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

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.

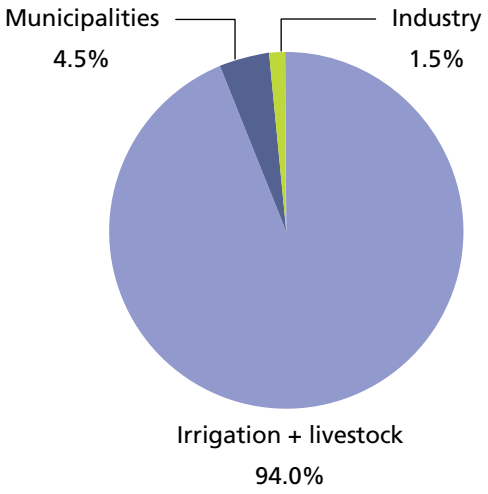
The transboundary implications of hydropower projects on water quality and quantity are numerous. The first risk of hydropower project development in the upstream area of the Mekong river is the negative impact on the environment and society. The second type of risk is geo-political, meaning the inevitable 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).

FIGURE 1
Water withdrawal by sector
Total 2.184 km^3 in 2006



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):

- 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

- 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.
- 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.

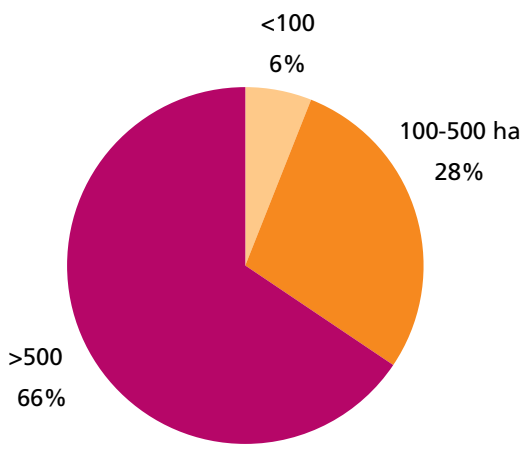
The Asian Development Bank (ADB) in 2003 approved a loan of US$18 million to develop irrigated agriculture to boost production in poor and neglected rural areas of northwest Cambodia. The loan for the Northwest Irrigation Sector Project assists in improving water resource management, providing rehabilitation 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).

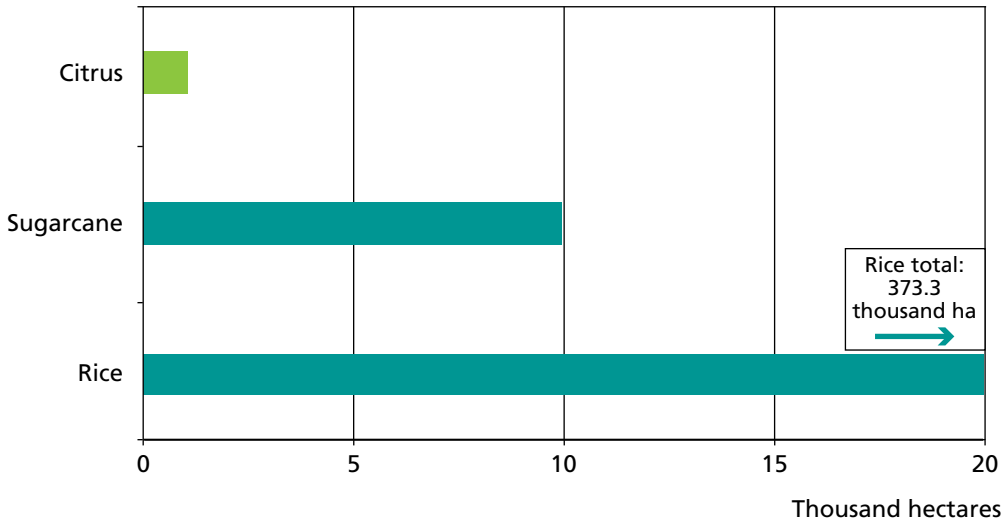
FIGURE 2
Type of full control irrigation schemes
Total 276 410 ha in 1993



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):

- **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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