection, WGS 1984
PHILIPPINES
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	30 000 000	ha
Cultivated area (arable land and area under permanent crops)	2009	10 450 000	ha
• as % of the total area of the country	2009	35	%
• arable land (annual crops + temp fallow + temp meadows)	2009	5 400 000	ha
• area under permanent crops	2009	5 050 000	ha
Population			
Total population	2009	91 703 000	inhabitants
• of which rural	2009	51	%
Population density	2009	306	inhabitants/km^2
Economically active population	2009	38 908 000	inhabitants
• as % of total population	2009	42	%
• female	2009	39	%
• male	2009	61	%
Population economically active in agriculture	2009	13 336 000	inhabitants
• as % of total economically active population	2009	34	%
• female	2009	24	%
• male	2009	76	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	161 196	million US$/yr
• value added in agriculture (% of GDP)	2009	15	%
• GDP per capita	2009	1 758	US$/yr
Human Development Index (highest = 1)	2010	0.638	
Access to improved drinking water sources			
Total population	2008	91	%
Urban population	2008	93	%
Rural population	2008	87	%

the Philippines have high mountain ranges, most of which lie along a generally north-south axis across the paths of movement of the important air streams. Thus, apart from variations in temperature caused by elevation, the orographic effects of mountains significantly influences regional rainfall patterns by causing increased precipitation on windward slopes and rain shadows in their lee during the monsoon periods.

The average annual rainfall is about2 348 mm/year, but it varies from around 960 mm in General Santos City in southeast Mindanao to more than 4 050 mm in Infanta in central Luzon. The most extreme annual rainfall events ever recorded are 94 mm at Vigan in Ilocos Sur (northern Luzon) in 1948 and 9 006 mm in Baguio City (northern Luzon) in 1910.

The rainfall pattern and annual amount are influenced mainly by altitude and wind. The northwest of the country has a dry season from November to April and a wet season during the rest of the year, called the southwest monsoon. The southeast receives rainfall all year round, but with a pronounced maximum from November to January during the northeast monsoon. In the areas not directly exposed to the winds, rainfall is evenly distributed throughout the year, or there are two seasons but not very pronounced. From November to April the weather is relatively dry while it is relatively wet the rest of the year. The lowest rainfall occurs in the provinces of Cebu, Bohol and Cotabato in the centre of the country.

The archipelago lies in the typhoon belt, and many islands are liable to extensive flooding and damage during the typhoon season from June to December. The frequency of typhoons is greater in the northern portion of the archipelago than in the south. Usually, two or three typhoons reach the country each year.

Population

In 2009, the total population was about 91.7 million, of which around 51 percent lived in rural areas (Table 1). The average annual demographic growth is an estimated 1.9 percent for 1999-2009. In 2009, the population density was 306 inhabitants/km^2 against 236 inhabitants/km^2, in 1996, ranging from 47 inhabitants/km^2 in Agusan del Sur in Region X in Mindanao to 348 inhabitants/km^2 in southern Tagalog in Region IV in Luzon, and more than 13 000 inhabitants/km^2 in the Capital Manila.

In 2008, 93 percent of the urban and 87 percent of the rural population had access to improved drinking water respectively.

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, gross domestic product (GDP) was US$161 196 million and agriculture accounted for 15 percent of GDP (Table 1). In 2009, the total population economically active in agriculture was about 13.3 million inhabitants or almost 34 percent of the economically active population, of which 24 percent were women.

Agriculture is the prime mover of the country's economy, being the least import-dependent activity. In 2006, all subsectors posted output gains except poultry, which contracted by 0.4 percent. The crops, livestock and fisheries subsectors performed well and expanded their outputs by 4.4, 2.6 and 6.3 percent respectively. The government's rice programme is moving the country towards self-sufficiency giving a 5 percent increase in production. Even maize, which had negative growth the year before, posted a remarkable increase of 15.8 percent in production in 2006.

The total food supply available for consumption in 2001 was more than adequate to meet the recommended nutrient allowance for the population. Despite a slight decrease of 0.2 percent compared to 2000, the country's per capita food supply exceeded the recommended dietary allowance. The food from animal origin increased by 5.6 percent, whereas food obtained from vegetables grew by 2.4 percent.

Since the early 1980s the Philippines has been a net importer of food and feed grains. Records available at the National Food Authority show that during practically all years from 1980 to 2006 rice was imported to augment the country's rice supply. This trend shows an increase from 0.19 million tonnes in 1980 to 2.14 million tonnes in 1998. In that year the country suffered through one of the worse droughts caused by El Niño. On the other hand, maize imports have generally declined from 1980 to 2006. They were highest in 1990 with 273 650 tonnes and lowest in 2004 with 9 144 tonnes. No maize was imported in 1991-1994, 1999, 2003 and 2006. The drop in net imports did not affect the food supply in terms of nutrient content because of sustained domestic food production.

WATER RESOURCES AND USE

Water resources

There are 421 rivers, not counting small mountain streams that sometimes swell to three times their size during rainy months. The rivers are an important means of transportation and a valuable source of irrigation water for fields and farms through which they pass. There are also 59 natural lakes and more than 100 000 ha of freshwater swamps.

The five principal river basins, cover more than 5 000 km^2, are:

- Ø Cagayan river basin in north Luzon (25 469 km^2);
- Ø Mindanao river basin on Mindanao island (23 169 km^2);
- Ø Agusan river basin on Mindanao island (10 921 km^2);
- Ø Pampanga river basin near Manila on Luzon island (9 759 km^2);
- Ø Agno river basin on Luzon island (5 952 km^2).

Only 18 river basins have an area greater than 1 000 km^2: eight are on the island of Mindanao, seven on Luzon, two on Panay and one on Negros Island. The smallest river basins are frequently under 50 km^2.

In order to have manageable units for comprehensive planning of water resources, the National Water Resources Board divided the country into 12 water resources regions. Major considerations taken into account in this regionalization were the hydrological boundaries defined by physiographic features and homogeneity in climate of the different parts of the country. In fact, these water resources regions generally correspond to the existing political regions. Minor deviations dictated by hydrography affected only northern Luzon and northern Mindanao.

The average annual precipitation is about2 348 mm (Table 2). The long-term average annual renewable surface water resources are an estimated 444 km^3. In nine years out of ten, the annual runoff exceeds 257 km^3. Groundwater resources are distributed in four major areas covering around 33 500 km^2: 10 000 km^2 in Cagayan, 9 000 km^2 in Central Luzon, 8 500 km^2 in Agusan, and 6 000 km^2 in Cotobato. Combined with smaller reservoirs already identified, this aggregates to about 50 000 km^2. The groundwater resources are an estimated 180 km^3/year, of

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	2 348	mm/yr
	-	704 340	million m^3/yr
Internal renewable water resources (long-term average)	-	479 000	million m^3/yr
Total actual renewable water resources	-	479 000	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	5 223	m^3/yr
Total dam capacity	2006	6 274.5	million m^3
Water withdrawal			
Total water withdrawal	2009	81 554.93	million m^3/yr
- irrigation + livestock	2009	67 065.65	million m^3/yr
- municipalities	2009	6 234.94	million m^3/yr
- industry	2009	8 254.34	million m^3/yr
• per inhabitant	2009	889	m^3/yr
Surface water and groundwater withdrawal	2009	81 554.93	million m^3/yr
• as % of total actual renewable water resources	2009	17.0	%
Non-conventional sources of water			
Produced wastewater	1993	74	million m^3/yr
Treated wastewater	1993	10	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

which 80 percent (145 km^3/year) constitute the base flow of the river systems. Total internal water resources are therefore 444+180-145=479 km^3/year.

Total exploitable water resources are about 146 km^3, of which 126 km^3 is exploitable renewable surface water and 20 km^3 is exploitable renewable groundwater.

There are 59 natural lakes and more than 100 000 ha freshwater swamps. The National Wetland Action Plan, in response to the country's commitments to the Ramsar Convention, nominated and designated the four major wetlands, with a total surface area of 68 404 ha, as sites for Wetlands of International Importance. These include the Olango Island (Cebu), Naujan Lake National Park (Oriental Mindoro), Agusan Marsh Wildlife Sanctuary (Agusan del Sur), and the Tubbataha Reefs National Marine Park in the middle of Central Sulu Sea. The Agusan Marsh Wildlife Sanctuary, 14 836 ha, is of particular importance because it includes a vast complex of freshwater marshes and watercourses with numerous shallow lakes and ponds in the upper basin of the Agusan river and its tributaries rising in the hills of eastern Mindanao.

A survey of surface water storage potential has identified sites for 438 major dams and 423 smaller dams (NWRB, 1978). Total dam capacity in 2006 was 6 274.5 million m^3. The National Irrigation Administration (NIA) has constructed seven large dams and small reservoirs for irrigation projects with a total capacity of 6 180 million m^3. In the Philippines, a dam is considered large when the storage capacity exceeds 50 million m^3 and the structural height is more than 30 m. The last large dam, constructed in 2002, is the San Roque dam with a total capacity of 850 million m^3. Two of the large dams, with a total capacity of 3 560 million m^3, are managed by the NIA: Magat for the Magat River Integrated Irrigation System (MRIIS) and Pantabangan for the Upper Pampanga River Integrated Irrigation System (UPRIIS). Three of the large dams, with a total capacity of 1 679 million m^3, are managed by the National Power Corporation (NPC): Angat, Ambuklao and Palangui IV. The NPC operates and manages three other dams in Mindanao, with a capacity of approximately 27.7 million m^3: Agus II, IV and V.

The Metropolitan Waterworks and Sewerage System (MWSS) manages two dams for municipal water supply and sanitation in the Metro-Manila areas: the La Mesa dam and Ipo dam with storage capacity of 51 and 36 million m^3 respectively. All other small dams have been created with various objectives within the framework of the small water impounding management (SWIM) projects and are jointly managed by the Bureau of Soils and Water Management (BSWM), the NIA and lately the Department of Agrarian Reform, which receive assistance through various international funding agencies. SWIM projects are represented by 350 units of 270 000 m^3 on average, accounting for 94.5 million m^3.

Water use

In 2009 total water withdrawal was an estimated 81 555 million m^3, of which 82 percent was for agricultural purposes (including 754 million m^3 of aquaculture), 8 percent for municipalities and 10 percent for industry (Table 2 and Figure 1). Other non-consumptive use of water includes hydropower (110 079 million m^3) and recreation (244 million m^3). In 1995, total water withdrawal was an estimated 55 422 million m^3, of which 88 percent for agriculture, 8 percent for municipal purposes and 4 percent for industry. In 2009, freshwater was the only source of water withdrawal, with 96 percent being surface water and 4 percent groundwater (Figure 2).

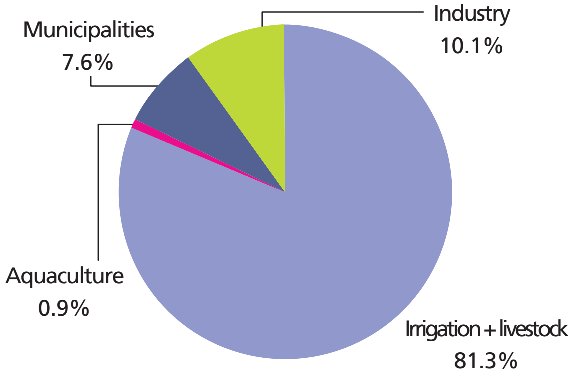
Private wells are extensively used in rural areas for domestic purposes. Municipal waterworks wells are drilled by the Local Water Utilities Administration for domestic purposes and deep wells have been drilled by the NIA for irrigation.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

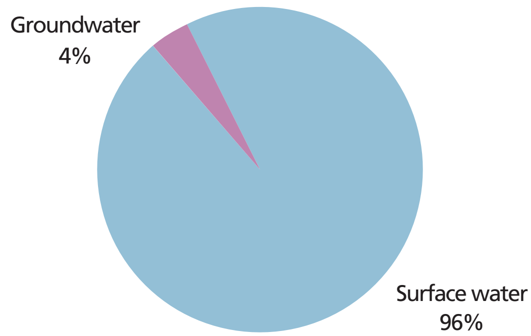
Irrigation development has been undertaken by rural communities (*Banawe* terraces, cooperative irrigation societies *(zanjera)* and lowland schemes near Manila). Earlier, the major irrigation investment periods have been during the 1920s, the post-war period and the 1970s and early 1980s when public involvement in the irrigation subsector was at its maximum. In this respect, the creation of the National Irrigation Administration (NIA) in 1964 has been decisive.

FIGURE 1
Water withdrawal by sector
Total 81.555 km³ in 2009



Irrigation development is highest in Luzon, containing approximately 51.1 percent of the total irrigated land, followed by Mindanao with 38.7 percent and Visayas with 10.2 percent. Luzon, the major investment area for irrigation development, is considered a 'hot spot' for global warming and climate change, because the irrigation systems are located in high temperature areas and are annually subjected to destructive typhoons and flooding.

FIGURE 2
Water withdrawal by source
Total 81.555 km³ in 2009



The irrigation potential in 2005 was an estimated 3.1 million ha, defined by the NIA local irrigation office as the land on slopes of less than 3 percent, which are considered to be the areas with minimum cost of development (Table 3). Aside from this simplified criteria, the Asian Development Bank (ADB) proposed considering additional criteria that allow the use of terraced rainfed lands covering a contiguous area of at least 100 ha, where water could easily be delivered. On the other hand, the World Bank proposed reassessing the irrigation potential to consider new settlements on agricultural land, water resources availability, development cost, need for flood control and drainage facilities.

In 2006, the area equipped for full control irrigation was an estimated 1 879 084 ha of which NIA's national irrigation systems (NIS) represent 38 percent, NIA's communal irrigation systems (CIS) account for 29 percent, small-scale irrigation systems (SSIP) represent 9 percent, private irrigation systems account for 9 percent and private irrigation systems irrigating crops other than rice account for 15 percent. In 1991, non-equipped cultivated wetlands and inland valley bottoms accounted for 39 478 ha, and in 2004 the non-equipped flood recession cropping area accounted for 63 814 ha, thus total water managed in 2006 was around1 982 376 ha. In 1992, the area equipped for full control irrigation was an estimated 1 532 751 ha, of which 42 percent were NIS, 48 percent CIS and 10 percent private schemes.

NIS schemes have been constructed, operated and maintained by the NIA. The construction cost is borne entirely by the NIA, while farmers pay for operation and maintenance (O&M).

TABLE 3
Irrigation and drainage

Irrigation potential	-	3 126 000	ha
Irrigation			
1. Full control irrigation: equipped area	2006	1 879 084	ha
- surface irrigation	2006	1 863 664	ha
- sprinkler irrigation	2006	4 500	ha
- localized irrigation	2006	10 920	ha
• % of area irrigated from surface water	2006	78.6	%
• % of area irrigated from groundwater	2006	5.7	%
• % of area irrigated from mixed surface water and groundwater	2006	15.7	%
• % of area irrigated from non-conventional sources of water		-	%
• area equipped for full control irrigation actually irrigated		-	ha
- as % of full control area equipped		-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		-	ha
3. Spate irrigation		-	ha
Total area equipped for irrigation (1+2+3)	**2006**	**1 879 084**	**ha**
• as % of cultivated area	2006	19	%
• % of total area equipped for irrigation actually irrigated		-	%
• average increase per year over the last 13 years	1993 - 2006	1.49	%
• power irrigated area as % of total area equipped	2006	14.1	%
4. Non-equipped cultivated wetlands and inland valley bottoms	1991	39 478	ha
5. Non-equipped flood recession cropping area	2004	63 814	ha
Total water-managed area (1+2+3+4+5)	**2006**	**1 982 376**	**ha**
• as % of cultivated area	2006	20	%
Full control irrigation schemes: **Criteria:**			
Small-scale schemes < 100 ha	2006	625 360	ha
Medium-scale schemes > 100 ha and < 1 000 ha	2006	548 978	ha
Large-scale schemes > 1 000 ha	2006	704 746	ha
Total number of households in irrigation		-	
Irrigated crops in full control irrigation schemes:			
Total irrigated grain production (wheat and barley)		-	metric tons
• as % of total grain production		-	%
Harvested crops:			
Total harvested irrigated cropped area	2006	2 695 825	ha
• Annual crops: total	2006	2 657 645	ha
- Rice (first season)	2006	1 117 800	ha
- Rice (second season)	2006	1 304 100	ha
- Maize	2006	96 600	ha
- Sugarcane	2006	65 000	ha
- Vegetables	2006	37 861	ha
- Tobacco	2006	23 884	ha
- Groundnuts	2006	12 400	ha
• Permanent crops: total	2006	38 180	ha
- Bananas	2006	14 210	ha
- Citrus	2006	1 970	ha
- Other permanent crops	2006	22 000	ha
Irrigated cropping intensity (on full control area equipped)	2006	143.5	%
Drainage - Environment:			
Total drained area	1993	1 470 691	ha
- part of the area equipped for irrigation drained	1993	1 470 691	ha
- other drained area (non-irrigated)		-	ha
• drained area as % of cultivated area	1993	15	%
Flood-protected areas		-	ha
Area salinized by irrigation	1999	300 000	ha
Population affected by water-related diseases	2000	866 411	inhabitants

In 1992, there were about 150 NIS schemes throughout the country. There are three main subtypes depending on water origin:

- Three large schemes: Magat with 80 977 ha; Upper Pampanga with 94 300 ha; and Angat Maasim with 31 485 ha are backed by multipurpose reservoirs. Although classified as single entities, they are actually conglomerates served by multiple diversion structures, which also utilize supplies from uncontrolled rivers crossing the irrigated area. Parts of the service area may be too high to be commanded by the reservoir and are commanded by pump schemes. In 1989, the cropping intensity on these schemes was about 89 percent during the wet season and 78 percent during the dry season.
- Run-of-the-river diversion schemes: Most are relatively small. These diversion schemes can be fairly complicated, with several intakes and reuse systems that are often developed over time in response to observed drainage flows. The largest schemes are located in the alluvial plains. In 1989, the cropping intensity on these schemes was about 72 percent during the wet season and 54 percent during the dry season.
- Pump schemes: In 1992, there were around seven schemes irrigated only by pumps, and five large NIS schemes served mainly by gravity flow but which use pumps for a part of their equipped area.

CIS schemes have been created either by the farmers themselves over the centuries, or more recently by the NIA and then turned over to the irrigation associations for O&M. Almost half of the communal schemes are in the province of Ilocos (northwest Luzon), which reflects a long history of irrigation based on private initiative in this area. These schemes are predominantly diversion schemes; although a few are served by small reservoirs built within the framework of the SWIM projects. The average size of the communal schemes is about 115 ha, but range from 40 to 4 000 ha. The smallest schemes are found in north Luzon, while in Mindanao Island these schemes are generally large, many of them being implemented by the government settlement programmes and then transferred to farmer groups. The association bears 10 percent of the direct cost of construction, and pays back the balance within 50 years at no interest.

Private schemes are generally supplied by pumps. They originated in publicly assisted river lift and groundwater development projects.

Table 4 reflects the rice-based areas with existing irrigation facilities. The Bureau of Agricultural Statistics (BAS) estimate was larger than the NIA estimate because BAS took into account privately-owned small-scale irrigation system such as shallow tubewells.

In 2008, of a total 748 593 ha of NIS schemes equipped, the actually irrigated area was around 61.5 percent during the wet season and 71.2 percent during the dry season. In 2005, the NIA developed 10 539 ha of new areas and rehabilitated 110 865 ha of existing systems. In 2007, the agency targeted development of 17 585 ha of new area and rehabilitation of 112 534 ha of existing areas. From 1974-2007, the BSWM completed and made operational a total of 177 190 ha and rehabilitated 3 538 ha of irrigated areas.

TABLE 4
Irrigation development by different system of the rice-based areas, in hectares, estimated by two institutions (2006)

System:	National Irrigation Administration (NIA)	Bureau of Agricultural Statistics (BAS)
National Irrigation Systems (NIS)	706 237	704 746
Communal Irrigation Systems (CIS)	481 669	548 978
Private Irrigation System	217 832	174 200
Total	**1 405 738**	**1 427 924**

Surface water development for irrigation is in the form of dams or reservoirs while groundwater development is through pumping from deep and shallow aquifers. Groundwater irrigation development, particularly from deep aquifers, is relatively expensive including O&M. This is one of the reasons why less groundwater is used for irrigation, aside from the fact that groundwater withdrawal is being reserved for municipal/drinking purposes owing to its inherent good quality. In 2007, surface water was used to irrigate 78.6 percent of the area equipped for irrigation, 5.7 percent by groundwater and 15.7 percent by mixed surface water and groundwater (Figure 3).

Surface irrigation is the major technique practiced in the Philippines owing to rice, which accounts for 1 863 664 ha or over 99 percent (Figure 4). Lowland paddy fields are flooded to prevent weeds and ensure yields. Sprinkler and localized irrigation systems, 4 500 ha and 10 920 ha respectively, are used on privately-owned large plantation areas such as for banana, pineapple and sugarcane. Their use is constrained by their relatively high investment cost and the skills required to operate and maintain them. Currently, the use of sprinkler and drip is being promoted, even for small-scale production systems, particularly in water-scarce areas. These include greenhouses producing high-value commercial crops, such as vegetables, where investment costs could be recovered over a shorter period.

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 1 879 084 ha in 2006

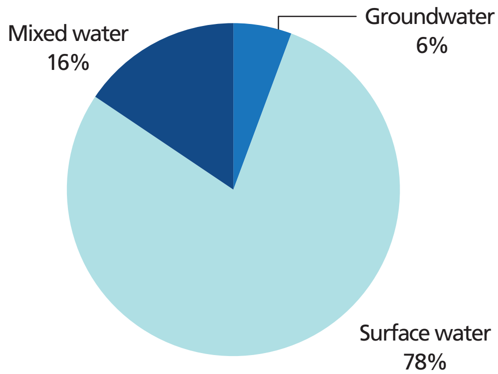
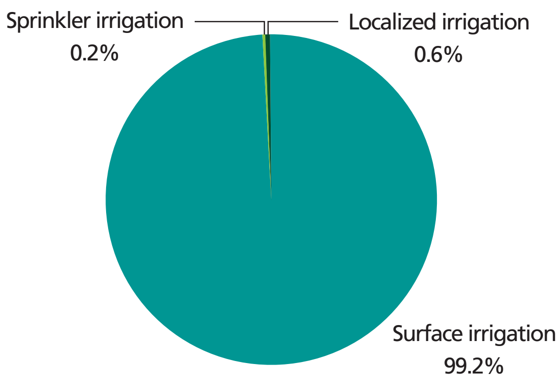


FIGURE 4
Irrigation techniques on area equipped for full control irrigation
Total 1 879 084 ha in 2006



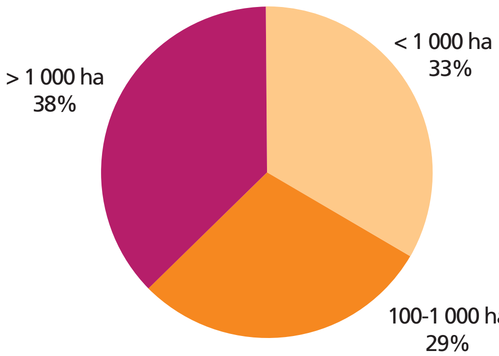
Irrigation schemes can be differentiated according to size of the service area (SA). In 2006, small irrigation systems (< 100 ha SA) accounted for 625 360 ha, medium irrigation systems (100-1 000 ha SA) for 548 978 ha, and large irrigation systems (> 1 000 ha SA) for 704 746 ha (Figure 5). In 1999, the average farm size was 2.2 ha.

Irrigation water from NIA dams, SWIP and diversion dams is distributed by gravity system, conveying the water through open lined main canals to lateral ditches into the farm paddy fields. Farm lands, at elevations higher than the canal, use pumps to siphon water into the paddy fields. Pumps are also used for extracting shallow groundwater.

Role of irrigation in agricultural production, economy and society

There are two cropping seasons in the Philippines. All schemes, equipped area and canal capacity, have been designed to provide supplementary irrigation to the entire irrigable area during the wet season. The area actually irrigated during the season should be 100 percent. In practice, this level is never reached owing to many reasons, such as over-optimistic design of service areas, flooding and waterlogging in the wet season, complexity of the irrigation system, pump performance, and conflicts between water supply, power and irrigation. The actually irrigated area varies significantly from one season to another, but it is always much lower than the area equipped for full control irrigation.

