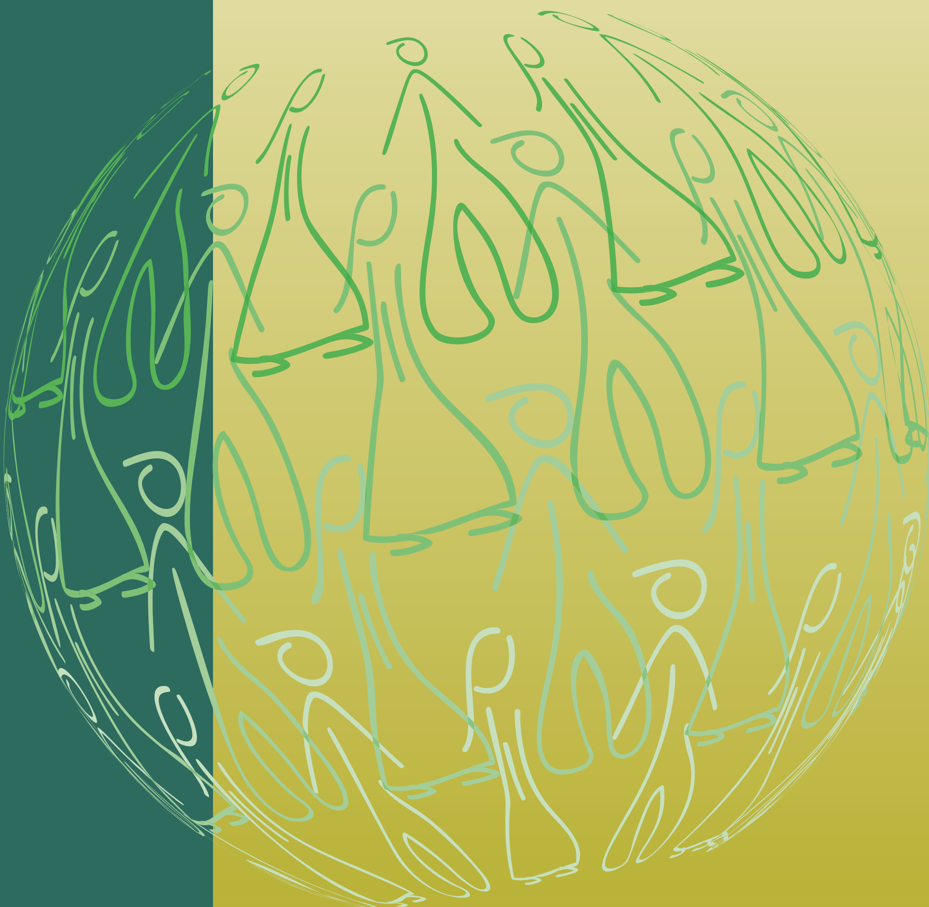
Agriculture, food *and* water



A contribution
to the *World Water*
Development Report

Agriculture, food *and* water

A contribution to the *World Water Development Report*

92-5-104943-2

Preface

Food and agriculture are by far the largest consumers of water. They require one thousand times more than we use to drink and one hundred times more than we use to meet basic personal needs, with up to 70 percent of the water we take from rivers and groundwater going into irrigation. Global food production has kept pace with population growth in recent decades; yet nearly 800 million people remain undernourished, and the population shift from rural to urban environments will certainly increase the pressures and problems associated with food security. A growing population will need more food and thus more water. What is the status of food production in the world? How can it be made more efficient without compromising the environment? What are the contributions from rainfed and irrigated agriculture and from fisheries? What role does the market play? What is the connection between food security and poverty? These questions are discussed in this publication. However, the question remains whether we shall rise to the challenge of feeding the world's hungry by being more efficient and productive in our use of water while still respecting the resource base and demands from competing sectors.

Acknowledgements

This publication is based on *Water for people – Water for life, the* United Nations *World Water Development Report* ©UNESCO–WWAP 2003, where it appears as Chapter 8 "Securing food for a growing population". The World Water Development Report was published jointly in 2003 by the United Nations Educational, Scientific and Cultural Organization (UNESCO) and Berghahn Books. A slightly modified version of Chapter 8 of the report is reproduced here by permission of UNESCO.

The World Water Development Report, prepared under the overall coordination of Gordon Young, is a joint report by the United Nations Agencies concerned with freshwater. This chapter was prepared by Wulf Klohn, with inputs and support from Jean-Marc Faurès, Domitille Vallée, Åse Eliasson, Jippe Hoogeveen and Jacob Burke, FAO, Land and Water Development Division, and with contributions from Uwe Barg, Jelle Bruinsma, Gerold Boedeker, Robert Bos, Andy Bullock, Karen Frenken, David Molden and David Smith. Annex 1 on the right to adequate food and the right to water was prepared by Kerstin Mechlem.

Special thanks are due to Simone Morini for the design and layout of this publication.