FIGURE 5
Type of full control irrigation schemes
Total 1 879 084 ha in 2006

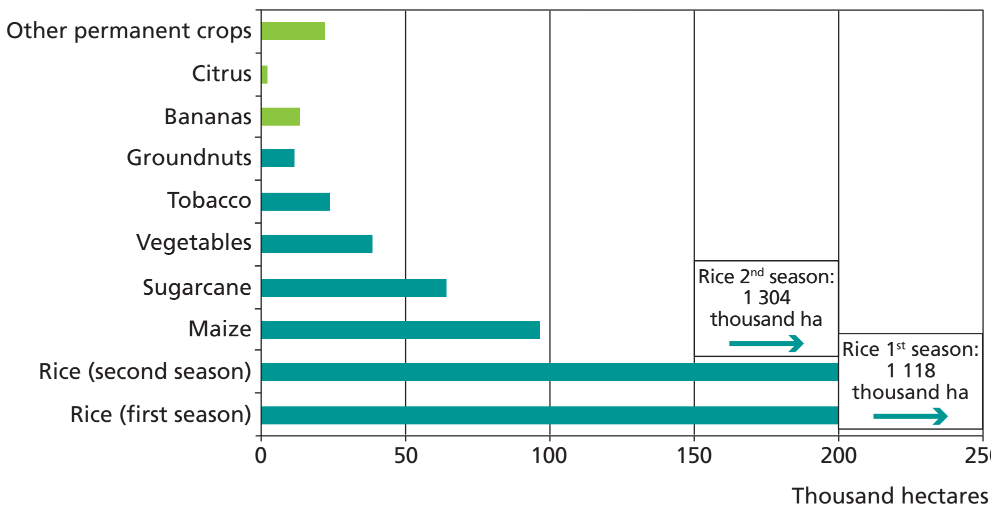


In 2006, the harvested irrigated crop area covered around 2 695 825 ha, of which 89.8 percent was for rice, 3.6 percent for maize, 2.4 percent for sugarcane and 1.4 percent for vegetables (Table 3 and Figure 6).

Paddy is cultivated throughout the country during the wet season and in some areas during the dry season when other crops with higher added value are also grown. The yields are much lower (30-40 percent) in the communal schemes than in the national schemes, because the water supplies are uncertain in the small catchment areas where communal schemes are located. On average, the 1992 yield for irrigated paddy was an estimated 3.34 tonnes/ha per season, which was 2.9 times the average yield of irrigated paddy in 1961. For rainfed paddy, the 1992 average yield was an estimated 2.07 tonnes/ha, which is twice the 1961 average yield. Irrigated rice paddy has a 65 percent higher gross return compared to non-irrigated. The sustained increase of water supply for rice production helps significantly satisfy the ever increasing food demand as well as improve food security.

Meanwhile, because of lack of finances to develop new land for irrigation, to help close the food gap, the focus has been on the development and improvement of technology and support services to improve rice production on rainfed land. The actual harvested rice area covered by irrigation facilities increased by almost twice from 1.43 million in 1970 to 2.42 million ha in 2006. The package of production technology, besides water provision, has made the country close to self-sufficient for rice, which is now placed at 97 percent, based on the average annual rice requirement of 118 kg per capita.

FIGURE 6
Irrigated crops on area equipped for full control irrigation
Total harvested area 2 695 825 ha in 2006 (cropping intensity on equipped area 143.5%)



Under the BSWM and the NIS schemes, the average cost of irrigation development is about US$3 277/ha for new schemes, while the cost of rehabilitating existing schemes is US$1 608/ha, and the annual cost of O&M is US$98/ha. The average cost of irrigation development in private schemes is aroundUS$556/ha; and the cost for rehabilitation of existing schemes is US$156/ha. The average cost of sprinkler irrigation and localized irrigation for on-farm installation is US$1 556/ha and US$2 222/ha respectively.

Status and evolution of drainage systems

In most schemes, drainage water from one field goes into another field downstream either through the irrigation canal or directly. It is, therefore, it is difficult to estimate the drained areas. In 1993, total drained area was an estimated 1 470 691 ha (Table 3).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

The National Water Resources Board (NWRB) is the overall government agency responsible for all the water resources in the Philippines. It coordinates, integrates and regulates all water-related activities that impact on the physical environment and the economy. The Board regulates water use with a water permit system and resolution of water use conflicts. It is also the lead agency for the adoption and localization of Integrated Water Resources Management (IWRM). The National Economic and Development Authority (NEDA) also plays important roles in the overall coordination in the planning and regulation of water resources.

The Department of Environment and Natural Resources (DENR) through the Environmental Management Bureau (EMB), is responsible for maintaining desirable water quality and implementing water quality management programmes such as classification of water bodies, water quality guidelines and effluent standards, discharge fee system and ambient effluent/monitoring, etc. The DENR has a new office, the River Basin Control Office, which will primarily oversee issues and concerns related to the implementation of integrated water resources management and development.

In 2005, the President created the Water and Sanitation Coordination Office (WASCO) at the Anti-Poverty Commission with the purpose of implementing the Presidents Priority Programme on Water for waterless municipalities. The Department of Health (DOH) monitors the quality of drinking water and regulates premises with sanitation installations.

The Department of Interior and Local Government (DILG) provides technical assistance and capability building to Local Government Units (LGUs) to help them manage water supply, sewerage and sanitation services.

The Department of Public Works and Highways (DPWH) is responsible for flood control and drainage infrastructures. The National Power Corporation (NPC) is responsible for the development of power sources including hydropower.

The Department of Agriculture, through the National Irrigation Administration (NIA) is responsible for irrigation development. In addition, through the Bureau of Soils and Water Management (BSWM), research and technologies for soil and water conservation and harnessing rainwater for agricultural use are developed for use of field extension staff of the local government units. The Agricultural Training Institute (ATI), on the other hand, assists in translating the packages of technologies into information and knowledge materials for the proper conservation and management of irrigation and water for improve agricultural production.

The Metropolitan Waterworks and Sewerage System (MWSS) is a Government owned and Controlled corporation established in 1971 and responsible for the provision of water, sewerage and sanitation services in Metro Manila and parts of the provinces of Cavite and the entire province of Rizal. In 1997, MWSS entered into a concession agreement on operation and maintenance with two concessionaires: the East Zone was awarded to Ayala corporation, which was named the Manila Water Company Inc. and the West Zone to Benpres Holding corporation named Maynilad Water Services Inc. The concession agreement will last for 25 years unless terminated sooner or extended.

The Local Water Utilities Administration (LWUA) governs local water districts in municipalities and cities, and review rates or charges established by local water utilities.

The Laguna Lake Development Authority was established in 1966 as a quasi-government agency that leads, promotes, and accelerates sustainable development in the Laguna de Bay Region. Regulatory and law-enforcement functions are carried out with provisions on environmental management, particularly on water quality monitoring, conservation of natural resources, and community-based natural resource management. This body is supposed to catalyse integrated water resources management (IWRM) in the Laguna de Bay Region, showcasing the symbiosis of humans and nature for sustainability, with a focus on preserving ecological integrity and promoting economic growth with equitable access to resources. From the viewpoint of governance this is a unique case. It is a self-sufficient IWRM authority with a high degree of autonomy for management and financing, and has been delegated the responsibilities of regulating water allocation and tax revenues.

Water management

Water quantity is becoming a limiting constraint for livelihoods and production. Water is not perceived yet as a critical and sensitive issue neither a real priority. There is no real concern about how water resources are used. However, there is a growing awareness and concern about the negative impacts of climate change and problems with pollution, poor water quality and hygiene issues, accompanying rapidly increasing population density.

With high population growth rates, water demand is increasing fast, yet there has been no adequate response. The discharge of domestic and industrial wastewater and agricultural runoff causes extensive pollution of the receiving water-bodies. This effluent is in the form of raw sewage, detergents, fertilizer, heavy metals, chemical products, oils and solid waste. As a consequence, conflicts between different water users have increased.

Institutional arrangements, policy implementation and conflict resolution for water supply and water resources are multi-level and the implementation mechanisms are relatively complex and fragmented. A number of private organizations and coalitions are playing advocacy roles.

The NIA organized a total of 140 Irrigators' Associations (IA) in both NIS and CIS nationwide with 15 951 farmer-members tilling 18 924 ha. Currently the total organized IA organized cover 1 109 684 ha, benefiting 735 879 member farmers. The NIA continues to provide assistance to the IAs in various aspects of their farming activities and community livelihood programmes.

In 1997, the Department of Agriculture (DA) launched, a comprehensive, nationwide irrigation research and development programme to support implementation of the Agriculture and Fisheries Modernization Act (AFMA). AFMA recognizes that sustained agricultural growth provides an enduring solution to the twin problems of poverty and food security. To ensure sustained agricultural growth and global competitiveness, crop agriculture must focus on irrigated areas and 30 percent of the AFMA budget is earmarked for irrigation. Further, AFMA was expanded by strengthening support services and infrastructure for fisheries and livestock.

Finances

In general, the national government sets aside funds annually for the rehabilitation and improvement of irrigation for almost 3 percent, or about 27 000 ha that are lost to poor maintenance and the inability of local communities to maintain irrigation canals and meet rehabilitation requirements as a result of the almost yearly damage caused by typhoons.

Policies and legislation

The Philippine Constitution (1987) provides for the national enabling environment and overarching policy on sustainable water use and water resources management. Right and access to water is well enshrined in the constitution.

The Water Code of the Philippines (1976) consolidated the laws governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources. It reiterates that the water belongs to the State and cannot be the subject of acquisitive prescription. The State may allow the use or the development of water resources by administrative concession, while the preference in the use and development of water shall consider current usage and be responsive to the changing needs of the country. It also reiterates that the measure and limit of appropriation of water shall be beneficial use, which is defined as the utilization of water in the right amount during the period that the water is needed for producing the benefits for which the water is appropriated. The administration and enforcement of the provisions of the Water Code is vested in the National Water Resources Council now National Water Resources Board. The Water Code is now being reviewed to tailor it to changing times and to meet current and future challenges in the water sector.

Presidential Decree No. 424 (1974) created the National Water Resources Council (NWRC), which was renamed the National Water Resources Board (NWRB) in 1987 by Executive Order 124-A. It has the power to coordinate and integrate water resources development and management activities.

The Environmental Code (1997) prescribes, among other things, the management guidelines aimed to protect and improve the quality of water resources through: classification of surface water and establishment of water quality

The Local Government Code (1991) provides for the empowerment of local executives in the delivery of basic services, which includes water supply and sanitation services.

Republic Act No. 9275 (2004), otherwise known as the Clean Water Act, applies to water quality management in all water bodies in the abatement and control of pollution from land-based sources. The water quality standards and regulations shall be enforced irrespective of sources of pollution. The act also provides that the DENR, in coordination with the NWRB, shall designate certain areas as water quality management areas using appropriate physiographic units such as watersheds, river basins or water resources regions.

The Philippine Water Supply Sector Roadmap is a joint effort of the National Economic Development Agency (NEDA) and NWRB, together with various sector stakeholders, such as national government agencies, water service providers and non-governmental organizations. It seeks to address the gaps and challenges previously identified by various sector studies conducted by international development agencies and research institutions, statistical data from the National Statistics Office (NSO) as well as monitoring data from various government agencies such as the Department of Interior and Local Government (DILG), Local Water Utilities Administration (LWUA) and the National Water Resources Board (NWRB). It is designed to help the country meet the sector's challenges and intended objectives by 2010 in line with the targets defined by the 2004-2010 MTPDP. In the longer term, it also aims to help the country meet the sector's challenge in achieving the MDG goals.

ENVIRONMENT AND HEALTH

The government, through the National Poverty Commission, has placed high premium on the issue of water and sanitation issues. The President's Priority Programme for water for waterless municipalities is classified into three main types of facilities: Level I, or point source system without distribution facilities, Level II, or communal faucet system, and Level III, or individual household connection system. Individual piped supplies (Level III) are provided by water districts, private operators, LGUs, and community-based organizations (CBOs). Shared water supplies are provided by LGUs and CBOs through *barangay* waterworks and sanitation associations (BWSAs) for point sources (Level I), and rural waterworks and sanitation associations (RWSAs) for communal faucet systems (Level II).

Non-poor urban households mostly rely on septic tanks, which have been found to be poorly constructed and maintained without provisions for dislodging, hence affecting their efficiency for primary treatment of water. Sewerage coverage is very low. Less than 8 percent of the households in Metro Manila have access to sewerage systems, while the over-all urban sewerage coverage is a measly 4 percent. Currently, the few sewerage systems that exist cater to commercial establishments and affluent communities. To ensure increasing and sustainable access to water supply and sanitation services, investment in the sector has to increase rapidly. Current investment is inadequate to achieve the targets consistent with achieving the MDGs. National government and donor financing must be matched by funds from local governments and appropriate participation of the private sector encouraged.

In 1995, water demand in Metro Manila alone exceeded the available groundwater resources. In the 2025 projection, all the major cities will face water problems if water supply depends on groundwater alone. The need to develop other water sources will be critical for sustaining the development of these areas.

The population affected by water-related diseases in 2000 was 866 411 (Table 3).

About 73.3 percent of the cultivated area is limited to only three low-value and low-yielding crops: rice, maize and coconut. Collectively, 42 percent of these croplands are degraded and are considered vulnerable to the impacts of extreme climate events and global warming and climate change phenomena. The BSWM reported about 23 million ha are suffering from various soil problems which is dominated by soil infertility and steep slopes, accounting for more than 70 percent of the total area of the country. In addition, a total of approximately 13.7 million ha are suffering from moderate to severe soil erosion, which is one major driver of the loss of soil fertility in sloping lands.

The main flood-affected areas are in the central region of Luzon, namely the Pampanga, Zambales and Tarlac provinces. About one million ha have been identified as flood-prone areas.

The Philippines has experienced temperature spikes, which could be the result of climate change. Since 1980, high temperatures have become more frequent along with extreme weather events. These include deadly and damaging typhoons, floods, landslides, severe El Niño and La Niña events, drought, and forest fires. Adversely affected sectors include agriculture, freshwater, coastal and marine resources and health.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Agricultural water is currently under threat by both climatic and non-climatic drivers. Changes in rainfall pattern will significantly disrupt cropping systems, particularly in rainfed areas. It will become more difficult and risky for farmers, in the face of climate change, to rely on rainfall for their planting calendar. Extreme climate events will likely impinge the hydrological system in most of the river basins and will mean water becoming either 'too much' or 'too little'. When water becomes too much, the potential effects include flooding from overflowing rivers and excessive runoff from sloping lands, which damage water infrastructure, such as dams, and irrigation and drainage systems. At the other end, higher temperatures and decreased precipitation mean too little water, resulting in a decreased water supply and an increased water demand, which might cause deterioration in the quality of freshwater bodies. There will be possible alterations in the distribution of surface water and groundwater owing to changes in recharging (gaining) and discharging (losing) patterns. Stream flows will be significantly reduced and groundwater levels will decline, particularly shallow aquifers may dry up if water extraction is not properly regulated. Non-climatic drivers owing to human activities will continuously provide more pressure on water resources resulting in growing competition among water users.

In view of the above scenario, agricultural water management should incorporate the judicious use of water resources and engineering measures. To be able to deal with 'too little water', focus needs to be placed on both the demand and supply side of water management through water sources rehabilitation, water conservation, and augmentation of water supply, such as the optimum utilization of wastewater as an alternative to water sources for irrigation. To be able to deal with ' too much water', drainage facilities that are used to immediately remove excess flood waters will need to be improved. The design of irrigation systems needs to be reviewed to include the effect of climate change and to incorporate properly designed drainage facilities to protect standing crops. The construction of rainwater harvesting structures (e.g. small water impounding project) to collect and store rainwater in the uplands could contribute to the mitigation of floods downstream and ensure available water during the dry season.

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Republic of Korea

GEOGRAPHY, CLIMATE AND POPULATION

Geography

The Republic of Korea is located in the semi-tropical area along the east coast of the Asian landmass. It is bounded by the Yellow Sea in the west, the Democratic People's Republic of Korea in the north, the Sea of Japan in the east, and is separated from Japan by the Korea Strait to the southeast and south. For administrative purposes, the country is divided into nine provinces and seven metropolitan cities. The capital is Seoul.

The country has a total land area of 99 900 km^2 and some 65 percent is mountainous, especially along the east coast with the highest point Halla-san at 1 950 m above sea level. The other main mountains are the Taebaek range, which cross the country from north to south with their highest point at Mount Sorak (1 708 m), and the Sobaek range running from the southwest to the northeast, of which the highest point is Chiri mountain (1 915 m). The plains are mainly located along the west and south coasts.

The cultivable area is relatively small and is largely spread along the southwest coast. Most of it has already been reclaimed and is intensively cultivated. In 2009, the total cultivated area was about 1 796 000 ha, of which 1 595 000 ha consisted of annual crops and 201 000 ha of permanent crops (Table 1).

Climate

The country's climate is determined by its latitude and geography, and there are four distinct seasons: spring, summer, autumn and winter. Winter is bitterly cold and is influenced primarily by cold Siberian fronts. Summer is hot and humid owing to the maritime Pacific high. The transitional seasons, spring and autumn are sunny and generally dry. Wind and precipitation are largely affected by the surrounding Pacific Ocean in the south and the Eurasian landmass in the north.

The mean annual rainfall is 1 274 mm, of which about 70 percent is concentrated during the summer months from June to September. The rainfall is evenly distributed over the country, with 1 300 mm in Seoul in the north, 1 100 mm in Taegu in the centre, and 1 400 mm in Pusan in the south. Typhoons accompanied by heavy rainfall during summer or early autumn often cause severe crop damage, as do the droughts before the beginning of the summer monsoon.

The mean monthly temperature varies from below freezing in winter to over 25 °C in summer. Frost-free days extend from around the end of April until mid-October, varying from 175 days a year in the north to 220 days in the south. Double cropping is practiced in the south.

Population

The total population in 2009 was about 48.0 million inhabitants, of which around 17 percent lived in rural areas (Table 1). With 480 inhabitants/km^2, the Republic of Korea is amongst the countries with the highest population density. The capital, Seoul, has the highest population


DEMOCRATIC PEOPLE'S REPUBLIC OF KOREA
Seoul
KANGWON
CHUNGCHONGBUK
Yellow Sea
Sea of Japan
Western Channel
Korea Strait
Eastern Channel
JAPAN
CHEJU
JAPAN
Legend
Administrative Boundary
Capital, Regional Capital, Town
Zone of Irrigation Development
River
Lake
Dam
REPUBLIC OF KOREA
FAO - AQUASTAT, 2011
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	9 990 000	ha
Cultivated area (arable land and area under permanent crops)	2009	1 796 000	ha
• as % of the total area of the country	2009	18	%
• arable land (annual crops + temp fallow + temp meadows)	2009	1 595 000	ha
• area under permanent crops	2009	201 000	ha
Population			
Total population	2009	47 964 000	inhabitants
• of which rural	2009	17	%
Population density	2009	480	inhabitants/km^2
Economically active population	2009	24 243 000	inhabitants
• as % of total population	2009	51	%
• female	2009	41	%
• male	2009	59	%
Population economically active in agriculture	2009	1 350 000	inhabitants
• as % of total economically active population	2009	6	%
• female	2009	44	%
• male	2009	56	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	832 512	million US$/yr
• value added in agriculture (% of GDP)	2009	2.6	%
• GDP per capita	2009	17 357	US$/yr
Human Development Index (highest = 1)	2010	0.877	
Access to improved drinking water sources			
Total population	2008	98	%
Urban population	2008	100	%
Rural population	2008	88	%

density, approaching 20 000 inhabitants/km^2 and the lowest density is in Cheju province with less than 284 inhabitants/km^2. The annual demographic growth for the period 1999-2009 was around 0.5 percent.

In 2008, access to improved drinking water sources reached 98 percent (100 and 88 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture in 2009 is an estimated 1 350 000 inhabitants, amounting to 6 percent of the economically active population, of which 44 percent are women. Each farmer has on average 0.52 ha. Gross domestic product (GDP) was US$832 512 million in 2009 (Table 1). Agriculture accounted for 2.6 percent of GDP, compared with 5.2 percent in 1999.

The absolute size of the area for rice cultivation has been decreasing continuously as such land has been diverted considerably to other purposes such as construction of public facilities, houses, factories and roads and growing of other crops. However, the ratio of the rice cultivation area to total arable land has been maintained at around 50 percent. There have been changes in the type of crop cultivated owing to changes in profitability as well as the impact from imported agricultural products.

Cultivation of grains, except rice, is decreasing as they have low profitability. On the contrary, the area of land used for growing vegetables and fruits and for greenhouse farming, which can yield more profit is increasing (MAF, 2005). Food crops grown in addition to rice are barley, soybeans, red bean, green bean, sweet potato, potato, maize, millet and sorghum. There is very little wheat cultivation because of the lack of competitiveness and therefore it is largely imported.

WATER RESOURCES AND USE

Water resources

Most of the rivers flow west and south through the plains. There are five main drainage systems, which altogether cover two-thirds of the territory:

- Han river basin in the northwest: average runoff 19.4 km^3/year, drainage area 26 018 km^2;
- Kum river basin in the west: average runoff 6.2 km^3/year, drainage area 9 810 km^2;
- Nakdong river basin in the south: average runoff 13.9 km^3/year, drainage area 23 817 km^2;
- Seomjin river basin in the south: average runoff 3.8 km^3/year, drainage area 4 897 km^2; and the
- Yeongsan river basin in the south: average runoff 2.6 km^3/year, drainage area 3 371 km^2.

The total annual volume of surface runoff produced internally is about 62.25 km^3, while internal groundwater resources are approximately 13.3 km^3. Since about 10.7 km^3 of groundwater resources comprise the base flow of the rivers, the total internal renewable water resources are an estimated 62.25+13.3-10.7 = 64.85 km^3/year. Some transboundary rivers cross the border with the Democratic People's Republic of Korea. Compared with the annual discharge of the Han river in the Democratic People's Republic of Korea (19.4 km^3/year with a catchment basin four times that of the basin flow into the Republic of Korea), the inflow to the Republic of Korea from the Democratic People's Republic of Korea is an estimated 4.85 km^3/year. The total average surface water discharge in the Republic of Korea is, therefore, an estimated 67.1 km^3/year, bringing the total renewable water resources to 69.7 km^3/year (Table 2). Owing to the intensive nature of the rainfall and the steeper natural channel slopes, about 37 percent of the annual water resources are flood runoffs, concentrated in summer.

During the last 60 years, a considerable effort has been made to regulate the course of rivers. Multipurpose river basin schemes have been developed for flood control, irrigation, community water supply and hydropower production. In 1997, there were 765 dams that were over 15 m high. There are more than 18 000 small irrigation reservoirs. Artificial lakes account for 93 percent of all lakes in the Republic of Korea. In 1994, the water storage for dams and reservoirs totals 16.2 km^3.

In 1997, total hydropower electricity generation amounted to 5 404 GWh, representing 2.4 percent of the country's total electricity generation.

In 1996, total produced wastewater was an estimated 7 947 million m^3. Only 4 180 million m^3 were treated.

International water issues

The Democratic People's Republic of Korea has built several dams on the Imjin river, a major waterway, including one a few kilometres north of the heavily armed border between the two states that have yet to sign a formal peace treaty to end the 1950-1953 Korean War. The river starts in the north and ends in the south to the northwest of Seoul. In 2009, the Republic of Korea made a complait to the Democratic People's Republic of Korea about a sudden release of water into the Imjin river flowing across their border that left six people missing in the south.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 274	mm/yr
	-	127 000	million m^3/yr
Internal renewable water resources (long-term average)	-	64 900	million m^3/yr
Total actual renewable water resources	-	69 700	million m^3/yr
Dependency ratio	-	6.96	%
Total actual renewable water resources per inhabitant	2009	1 453	m^3/yr
Total dam capacity	1994	16 200	million m^3
Water withdrawal			
Total water withdrawal	2002	25 470	million m^3/yr
- irrigation + livestock	2002	15 800	million m^3/yr
- municipalities	2002	6 620	million m^3/yr
- industry	2002	3 050	million m^3/yr
• per inhabitant	2002	549	m^3/yr
Surface water and groundwater withdrawal	2002	25 470	million m^3/yr
• as % of total actual renewable water resources	2002	36.5	%
Non-conventional sources of water			
Produced wastewater	1996	7 947	million m^3/yr
Treated wastewater	1996	4 180	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced	2000	0.16	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

The Democratic People's Republic of Korea has failed to notify the Republic of Korea ahead of releasing water on several previous occasions, resulting in flood damage in the south (Reuters, 2009). So far, there is no cooperation between the two countries on flood control and the establishment of warning systems.

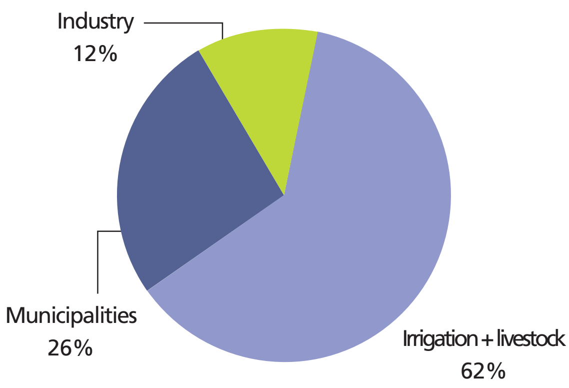
In 2005, the Republic of Korea constructed the Peace dam on the Bukhan river, the only dam in the world constructed with no reservoir. The aim of the dam is to prevent flooding coming from the Imnam dam in the Democratic People's Republic of Korea.

Water use

In 2002, total water withdrawal was an estimated 25.47 km^3, of which 15.8 km^3 (62 percent) for agriculture, 6.62 km^3 (26 percent) for municipalities and 3.05 km^3 (12 percent) for industries (Table 2 and Figure 1).

Rapid industrialization and economic growth have changed the pattern of water demand. Municipal and industrial water withdrawal increased steadily from 10 and almost 0 percent respectively in 1975 to 26 and 11 percent respectively in 1994, while agricultural water withdrawal decreased from 90 to 63 percent in the same period.

FIGURE 1
Water withdrawal by sector
Total 25.47 km^3 in 2002



In 2000, approximately 0.16 million m^3 of seawater was being desalinized at 16 stations to supply drinking water, mostly on island areas (ICID, 2002).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation development in Korea has a long history. Weirs (headworks) were built in the first century, and the first reservoirs were constructed at the end of the fourth century. Historical records show that in 1910 there were about 26 000 diversion weirs, ponds and dykes for irrigation water supply.

Irrigation development in the Republic of Korea can be divided into three stages:

- Stage I, before 1945, when numerous small-scale systems were constructed by mobilizing local technology;
- Stage II, 1946-1961, when existing systems damaged by the war were repaired;
- Stage III, since 1961, when large-scale comprehensive agricultural development projects have been implemented. During this stage, the Government invested large amounts from international loans for the development and rehabilitation of irrigation systems and for the improvement of technical, institutional and social aspects of irrigation.

In 1982, the estimation of water requirements for irrigation was adjusted to cover the ten-year drought frequency, and an inventory of existing irrigation systems throughout the country was prepared to identify rehabilitation requirements. As a result, many systems with insufficient capacities were categorized for rehabilitation.

In 2007, the irrigation potential area was taken as being the same as the total cultivated area, or 1 782 000 ha, since it is considered that all cultivable land is currently under cultivation. In 2002, total irrigated area was around 880 400 ha, a reduction compared to 1996, since some land has been diverted to other purposes such as construction of public facilities, houses and factories (Table 3).

Irrigation systems cover approximately half of the cultivated area. However, most of the cultivated areas are irrigated by virtually any means during the critical crop periods when threatened by drought. Typically, in high valleys where irrigation systems are not economically viable, farmers irrigate by pumping water from rivers, streams and reservoirs using small portable pumps or power tillers.

As fertile paddy fields can be more easily and economically developed on flat plains than hilly areas, more farmland and, consequently, the accompanying irrigation systems have been developed by reclaiming river plains and tidelands. This partly explains why surface drainage predominates. It is difficult to find a large and shallow river-swamp left idle. Irrigation development along the west coast is often implemented as part of tideland reclamation.

In 1996, out of a total irrigated area of 888 800 ha the area served by surface water was an estimated843 500 ha (95 percent) of which 65 percent was fed by 18 000 reservoirs, 21 percent by 6 000 pumping stations, and 14 percent by 18 000 headworks. The area served by groundwater accounted for 45 300 ha (5 percent) (Figure 2).

In 1996, small schemes (< 50 ha) covered 41 percent of the total equipped area for irrigation, medium-size schemes (50–3 000 ha) 41 percent and large schemes (>3 000 ha) 18 percent (Figure 3). Using local government budgets, small systems are constructed by the cities or counties, and handed over to farmers' organizations for operation and maintenance (O&M).

TABLE 3
Irrigation and drainage

Irrigation potential		2007	1 782 000	ha
Irrigation				
1. Full control irrigation: equipped area		2002	880 400	ha
- surface irrigation		1996	888 800	ha
- sprinkler irrigation		1996	0	ha
- localized irrigation		1996	0	ha
• % of area irrigated from surface water		1996	94.9	%
• % of area irrigated from groundwater		1996	5.1	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated			-	ha
- as % of full control area equipped			-	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2002**	**880 400**	**ha**
• as % of cultivated area		2002	47	%
• % of total area equipped for irrigation actually irrigated			-	%
• average increase per year over the last 12 years		1990-2002	-0.92	%
• power irrigated area as % of total area equipped		1996	20	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2002**	**880 400**	**ha**
• as % of cultivated area		2002	47	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< 50 ha	1996	362 230	ha
Medium-scale schemes		1996	369 630	ha
Large-scale schemes	> 3 000 ha	1996	156 930	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2006	1 038 000	ha
• Annual crops: total		2006	991 000	ha
- Rice		2006	760 000	ha
- Maize		2006	3 000	ha
- Potatoes		2006	19 000	ha
- Sweet potatoes		2006	12 000	ha
- Vegetables		2006	137 000	ha
- Soybeans		2006	48 000	ha
- Other annual crops		2006	12 000	ha
• Permanent crops: total		2006	47 000	ha
- Citrus		2006	8 000	ha
- Fruit trees		2006	39 000	ha
Irrigated cropping intensity (on full control area)		2006	118	%
Drainage - Environment:				
Total drained area		1996	1 039 000	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		1996	53	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases		2000	-	inhabitants

FIGURE 2
Source of irrigation water on area equipped for full control irrigation
Total 888 800 ha in 1996

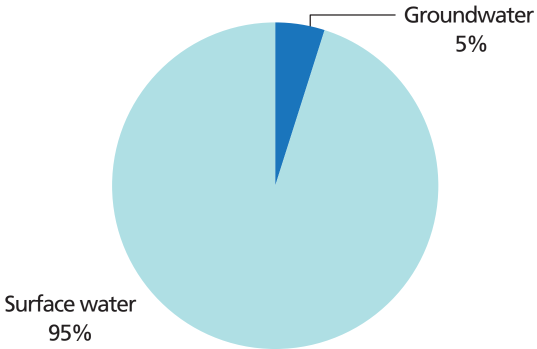
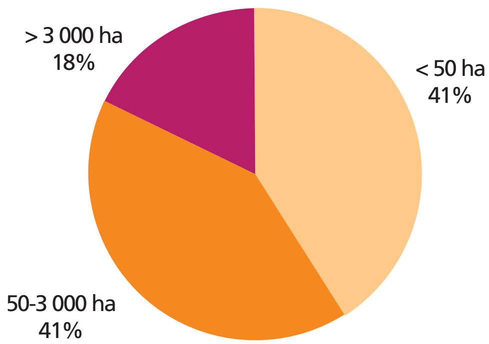


FIGURE 3
Type of full control irrigation schemes
Total 888 800 ha in 1996



Medium-size systems are funded from the central government's budget, constructed by the provinces, and handed over for O&M to Farmland Improvement Associations (FLIAs). Large systems are financed by the central government, executed by the Rural Development Corporation (RDC), and then handed over to FLIAs for O&M. In any case, the full cost of construction is paid for by the Government. There are some privately developed and owned irrigation systems, but no data are available on their area.

Role of irrigation in agricultural production, economy and society

Total harvested irrigated cropped area in 2006 was around 1 038 000 ha. The major irrigated crops are paddy rice accounting for 73 percent of the total harvested area, followed by vegetables, which represent 13 percent, soybeans 5 percent and perennial crops 5 percent of which citrus accounts for 17 percent (Table 3 and Figure 4). Winter barley is mostly sown on paddy fields after the rice harvest in autumn, and grown without irrigation during the winter with residual soil moisture until spring. Wheat and maize are seldom cultivated on irrigated paddy for economic reasons. The average yield of irrigated rice was 6.8 tonnes/ha for single cultivation in 1996. In that year, approximately 76 percent of all paddy was under irrigation.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO AGRICULTURAL WATER USE

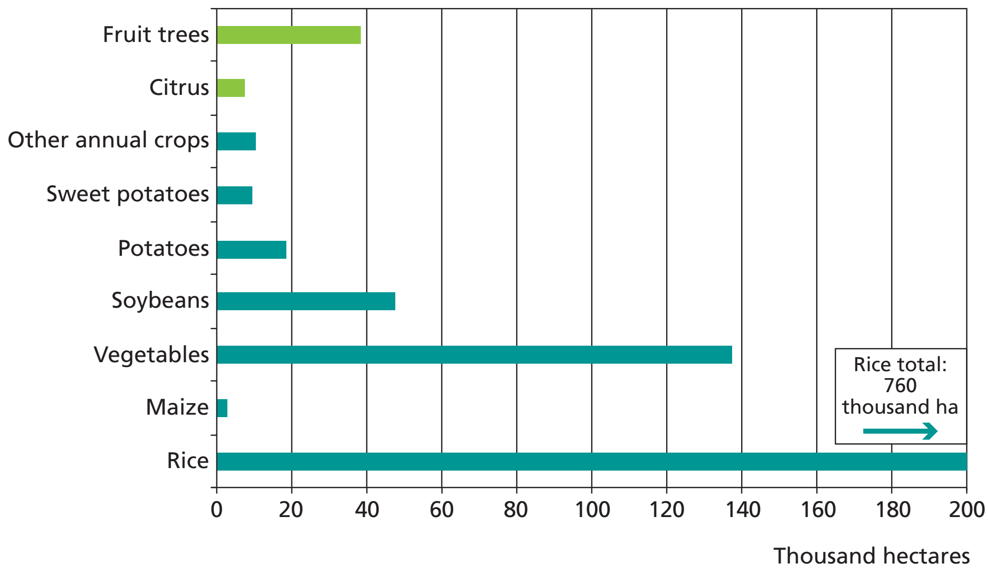
Institutions

The main institutions involved in water resources management and in irrigation and drainage include the Ministry for Food, Agriculture, Forestry and Fisheries (MIFAFF), the Ministry of Environment (MOE), the Ministry of Land, Transport and Maritime Affairs (MLTM), the Rural Development Corporation (RDC), the Federation of Farmland Improvement Association (FFIA), the FLIAs and the WUAs.

The mandate of MIFAFF is to provide consumers safe agro-food in a stable manner, strengthen agricultural competitiveness so that rural society can become a place for sustainable agriculture, enjoyable life and leisure. MIFAFF, through the Rural Development Bureau (RDB), is responsible for policy, planning and financing of all rural infrastructure projects, and for the supervision of local government institutions, the RDC, the FFIA, the FLIAs and the WUAs.

The RDC is a semi-autonomous agency, which carries out the planning, study, design, and supervision of the rural infrastructure projects and overseas the execution of large-scale agricultural development projects, the O&M of the important facilities of large-scale

FIGURE 4
Irrigation techniques on area equipped for full control irrigation
Total harvested area 1 038 000 ha in 2006 (cropping intensity on equipped area: 118%)



agricultural development projects, and the provision of O&M training courses for FLIA staff as well as engineering and administrative training courses for its own staff.

The FFIA is a public corporation, which mainly carries out the planning, design, and supervision of the farmland improvement projects for farmland consolidation as well as providing guidance on the operational improvement of FLIAs. There are 105 FLIAs in the country, which are responsible for the O&M of public irrigation systems.

WUAs are organized by farmers for the O&M of small irrigation systems that are not included in FLIA systems. The small systems are constructed and/or rehabilitated by the Government through the cities or the counties before being transferred to WUAs.

The Korean National Committee on Irrigation and Drainage (KCID) is involved in irrigation and drainage issues.

In 1999, the Office of the Prime Minister set up a plan to establish a "national information system for water management" to improve information exchange on water-related issues and thus avoid double work and investment. This led to the creation in 2003 of the "Rural and agricultural water resources information system (RAWRIS)" by MIFAFF (in charge of agricultural water), MOE (in charge of water quality) and MLTM (in charge of water quantity).

Water management

Even though the annual mean precipitation is more than 1 200 mm, the Republic of Korea often experiences drought because of the large variations in rainfall, making the management of water resources difficult (MAF, 2005).

The MIFAFF, within its environmentally-friendly agriculture promotion plan (1996-2010), reinforced water quality control and has implemented a water quality improvement programme for agricultural use.

Agricultural water withdrawal is generally decreasing, but peak irrigation water requirements are tending to increase because of the extensive use of rice-transplanting machines, which has led to a reduced duration of the spring transplanting period. As the remaining development options become increasingly expensive, emphasis is being placed on the efficient use of water resources and on the rehabilitation and upgrading of existing systems.

Urbanization and industrialization have caused water withdrawal in and near cities and industrial sites to increase more rapidly. Water quality is deteriorating rapidly in the natural channels and reservoirs.

Finances

The cost of developing conveyance systems down to secondary canals was approximately US$5 000/ha of irrigated area in 1989. Farmers still provide labour for the final land leveling of paddies to avoid possible dissatisfaction or disputes over quality control. In 1999, the cost of land acquisition was being paid for by the Government. Farmers paid more than 6 000 won (US$7.72) per 0.1 ha of paddy as an annual fee.

Policies and legislation

Rice policy reform is to abolish the government purchasing system, and to introduce a public stockholding system and direct income support mechanism.

ENVIRONMENT AND HEALTH

The Ministry of Agriculture has been implementing an environmentally-friendly agriculture promotion plan in three stages over the 15 year-period 1996-2010, five years for each stage, in accordance with the policy for environmentally-friendly agriculture. The main purposes are:

1. to minimize pollutants coming from chemical fertilizers, agricultural chemicals, livestock and poultry waste;
2. to maintain and improve agricultural resources including soil and water purity;
3. to support farm household practicing environmentally-friendly agriculture to distribute products for sale (MAF, 2005).

Abnormal weather, in particular, causes direct damage to crops and yields. Being a peninsular surrounded by the sea, the Republic of Korea suffers from huge damage every year caused by typhoons. Typhoons usually hit the country from August to September when most crops, including rice, fruit and vegetables, fully ripen resulting in tremendous loss.

MAIN SOURCES OF INFORMATION

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Sri Lanka

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Sri Lanka is a tropical island lying close to the southeast tip of India. Its land area is 65 610 km^2 (Table 1). Three-quarters of the land consist of a broad first peneplain with an average elevation of 75 m above sea level. A second peneplain rises to 500 m, and towards the south, a third peneplain rises steeply to form a mountain massif that reaches an elevation of 2 500 m. For administrative purposes, the country is divided into nine provinces: Central, Eastern, North Central, Northern, North Western, Sabaragamuwa, Southern, Uva and Western. The capital is Colombo.

In 2009, the total cultivated area was approximately 2.17 million ha of which 1.20 million ha for annual crops such as rice, kurrakkan, maize, green gram, green chilies and cowpea and 0.97 million ha of permanent crops such as fruits, tea, rubber, sugarcane and coconut.

Climate

The island receives rain mainly during two monsoons. Rainfall intensity varies markedly across the island. Based on rainfall, several agroclimatic regions can be recognized, such as wet zone, intermediate zone, dry zone and arid zone. Depending on the rainfall pattern, climatologists divide Sri Lanka's climatic year into five seasons:

- The convectional-convergence period (March to mid-April) is when the island comes under the influence of the inter-tropical convergence zone.
- The pre-monsoon period (mid-April to late May) presents transitional weather patterns, with convectional weather gradually being suppressed by surges of the southwest monsoon.
- The southwest monsoon (late May to late September) brings the largest amount of rainfall to the southwest lowlands and windward slopes of the central hills. After the rains, dry desiccating monsoon winds blow across the north, north-central and southeast regions.
- The convectional cyclonic period (late September to late November) begins with the weakening of the southwest monsoon. This period can include cyclones and may result in heavy rainfall.
- The northeast monsoon (November to February), though weak compared to the southwest monsoon, brings agriculturally important rainfall to the northern and eastern parts of the island.

There is considerable variation around the national mean annual rainfall of 2 000 mm. The highest rainfall occurs in the central highlands and maximum values are on the western slopes with several stations recording values exceeding 5 000 mm (Maliboda, 5 330 mm; Weweltalawa estate, 5 258 mm; and Kenilworth estate, 5 085 mm). Mean annual rainfall values on the eastern slopes are less than 3 500 mm. Rainfall is lowest in the northwest and southwest lowlands with a minimum value of 935 mm recorded at the Ambalantota gauging station.

Mean annual temperature is about 27 °C in the lowlands and 15 °C in the central highlands. The temperature decreases with increasing altitude, approximately 2 °C per 300 m of elevation.


INDIA
Palk Strait
Palk Bay
Jaffna
Jaffna Peninsula
NORTHERN
Gulf of Mannar
Bay of Bengal
Trincomalee
Muttur
NORTH CENTRAL
Anuradhapura
NORTH WESTERN
EASTERN
CENTRAL
Chilaw
Negombo
Colombo
WESTERN
UVA
Badulla
Laccadive Sea
SABARAGAMUWA
SOUTHERN
Galle
Matara
Legend
International Boundary
Administrative Boundary
Capital, Regional Capital, Town
River
Lake
Dam
Zone of Irrigation Development
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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	6 561 000	ha
Cultivated area (arable land and area under permanent crops)	2009	2 170 000	ha
• as % of the total area of the country	2009	33	%
• arable land (annual crops + temp fallow + temp meadows)	2009	1 200 000	ha
• area under permanent crops	2009	970 000	ha
Population			
Total population	2009	20 669 000	inhabitants
• of which rural	2009	86	%
Population density	2009	315	inhabitants/km^2
Economically active population	2009	9 372 000	inhabitants
• as % of total population	2009	45	%
• female	2009	38	%
• male	2009	62	%
Population economically active in agriculture	2009	4 012 000	inhabitants
• as % of total economically active population	2009	43	%
• female	2009	37	%
• male	2009	63	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	41 979	million US$/yr
• value added in agriculture (% of GDP)	2009	13	%
• GDP per capita	2009	2 031	US$/yr
Human Development Index (highest = 1)	2010	0.658	
Access to improved drinking water sources			
Total population	2008	90	%
Urban population	2008	98	%
Rural population	2008	88	%

Population

In 2009, the total population was just over 21 million, of which around 86 percent lived in rural areas (Table 1). The average population density is 315 inhabitants/km^2. The population is concentrated largely in the wet zone (southwest coastal regions and central regions). Much of the dry zone remains sparsely populated. During the period 1999-2009 the annual population growth rate was an estimated 1.1 percent.

In 2008, access to improved drinking water sources reached 90 percent (98 and 88 percent for the urban and rural population respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture in 2009 was around 4.0 million, amounting to 43 percent of the total economically active population. Around 37 percent of the population economically active in agriculture are women. In 2009, the gross domestic product (GDP) was US$41 979 million of which agriculture accounted for 13 percent (Table 1).

The total rice harvested area in 2008 was 1 032 859 ha of which the main Maha rice, normally harvested until March, accounted for 568 352 ha. The secondary Yala rice, which is planted from April and normally represents one-third of total production, accounted for 464 507 ha. In 1988, the total rice harvested area was 815 560 ha, of which 498 554 ha was Maha rice and 317 006 ha Yala rice. Total rice production was an estimated 3 876 400 tonnes in 2008, giving an average yield of 4 184 kg/ha (Department of Census and Statistics, 2010).

WATER RESOURCES AND USE

Water resources

Sri Lanka's radial network of rivers begins in the central highlands. There are about 103 distinct river basins covering 90 percent of the island. The southwestern part of the island has seven major basins with catchment areas ranging from 620 to 2 700 km^2. They are, from north to south: Maha river (1 528 km^2), Attanagalu river (736 km^2), Kelani river (2 292 km^2), Kalu river (2 719 km^2), Bentota river (629 km^2), Gin river (932 km^2) and Nilwala river (971 km^2). An exception to the radial pattern is the largest basin, that of the 335 km long Mahaweli river, which has a catchment area of 10 448 km^2. After leaving the central highlands, it runs almost north for 90 km from Minipe to Manampitiya and then a further 70 km through several distributaries as far as Verugal and Mutur on the east coast. Most Sri Lankan river basins are small. Only 17 of the 103 basins exceed 1 000 km^2.

Besides the Mahaweli basin, four others exceed 2 500 km^2. Three of these (Deduru river, Kalu river and Malvathu river) have their entire catchment area in the dry zone, and only Kalu river is in the wet zone. The total runoff in Sri Lanka is an estimated 52 km^3/year (Table 2). Considering 75 and 50 percent dependability rainfall, annual runoff estimates are 42 and 49 km^3 respectively (Amarasinghe, 2009).

There are six types of aquifers: the shallow karstic aquifer of the Jaffna Peninsula, deep confined aquifers, coastal sand aquifers, alluvial aquifers, the shallow regolith aquifer of the Hard Rock

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 712	mm/yr
	-	112 300	million m^3/yr
Internal renewable water resources (long-term average)	-	52 800	million m^3/yr
Total actual renewable water resources	-	52 800	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	2 555	m^3/yr
Total dam capacity	1996	5 942	million m^3
Water withdrawal			
Total water withdrawal	2005	12 950	million m^3/yr
- irrigation + livestock	2005	11 314	million m^3/yr
- municipalities	2005	805	million m^3/yr
- industry	2005	831	million m^3/yr
• per inhabitant	2005	653	m^3/yr
Surface water and groundwater withdrawal	2005	12 950	million m^3/yr
• as % of total actual renewable water resources	2005	24.5	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

Region and the southwestern lateritic (cabook) aquifer (WRB, 2005). Sri Lanka's largest aquifer extends over 200 km in the northwestern and northern coastal areas. The internal renewable groundwater resources are an estimated 7.8 km^3, most (estimated as 7 km^3/year) returning to the river systems and being included in the estimate for surface water resources. Therefore the total renewable water resources are an estimated 52.8 km^3/year.

The Kalu, Kelani, Gin, Bentota, and Nilwala river basins cover only 13 percent of the land area, but are where 30 percent of the population live and where 38 percent of the total renewable water resources (TRWR) are located. The basin of the Mahaweli river, the longest river, covers 17 percent of the total area of the country, supports 17 percent of the population and carries 19 percent of TRWR. The basin of the eastward flowing Gal river, known for its irrigated rice production, covers 3 percent of the land area and has 2 percent of TRWR (Amarasinghe, 2009).

Most of the studies on water scarcity assessment rank Sri Lanka as a country with either little or no water scarcity or moderate water-scarcity conditions, but they do not consider the spatial and temporal variation of water availability. Sri Lanka experiences high seasonal and spatial variations in rainfall as a result of the bi-monsoonal climatic pattern (northeast monsoon from October to March and southwest monsoon from April to September). Large areas of the country are drought prone. Droughts occur to different degrees in both semi-arid and humid zones (Matin *et al.,* 2009). Dry-zone districts, comprising 75 percent of the country, contribute to only 49 percent and 29 percent of the *maha* and *yala* season runoff. Thus, storing water for irrigation in the *yala* season (April to September) is essential in many river basins (Amarasinghe, 2009).

In 1996, the total dam capacity was 5.94 km^3. Dams in Sri Lanka are classed according to the materials they use. They are mainly earthen, rockfill or concrete dams. Earthen dams are the most common type, the longest being the Parakrama Samudraya dam, which is 13.5 km long and has a storage capacity of 0.13 km^3. The highest, in this category, is the Senanayake Samudraya dam, built under the Gal river multipurpose scheme project, with a height of 34 m and a storage capacity of 0.95 km^3. The Victoria dam, built under the Mahaweli basin multipurpose project, is the highest concrete (double curvature) dam with a height of 106 m and a storage capacity of 0.73 km^3. Within this project, which begun in 1977, other multipurpose reservoirs were constructed such as the Kothmale, Randenigala, Rentembe, and Maduru Oya.

Between 1950 and 1975 the activities of the Irrigation Department focused on the construction and augmentation of major reservoirs such as Kantale, Hurulu Wewa, Padawiya, Kaudulla, Rajangana and Wahalkada (ID, 2010). The total capacity of dams built for irrigation is around 3.37 km^3.

The gross theoretical hydropower potential in Sri Lanka is an estimated 8 000 GWh/year. In 1997, 16 hydropower plants were in operation with an installed capacity of 1 103 MW. Hydropower accounted for 81 percent of electricity generation.

In 2009, the company Befesa Agua signed a contract for a major water treatment project for the greater Ratnapura area (Sabaragamuwa Province). Currently, the capacity of the existing system is inadequate to meet the area's future demand. The Ratnapura project is composed of raw water intakes located in the Kalu river, raw water transmission lines between the intakes and the treatment plant, the construction of one reservoir with a capacity of 2 500 m^3, the construction of a water treatment plant in Muwagama with a capacity of 13 000 m^3/day and transmission pipelines from the treatment plant to different reservoirs (Befesa Agua International News, 2009). This project, designed to meet the estimated water demand for the horizon year 2025, will ensure the provision of potable water to Ratnapura city and its environs, which will benefit a population of 100 000 inhabitants (Infoagua, 2010).

Water use

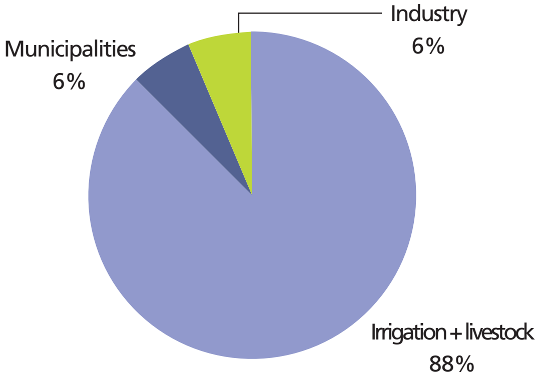
Large-scale development of water resources for irrigation and hydropower has progressed rapidly in the last 50 years. In 2005, the total water withdrawal was an estimated 12.95 km^3, of which about 11.31 km^3 (87.4 percent) for agriculture, 0.81 km^3 (6.2 percent) for municipalities and 0.83 km^3 (6.4 percent) for industries (Table 2 and Figure 1). Irrigation withdrawal for rice represent 10.63 km^3. Irrigation total withdrawals are estimated assuming 35 percent of irrigation efficiency. The Eastern, North-Western, and North-Central provinces and Hambantota in the Southern Province account for 76 percent of the total withdrawals (Amarasinghe, 2009).

Groundwater resources are widely used for domestic, commercial and industrial purposes, and small-scale irrigation. About 80 percent of rural domestic water supply needs are met by groundwater from dug wells and tubewells. In many areas, where surface water systems are not fully reliable, groundwater provides industrial and commercial users with a margin of safety. Most industries in the country depend heavily on deep wells where groundwater is safe and of good quality, and can be self-managed. The demand for groundwater in Sri Lanka is steadily increasing, especially for urban and rural water supplies, irrigated agriculture, industries, aquaculture, small and medium enterprises and urban housing schemes. The rapid expansion of these projects is exerting much pressure on available groundwater resources (WRB, 2005).

Sri Lanka is covered with a network of thousands of artificial lakes and ponds, known locally as ‘tanks’ (after *tanque,* the Portuguese word for reservoir). Some are truly massive, many are thousands of years old and almost all show a high degree of sophistication in their construction and design (Goldsmith *et al.,* 1984). A recent study undertaken by the International Water Management Institute (IWMI) in Sri Lanka’s dry zone, where groundwater use for farming is greatest, highlighted a significant rise in the numbers of water pumps and ‘agro-wells’ (wells used mainly for agriculture) sunk over the past few decades. Researchers estimated that there are close to 50 000 agro-wells in the dry zone. The number of pumps is higher, around 100 000, as it includes those used to pump water from rivers, irrigation canals and tanks, and not just those fitted to agro-wells. This boom in agro-well construction occurred partly because a government subsidy programme for brick and concrete-lined wells was introduced in 1989, but also because many aquifers are quite close to the surface, which makes digging shallow wells and drilling tubewells relatively cheap (IWMI, 2005).

On a nation-wide basis, piped water systems deliver safe water to almost 90 percent of the nation’s urban population, and protected wells to approximately 60 percent of the rural population. The National Water Supply and Drainage Board (NWSDB) distributes the major portion of the, mostly urban, water requirement of the country, over 310 million m^3 per year to cater for a population of over 5.3 million. Many of the large urban centres along the coast get their water supply from river systems. They are experiencing water supply interruptions as a result of salinity intrusions in the lower reaches of these rivers (WRB, 2005).

FIGURE 1
Water withdrawal by sector
Total 12.95 km^3 in 2005



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation activities in Sri Lanka date back 2 500 years. Initially, these activities started with a small-scale village tank and a simple channel system. Later, from the fourth to the end of the twelfth century, these systems were developed. Dams were built to intercept river flows across shallow valleys, or water flowing down perennial rivers was diverted by weirs and it conveyed through long excavated canals to be impounded in large reservoirs at appropriate locations to supply large areas.

However, most of these systems fell into disuse and were abandoned after the twelfth century. In the nineteenth century, some of the tanks, such as those at Kalawewa, Tissa Wewa and Kantale, were restored. In 1857, an irrigation ordinance was introduced to give legislative status to the rules governing irrigation activities. In 1900, during the colonial period, British Governors established the Irrigation Department, a separate department distinct from the former Public Works, to handle irrigation works. In the early 1930-1940 period there was the need to resettle people in the dry zone of Sri Lanka and greater emphasis was placed on the local effort to produce food. This resulted in putting the Irrigation Department in the front line of development activities (ID, 2010).

The Gal river multipurpose scheme and reservoir, launched in 1952, was the first major multipurpose project ever undertaken in Sri Lanka, which was followed in the 1960s by Mahaweli, the largest multipurpose scheme. These multipurpose projects were not only to develop irrigation and settlement but also to generate hydropower. The Mahaweli project, which is by far the largest government project in the country, envisaged the development of more than 300 000 ha of new irrigated land and the generation of 800 MW of hydropower at the completion of the project.

The Land Reform Act of 1972 limits the private ownership of land to a ceiling of 10 ha/person for paddy, 20 ha for tea, rubber and coconut, and 0.2 ha for residents. This act also established a land reform commission with the power to acquire and dispose of properties.

During the period 1985-1992 the Major Irrigation Rehabilitation project took place, funded by the World Bank. A 150 ha pilot project was implemented in a distributary canal in the Rajangana system with two structural modifications: an automatic constant downstream level gate associated with modular distributors at the head of the distributary canal, and baffle distributors at the head of field canals. During the period 1992-1998, the National Irrigation Rehabilitation project was implemented. This project undertook many major systems for rehabilitation under World Bank funding (Godaliyadda *et al.,* 1998). Recently, the International Development Association (IDA) of the World Bank has funded the North-East Irrigated Agriculture Project to restore irrigation schemes and rural roads as a means of restoring food security for displaced communities.

Given the state of irrigation development and the present level of technology in agriculture and in construction engineering, since the mid-1990s little economic potential is left to be exploited by new irrigation construction. Hence, it is reasonable to assume that the country has reached its irrigation potential, but there is large scope for improvement of the existing areas.

The total area equipped fro irrigation is 570 000 ha, which has not changed since the mid to late 1990s (Table 3). From 1963 to 1993, the area irrigated by major irrigation schemes increased by about 110 percent, mainly as a result of the major irrigation projects implemented by the Government. The total water managed area increased by 17 percent during the period 1989-1999.

In Sri Lanka, irrigation schemes can be classed as minor, medium or major depending on the area they serve. Minor schemes provide facilities for less than 80 ha. They serve about 200 000 ha (35 percent). Medium schemes, providing facilities for areas of 80-400 ha, serve 61 000 ha (11 percent). Major schemes provide facilities for more than 400 ha and serve the remaining 309 000 ha (54 percent) (Figure 2).

TABLE 3
Irrigation and drainage

Irrigation potential			570 000	ha
Irrigation				
1. Full control irrigation: equipped area		2006	570 000	ha
- surface irrigation		2006	570 000	ha
- sprinkler irrigation		2006	0	ha
- localized irrigation		2006	0	ha
• % of area irrigated from surface water		2002	98.8	%
• % of area irrigated from groundwater		2002	1.2	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2006	462 500	ha
- as % of full control area equipped		2006	81	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2006**	**570 000**	**ha**
• as % of cultivated area		2006	29	%
• % of total area equipped for irrigation actually irrigated		2006	81	%
• average increase per year over the last 10 years		1995-2006	0	%
• power irrigated area as % of total area equipped		1995	30	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2006**	**570 000**	**ha**
• as % of cultivated area		2006	29	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< 80 ha	2006	200 000	ha
Medium-scale schemes	80-400 ha	2006	61 000	ha
Large-scale schemes	> 400 ha	2006	309 000	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2006	744 000	ha
• Annual crops: total		2006	736 600	ha
- Rice		2006	699 900	ha
- Maize		2006	700	ha
- Other cereals		2006	100	ha
- Pulses		2006	800	ha
- Oil crops		2006	4 100	ha
- Roots and tubers		2006	4 300	ha
- Vegetables		2006	9 300	ha
- Sugarcane		2006	17 400	ha
• Permanent crops: total		2006	7 400	ha
- Fruits		2006	7 400	ha
Irrigated cropping intensity (on actually irrigated area)		2006	156	%
Drainage - Environment:				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases			-	inhabitants

The major irrigation schemes can be classed as:

- storage schemes;
- diversion schemes;
- lift irrigation schemes; and
- drainage, flood control and saltwater exclusion schemes.

Storage schemes have two purposes: storage and flood control. Water is impounded in tanks by building dams across valleys, and then released when required to service areas downstream.

Diversion weirs, commonly called *anicuts,* are constructed in perennial streams in the wet zone to convey water to the fields below. Here, a masonry or concrete wall is built across the stream to head up and divert water. The diverted water is distributed to the fields by gravity.

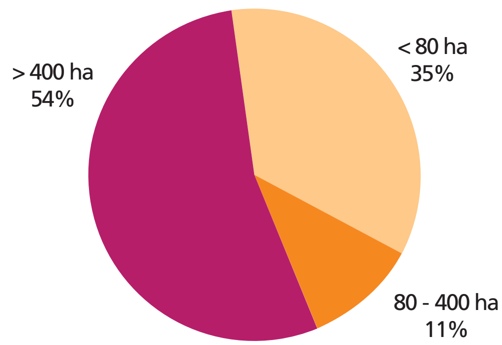
Lift irrigation schemes with mechanically or electrically operated pumps were introduced during the 1990s to irrigate the highlands.

In 1995, it was estimated that around 1 000 ha were being irrigated by groundwater wells. In 2002, equipped area irrigated by groundwater was 6 828 ha (Department of Census and Statistics, 2009) (Figure 3).

Surface irrigation dominates in Sri Lanka, with the main surface irrigation methods being basin and furrow irrigation.

Agriculture in the Kalu, Kelani, Gin, Bentota, and Nilwala river basins is mainly rainfed, and dominated by plantation crops such as rubber, coconut and tea. The Mahaweli river basin is the most important basin for irrigated agriculture in the country. The basin of the Gal river is known for its irrigated rice production. The Jaffna Peninsula mainly uses groundwater for agriculture requirements (Amarasinghe, 2009).

FIGURE 2
Type of full control irrigation schemes
Total 570 000 ha in 2006



Role of irrigation in agricultural production, economy and society

In 2006, the total harvested irrigated cropped area was an estimated 744 000 ha, of which 699 900 ha was rice representing 94 percent of the cropped area. Other important crops are sugarcane, vegetables, fruits, roots and tubers and oil crops accounting for 17 400 ha (2.3 percent), 9 300 ha (1.3 percent), 7 400 ha (1.0 percent), 4 300 ha (0.6 percent) and 4 100 ha (0.6 percent) respectively. Pulses account for 800 ha, maize for 700 ha and other cereals for 100 ha (Table 3, Table 4, Table 5 and Figure 4) (Amarasinghe, 2009). In 2006, the total harvested rainfed cropped area represented 1 311 200 ha, thus, total harvested cropped area accounted for 2 055 200 ha.

FIGURE 3
Source of irrigation water on area equipped for full control irrigation
Total 570 000 ha in 2002

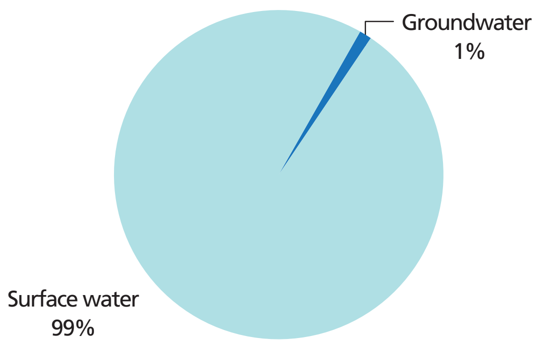


TABLE 4
Irrigated and rainfed harvested cropped area (1 000 ha) (2006)

	Irrigated crops			Rainfed crops			Total		
Crops	**Maha**	**Yala**	**Total**	**Maha**	**Yala**	**Total**	**Maha**	**Yala**	**Total**
Paddy	423.5	276.3	699.9	162.4	37.9	200.3	585.9	314.3	900.2
Maize	0.0	0.7	0.7	23.5	3.7	27.2	23.5	4.4	27.9
Other cereals	0.0	0.1	0.1	4.7	0.9	5.6	4.7	1.1	5.7
Pulses	0.0	0.8	0.8	18.2	6.4	24.7	18.2	7.2	25.5
Oil crops	1.4	2.8	4.1	10.3	7.9	18.2	11.6	10.7	22.3
Roots and tubers	0.0	4.3	4.3	21.1	16.9	37.9	21.1	21.2	42.2
Vegetables	3.8	5.5	9.3	43.4	28.7	72.1	47.2	34.2	81.4
Sugarcane			17.4			-			17.4
Total seasonal crops	**-**	**-**	**736.6**	**283.6**	**102.4**	**386.0**	**-**	**-**	**1 122.6**
Fruits			7.4			91.8			99.2
Tea			-			212.7			212.7
Rubber			-			116.5			116.5
Coconut			-			394.8			394.8
Other						109.4			109.4
Total permanent crops			**7.4**			**925.2**			**932.6**
Grand total	**-**	**-**	**744.0**	**283.6**	**102.4**	**1 311.2**	**-**	**-**	**2 055.2**

Two-thirds of the total harvested irrigated cropped area is located in Eastern, North-Western and North-Central provinces. Over 80 percent of the total harvested area in Ampara, Manner and Polonnaruwa districts are irrigated (Amarasinghe, 2009).

In 2006, rice accounted for only 44 percent of the total harvested cropped area, but irrigated rice accounted for 94 percent of the irrigated harvested area. Of the total harvested rice area of 900 000 ha, 78 percent, or 699 000 ha, was irrigated (Amarasinghe, 2009).

In 1985, the average cost of developing major surface irrigation schemes was US$1 350/ha. In 1993, the average operation and maintenance cost for a major surface irrigation scheme, such as Kaudulla, was US$12/ha/year.

Studies have revealed that the cost-benefit ratio of investments in irrigation construction fell sharply in the early 1980s and hit a record low in 1986.

Status and evolution of drainage systems

In the wet zone, flood control and drainage schemes have been incorporated into the irrigation system mainly in the lower reaches of rivers. In the coastal areas, saltwater exclusion schemes have been commissioned where water salinity affects agriculture. Flood bunds and pumps are the main features in flood protection schemes, whereas gated regulators are adopted in saltwater exclusion schemes.

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO AGRICULTURAL WATER USE

Institutions

Although water is managed as an input to major development sectors such as irrigation, hydropower and human and industrial water supply, there is little coordination between these sectors. It is estimated that there are more than 50 government and semi-government institutions dealing with subjects relating to water in Sri Lanka, with little coordination.

TABLE 5
Irrigated cropped area by province and district (1 000 ha) (2006)

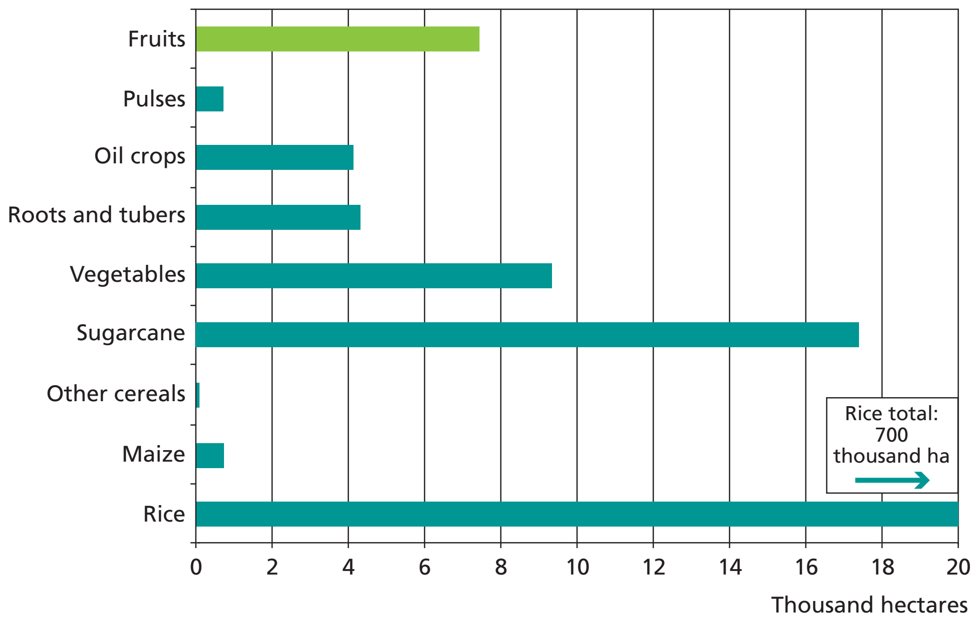
Provinces and districts	HCA*	HICA*	HICA % of HCA	RCA*	RCA % HCA	RICA*	RICA % HICA
Sri Lanka	**2 055**	**744**	**36**	**900**	**44**	**699**	**94**
Wet-zone	674	67	10	152	23	65	98
Dry-zone	1 381	677	49	748	54	634	94
Provinces	**% of HCA**	**% of HICA**		**% of RCA**		**% of RICA**	
Western	9	1	4	4	23	1	100
Central	10	6	23	6	26	6	95
Southern	12	8	27	11	42	9	99
Northern	5	6	51	6	65	5	83
Eastern	13	23	70	24	86	25	100
North Western	18	13	28	14	36	13	93
North Central	15	30	77	24	76	31	97
Uva	9	9	39	6	32	7	71
Sabaragamuwa	10	3	13	5	20	3	96
Districts	**% of HCA**	**% of HICA**		**% of RCA**		**% of RICA**	
Colombo	1	0	6	1	23	0	100
Gampaha	3	0	4	1	16	0	100
Kalutara	4	0	4	3	30	0	100
Kandy	3	2	24	2	31	2	97
Matale	3	3	38	3	42	3	91
Nuwara Eliya	4	1	10	1	10	1	100
Galle	4	0	0	2	28	0	100
Hambantota	5	7	50	6	52	7	99
Matara	3	2	18	3	41	2	100
Jaffna	1	1	27	1	45	0	0
Kilinochchi	1	2	45	2	76	2	94
Mannar	1	1	84	1	84	1	100
Mullaitivu	1	1	45	1	62	1	87
Vavuniya	1	1	64	1	58	1	88
Ampara	7	15	81	13	85	16	100
Batticaloa	4	5	48	7	86	5	99
Trincomalee	2	4	72	4	86	4	100
Kurunegala	14	11	28	12	39	11	95
Puttalam	4	3	27	2	23	2	83
Anuradhapura	9	16	69	13	68	16	96
Polonnaruwa	6	13	88	11	89	14	100
Badulla	5	4	35	4	36	4	93
Moneragala	4	5	43	3	28	3	50
Kegalle	4	0	5	2	18	1	100
Ratnapura	6	3	18	3	22	3	96

*HCA: Harvested cropped area; HICA: Harvested irrigated cropped area; RCA: Rice cropped area; RICA: Rice irrigated cropped area

At national level, the main institutions are (Nanayakkara, 2009):

- Irrigation Department (ID), established in 1900: the principal government organization responsible for the regulation and control of inland water. It is responsible for planning, design, construction, operation and management of all major and medium irrigation

FIGURE 4
Irrigated crops on area equipped for full control irrigation
Total harvested area 744 000 ha in 2006 (cropping intensity on actually irrigated full control area: 156%)



schemes and for works related to flood control, drainage and salinity extrusion.

- Ceylon Electricity Board (CEB): is responsible for power generation, transmission and distribution.
- Mahaweli Authority of Sri Lanka (MASL), was established in 1979: is responsible for water and related infrastructure development in designated basins, not only in Mahaweli project.
- National Water Supply and Drainage Board (NWSDB): is the regulator for drinking water and operator of integrated urban and small town schemes.
- Department of Agrarian Development: is responsible for village irrigation.
- Department of Fisheries Aquaculture: is responsible for fisheries management.
- National Aquatic Research Agency (NARA): is responsible for aquaculture and fisheries research.
- National Aquaculture Development Authority (NAQDA): is responsible for the development of aquaculture and inland fisheries.
- Water Resources Board (WRB), was established in 1968: is responsible for hydrogeological investigations.
- Central Environmental Authority (CEA): is responsible for environmental quality standards and environmental impact assessment procedures (tolerance limits for discharge of effluents into inland waters).

The following institutions have been proposed:

- Water Resources Council (WRC): would be the policy formulating body for water resources allocation.
- National Water Resources Authority (NWRA): would be responsible for water rights and bulk entitlements.

At provincial level, the main institutions are:

- Provincial Ministry of Irrigation;

- Ø Provincial Ministry of Local Government.

At divisional level, the main water managers are:

- Ø Divisional Secretary: is responsible for the Divisional Agricultural Committee, and Kanna meetings.
- Ø Farmer organizations: are responsible for operation and maintenance of field channels, and distributory channels, village irrigation.

At local government level the main water managers are:

- Ø Municipal Councils: urban water supply systems;
- Ø Urban Councils: unintegrated urban systems, small towns water supply schemes;
- Ø Pradeshiya Sabha: responsible of rural water supply schemes.

At village level, community-based organizations (CBOs) and non-governmental organizations (NGOs) represent community water supply schemes (piped, gravity schemes, rainwater harvesting schemes).

Water management

Freshwater resources in Sri Lanka remain a free public good, with the State acting as the trustee and custodian of the resource. Water rights are linked to land ownership and, as such, landowners are regarded as owning the water underneath their land and have the right to pump all the water from the common aquifer, lowering the water table. Furthermore, they may use or abuse all the rain that falls on their land. However, all the streams that flow across private land fall within the public domain (Nanayakkara, 2009).

Irrigation development, operation and maintenance and rehabilitation have been predominantly state activities. However, in the 1970s participatory approaches were incorporated in certain irrigation rehabilitation projects. A national programme of water management was initiated 1981-1983 in 24 major systems covering about 80 000 ha. Positive results were achieved, and a programme for the Integrated Management of Major Irrigation Schemes (INMAS) was launched in 1984 in 37 major systems covering 155 000 ha. This was the first official attempt, at the national level, to mobilize farmers in participatory management for major irrigation. Key elements of the programme included the creation of Farmer Organizations and Project Management Committees (Brewer, 2004). In 1988, the government accepted the policy of participatory management including beneficiary involvement at all stages of decision-making and in the management of irrigation schemes.

In 1994, the Institutional Assessment for Comprehensive Water Resources Management Project was completed. This was executed by the National Planning Department of Sri Lanka in association with more than 30 agencies and organizations concerned with water resources development and management. Technical assistance was provided by the Asian Development Bank and the United States Agency for International Development (USAID). The strategic framework formulated and adopted by the project steering committee for the process of comprehensive water resources management included nine elements under three main headings:

1. The policy and legal basis:
   - Ø national policies and goals;
   - Ø water sector policies and goals;
   - Ø laws and regulations.
2. The actors:
   - Ø government agencies;
   - Ø communities;

- Ø private sector;
- Ø mechanism for collaboration.

3. The information and technology basis:
   - Ø technology and research and development;
   - Ø data and information.

On the basis of this strategic framework, a time-bound action plan was drawn up which focused on:

- Ø national water policy: to develop a national water policy;
- Ø national water legislation and regulations: to prepare and enact a national water act through amendments to water related legislation;
- Ø institutional development: to define water sector functions and create an independent agency for water resources management to strengthen the capacity of water sector agencies to carry out these functions;
- Ø river basin planning: to carry out comprehensive planning in selected watersheds; and
- Ø information systems and public consultation: to establish an improved system to provide data and information required by decision-makers and others concerned, including the public.

In July 1995, the Government approved the implementation of the strategic framework and action plan together with the establishment of the Water Resources Council to oversee the implementation of the action plan.

There is a need to rehabilitate or modernize existing schemes to increase their overall productivity. In addition, systems are being designed to diversify cropping and achieve higher cropping intensities and proper watershed management. Currently, the government of Sri Lanka is attempting to transform the way irrigation schemes are operated, maintained, and financed. The goals are to improve the productivity of irrigated agriculture and to reduce government expenditures on irrigation operation and maintenance. The core of this effort is a policy, called ‘participatory management’, to transfer irrigation management responsibilities to farmer organizations (Brewer, 2004).

No effective systems for groundwater planning or management have been put in place. Developing such systems is a challenge because a large number of scattered farmers are involved, and because there are seven different types of aquifer on the island, five of which are in the dry zone, each with its own constraints and opportunities. Certainly, much more detailed information on each particular resource and how it is being used is needed. Even very basic information, such as the actual number of agro-wells throughout the country is currently unavailable. Data on groundwater collected by some agencies are inconsistent, unreliable, and lack sufficient coverage (IWMI, 2005).

Finances

In 1984, the government instituted an irrigation fee for the first time (Brewer, 2004).

In 2010 Sri Lanka received a US$16 million loan from the Organization for the Petroleum Exporting Countries Fund (OPEC) for International Development for an irrigation project in the island’s central region. The Kalu river development project is part of the Moragahakanda development programme. The first phase of the project is estimated to cost US$167 million. The Kalu river dam, which will be 67 m high and 546 long with two saddle dams, would cost US$102.2 million to build. The Kuwait Fund for Arab Economic Development is providing US$37 million, the Saudi Fund for Development US$46 million and the balance will be borne by the government of Sri Lanka (LBO, 2010).

Policies and legislation

There are over 50 acts of parliament concerning the water sector. These laws have been enacted over time to meet specific needs, often with little consideration for existing legislation or future needs. Laws are administered by numerous agencies with a wide range of responsibilities, and there are overlaps, gaps and conflicting jurisdictions.

ENVIRONMENT AND HEALTH

The quality of the groundwater is generally fairly good and relatively constant throughout the year. However, in the northern and northwestern coastal areas excessive concentrations of iron and nitrates, from agrochemicals and fertilizers, have been reported. Furthermore, as a result of the uncontrolled abstraction of groundwater for domestic and agricultural uses, brackish water intrusion has occurred in the coastal areas.

It has been shown that large water development projects have increased the malariogenic potential of areas through increased vector propagation, aggregation of labour and resettlement from non-malarious areas of people with no immunity.

High incidences of water-related illness indicate that there are serious water quality problems.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Sri Lanka's population will peak in the early 2040s, with an addition of 15 percent to the population. Given the high level of water development for irrigation, increasing irrigation efficiency is one of the feasible options available for meeting future water demand. If irrigation efficiency is increased to 45 percent from the currently assumed level of 35 percent, the irrigation demand shall decrease by 22 percent. The major irrigated areas will contribute to 78 percent of the reduction in demand through this level of efficiency increase. If irrigation efficiency is increased to 55 percent, irrigation demand will decrease by 35 percent. A decrease in irrigation demand in such a scenario is more than 3.9 km^3, which is equivalent to about 32 percent of the total water demand. Such scenarios of efficiency growth show that if the currently developed water supply is properly managed, only a part of these water savings is adequate for meeting future irrigation demand (Amarasinghe, 2009).

Note:

The expressions 'Oya' and 'Ganga' that are often added to the names of rivers, mean 'river' in Singhalese. Therefore, in this English version of the country profile, these words have been removed from the name of the river and replaced by the word 'River'. As an example, Kelani ganga has been changed to Kelani river and Maha oya has been changed to Maha river.

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Thailand

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Thailand covers an area of 513 120 km^2 and is located in the southeastern region of the continent of Asia (Table 1). Its immediate neighbours are Myanmar to the north and the northwest, Lao People's Democratic Republic to the northeast, Cambodia to the east and Malaysia to the south. The water bodies that skirt Thailand are the Mekong river in the east that forms Thailand's natural boundary with Laos, the Gulf of Thailand to the southeast and the Indian Ocean and the Andaman Sea to the southwest.

Administratively, the country is divided into 76 *changwats* (provinces), 4 regions and the Bangkok Metropolitan area. The four regions correspond approximately to the physiographical regions of Thailand: the northern region is mountainous with forests; the northeast is dry and consists of a plateau that borders the Mekong river; the central region is an extensive plain subject to flooding; and the southern part is a peninsula.

About 26.79 million ha are considered as cultivable, which represents 52 percent of the country. In 2009, the cultivated area was an estimated 18.995 million ha. Of this total, 15.300 million were under annual crops (mainly paddy rice) and the remaining 3.695 million ha were under permanent crops.

Climate

The climate is mainly governed by the alternation between the southwest monsoon, which brings heavy rainfalls (May-October), and the northeast monsoon, which is comparatively dry and cool (October-February). The transitional period (March-April) is characterized by heavy thunderstorms.

The average annual rainfall is about1 622 mm. It ranges from 1 100 mm in the central plain and the northeast of the country to 4 000 mm in the southern peninsula near the Andaman Sea.

Population

The total population was an around 68.7 million in 2009, of which 66 percent lived in rural areas, compared with 69 percent in 1999. During the period 1999-2009 the annual population growth rate was an estimated 0.97 percent. The population density is about 134 inhabitants/km^2.

In 2008, 98 percent of the population had access to improved water sources (99 and 98 percent in urban and rural areas respectively). Sanitation coverage accounted for 96 percent (95 and 96 percent in urban and rural areas respectively).

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, the total economically active population was 39.5 million, or slightly more than


MYANMAR
LAO PEOPLE'S DEMOCRATIC REPUBLIC
CHINA
South China Sea
CAMBODIA
VIET NAM
Andaman Sea
Gulf of Thailand
Indian Ocean
MALAYSIA
Chiang Mai
Surat Thani
Nakhon Si Thammarat
Songkhla
Chao Phraya
Bangkok
Legend
International Boundary
Administrative Boundary
Capital, Town
Zone of Irrigation Development
River
Canal
Lake
Dam
THAILAND
FAO - AQUASTAT, 2011
Disclaimer
The designations employed and the presentation of material in this publication do not imply the expression of any opinion whatsoever on the part of the Food and Agriculture Organization of the United Nations concerning the legal status of any country, territory, city or area or of its authorities, or concerning the delimitation of its frontiers or boundaries.

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	51 312 000	ha
Cultivated area (arable land and area under permanent crops)	2009	18 995 000	ha
• as % of the total area of the country	2009	37	%
• arable land (annual crops + temp fallow + temp meadows)	2009	15 300 000	ha
• area under permanent crops	2009	3 695 000	ha
Population			
Total population	2009	68 706 000	inhabitants
• of which rural	2009	66	%
Population density	2009	134	inhabitants/km^2
Economically active population	2009	39 513 000	inhabitants
• as % of total population	2009	58	%
• female	2009	46	%
• male	2009	54	%
Population economically active in agriculture	2009	19 494 000	inhabitants
• as % of total economically active population	2009	49	%
• female	2009	45	%
• male	2009	55	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	263 772	million US$/yr
• value added in agriculture (% of GDP)	2009	12	%
• GDP per capita	2009	3 839	US$/yr
Human Development Index (highest = 1)	2010	0.654	
Access to improved drinking water sources			
Total population	2008	98	%
Urban population	2008	99	%
Rural population	2008	98	%

58 percent of the total population. The economically active population in agriculture was around 19.4 million (49 percent of total active population) of which women represented 45 percent. In 2009, Thailand's gross domestic product (GDP) was US$263 772 million of which agriculture sector accounted for 12 percent (Table 1).

According to the Food and Agriculture Organization of the United Nations (FAO), Thailand's yearly hungry people reduce from 16.8 million (30 percent of total population) during 1990-92, to 13.8 million (23 percent) during 1995-1997, and 13.4 million (21 percent) during 2001-2003.

In 2003, food exports accounted for 24.6 million and food imports accounted for 8.4 million tonnes.

WATER RESOURCES AND USE

Water resources

Thailand can be divided into seven river basins, but in the literature it is generally divided into 25 subbasins. Figure 1 and Table 2 show the location and the characteristics of the 25 major river subbasins and indicate the total surface water resources, 213.35 km^3/year. Aquifer recharge from rainfall is around41.90 km^3/year (about 5-6 percent of the total precipitation).

FIGURE 1
The 25 Sub-basins of Thailand

Approximately 30.70 km^3/year are estimated to return to the river system (overlap). The total internal water resources of Thailand are therefore about 224.55 km^3/year.

Thailand shares three major river systems with its neighbours: the Mekong river forms the border with Lao People's Democratic Republic in the north and east (about 18 percent of the total Mekong catchment area is located in Thailand), the Salween river is on the northwestern border with Myanmar, and the Kolok river is on the southern border with Malaysia. This last river, originating in Thailand and then bordering between Thailand and Malaysia, is very short with a total length of just over 100 km.

The Mekong river constitutes an additional external resource for Thailand, which has been estimated as half the discharge of the river, Thailand's contribution to this river has to be deducted over a long distance. The flow of the Mekong river at the point where it enters Lao People's Democratic Republic near Pakxé is about 280 km^3/year. The contribution of Thailand to the Mekong river is an estimated 51.9 km^3/year This gives an accounted flow of the Mekong border river for Thailand of 114.05 km^3/year. The Salween river on the border with Myanmar, with an estimated flow of 200 km^3/year, flows only over a relatively short distance on the border. It is therefore considered that there is not much contribution from Thailand over that short distance and the accounted flow is 200/2=100 km^3/year.

By adding the internal and external resources together, the total renewable water resources are approximately 438.6 km^3/year (Table 3).

Total exploitable water is an estimated 125.98 km^3/year, consisting of 75.64 km^3/year regular renewable surface water, 27.34 km^3/year irregular renewable surface water and 23.00 km^3/year regular renewable groundwater.

Total large dam capacity is an estimated 68.28 km^3 in 2007, which is about 32 percent of the annual runoff. However, many dams have been over-designed, compared with the annual recharge obtainable. There are four categories of dams in Thailand:

- Large dams with hydropower component are built by the Electricity Generating Authority of Thailand (EGAT), the Royal Irrigation Department (RID) or the Department of Energy Development and Promotion and managed by the EGAT. Their total capacity is an estimated 62.87 km^3. All these dams are multipurpose dams, and the irrigation component receives priority over the other components.
- Large dams without hydropower, and therefore mainly destined for irrigation, are operated by the RID. Their total capacity was an estimated 5.41 km^3 in 2003.

TABLE 2

Characteristics of the 25 major river sub-basins (Source: Hydrologist Assembly, 2006)

No	Basin (Sub Nation)	Catchment area (within the country)		Mean annual runoff (country's contribution)		Area equipped for irrigation	
		km^2	%	km^3	%	ha	%
1	Salawin	17 918	3.50	8.38	3.93	38 560	0.60
2	Mekong	57 424	11.23	30.77	14.42	400 960	6.25
3	Kok	7 895	1.54	4.18	1.96	77 600	1.21
4	Chi	49 476	9.68	11.24	5.27	461 280	7.19
5	Mun	69 700	13.63	19.50	9.14	501 280	7.81
6	Ping	33 896	6.63	8.73	4.09	597 760	9.32
7	Wang	10 792	2.11	1.62	0.76	92 640	1.44
8	Yom	23 616	4.62	3.66	1.71	404 320	6.30
9	Nan	34 331	6.71	12.01	5.63	421 760	6.57
10	Chao Phraya	20 125	3.94	1.73	0.81	1 161 440	18.11
11	Sakae Krang	5 192	1.02	1.12	0.53	106 400	1.66
12	Pasak	16 292	3.19	2.90	1.36	145 600	2.27
13	Tha Chin	13 681	2.68	1.36	0.64	613 440	9.56
14	Mae Klong	30 836	6.03	15.13	7.09	226 880	3.54
15	Prachin Buri	10 481	2.05	5.09	2.39	128 640	2.01
16	Bang Pakong	7 977	1.56	3.34	1.57	153 440	2.39
17	Tonle SAP	4 150	0.81	2.39	1.12	18 720	0.29
18	East Coast - Gulf	13 829	2.70	12.98	6.08	114 720	1.79
19	Phetchaburi	5 603	1.10	1.38	0.65	76 480	1.19
20	West Coast	6 744	1.32	1.34	0.63	76 000	1.18
21	Southeast Coast	26 353	5.15	22.26	10.43	320 640	5.00
22	Tapi	12 224	2.39	10.53	4.94	35 840	0.56
23	Songkhla dam	8 495	1.66	6.63	3.11	120 800	1.88
24	Pattani	3 858	0.75	2.67	1.25	43 520	0.68
25	Southwest Coast	20 473	4.00	22.40	10.50	76 160	1.19
	Total	**511 361**	**100.00**	**213.35**	**100.00**	**6 414 800**	**100.00**

- Ø Medium dams, similar to large dams with no hydropower, are also under RID. Reasons for not classifying these as large dams are:
  1. to avoid environmental assessment, and
  2. to shorten budget processing and construction times to cope with high priority areas.
- Ø Small dams used to be under RID, but are now under local governments. Most of these small dams are for domestic and subsistence irrigation purposes.

There are five dams with a capacity of more than 5 km^3: Srinagarind (17.75 km^3), Bhumipol (13.46 km^3), Sirikit (9.51 km^3), Vaijiralongkorn (8.86 km^3) and Rat Cha Prapa (5.64 km^3).

There are five main dams on the Mekong river basin in Thailand, the Sirindhorn (1 966 million m^3), Chulabhorn (188 million m^3), Ubol Ratana (2 264 million m^3), Pak Mun (114 million m^3) and Lam Ta Khong (310 million m^3).

International water issues

In general, Thailand's international water issues stem from the country's thirst for water, hydroelectricity, and utilization of coastal areas. The main issues include:

- Ø The Mekong river Treaty (1995): This is a treaty between Thailand, Lao People's

TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 622	mm/yr
	-	832 435	million m^3/yr
Internal renewable water resources (long-term average)	-	224 559	million m^3/yr
Total actual renewable water resources	-	438 609	million m^3/yr
Dependency ratio	-	48.8	%
Total actual renewable water resources per inhabitant	2009	6 384	m^3/yr
Total dam capacity	2007	68 281.1	million m^3
Water withdrawal			
Total water withdrawal	2007	57 302	million m^3/yr
- irrigation + livestock	2007	51 786	million m^3/yr
- municipalities	2007	2 739	million m^3/yr
- industry	2007	2 777	million m^3/yr
• per inhabitant	2007	845	m^3/yr
Surface water and groundwater withdrawal	2007	57 302	million m^3/yr
• as % of total actual renewable water resources	2007	13.1	%
Non-conventional sources of water			
Produced wastewater	2007	2 191	million m^3/yr
Treated wastewater	2007	523	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced			million m^3/yr
Reused agricultural drainage water			million m^3/yr

Democratic Republic, Vietnam and Cambodia. The treaty specifies the method of cooperation and conflict resolution among the countries involved, but does not propose any sharing of water between the riparian countries.

- Myanmar: There are a number dams that are planned or under-construction both inside Myanmar and on the border that international non-governmental organizations (NGOs) question because of their possible environmental impact. No agreements have been signed on the Salween river.
- Lao People's Democratic Republic: Issues are similar to Myanmar but include existing dams that supply electricity to Thailand.
- Cambodia: Issues are similar to Myanmar but include natural resources in coastal areas.

Water use

In 2007, total water withdrawal was an estimated 57.3 km^3, of which 90.4 percent was for agricultural, 4.8 percent for municipal and 4.8 percent for industry (Table 3 and Figure 2). In 1990, total water withdrawal was an estimated 33.1 km^3, of which 91 percent was for agricultural purposes, 5 percent for municipal use and 4 percent for industrial use. Of the total withdrawal of 57.3 km^3, 82.9 percent was surface water and 17.1 percent was groundwater (Figure 3).

Wastewater treatment is not common. Industrial wastewater is generally discharged into rivers and canals. About 2 191 million m^3 of wastewater were produced in 2003. In 2007, some 523 million m^3 of wastewater were treated. Numerous wastewater treatment projects are being developed in the Bangkok metropolitan area. There is no reuse of treated wastewater in Thailand.

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Irrigation from river diversion and reservoirs started in the north seven centuries ago. In modern times, canal construction for irrigation started at the beginning of the last century, in parallel with the creation of the RID. The aim was to maintain water in canals for irrigation and navigation, and to drain paddy fields during periods of flooding. Irrigation has traditionally been supplementary irrigation for the wet season. It is only recently that schemes have been designed for dry season irrigation.

The irrigation potential for the wet season can be roughly estimated as 12.2 million ha, considering both soil and water availability but excluding basin transfers (World Bank, 1985). New estimates consider that irrigation potential accounts for 9.5 million ha (Thai Hydrologist Assembly, 2007).

In 2007, the area equipped for wet season irrigation was an estimated 6 414 800 ha. In 2005, the regional distribution of irrigated area in the wet season was 54 percent in the central plain, 18 percent in the north, 14 percent in the northeast and 14 percent in the south. In 1995, the area equipped for wet season irrigation was an estimated 5 003 724 ha, of which 47 percent in the central plain, 24 percent in the north, 19 percent in the northeast and 10 percent in the south.

In 2007, the area actually irrigated was an estimated 5 089 914 ha, or 79 percent of the equipped area (Table 4).

Surface irrigation is the only technology used in the schemes. Sprinkler and localized irrigation are at an experimental stage only for fruit trees. Generally surface water is used, accounting for 90.9 percent of the total area equipped for irrigation (Figure 4).

Early systems were designed to operate at full capacity only in the wet season. The canal capacities and control regulators are inadequate for the increasing demand for dry season irrigation. Furthermore, irrigation water demand has to compete with demand from other sectors. This becomes a sensitive issue during the dry season. A certain flow of water must be maintained for navigation, to prevent saltwater intrusion, and to supply water for domestic and industrial purposes in the Bangkok area. In the dry season, water resources can no longer meet the increasing water demand from all sectors, and particularly from the irrigation subsector, which needs to withdraw more and more water because of the development of dry season irrigation. This water competition has led to poor agricultural performance in recent dry seasons.

Dry season irrigation is practiced on 60 percent of the equipped area, up from 18 percent in 1994.

FIGURE 2
Water withdrawal by sector
Total 57 302 km^3 in 2007

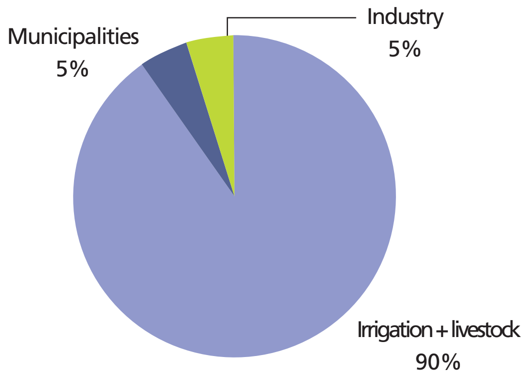


FIGURE 3
Water withdrawal by source
Total 57 302 km^3 in 2007

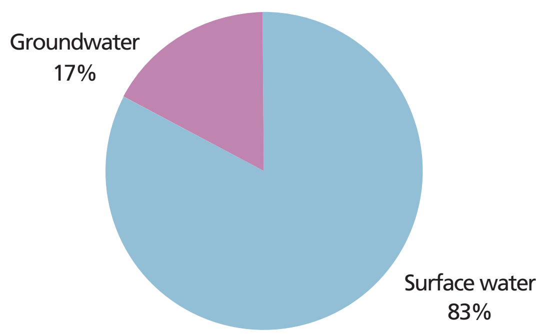


TABLE 4
Irrigation and drainage

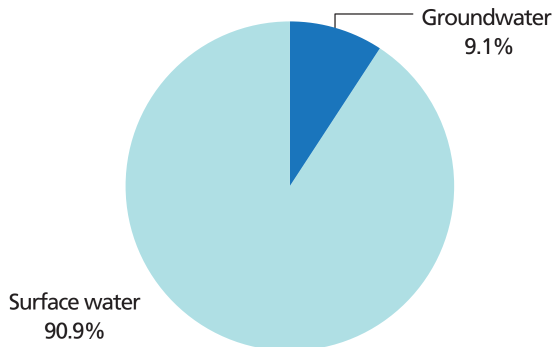
Irrigation potential			12 245 000	ha
Irrigation				
1. Full control irrigation: equipped area		2007	6 414 800	ha
- surface irrigation		2007	6 414 800	ha
- sprinkler irrigation				ha
- localized irrigation				ha
• % of area irrigated from surface water		2007	909	%
• % of area irrigated from groundwater		2007	91	%
• % of area irrigated from mixed surface water and groundwater				%
• % of area irrigated from non-conventional sources of water				%
• area equipped for full control irrigation actually irrigated		2007	5 059 914	ha
- as % of full control area equipped		2007	79	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2007**	**6 414 800**	**ha**
• as % of cultivated area		2007	34	%
• % of total area equipped for irrigation actually irrigated		2007	79	%
• average increase per year over the last 9 years		1995-2007	21	%
• power irrigated area as % of total area equipped		2007	72	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2007**	**6 414 800**	**ha**
• as % of cultivated area		2007	34	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< 1 year construction	2007	2 848 240	ha
Medium-scale schemes	> 1 year construction and < 12 800 ha	2007	898 880	ha
Large-scale schemes	> 12 800 ha	2007	2 667 680	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area		2007	7 387 072	ha
• Annual crops: total		2007	6 644 913	ha
- Rice (first season)		2007	2 327 158	ha
- Rice (second season)		2007	3 940 922	ha
- Sugarcane		2007	256 016	ha
- Vegetables		2007	83 421	ha
- Other annual crops		2007	37 396	ha
• Permanent crops: total		2007	742 159	ha
- Other permanent crops		2007	742 159	ha
Irrigated cropping intensity (on full control area actually irrigated)		2007	146	%
Drainage - Environment:				
Total drained area		-	-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation		1999	400 000	ha
Population affected by water-related diseases		1995	960 000	inhabitants

Small-scale projects are those that can be completed within one year and without land compensation. The schemes that cannot be completed within one year, or that need land compensation are considered medium-scale. Schemes are classed as large-scale if there is a storage capacity of more than 100 million m3 or if they can irrigate at least 80 000 *rais* (12 800 ha). Irrigated areas can be divided into the three categories(Figure 5):

- There were 83 large-scale projects under the Royal Irrigation Department (RID) and operational by 2002 with a combined storage volume of 6 662 million m^3. In 2007, the total command area was about 2.7 million ha. Water management in these projects is the responsibility of RID and water user groups.
- There were 607 medium-scale projects by 2002 with a combined storage volume of 3 191 million m^3. In 2007, the total command area was 898 880 ha. Water management in these projects is also the responsibility of RID and water user groups.
- There were 10 606 small-scale projects by 2002 with a combined storage volume of 2 110 million m^3. In 2007, the total benefit area was around 2.4 million ha. Water management in these projects is the responsibility of local governments and water user groups.

By 1999, there were 1 985 pumping projects. Essentially these are small-scale projects with electrical pumping from nearby waterways. In 2007, their combined command area was 460 000 ha, mainly in the northeast and north. Water management in these projects is the responsibility of RID and water user groups. Management responsibility is to be transferred to Local Governments.

FIGURE 4
Source of irrigation water on area equipped for full control irrigation
Total 6 414 800 ha in 2007



Role of irrigation in agricultural production, economy and society

In 2007, total harvested irrigated cropped area was an estimated 7 387 072 ha. Rice accounts for 6 268 080 ha (2 327 158 ha first season rice and 3 940 922 ha second season rice), or 84.9 percent of the harvested irrigated copped area, vegetables represent 83 421 ha (1.1 percent), sugarcane 256 016 ha (3.5 percent), other annual crops (tobacco, cotton, etc.) 37 396 ha (0.5 percent) and permanent crops 742 159 ha (10.1 percent) (Table 4 and Figure 6). There are also 233 033 ha of fish ponds, which are irrigated and not taken into account in the total, because they are not a crop.

Irrigation development costs US$3 647/ha as follows: construction of head work US$2 187/ha, conveyance system US$860/ha, field system US$600/ha and maintenance cost US$33/ha per year.

FIGURE 5
Type of full control irrigation schemes
Total 6 414 800 ha in 2007

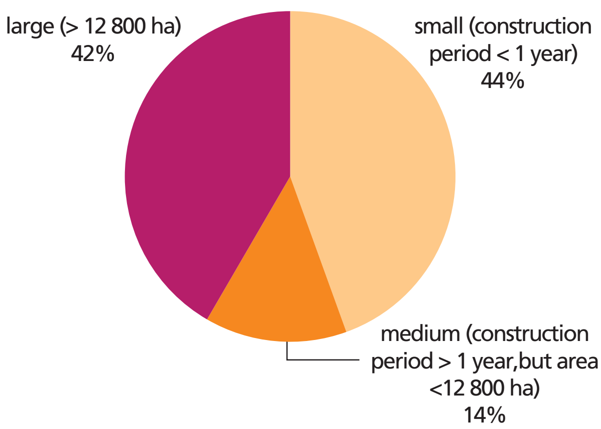
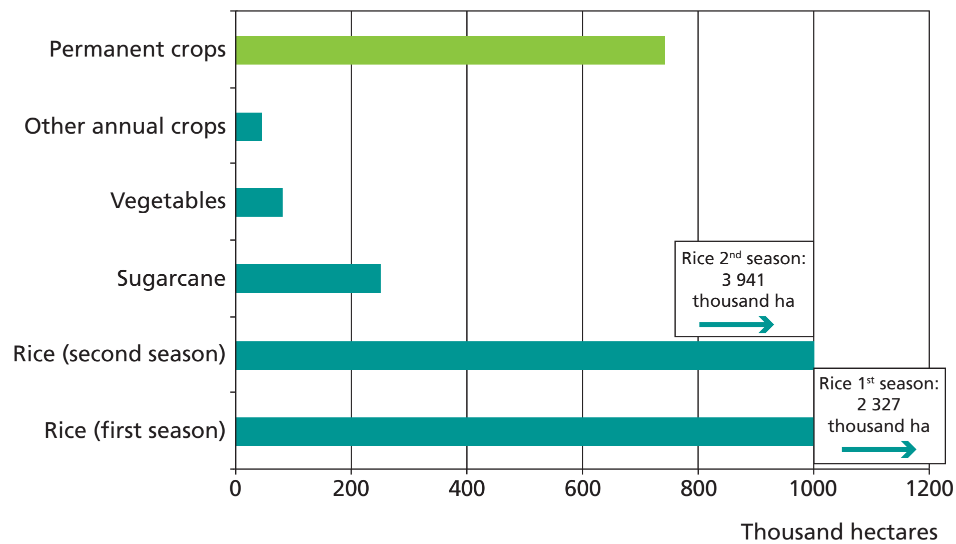


FIGURE 6

Irrigated crops on area equipped for full control irrigation

Total harvested area 7 387 072 ha in 2007 (cropping intensity on actually irrigated area: 146%)



Poverty is observed to be concentrated in non-irrigated areas (or rainfed areas).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

In total there are 31 ministerial departments under ten ministries, one independent agency and six national committees that are involved in water resources development. They are responsible for water policy, irrigation, domestic and/or industrial water supply, fisheries, flood alleviation, hydropower generation, navigation or water quality.

The National Water Resources Committee (NWRC), under the Office of the Prime Minister, is responsible for setting a policy to develop water resources throughout the country.

In general, the Ministry of Natural Resources and Environment (MONRE) is responsible for policy planning while the Ministry of Agriculture and Cooperatives (MOAC) is responsible for implementation.

The National Economic and Social Development Board is responsible for economic planning.

The Department of Groundwater Resources, under the MONRE, monitors groundwater resources, while surface water monitoring is mainly carried out by the Department of Water Resources, and the Royal Irrigation Department, which has its own network.

Many departments or agencies are involved in water supply for domestic or industrial purposes. The main one is the Metropolitan (or Provincial, outside Bangkok) Waterworks Authority. Wastewater treatment and water quality are mainly the responsibility of the Ministry of National Resource and Environment.

Large dams are operated either by RID or by the Electricity Generating Authority of Thailand (EGAT), while small dams have been developed by the Land Development Department or the Department of Water Resources.

The Harbour Department is in charge of protecting inland waterways, and of issuing licenses for navigation.

Irrigation is managed by the RID for public schemes, or by the Department of Water Resources. The RID is the supervising agency for private irrigation.

Water management

There are four levels of water user organization in the irrigation areas:

- Water User Group (WUG): These are the smallest groups, responsible for one tertiary irrigation canal. In 2004, there are 14 930 WUG with 358 846 farmer members.
- Integrated Water Users Group (IWUG): This is integration of many WUG to cover one level up of irrigation canals, the secondary canals. In 2004, there are 410 IWUG with 234 203 farmer members.
- Water Users Association (WUA): This is a legally recognized IWUG. In 2004, there are 40 WUA with 17 575 farmer members. IWUG is not profit oriented.
- Water Users Cooperative (WUC): This is the cooperative form of a WUA. In 2004, there are 83 WUC with 53 158 farmer members. WUC is business-oriented.

Participatory irrigation management (PIM) and cost sharing in water management are encouraged in all the RID irrigation areas but not widespread.

Policies and legislation

By 2025, Thailand is projected to have sufficient water of good quality for all users as a result of its efficient management, organization and a legal system that ensures the equitable and sustainable use of its water resources with due consideration to the quality of life and participation of all stakeholders.

Thailand's nine-point National Water Policy and Vision, as set forth by RID, details how this will be implemented:

- Accelerate promulgation of a Draft Water Act as the framework for national water management by reviewing the draft and implementing all necessary steps to make it effective, including reviewing existing laws and regulations.
- Create water management organizations both at national and river basin level with supportive legislation. The national organization is responsible for formulating national policies, monitoring and coordinating activities to fulfill the policies. The river basin organizations are responsible for preparing water management plans through a participatory approach.
- Emphasize suitable and equitable water allocation for all water use sectors and fulfill basic water requirements in agriculture and domestic uses, to be achieved by establishing efficient and sustainable individual river basin water use priorities under clear water allocation criteria, incorporating beneficiary cost-sharing based on the ability to pay and the level of services used.
- Formulate clear directions for raw water provision and development compatible with basin potentials and demand, ensuring suitable quality while conserving natural resources and maintaining the environment.
- Provide and develop raw water sources for farmers extensively and equitably in response

to water demand for sustainable agriculture and domestic uses, similar to deliveries of other basic governmental infrastructure services.

Most laws related to water management are outdated. All existing laws are focused on individual aspect of water management and none on a holistic view (IWRM). There is no law specifying water rights. Currently there is a draft Water Law that specifies water rights, river basin organizations and national apex body for water management. This draft passed the cabinet in June 2007, and is waiting for approval from the parliament. Earlier versions of this law have been at this stage before but failed to pass.

ENVIRONMENT AND HEALTH

In 2004, surface water quality classified as ‘good’, ‘fair’ and ‘poor’ accounted for 48 percent, 32 percent and 20 percent respectively. The classification carried out by analysing the quality of samples of water taken from natural waterways throughout the country. The overall situation has improved compared to 2003. Critical areas are: lower Chao Phraya in central Thailand and Lower Lam Takong in northeast Thailand. In the North, Northeast and South water quality is good (surface water quality) and improving, while the Central is good with mixed improvement, and the East is fair and stable.

In 1999, in the northeast, 10 percent of the irrigated land was affected by salt. The presence of the salt bearing nature of the soil parent material has been identified as the primary cause. Other activities, such as irrigation, could be classed as secondary causes for accelerating this condition locally. Many programmes have been launched to correctly manage cash crops and paddy on saline soils. Salinization is now reported to be affecting large areas in the coastal parts of the central plain.

Bangkok faces problems of both too much and too little water. Flooding occurs frequently in the wet season owing to low average elevation, high tides and inadequate drainage. The Metropolitan Waterworks Authority is unable to supply water to meet all domestic and industrial demand. As a result, in the outskirts of Bangkok, private and industrial abstraction of groundwater exceeds the safe yield of the aquifer. This accelerates the rate of land subsidence (5-10 cm/year), which in turn aggravates the problem of flooding. Indeed, subsidence has caused some parts of the drainage systems to be below the normal water level and has thus rendered them ineffective.

The minimal discharge to maintain a water level of 1.7 m for navigation (this means 300 m^3/s released in the navigation channel from Nakhon Sawan to the Chao Phraya dam, and 80 m^3/s downstream of the dam) cannot be maintained because large amounts of water are diverted from the river for dry season irrigation in the northern and central regions. This has reduced the volume of inland waterway transport fivefold between 1978 and 1990. The volumes of water released by the Bhumipol and Sirikit dams are increasingly important to prevent saltwater intrusion, even if they do not meet the navigation demand.

Leptospirosis seems to prevail in flood-prone and irrigation areas, but is under control. There are no clear impacts (positive or negative) of irrigation on health. This is probably the result of a the complicated interaction between socio-economic factors and land use changes. People whose paddy is in irrigation areas are better off economically than those in rainfed areas and hence can afford better health care. Changes in land use transform remote irrigation areas into suburban areas with reasonable road access. As noted above, poverty is less in irrigation areas than in rainfed areas.

During the period 1984-2007 Thailand has 317 513 cases of HIV, resulting in 87 643 deaths. Most HIV cases occur in the services and agriculture sectors in age ranges from 25 to 34 years.

In 1999, the main water-borne diseases were acute diarrhoea (affecting 1.48 percent of the population) dysentery (0.14 percent) and enteric fever (0.03 percent). Malaria, as a water-related disease, affected 0.12 percent of the population.

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

Water management in agriculture is said to have to focus on improving water-use efficiency. Reasons for this are:

- the trend indicates that Thailand's water shortage is emerging;
- the agriculture sector consumes the largest proportion of water.

Improving agricultural water-use efficiency must be done through IWRM and must be river basin oriented. To do so, organization and institutional tools must be in place. Organization tools include river Basin Organizations, Apex body and line agencies. Institutional tools include laws, policy and strategies.

In tandem with improving agricultural water-use efficiency, the farmers should move from traditional agriculture to modern agriculture, making use of high technology such as precise water control.

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Timor-Leste

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Timor-Leste is a country in maritime Southeast Asia, covering a total area of 14 870 km^2 (Table 1). It is located northwest of Australia in the Lesser Sunda Islands at the eastern end of the Indonesian archipelago. It includes the eastern half of the island of Timor, the Oecussi (Ambeno) region on the northwest portion of the island of Timor, and the islands of Pulau Atauro and Pulau Jaco. The topography consists of a narrow plain around the coast and a central mountain range dominating the country.

The country is divided into 13 districts: Aileu, Ainaro, Baucau, Bobonaro (Maliana), Cova-Lima (Suai), Dili, Ermera (Gleno), Lautem (Los Palos), Liquica, Manatuto, Manufahi (Same), Oecussi (Ambeno), Viqueque. The name of the district capital is the same as the name in seven of the districts, for the other six the name of the district capital is in brackets.

The total cultivated area in 2009 was an estimated 225 000 ha of which 165 000 ha for annual crops and 60 000 ha for permanent crops.

Climate

The climate of Timor-Leste is characterized by extreme conditions. In the north of the island there is little or no rain for almost eight months of the year. The island has a monsoon climate, typical for the Asian tropics. From December to March northwest to southwest winds prevail, bringing the principal wet season for the year to most parts of the island. From May until October southeast to northeast winds prevail, bringing mostly dry conditions, except on the south coast and the southern slopes where the wet season persists until July. Average annual rainfall is around 1 500 mm, varying from 565 mm at Manatuto along the north coast to 2 837 mm at Lolotai in the central-western mountains. As is common in most tropical locations, extremely heavy rainfall occasionally occurs in Timor-Leste during relatively short time intervals.

There is little temperature variation on either a diurnal or a seasonal basis. Temperature variations mainly occur with altitude. Average annual temperatures decrease from 27 °C at sea level to 24 °C at 500 m; 21 °C at 1 000 m; 18°C at 1 500 m and 14°C at 2 000 m. Relative humidity varies between 70 and 80 percent, which makes the climate humid in general, but pleasant (MAFF, 2004).

Population

In 2009, the total population was almost 1.1 million, of which around 72 percent lived in rural areas (Table 1). The average population density is about74 inhabitants/km^2. Annual average growth rate during the period 1999-2009 was 2.9 percent.

In 2008, access to improved drinking water sources reached 69 percent (86 and 63 percent for the urban and rural population respectively), while access to improved sanitation accounted for 50 percent (76 and 40 percent for the urban and rural population respectively).


TIMOR-LESTE
Legend
FAO - AQUASTAT, 2011
INDONESIA
INDONESIA
Banda Sea
Timor Sea
Dili

TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	1 487 000	ha
Cultivated area (arable land and area under permanent crops)	2009	225 000	ha
• as % of the total area of the country	2009	15	%
• arable land (annual crops + temp fallow + temp meadows)	2009	165 000	ha
• area under permanent crops	2009	60 000	ha
Population			
Total population	2009	1 100 000	inhabitants
• of which rural	2009	72	%
Population density	2009	74	inhabitants/km^2
Economically active population	2009	432 000	inhabitants
• as % of total population	2009	39	%
• female	2009	41	%
• male	2009	59	%
Population economically active in agriculture	2009	344 000	inhabitants
• as % of total economically active population	2009	80	%
• female	2009	45	%
• male	2009	55	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	558	million US$/yr
• value added in agriculture (% of GDP)	2001	25.4	%
• GDP per capita	2009	507	US$/yr
Human Development Index (highest = 1)	2010	0.502	
Access to improved drinking water sources			
Total population	2008	69	%
Urban population	2008	86	%
Rural population	2008	63	%

ECONOMY, AGRICULTURE AND FOOD SECURITY

The total population economically active in agriculture in 2009 was an estimated 344 000 inhabitants, amounting to 80 percent of the economically active population. Women are about 45 percent of the economically active population in agriculture. In 2009, the gross domestic product (GDP) was US$558 million. In 2001, agriculture accounted for 25.4 percent of the GDP (Table 1). Agriculture in Timor-Leste is the most important economic sector.

Agriculture is the main activity in Timor-Leste, providing subsistence to about 80 percent of the population. It also generates an average of 90 percent of the exports, mainly coffee. Most farmers practice subsistence farming, planting and harvesting what they need for a simple life-style, collecting wild foods and traditional medicines, and the animals are very much left free to grow and reproduce. There are almost no large-scale farms except for missions

In the first three-quarters of the last century, the Portuguese Agronomic (or Agriculture) Mission tried to stimulate food production (rice) on the coastal plains, leaving the mountains for coffee. The coffee production system provides a three-layer sustainable ecosystem composed of shade trees which are usually a legume, coffee plants, and grasses. These protect the soil, provide income and employment.

A government priority is to obtain food security for the entire country. The Agriculture Rehabilitation Programme is trying to restore the rice irrigation schemes and rural roads, and Cooperativa Café Timor and others have been sponsoring the rebirth of the coffee sector (Fontes, 2004).

The principal staple crops are rice and maize, with estimated production areas of 38 000 ha for rice and 120 000 ha for maize. However, land suitable for rice production is limited and maize is more widely grown in the uplands including hillsides. As agriculture is dependent on gravity irrigation, irrigation water in many of the irrigated rice areas is available only when the river water level has increased to the level of the intake of the irrigation systems.

Other food crops grown in Timor-Leste include cassava, sweet potato, taro, bananas, squash, kidney beans, soybeans, mungbean, peanut and white potato. Almost every household grows cassava. Together with sweet potato and taro, it provides the source of calorific energy when rice or maize have run out. Cassava and sweet potato grown on about 55 000 ha and 32 000 ha respectively.

Most common commercial crops are Arabica coffee, *chimeri* (candlenut tree), vanilla and coconut. Coffee is grown largely at high elevations in the districts of Liquica, Ermera, Ainaro, Bobonaro and Aileu.

Cropping systems vary depending on topography, elevation, and rainfall pattern. One or two crops of rice dominate the cropping system in the irrigated or rainfed areas of the northern lowlands. Where no irrigation water is available and topographic and hydrologic conditions do not permit growing of flooded rice, maize or peanut followed by cassava, sweet potato, or beans are commonly grown. Cropping systems on the northern slopes include single or two crops of flooded rice, maize followed by cassava, sweet potato or pumpkin, or mixed cropping of maize, cassava, kidney beans or peanut, and sweet potato. In the northern and southern highlands, households still grow rice in small areas supplied by communal systems, maize, cassava, sweet potato, beans, and kantas. On the southern slopes, farmers grow maize followed by cassava or mixed cropping of maize with cassava, sweet potato, and peanut but because of the relatively longer wet period, cropping systems are usually of longer duration (MAFF, 2004).

WATER RESOURCES AND USE

Water resources

Timor-Leste has been broadly divided into twelve ‘Hydrologic Units’, which are groupings of climatologically and physiographically similar and adjacent river basins. Each of these hydrologic units comprise a number of rivers, 29 main river systems in total, of which 12 in the north and 17 in the south. All rivers are generally short and fast-flowing (AWRF, 2006). Table 2 presents the units with the corresponding area in the country. The total length of the rivers is about 4 286 km with a total river surface area of around 18 342 ha (La’o Hamutuk, 2010).

The largest river system is Loes river system with a total area of 2 184 km^2 (covering almost 15 percent of the country). It is also the longest river (80 km long), followed by the Laclo river system and the Clere and Belulic river system with 2 024 km^2 and 1 917 km^2 respectively. Given the temporal variations in rainfall and the low capacity of upland areas to hold water, very few rivers flow all year round, most being ephemeral but generally with significant underbed flows in the lower reaches (AWRF, 2006).

Internal renewable surface water resources are about 8.129 km^3/year and groundwater resources at 0.886 km^3/year. An estimated 0.8 km^3/year or 90 percent returns to the rivers as base flow and may be considered to be the overlap between surface water and groundwater. Therefore,

TABLE 2
Hydrologic units in Timor-Leste

Name of unit	Area (km^2)	As % of country
Loes	2 184	14.7
Laclo	2 024	13.6
Clere and Belulic	1 917	12.9
Irabere	1 614	10.9
Mola and Tafara	1 533	10.3
Seical	1 510	10.2
Tukan and Sahen	1 375	9.2
Laleia	1 006	6.8
Lifau and Tono Besi	812	5.5
Vero	744	5.0
Atauro Island	140	0.9
Jaco Island	11	0.1
Total	**14 870**	**100.0**

total internal renewable water resources (IRWR) are estimated as8.215 km^3/year (8.129+0.886-0.8). The sustainable yield of the aquifers, which can be considered to be the exploitable groundwater, is around0.266 km^3/year (AWRF, 2006).

Some river basins are shared with Indonesia in the border area and Oecussi district. About 9 percent of the Loes river basin, 20 percent of the Tono river basin and 60 percent of the Noel Besi river basin lie in Indonesia, the latter two being in Oecussi district. However, no information on the amount of water crossing the borders is available.

There are several water resources that can be potentially used on a large scale in districts of Manatuto and Aileu where the watershed contains a fairly spacious catchment area, which results in a relatively high water availability. In these regions, multipurpose dams could be built to fulfil raw water and electricity (hydropower) needs. Several locations have been identified where hydropower dams can be built. One of the assessed locations is in Daisoli region.

Timor-Leste has only one large freshwater lake, Lake Ira Lalaru, a large, shallow, seasonally fluctuating lake, which has formed in the lowest part of the Fuiloro plateau, covering between 10 and 55 km^2 depending on the season. Lake Ira Lalaro has a catchment area of 406 km^2, but apart from very heavy rainfall events the catchment characteristically produces little runoff as the lake is situated in a limestone karstic area. While several small watercourses drain into the lake none of these are perennial (AWRF, 2006).

According to the Strategic Development Plan, some dams are planned for construction before 2015: Comoro dam in Dili, Laclo and Sahen dams in Manatuto, Irabele dam in Viqueque, and Caraulun dam in Manufahi (La'o Hamutuk, 2010).

Water use

Total water withdrawal in 2004 was an estimated 1 172 million m^3, of which 1 071 million m^3 (91.4 percent) for agriculture, 99 million m^3 (8.4 percent) for municipalities, and 2 million m^3 (0.2 percent) for industry (Table 3 and Figure 1).

There has been little development of hydropower, there are only a few micro-hydropower plants, one of which is the micro-hydropower plant in Gariuai with a capacity of 325 KW (La'o Hamutuk, 2010).

IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Following an overwhelming vote for independence from Indonesia in an United Nations-backed plebiscite in August 1999, pro-Jakarta militias destroyed most of the infrastructure including irrigation and water supply systems. A country that was in ruins is slowly rebuilding itself with international help. Since October 1999, the United Nations Development Programme (UNDP) has been playing a key role in the irrigation sector. In a rapid response to a potential food crisis

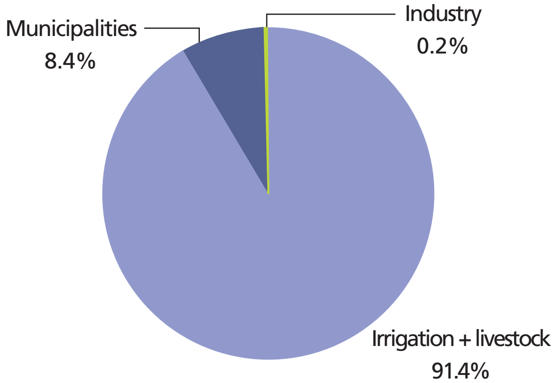
TABLE 3
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 500	mm/yr
	-	22 300	million m^3/yr
Internal renewable water resources (long-term average)	-	8 215	million m^3/yr
Total actual renewable water resources	-	8 215	million m^3/yr
Dependency ratio	-	0	%
Total actual renewable water resources per inhabitant	2009	7 468	m^3/yr
Total dam capacity	-	-	million m^3
Water withdrawal			
Total water withdrawal	2004	1 172	million m^3/yr
- irrigation + livestock	2004	1 071	million m^3/yr
- municipalities	2004	99	million m^3/yr
- industry	2004	2	million m^3/yr
• per inhabitant	2004	1 203	m^3/yr
Surface water and groundwater withdrawal	2004	1 172	million m^3/yr
• as % of total actual renewable water resources	2004	14.27	%
Non-conventional sources of water			
Produced wastewater		-	million m^3/yr
Treated wastewater		-	million m^3/yr
Reused treated wastewater		-	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

resulting from lack of cultivation during the rice planting season in Manatuto, 80 km east of Dili, UNDP designed an irrigation project to rehabilitate the damaged rice watering systems. This enabled farmers to restart rice cultivation. The rehabilitation work also provided employment and modern technology for rice cultivation was passed onto farmers (UNDP, 2000).

Before the destruction in 1999, the total design irrigation area in Timor-Leste was an estimated 72 159 ha covering more than 427 schemes. In 2002 only 34 649 ha or 48 percent was left, of which 5 384 ha are technical schemes, 7 770 ha semi-technical schemes and 21 495 ha traditional schemes (Table 4 and Table 5). MAFF is also transferring the irrigation schemes to community-based management.

FIGURE 1
Water withdrawal by sector
Total 1.172 km^3 in 2004



This will be a long task involving significant cultural change and the irrigators are only slowly starting to take over themselves, since all operation and maintenance before was done by the Indonesian administration. Irrigation demand is presently low because of the lack of commodity marketing arrangements, conveyance systems and infrastructure, which makes internal transport highly costly (ADB, 2002). Based on national reports, and the situation in neighbouring Indonesia, the area irrigated by groundwater is about 2 percent of the total area equipped for irrigation (Figure 2).

The Japan International Cooperation Agency (JICA) implemented the Irrigation and Rice

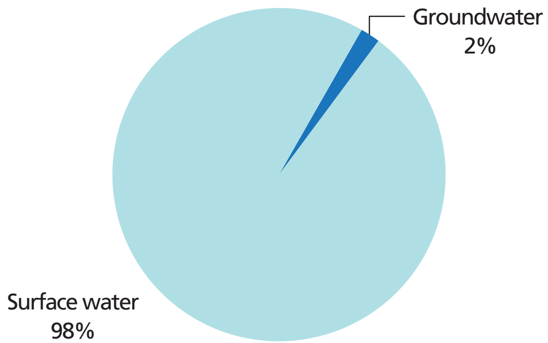
TABLE 4
Irrigation and drainage

Irrigation potential			-	ha
Irrigation				
1. Full control irrigation: equipped area		2002	34 649	ha
- surface irrigation			-	ha
- sprinkler irrigation			-	ha
- localized irrigation			-	ha
• % of area irrigated from surface water		2002	98	%
• % of area irrigated from groundwater		2002	2	%
• % of area irrigated from mixed surface water and groundwater			-	%
• % of area irrigated from non-conventional sources of water			-	%
• area equipped for full control irrigation actually irrigated		2002	28 907	ha
- as % of full control area equipped		2002	83.4	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)		2002	0	ha
3. Spate irrigation		2002	0	ha
Total area equipped for irrigation (1+2+3)		**2002**	**34 649**	**ha**
• as % of cultivated area		2002	16	%
• % of total area equipped for irrigation actually irrigated		2002	83.4	%
• average increase per year over the last 12 years			-	%
• power irrigated area as % of total area equipped			-	%
4. Non-equipped cultivated wetlands and inland valley bottoms		2002	0	ha
5. Non-equipped flood recession cropping area		2002	0	ha
Total water-managed area (1+2+3+4+5)		**2002**	**34 649**	**ha**
• as % of cultivated area		2002	16	%
Full control irrigation schemes:	**Criteria:**			
Small-scale schemes	< ha		-	ha
Medium-scale schemes			-	ha
Large-scale schemes	> ha		-	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes:				
Total irrigated grain production			-	metric tons
• as % of total grain production			-	%
Harvested crops:				
Total harvested irrigated cropped area			-	ha
• Annual crops: total			-	ha
- Rice			-	ha
- Maize			-	ha
- Other annual crops			-	ha
• Permanent crops: total			-	ha
- Other perennial crops			-	ha
Irrigated cropping intensity (on full control equipped actually irrigated area)			-	%
Drainage - Environment:				
Total drained area			-	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area			-	%
Flood-protected areas			-	ha
Area salinized by irrigation			-	ha
Population affected by water-related diseases		1995	-	inhabitants

TABLE 5
Irrigation schemes and irrigation areas, March 2002 (ADB, 2002)

	Number of schemes	Pre-1999 design area (ha)	Area currently functioning (ha)	Percentage functional (%)
Technical schemes	24	10 587	5 384	51
Semi-technical schemes	58	18 320	7 770	42
Traditional schemes	345	43 252	21 495	50
Total	**427**	**72 159**	**34 649**	**48**

FIGURE 2
Source of irrigation water on area equipped for full control irrigation
Total 34 649 ha in 2002



Cultivation Project in Manatuto District (06/2005-03/2010). This was to improve productivity of rice on approximately 505 ha of the irrigated area. The objectives of the project was to improve the existing irrigated rice farming system on around 505 ha and establish a functional water Uuser association (WUA) (JICA, 2008).

JICA has supported the Rehabilitation and Improvement of Maliana I Irrigation System Project (02/2008-11/2008). This aimed to distribute a stable supply of irrigation water to Maliana I Irrigation area. This was accomplished by rehabilitating the Maliana I intake weir and irrigation canals and constructing related facilities. The project expected to increase the amount of water taken from Bulobo river and to expand the irrigation area from 600 ha to 1 050 ha to increase rice production (JICA, 2008).

Role of irrigation in agricultural production, economy and society

Rice is the key food and cash crop. The major impediments to rice cultivation are the shortage of irrigation water and the lack of cattle and tractors to speed up cultivation. The main rice crop in Timor-Leste is grown in the wet season from November to March (UNDP, 2000).

Less than 20 percent of the irrigated rice areas produce a second crop of rice within the year. Yield per hectare is low compared to other rice-growing countries in Asia, largely because of poor application of improved technologies including use of quality seeds, fertilizer, and sometimes the limited supply of irrigation water. Because of high cost, among other reasons, farmers do not normally use fertilizer to produce rice. Use of poor quality seeds, poor soil conditions, drought, and occasionally pests and diseases are the usual causes of low maize yields. About 81 percent of households grow maize (MAFF, 2004).

WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

Institutions

In mid-2001 a proposal to establish a single agency with responsibility for water resources was not accepted. The present arrangements are therefore built around a requirement for coordination among agencies, without any main body or specific coordinating mechanism in place (ADB, 2002).

The main institutions related to water and agriculture are:

- Ø Ministry of Agriculture, Forestry and Fisheries (MAFF): Mainly responsible for policy formulation, economic coordination and planning concerning food grain, other agricultural crops and livestock. It contains the Irrigation Division.
- Ø Ministry of Development: Responsible for national policy programmes and plans regarding environment, pollution, ecology.
- Ø National Directorate of Environmental Services (DNSMA in Portuguese): Responsible for pollution control, environmental policy, impact assessments, monitoring and awareness raising, and biodiversity. It is contained in the Secretariat for Environment Coordination, Territorial Ordering and Physical Development.
- Ø Ministry of Natural Resources, Minerals and Energy Policy (MNRMEP): The role of this new ministry, as stated in the 2005/2006 budget papers, is to manage the natural resources of Timor-Leste efficiently and in a consistent and an environmentally acceptable way (AWRF, 2006).

Water management

Water resources in Timor-Leste are optimally managed (La'o Hamutuk, 2010).

WaterAid has worked in Timor-Leste since 2005 helping the country's poorest people gain access to safe, sustainable water supplies and sanitation (Water Aid Australia, 2010).

In 2008, the Ministry of Agriculture, Forestry and Fisheries (MAFF) sought to appoint an Irrigation Consultant to assist the Irrigation Division to identify the required action to repair and maintain selected irrigation schemes and provide technical advice on planned rebuilding of other irrigation schemes (DebNetJobs, 2008).

According to the Strategic Development Plan, presented in 2010, the framework and policy direction of the development of the water resources must be gradually implemented as follows:

- Ø Short-term (2010-2015): Formulation of a policy to preserve the water cycle balance. The short-term purpose and objectives are to protect the hydrology cycle to safeguard the natural conservation balance, especially forest, river, watershed, sea and coastal area conservation. Ongoing development must consider the environmental conservation factor.
- Ø Mid-term (2015-2020): Utilization of water resources to meet the water demand of the society and to fulfill the energy demand. The mid-term purpose and objectives are to exploit water resources with appropriate technological use such as barrages and hydropower, with the intention of fulfilling water and energy demand of the society as the number of population grows.
- Ø Long-term (>2020): Reduction of the dependency on diesel power generators, to be replaced using hydropower. The long-term purpose and objectives are to reduce the burden of diesel power generator use, since it is uneconomical and environmentally unfriendly for natural conservation.

Finances

The agricultural and rural sectors were severely disrupted owing to the civil disturbances in 1999 when the previous Indonesian system of highly subsidised support was withdrawn and a great deal of physical damage inflicted on the people, infrastructure and rural market systems. The donor community, through the World Bank, established the Trust Fund for Timor-Leste to provide financial means to rehabilitate many structures and mechanisms that were damaged or destroyed during the last months of occupation. In the agricultural sector, funds were channelled through the MAFF-managed Agricultural Rehabilitation Projects: ARP I, ARP

II and ARP III. ARP I started in August 2000, which was completed in September 2002, including the rehabilitation of small irrigation schemes.

ARP II started in October 2001 and was completed in December 2004, continuing the restoration of agriculture assets, irrigation infrastructure and restoration of vaccination services with the general objective of improving the food security of rural families and increasing agricultural production in selected areas. ARP III began in April 2004 and was finished in 2007, the objective was to strengthen the capacity of MAFF and its development partners and assist rural communities sustainably increase their production and income (MAFF, 2004).

Policies and legislation

The current limited demand for water development lends weight to the view that comprehensive and sophisticated policies are not warranted. However, the water and sanitation and the irrigation agencies all perceive the need for a water resources policy from their perspective (ADB, 2002).

ENVIRONMENT AND HEALTH

Timor-Leste, thanks to its agricultural economy and the absence of large population centres, does not suffer from the problems of industrialization. It will, nevertheless, suffer from global climate change. There are other environmental problems that can affect its future. Soil erosion, caused by both high rainfall (it rains more than 1 750 mm/year on 65 percent of the island) and by the great slope of the mountain areas, can be serious. Itinerant agriculture, deforestation and the subsequent loss of vegetation may have consequences that are difficult to reverse and may cause a reduction in crop production. On the positive side, farmers hardly ever use agrochemicals, which means that the farm produce can almost all be classified as organically grown (MAFF, 2004)

The rains can bring with them large-scale flooding that washes pollution into the waterways. This water quality is often poor. The climate is favourable to mosquitoes, and the poor sanitation in the cities means that malaria is one of the major causes of death, which impacts economic and educational development. WaterAid Australia's programme aims to deliver sustainable, community-managed water and sanitation services to rural communities in Aileu district as well as health and hygiene education in Aileu, Baucau, Manatuto and Lautem districts (Water Aid Australia, 2010).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

According to the Strategic Development Plan (2010-2020), the work plan related to agricultural water management includes:

- Ø preparing hydrology and climatology data that has already been measured;
- Ø making an inventory of the operational state of water infrastructure;
- Ø reviewing of every watershed;
- Ø increasing the capacity of clean water availability;
- Ø increasing the number of irrigated areas in conjunction with the increase of raw water sources;
- Ø renovating existing barrages to enhance performance and establishing new reservoirs in areas to meet the demands for drinking and irrigation water;
- Ø improving and expanding flood control check dams; and
- Ø establishing multipurpose dams to meet clean water, irrigation and power plant demand.

With the growing economic needs of the people, it will be necessary to move beyond the existing crops. It is felt that the production of higher value crops (cashew nuts, mangos, spices, vanilla, restoration of sandalwood, pineapples, passion fruit, guavas, cut flowers) associated with processing (roasting of nuts, mango pulp, guava jam, passion fruit concentrate) are the next stage in the development of the agriculture sector (Fontes, 2004).

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Viet Nam

GEOGRAPHY, CLIMATE AND POPULATION

Geography

Viet Nam is located in the eastern part of the Indochina peninsula, bordered by China in the north, the South China Sea in the east and south, the Gulf of Thailand in the southwest, and Cambodia and Lao People's Democratic Republic in the west. The total area of the country is 331 052 km^2 (Table 1). The country is divided into 64 provinces including the capital Hanoi. Based on topographic, climatic and socio-economic conditions, these provinces are grouped into eight regions from north to south: North West, North East, Red river delta, North Central Coast, South Central Coast, Central Highland, South East and Mekong river delta.

Mountains and hills cover more than three-quarters of the territory, although over 70 percent of the country lies below 500 m above sea level. Viet Nam has a dense hydrographic network. About 25 percent of the total land area is covered by plains, the most important being the Bac Bo in the north and Nam Bo in the south, corresponding to the courses of the Red river and Mekong river respectively.

In 2009, the total cultivated area was 9.63 million ha, of which 6.28 million ha was arable land and 3.35 million ha under permanent crops. Rice is by far the largest crop, followed by amongst others maize, coffee, rubber, tubers, vegetables and coconut.

Climate

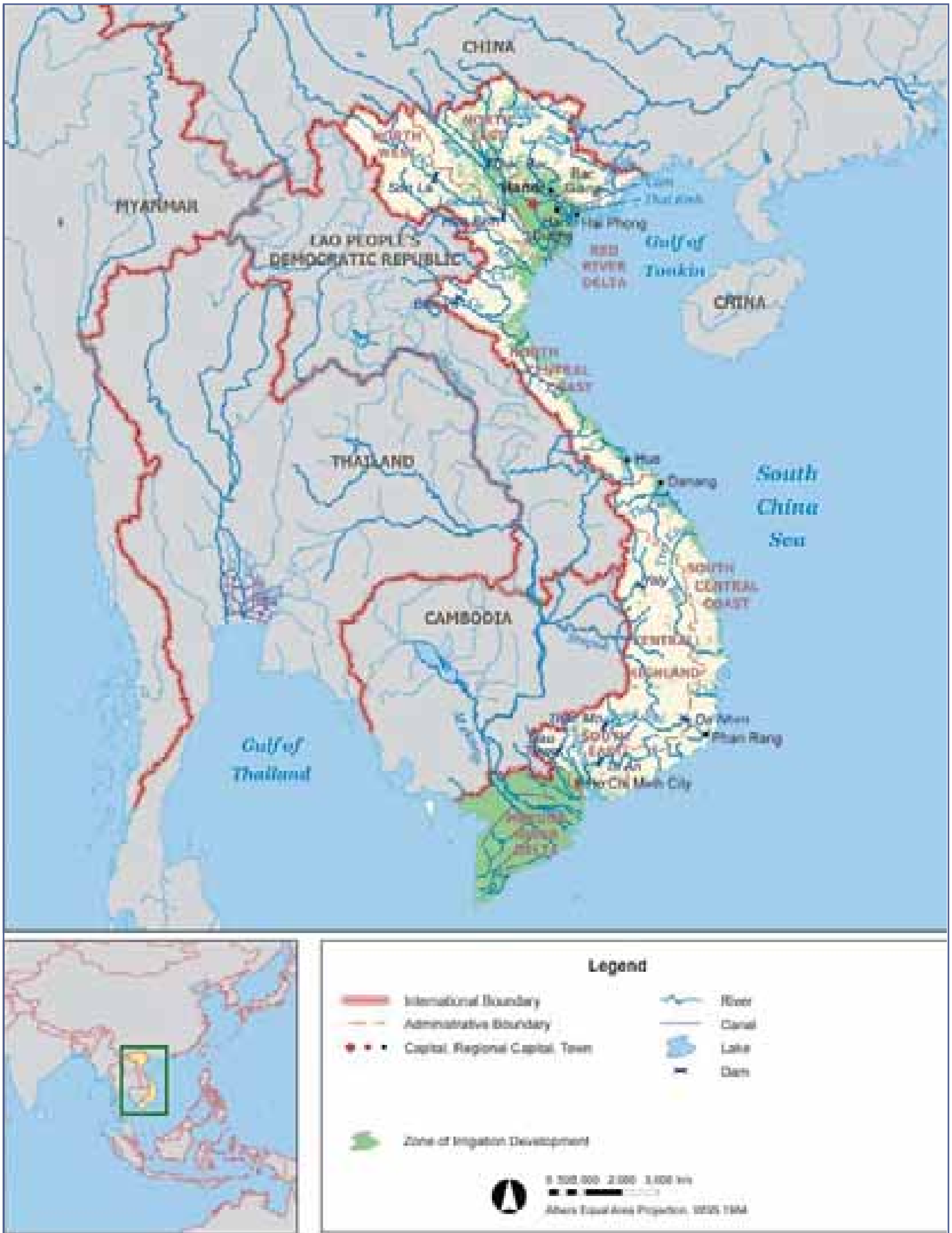
Viet Nam is located in a complicated climatic zone: hot, humid and rainy. It is characterized by a subtropical climate with four separate seasons – spring, summer, autumn and winter – in the north and a tropical climate with only two seasons – dry and wet – in the south. Average annual precipitation is around 1 820 mm (Table 2). It varies from an average 1 600 to 2 200 mm in the midlands and plains and 2 000 to 2 500 mm in the mountainous areas. A minimum of 650 mm can be found in Phan Rang in the South Central region and a maximum of 4 760 mm in Bac Quang in the North East region. The rainy season lasts from April-May to October-November.

The driest periods are either from December to February or from January to March depending on specific location. Central Viet Nam is often affected by hurricanes and storms and very large waves from the South China Sea. Annual average evaporation is 953 mm. Average temperature varies from 15 °C in winter to 25 °C in summer. Temperature during the hottest days is 38-40 °C and, during the coldest days, 11-14 °C in the north.

Population

The total population in 2009 was around 86.9 million, of which 70 percent lived in rural areas (Table 1). The estimated average annual population growth rate for 1999-2009 was an estimated 1. 1 percent. Population density in 2009 was about 263 inhabitants/km^2.

In 2008, the rate of urban population with access to improved water supply was 99 percent whereas that of the rural population was 92 percent.



VIET NAM

FAO - AQUASTAT, 2011

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TABLE 1
Basic statistics and population

Physical areas			
Area of the country	2009	33 105 200	ha
Cultivated area (arable land and area under permanent crops)	2009	9 630 000	ha
• as % of the total area of the country	2009	29	%
• arable land (annual crops + temp fallow + temp meadows)	2009	6 280 000	ha
• area under permanent crops	2009	3 350 000	ha
Population			
Total population	2009	86 901 000	inhabitants
• of which rural	2009	70	%
Population density	2009	263	inhabitants/km^2
Economically active population	2009	46 076 000	inhabitants
• as % of total population	2009	53	%
• female	2009	49	%
• male	2009	51	%
Population economically active in agriculture	2009	29 301 000	inhabitants
• as % of total economically active population	2009	64	%
• female	2009	49	%
• male	2009	51	%
Economy and development			
Gross Domestic Product (GDP) (current US$)	2009	90 091	million US$/yr
• value added in agriculture (% of GDP)	2009	21	%
• GDP per capita	2009	1 037	US$/yr
Human Development Index (highest = 1)	2010	0.572	
Access to improved drinking water sources			
Total population	2008	94	%
Urban population	2008	99	%
Rural population	2008	92	%

ECONOMY, AGRICULTURE AND FOOD SECURITY

In 2009, gross domestic product (GDP) of Viet Nam was US$90 091 million, with a value added in agriculture reaching the 21 percent of the GDP. The total economically active population was about 46.1 million inhabitants (49 percent female) of which 29.3 million are active in agriculture (49 percent female) (Table 1). The average annual unemployment rate was 5.8 percent during the period 2001–2005.

Agriculture plays a very important role in socio-economic development, in poverty alleviation and in food security. Recently, the country has become one of the three top countries in the world for rice exports, together with Thailand and the United States.

The production of cereals, sugar, roots, tubers and meat is large enough to ensure both domestic consumption and provide a surplus for export. However, the country's production capacity for vegetable oils and milk does not meet domestic demand.

About one-fifth of all rural households are headed by women. Gender inequality between male and female headed households in the agricultural sector, identified on the basis of the 2006 rural, agriculture and fishery census, includes inequalities related to access to land, land size, irrigated land cultivated land. National level results show that access to agricultural land in rural areas by households headed by women is 13 percent lower than that for households headed by men.

TABLE 2
Water: sources and use

Renewable freshwater resources			
Precipitation (long-term average)	-	1 821	mm/yr
	-	603 000	million m^3/yr
Internal renewable water resources (long-term average)	-	359 400	million m^3/yr
Total actual renewable water resources	-	884 100	million m^3/yr
Dependency ratio	-	59.4	%
Total actual renewable water resources per inhabitant	2009	10 174	m^3/yr
Total dam capacity	2009	28 038	million m^3
Water withdrawal			
Total water withdrawal	2005	82 031	million m^3/yr
- irrigation + livestock	2005	77 751	million m^3/yr
- municipalities	2005	1 206	million m^3/yr
- industry	2005	3 074	million m^3/yr
• per inhabitant	2005	986	m^3/yr
Surface water and groundwater withdrawal	2005	82 031	million m^3/yr
• as % of total actual renewable water resources	2005	9.3	%
Non-conventional sources of water			
Produced wastewater	2003	1 100	million m^3/yr
Treated wastewater	2003	250	million m^3/yr
Reused treated wastewater	2003	175	million m^3/yr
Desalinated water produced		-	million m^3/yr
Reused agricultural drainage water		-	million m^3/yr

The average area of land accessed by households headed by women a is 27 percent smaller than that of male headed households. Further, the size of irrigated land among female headed households is 41 percent less compared to that of male headed households. Less than 10 percent of all commercial farms in Viet Nam are owned by households headed by women. Other gender inequalities include access to information and communication, access to loans and livestock production (FAO, 2010).

WATER RESOURCES AND USE

Water resources

The distribution of water resources is highly variable during the year owing to unevenly distributed monsoon rainfall. High variations, combined with limited storage and flood control infrastructure, result in devastating floods in the wet season and extreme low flows in the dry season. About 70-75 percent of the annual runoff is generated in three to four months.

Viet Nam has a dense network of 2 360 rivers with a length of more than 10 km each. There are 16 river basins that are larger than 2 000 km^2, eight of which have a catchment area larger than 10 000 km^2 (Table 3). Other basins are either have a small area, such as Tien Yen and Muc, or have several small coastal rivers grouped together, such as Giang/Huong, Tra Khuc and Cai-Luy. The eight major basins represent 77 percent of the country's area. The largest basins are the Mekong and the Red river/Thai Binh, covering 45 percent of the territory.

Almost 60 percent of the total water resources are generated outside the country, making the country susceptible to decisions made about water resources in upstream countries. The total area of all international basins in and outside Viet Nam is to 1.2 million km^2.

TABLE 3
Eight large river basins in Viet Nam

River basin	Total area of basin (km²)	Area of basin in Viet Nam (km²)	% of basin in Viet Nam	% of Viet Nam in basin
Mekong	795 000	63 600	8	19
Red River-Thai Binh (includes Da River basin)	155 000	85 250	55	26
Dong Nai	44 100	37 485	85	12
Ma-Chu	28 400	17 608	62	5
Ca	27 200	17 680	65	5
Ba	13 900	13 900	100	4
Ky Cung-Bang Giang	11 220	10 547	94	3
Thu Bon	10 350	10 350	100	3
Total	**1 086 170**	**256 420**		**77**

Viet Nam has abundant surface water resources in terms of total runoff, which accounts for 848 km^3/year on average, but the shortage of water is aggravated during the 6-7 months dry season when the runoff is only 15-30 percent of this total. About 323 km^3/year (38 percent) of the total runoff are generated within the country.

More than 90 percent of the Mekong river basin and 45 percent of the Red river basin lie outside Viet Nam. The Ma and Ca rivers both have about 40 percent of their basin area outside the country and the Dong Nai 15 percent. The average annual contribution from neighbouring countries to the runoff in Viet Nam is around 524.71 km^3, including 470.1 km^3 (Mekong) and 1.41 km^3 (Dong Nai) from Cambodia, 44.1 km^3 (Red) from China, and 9.1 km^3 (Ca and Ma) from Lao People's Democratic Republic.

Internal renewable groundwater resources are abundant, an estimated 71.418 km^3/year. Over 50 percent of these resources are in the central part, about 40 percent in the north and 10 percent in the south. A large amount of water is stored in unconsolidated alluvial sand and gravel geological formations found in plains and valleys. An estimated 35 km^3/year returns to the rivers as base flow and can be considered to be the overlap between surface water and groundwater. Therefore total Internal Renewable Water Resources (IRWR) are an estimated 359.418 km^3/year (=323+71.418-35). By adding together the internal and external water resources, the total renewable water resources are an estimated 884.128 km^3/year.

The exploitable groundwater resources are about 6-7 km^3/year. In some areas, over-exploitation has caused water tables to fall, which has contributed to further land subsidence and salinity intrusion, especially in the Mekong river delta.

Viet Nam is rich in freshwater and marine wetlands, which are mainly distributed in the Red river and the Mekong river deltas and along the 3 260 km coastline. The *Directory of Asian Wetlands* lists over 25 wetland sites in Viet Nam that meet the criteria for 'Wetlands of International Importance'. Despite this the only designated site under the Ramsar Convention is the Xuan Thuy National Park, a 12 000 ha mangrove in the Red river delta region. However, there are plans for additional Ramsar sites, including the Tram Chim National Park in Dong Thap province in the Mekong river delta.

In 2000, Can Gio mangrove forest was designated as 'Man and Biosphere Reserve' by the United Nations Educational, Scientific and Cultural Organization (UNESCO), Viet Nam's first protected area. More wetland sites are being proposed for inclusion in a list of protected areas. Also, to fulfil the government commitments to the Ramsar Convention, the Ministry of Natural Resources and Environment (MONRE) has submitted a government decree on wetland conservation and sustainable utilization to the Prime Minister. A national strategy on wetland management and conservation was approved in 2003.

There are two natural lakes in Viet Nam: Lake Ho-Tay with a surface area of 4.13 km^2 and a volume of 8 million m^3, and Lake Ba Be with a surface area of 4.5 km^2 and a volume of 90 million m^3.

Viet Nam has 800 medium and larg dams and reservoirs, and 1 967 reservoirs with a storage capacity of at least 0.2 km^3. In 2009, total dam capacity was about 28 km^3. Seven dams have a capacity of more than 1 km^3: Hoa Binh (9.5 km^3), Thac Ba (2.9 km^3), Tri An (2.8 km^3), Tuyen Quang (2.2 km^3), Dau Tieng (1.6 km^3), Thac Mo (1.4 km^3) and Yaly (1.0 km^3). Another four dams of over 1 km^3 are under construction: Son La (9.3 km^3), Phuoc Hoa (2.5 km^3), Ban Ve (1.8 km^3) and Cua Dat (1.4 km^3). Most reservoirs are multipurpose: hydropower, flood control, navigation, irrigation and fisheries.

Viet Nam has an estimated hydropower potential of about 14 000 to 17 000 MW of which nearly 3 600 MW have been developed, and about 800 MW are under construction. The National Hydropower Plan Study plans a possible installation of an additional 5 045 MW. Hydropower is a non-consumptive use of water, but the need to maintain a certain water level may negatively affect availability downstream. This may cause local drought and water use conflicts between hydropower and agriculture downstream, and sudden releases may cause flooding and river erosion. Therefore, the operation of hydropower plants needs to be coordinated with other water using sectors, mainly agriculture.

In 2003, out of a total of 1 100 million m^3 of wastewater produced, about 250 million m^3 were treated, of which 70 percent (175 million m^3) were reused (Table 2).

International water issues

Viet Nam is a downstream riparian state for most of its transboundary rivers, of which the six major ones are: the Bang-Ky Cung and Red rivers, coming from China; the Ma and Ca, coming from Lao People's Democratic Republic; and the Dong Nai and Mekong, coming from Cambodia. Most of the rivers flow to the Gulf of Tonkin and the South China Sea. The Bang-Ky Cung flows to China, and the Srepok to the Mekong in Cambodia.

The government has obtained many agreements with the neighbouring countries related to the exploitation and management of these rivers, such as water allocation, pollution management, flood control and others. The agreement established in 1995 by the four lower Mekong riparian countries offers new opportunities for regional collaboration in developing the basin's water and related ecological resources. Some examples of promising collaboration are related to flood control in the Mekong delta with Cambodia, and the possible importation of hydropower from upper riparians.

Water use

In 2005, the total annual water withdrawal for agriculture, industries and municipal purposes was an estimated 82.03 km^3. Irrigated agriculture uses the most water, accounting for 77.75 km^3 or 94.8 percent of total water withdrawals (Table 2 and Figure 1). Industrial and municipal sectors account for 3.07 km^3 (3.7 percent) and 1.21 km^3 (1.5 percent) respectively. In 1990, total annual water withdrawal was around 54.3 km^3, of which agriculture accounted for 86 percent, industrial use for 10 percent and municipal use for 4 percent.

In 2005, primary surface water withdrawal was around80.45 km^3 (98.1 percent of total water withdrawal), while primary groundwater withdrawal accounted for only 1.40 km^3 (1.7 percent) (Figure 2). Groundwater is mainly used for municipal water supply in urban areas. In 2003, reused treated wastewater was about 175 million m^3, which represents 0.2 percent of total water withdrawal. In 1990, it was estimated that less than 1.5 percent of the water withdrawal was met by groundwater.

FIGURE 1
Water withdrawal by sector
Total 82.031 km³ in 2005

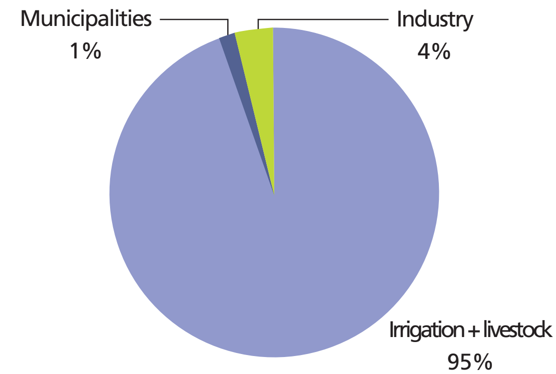
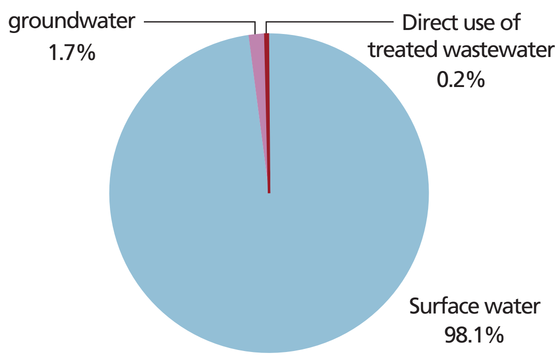


FIGURE 2
Water withdrawal by source
Total 82.031 km³ in 2005



IRRIGATION AND DRAINAGE DEVELOPMENT

Evolution of irrigation development

Small indigenous irrigation systems have long been employed in Viet Nam. Modern irrigation development stagnated until reunification of the country in 1975.

Early post-1975 growth was in small and medium irrigation schemes, while during the period 1985-1990 growth was concentrated in large irrigation and multipurpose schemes. The total irrigated area expanded at a rate of 2.9 percent/year in the period 1980-1987, while between 1988 and 1994 it was 4.58 percent/year. In 1994, there were about 3 million ha of irrigated land in Viet Nam.

The irrigation potential has been evaluated as 9 400 000 ha (Table 4). In 2005, the total equipped area for irrigation accounted for 4 585 500 ha or 48.8 percent of the potential. The actually irrigated area was 100 percent of the area equipped for irrigation. Although the potential for irrigation development is large, upgrading the existing and constructing new irrigation systems requires a huge amount of capital. This, indeed, is a considerable challenge for the country because of limited national budget and external assistance.

In 2005, surface irrigation accounted for 99.98 percent of the total area equipped for irrigation, while sprinkler irrigation accounted for 0.02 percent (Figure 3). In 2005, 99 percent of the area equipped for irrigation was irrigated by surface water, while groundwater accounted for 1 percent (Figure 4).

The average yearly increase during the period 1994-2005 was around 3.9 percent. During this period Viet Nam invested in the water sector, which included construction of new infrastructure and rehabilitation of existing works especially irrigation and drainage systems.

There are 1 638 297 ha of small irrigation systems (< 5 000 ha), 1 202 390 ha of medium irrigation schemes (5 000 – 50 000 ha) and 1 744 813 ha of large irrigation schemes (> 50 000 ha) (Figure 5). About 2 148 140 ha were power irrigated. In 1994, two-thirds of the total irrigation area was in the two large deltas (37 percent in the Red delta, and 27 percent in the Mekong delta).

In 1994, of the total irrigated area, formal government schemes covered about 54.4 percent, equipped with pumped or gravity irrigation. The remaining area was private land, which

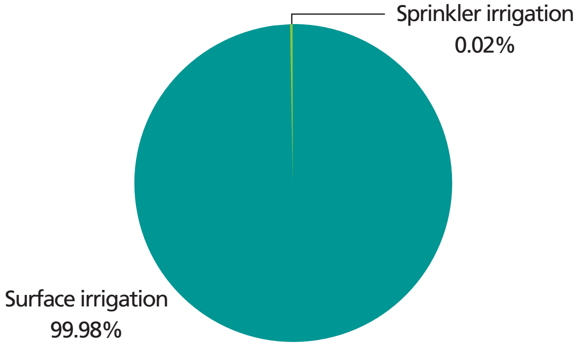
TABLE 4
Irrigation and drainage

Irrigation potential			9 400 000	ha
Irrigation				
1. Full control irrigation: equipped area		2005	4 585 500	ha
- surface irrigation		2005	4 584 400	ha
- sprinkler irrigation		2005	1 100	ha
- localized irrigation			-	ha
• % of area irrigated from surface water		2005	99	%
• % of area irrigated from groundwater		2005	1	%
• % of area irrigated from mixed surface water and groundwater				%
• % of area irrigated from mixed non-conventional sources of water				%
• area equipped for full control irrigation actually irrigated		2005	4 585 500	ha
- as % of full control area equipped		2005	100	%
2. Equipped lowlands (wetland, ivb, flood plains, mangroves)			-	ha
3. Spate irrigation			-	ha
Total area equipped for irrigation (1+2+3)		**2005**	**4 585 500**	**ha**
• as % of cultivated area		2005	49	%
• % of total area equipped for irrigation actually irrigated		2005	100	%
• average increase per year over the last 11 years		1994-2005	3.9	%
• power irrigated area as % of total area equipped		2006	47	%
4. Non-equipped cultivated wetlands and inland valley bottoms			-	ha
5. Non-equipped flood recession cropping area			-	ha
Total water-managed area (1+2+3+4+5)		**2005**	**4 585 500**	**ha**
• as % of cultivated area		2005	49	%
Full control irrigation schemes	**Criteria**			
Small-scale schemes	< 5 000 ha	2005	1 638 297	ha
Medium-scale schemes	> 5 000 ha and < 50 000 ha	2005	1 202 390	ha
Large-scale schemes	> 50 000 ha	2005	1 744 813	ha
Total number of households in irrigation			-	
Irrigated crops in full control irrigation schemes				
Total irrigated grain production (wheat and barley)			-	metric tons
• as % of total grain production			-	%
Harvested crops				
Total harvested irrigated cropped area		2005	8 728 192	ha
• Annual crops: total		2005	7 743 297	ha
- Rice		2005	6 842 127	ha
- Maize		2005	265 540	ha
- Sweet potatoes		2005	99 532	ha
- Cassava		2005	167 920	ha
- Groundnuts		2005	139 304	ha
- Soyabeans		2005	97 119	ha
- Sugarcane		2005	105 800	ha
- Cotton		2005	14 790	ha
- Tobacco		2005	8 600	ha
- Other annual crops		2005	2 565	ha
• Permanent crops: total		2005	984 895	ha
- Bananas		2005	54 626	ha
- Citrus		2005	46 068	ha
- Coffee		2005	259 607	ha
- Tea		2005	62 551	ha
- Rubber		2005	253 690	ha
- Coconuts		2005	25 041	ha
- Other permanent crops		2005	283 312	ha
Irrigated cropping intensity (on full control area actually irrigated)		2005	190	%
Drainage - Environment				
Total drained area		2006	2 538 844	ha
- part of the area equipped for irrigation drained			-	ha
- other drained area (non-irrigated)			-	ha
• drained area as % of cultivated area		2006	27	%
Flood-protected areas			-	ha
Area salinized by irrigation		1999	300 000	ha
Population affected by water-related diseases			-	inhabitants

was irrigated by swing baskets, buckets, small private pumps and small gravity diversion systems. This type of irrigation is concentrated in the Mekong delta and, to a much lesser extent, in the Red delta. Some 59 percent of the pump irrigation capacity is electrically driven, the remainder relies on oil powered engines.

Currently, Viet Nam has 75 large hydraulic works, 5 000 irrigation culverts and drainage sewers (large), and over 10 000 pumping stations (large and medium) with the total capacity of 24.8 million m^3/h.

FIGURE 3
Irrigation techniques on area equipped for full control irrigation - Total 4 585 500 ha in 2005



Role of irrigation in agricultural production, economy and society

Irrigated agriculture plays a very important role in the socio-economic development of the country for poverty reduction, food security, gender equity improvement in rural areas, and the improvement of cropping patterns and the environment. Areas relying on full irrigation attained an average paddy yield of 4.89 tonnes/ha for the entire country. The highest paddy yield of 5.44 tonnes/ha was in the Red River Delta and the lowest paddy yield of 3.58 tonnes/ha was in the North West.

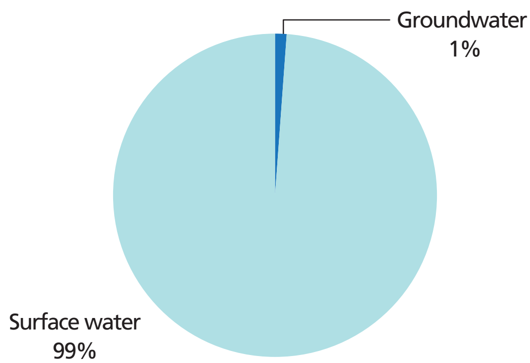
In 2005, the value of cereals produced was about US$7 000 million. As reported in 2005, the total harvested irrigated cropped area was around 8 728 192 ha. The main crops are cereals, such as rice (6 842 000 ha) and maize (265 540 ha), and industrial trees such as coffee (259 600 ha) and rubber (253 700 ha) (Table 4 and Figure 6). In 1994, the harvested irrigated rice area was 5 460 000 ha on a physical area of 2 100 000 ha, giving an irrigated rice cropping intensity of 2.6.

In 2004, the average cost of irrigation development on public schemes was aboutUS$3 875/ha, while in 2006, on-farm installation of sprinkler irrigation was almost US$4 700/ha. The cost of operation and maintenance (O&M) on public schemes was US$7/ha.

Status and evolution of drainage development

In 2006, the drainage systems covered 2 538 000 ha, mostly in the northern and central parts of the country, particularly the Red river delta (Table 4). Interestingly, almost all pumping irrigation stations in Viet Nam, particularly in the Red river delta, are responsible for drainage. In 2004, the average cost of drainage development on public schemes was US$620/ha.

FIGURE 4
Source of irrigation water on area equipped for full control irrigation
Total 4 585 500 ha in 2005



WATER MANAGEMENT, POLICIES AND LEGISLATION RELATED TO WATER USE IN AGRICULTURE

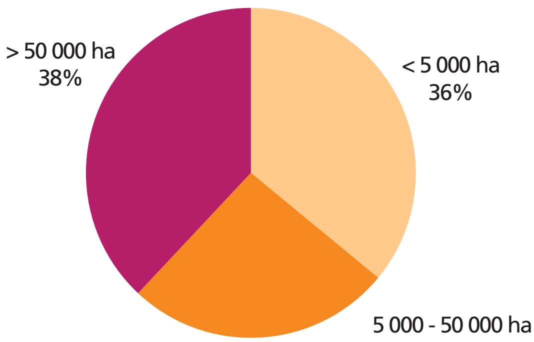
Institutions

According to the Water Law, the government is responsible for the state management of water

FIGURE 5

Type of full control irrigation schemes

Total 4 585 500 ha in 2005



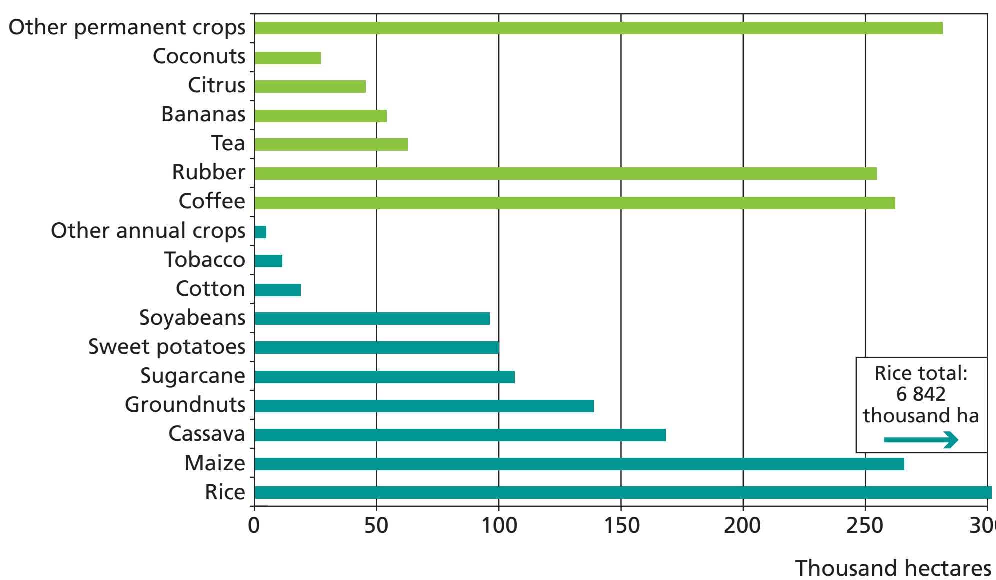
resources through the Ministry of Natural Resources and Environment (MONRE), which was transferred from the Ministry of Agriculture and Rural Development (MARD), while the service function of irrigation and rural water supply remains with MARD. However, the National Water Resources Council (NWRC), which manages water resources, is above the ministries and below the Prime Minister's Office. At province and district level, the Provincial Peoples Committees, which is directly controlled by the central government, are responsible for implementation in their own jurisdiction. Specific functions of water resources management and water use are allocated to ministries and non-line agencies are as follows:

- Ministry of Natural Resources and Environment is responsible for water resources management.
- Ministry of Agriculture and Rural Development is responsible for the management of flood and typhoon protection systems, hydraulic structures, wetland management, and rural water supply and sanitation.
- Ministry of Industry is responsible for the construction, O&M of hydropower facilities.
- Ministry of Construction is responsible for the spatial planning and construction of urban water supply, sanitation and drainage facilities.
- Ministry of Transport is responsible for the planning, construction and management of waterway transport systems.

FIGURE 6

Harvested crops on area equipped for full control irrigation

Total harvested area 8 728 192 ha in 2005 (cropping intensity on actually irrigated area: 190% in 2005)



- Ø Ministry of Fisheries is responsible for the protection and exploitation of aquatic resources.
- Ø Ministry of Health is responsible for the management of drinking water quality.
- Ø Ministry of Planning is responsible for the planning and investment in the water and investment resources sector.
- Ø Ministry of Finance is responsible for the development of policies on taxes and fees for water resources.

Water management

In Viet Nam the water sector has no overall integrated strategy and action plan at national or regional basin level. However, strategies and action plans exist for a number of the subsectors. In 2000 the NWRC and in 2001 three Boards for River Basin Planning and Management were established to work under the government as advisory, coordination and planning units. With the creation of MONRE in 2002, the responsibilities of the state management of water resources were assigned to the Agency of Water Resources Management within MONRE. This important change shows a separation of state management and service functions for water resources. Previously, both water resources management and service functions were the responsibility of the Agency of Water Resources and Hydraulic Works Management under MARD.

A national strategy of participatory irrigation management (PIM), together with an action plan approved in 2004 is being implemented. Many water user organizations have been established to take over management of irrigation at the local level (tertiary system of canals and intakes) for the entire country, besides the conventional model of irrigation management, which is by agricultural cooperatives responsible for irrigation and drainage. Management of O&M for secondary and main systems and headworks falls under irrigation management companies/enterprises (IMCs/IMEs), defined as public units providing public goods.

The existing environmental information and reporting system iis comprised of a national network of environmental monitoring stations, as well as environmental monitoring at the provincial level. The Environmental Monitoring Network is managed by the National Environmental Agency (NEA) of the Ministry of Science, Technology and Environment (MOSTE). By 2002, the network had expanded to 21 stations, which conduct monitoring at 250 locations in 45 provinces. Since the establishment of MONRE, the responsibility of producing the state of environment (SOE) reports lies with the Department of Environment and data collection is a mandate of the Office of Data and Information under Viet Nam Environmental Protection Agency (VEPA).

The objective of the 1999 to 2007 Mekong Delta's Water Resources Project, was to increase agricultural production, reduce rural poverty, improve living conditions in the project area, and facilitate sustainable water resources development and management in the Mekong Delta.

Finance

The proportion of government expenditures on water-related activities, as part of the total national budget expenditure has declined. Public expenditure for the water sector has increased at an annual average of 8.9 percent during the period 1996-2001. Although spending on water resource management is far too little compared to investment (less than 1 percent) and accounts for less than 10 percent of the current budget expenditure, public investment in the water sector comprised a considerable proportion of the national budget investment from 1996 to 1998 (about 33 percent). This has declined since 1999 owing to a shift in the focus of the national budget 'towards banking systems and improviement of state-owned enterprises. The main investments are made in irrigation, clean water supply and drainage. In 2001, Viet Nam spent about US$560 million in the water sector, which was 6.8 percent of total budget expenditure.

Irrigation fees were first established in 1984 in some provinces, such as Vinh Long in the Mekong River Delta Region. Funds are received as payments from farmers who are water user for irrigation fees and the government budget subsidy. The method of cost recovery for irrigation is stipulated in Decree No. 43/2003/NĐ-CP.

According to this decree, the basic fees decided for the specific regions are based on the levels of irrigation services provision and fully irrigated area, and other fees of the various levels of partly irrigated areas are decided based on the basic fees that depend on the natural features and socio-economic development of the regions. In the Red river delta, for example, the irrigation and drainage fee for pumping irrigation services is from US$33/ha to US$50/ha in the spring, and from US$30/ha to US$ 47/ha in the summer.

Policies and legislation

Viet Nam has a relatively comprehensive framework of institutions and polices for managing water, irrigation and drainage, such as Water Law (1998, effective from 1/1/1999), Ordnance No. 32/2001/PL-UBTVQH10 on the exploitation and protection of hydraulic works (2001), Decree No. 31/2005/NĐ-CP on the production and supply of public services, Circular No. 90/2004/ TTLT/BTC-BNN on guidelines or financial management of the State Enterprises in the exploitation of hydraulic works, and Decree No. 43/2003/NĐ-CP on the specific regulation of enforcing some articles of the Ordinance No. 32/2001/PL-UBTVQH10.

The Water Law is a major step towards integrated water resources management. Currently, only partial progress has been made in implementing the reforms it embodies. The secondary legislation necessary for implementing many of the law's objectives have not yet been developed. The law is basically formulated as a flexible legal framework and a number of decrees were subsequently added. These decrees define the roles, functions, and responsibilities of the institutional bodies for carrying out the water law. The legislative framework is described in circulars on guidance, proceedings of licensing exploitation and utilization of surface water, and licensing of discharging wastewater into water sources.

The 'Socio-Economic Development Strategy for 2001-2010' proposed a number of water-related strategies/objectives. With the approval in 2005 of a National Water Resources Development to 2020, the water sector has an overall integrated strategy and action plan at the national and regional basin level. In addition, strategies and action plans exist for a number of subsectors:

- Strategy for Rural Agriculture Development in the Industrialization and Modernization Period to2010 (MARD, July 2000);
- Agriculture and Rural Development Plan (2001- 2005) (MARD, August 2000);
- National Strategy for Rural Water Supply and Sanitation (NRWSS);
- Second National Strategy and Action Plan for Disaster Mitigation and Management in Viet Nam from 2001 to 2020 (MARD and Central Committee for Flood and Storm Control, December 2001.

ENVIRONMENT AND HEALTH

Although data on water quality are poor, recorded evidence shows the pollution level is increasing for surface water, groundwater and coastal waters. Although the quality of the upstream river water is generally good, downstream sections of major rivers reveal low water quality. Most of the lakes and canals in urban areas are fast becoming sewage sinks. Groundwater shows pockets of contamination and intrusion of salinity. Rapid urbanization and industrialization in coastal areas, port and marine transport development, expansion in coastal tourism, and an increase in the number of oil spills contribute to the deterioration of coastal water quality.

The National Monitoring Network (NMN) covers four rivers running through the main urban areas the: Red (Hanoi), Cam (Haiphong), Huong (Hue) and Saigon (Ho Chi Minh City). Other rivers are being monitored in the various regions. Trends indicate that the levels of two primary pollution indicators, Ammonia-nitrogen (NH_4-N) and biochemical oxygen demand (BOD), vary considerably and exceed national water quality class A standards. The problems are worse during the dry season, when river flows are reduced. Industrial and other pollution adds to the human waste from the households areas. Around 70 industrial parks have been developed, with more than 1 000 hospitals nationwide some million m^3 of untreated wastewater is discharged from these sources per day.

According to MONRE, about 4 000 enterprises discharge wastewater, of which 439 enterprises are the most serious and have been reallocated or closed or will have to adapt cleaner technologies and treatment of their wastewater. Rivers in urban areas, especially major cities, are seriously polluted by untreated industrial wastewater. Surveys conducted by the Institute of Tropical Techniques and Environmental Protection show that the content of contaminants in rivers in Hanoi, Ho Chi Minh City, Hai Phong, Hai Duong, Bac Giang, Hue, Da Nang, Quang Nam and Dong Nai, are much higher than permissible levels.

Untreated industrial wastewater discharging into rivers is the main source of pollution. According to the institute, industrial parks (IPs) and export processing zones (EPZs) in the Southern Key Economic Zone discharge over 137 000 m^3 of wastewater containing nearly 93 tonnes of waste into the Dong Nai, Thi Vai and Saigon rivers each day. Meanwhile, 2 out of 12 IPs and EPZs in Ho Chi Minh City, 3 out of 17 in Dong Nai, 2 out of 13 in Binh Duong, and none of the IPs and EPZs in Ba Ria-Vung Tau province (South East Region) have wastewater treatment facilities. According to environmentalists, the Southern Key Economic Zone needed US$380 million in 2005 and US$867 million in 2010 to deal with environmental pollution.

Within cities, lakes, streams, and canals increasingly serve as sinks for municipal and industrial wastes. Most of the lakes in Hanoi are seriously polluted with high BOD levels. Similarly, four small rivers in Hanoi and five canals in Ho Chi Minh City have levels of dissolved oxygen (DO) as low as 0-2 mg/litre, and BOD levels as high as 50-200 mg/litre.

Groundwater is emerging as an important source of water for municipal, industrial, and agricultural use. While the quality of groundwater remains good, there are some pockets of contamination. There is evidence of pollution from poorly maintained septic tanks, garbage dumping, and industrial effluents and overexploitation in parts of Hanoi, Ho Chi Minh City and the Mekong river delta.

Although there have been improvements in the provision of safe water to urban and rural populations, water-borne diseases are still a major problem. Dysentery and diarrhoea are widespread. In four years, recently, there were 6 million cases requiring treatment for water-borne diseases, which incurred a cost of US$27 million for treatment of cholera, typhoid, dysentery and malaria.

The cost of treating polluted water varies considerably depending on the quality of the raw water, which either comes from rivers, reservoirs or groundwater. However, typical treatment costs vary from US$1/$m^3$ to US$1.5/$m^3$. The tariffs consumers pay depend on the use of the water. Typically, municipal tariffs vary from US$1.2/$m^3$ to US$1.7/$m^3$. Factories and other business users may pay up to US$5.6/$m^3$.

In early September 2001, a major oil spill occurred off the coast of Ba Ria-Vung Tau province (South East Region) after a collision between a Vietnamese tanker and a Taiwanese ship. As a result, some 900 m^3 of DO oil poured into the Ba Ria-Vung Tau coastal area, causing extensive environmental damage at nearby tourist beaches, shrimp farms and mangrove forests. Total financial losses caused by the disaster were an estimated US$17 million and costs for cleaning up polluted waters and beaches reached US$4 million.

Flooding is an annual event in northern Viet Nam and the cause of enormous losses. With as much as 80 percent of the population living on the coastal plains and deltas, costs incurred from floods and typhoons are colossal. For the seven years from 1995 to 2002 the costs were US$1 250 million. Also the loss of lives, homesteads and general suffering of the people are immense. During 1995-2002 the human losses from typhoons and floods totalled 3 342 persons. In a study undertaken by United Nations Development Programme (UNDP), it was estimated that the average annual losses in the Red river delta and along the central coast could be substantially more than US$130 million. In a study undertaken by the Asian Development Bank, it was found that the average annual damage from flooding for the area protected by the dyke around Hanoi alone amounted to well over US$50 million per year.

The number of adults with HIV/AIDS was 0.5 percent of the total population. In 2005 the estimated number of people needing antiretroviral therapy (0-49 years) was 25 000 people (WHO/UNAIDS, 2005).

PROSPECTS FOR AGRICULTURAL WATER MANAGEMENT

According to the national strategy of water resources development, as a result of climate change total annual runoff could decrease by 2025 to 807 km^3 (89 km^3 in the dry season); by 2070 to 765 km^3 (76 km^3 in the dry season) and by 2100 to 722 km^3 (72 km^3 in the dry season).

The government has enacted laws, created institutions, expanded investments and decentralized authority to manage the country's vast water resources efficiently and sustainably. However, rapid economic development, high population growth, worsening environmental conditions and frequent natural disasters are overwhelming the capacity of the existing policy and institutional framework and in turn are undermining the effectiveness of numerous government interventions. Given this history and context, the management of water resources is one of the most critical issues in Viet Nam.

To achieve the objective of sustainable management of the country's vast water resources, these key challenges need to be addressed:

- strengthening of institutions and policies for integrated water resources management;
- expanding and diversifying investment in infrastructure for the water sector, while paying more attention to financing for the management side;
- improving compliance and enforcement; and
- deepening community (users) participation.

The core issues in tackling the challenges are adopting an integrated river basin approach, greater and more sufficient adaptation to the water-related vulnerability and susceptibility, expanded and more efficient services for irrigation and municipal water supply, and curbing water pollution and its health impacts on the poor. More proactive engagement in regional riparian cooperation, improving information management, complete separation of the water management and service functions, further decentralization of management authorities, and strengthening of institutional capacity would provide Viet Nam with the required management tools that will address equity, efficiency and environmental sustainability of its water resources.

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AQUASTAT Survey – 2011

The AQUASTAT Programme was initiated with a view to presenting a comprehensive picture of water resources and irrigation in the countries of Africa, Asia, Latin America and the Caribbean and providing systematic, up-to-date and reliable information on water for agriculture and rural development. This report presents the results of the most recent survey carried out in the 22 countries of the Southern and Eastern Asia region, and it analyses the changes that have occurred in the ten years since the first survey. Following the AQUASTAT methodology, the survey relied as much as possible on country-based statistics and information. The report consists of four sections. Section I describes in detail the methodology used. Section II contains the regional analysis which presents a synopsis on water resources development and irrigation in the region. Section III contains a more detailed description of four transboundary river basins: the Ganges-Brahmaputra-Meghna, Indus, Mekong and Salween river basins. Finally, Section IV contains the detailed profiles on the situation in each country: Bangladesh, Bhutan, Brunei Darussalam, Cambodia, China, Democratic People's Republic of Korea, India, Indonesia, Lao People's Democratic Republic, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Pakistan, Papua New Guinea, Philippines, Republic of Korea, Sri Lanka, Thailand, Timor-Leste and Viet Nam.

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