Credits for cover images are:
FAO/17011/G. Bizzarri
FAO/16242/P. Johnson

Table of contents

Acronyms

AQUASTAT	FAO's information system on water and agriculture
DAC	Development Assistance Committee (OECD Department)
FAO	Food and Agriculture Organization of the United Nations
GDP	Gross Domestic Product
GIS	Geographic Information Systems
GNP	Gross National Product
IFAD	International Fund for Agriculture and Development
IIED	International Institute for Environment and Development
IWMI	International Water Management Institute
IWRM	Integrated Water Resources Management
NEPAD	New Partnership for Africa's Development
NGO	Non-governmental Organization
OECD	Organization for Economic Cooperation and Development
OMVS	Organization for the Development of the Senegal River *(Organisation pour la mise en valeur du fleuve Sénégal)*
UN	United Nations
UNESCO	United Nations Educational, Scientific and Cultural Organization
WCD	World Commission on Dams
WHO	World Health Organization
WWAP	World Water Assessment Programme
WWDR	World Water Development Report

The world water development report

The World Water Development Report (WWDR) is a periodic review, continuously updated, designed to give an authoritative picture of the state of the world's freshwater resources and our stewardship of them. The WWDR builds upon past assessments and will constitute a continuing series of assessments in the future. The WWDR is targeted to all those involved in the formulation and implementation of water-related policies and investments, and aims to influence strategies and practices at the local, national and international levels. While a broad, global picture is given, particular emphasis is placed on developing-country situations, where management capacities are likely to be weaker, with the intention of identifying areas in particular need of attention. It lays the foundations for efficient and effective capacity-building in areas where stewardship challenges are greatest.

As a UN-led exercise, the preparation of the WWDR is a joint effort of the UN and its member states to collect and prepare reliable data in a harmonized and meaningful manner. Data and information used in the report are from official sources such as national authorities and basin agencies, or equivalents. National and local governments, institutions and universities, user associations, the private sector, nongovernmental organizations and national consultants are also involved. The first edition of the WWDR offers an inaugural assessment of progress since the Rio Summit.

The Secretariat of the World Water Assessment Programme (WWAP), in charge of the preparation of the WWDR, is hosted by UNESCO. More details about the WWAP can be obtained through Internet at: www.unesco.org/water/wwap.

CHAPTER **ONE**

Introduction

Since the 1960s, the world food system has responded to a doubling of the world population, providing more food per capita at progressively lower prices. Global nutrition has consistently improved. This performance was possible through a combination of high-yielding seeds, irrigation, plant nutrition and pest control. In the process, large quantities of water were appropriated for agriculture. As population keeps increasing, albeit at a slower rate, more food and livestock feed need to be produced in the future and more water applied to this purpose. Water withdrawals for irrigation in developing countries are expected to increase by an aggregated 14 percent until 2030, while irrigation water use efficiency is expected to improve by an average 4 percent. Water-scarcity stress is foreseen to grow locally and in some cases regionally and a number of countries will have to rely more on trade for their food security.

While food production is satisfying market demand at historically low prices, an estimated 777 million people in developing countries do not have access to sufficient and adequate food because they do not have the resources to buy it or, in the case of subsistence farmers, to produce it. In spite of the overall improvement in the nutritional situation, the absolute number of undernourished people is reducing at a much slower rate than had been anticipated. The 1996 World Food Summit (see Annex 1)set a target of reducing the number of chronically hungry people to about 400 million, but current projections indicate that this figure may be achieved fifteen years later than targeted, i.e. by 2030, unless decisive policy and financial action is taken.
Irrigated agriculture will by necessity claim large quantities of water to produce the food required to feed the world. Irrigation-water management has a long way to go to adapt to the new production requirements and reconcile competing claims from other economic sectors and calls for environmental protection. However, water-saving technologies are available and can significantly reduce the waste of water. In addition, the political, legal and institutional framework to support improved water productivity in irrigated agriculture also shows signs of adaptation. Water-management trends point to empowering stakeholders, with a priority for the poor and the marginalized. At the same time, the water needs for human health and for the aquatic environment call for closer attention. The message from agriculture, which will remain globally the largest water user, is cautiously optimistic.

At the start of the twenty-first century, agriculture is using a global average of 70 percent of all water withdrawals from rivers, lakes and aquifers. The Food and Agriculture Organization (FAO, 200b) anticipates a net expansion of irrigated land of some 45 million ha in ninety-three developing countries (for a total of 242 million ha in 2030) and projects that agricultural water withdrawals will increase by some 14 percent from 2000 to 2030 to meet future food production needs. The analysis indicates a projected annual growth rate of 0.6 percent, compared with the 1.9 percent observed in the period from 1963 to 1999.

Only a part of agricultural water withdrawals are effectively used in the production of food or other agricultural commodities; a large proportion of water may not reach the crop plants because it evaporates or infiltrates during conduction, evaporates from the soil in the field, or is used by non-productive growth such as weeds. Irrespective of the actual outcomes, it is important to highlight the fact that water allocations for agriculture will face increasing competition from other higher utility uses – municipal, industrial uses and calls for water to be left in the environment. Under these circumstances it is crucial that the role of water in securing food supply is understood and the potential for improving overall agricultural productivity with respect to water fully realized.

In this report, the facts about past, present and future water demand in food production and food security are discussed. For the purpose of discussion, three groups of countries are identified: developing countries, industrialized countries and countries in transition. Developing countries call for special attention because demographic growth rates are high and the potential demand for food is not yet satisfied. This group of countries is considered in regional groupings, that is: sub-Saharan Africa, Near East/North Africa, Latin America and the Caribbean, South Asia and East Asia. It should always be kept in mind that aggregate and average figures tend to hide as much as or more than they reveal. Water problems are always local or, at most, regional in nature, and may vary over time. Countries with large territories also have a large diversity of situations, including arid and humid regions and plains as well as mountains.

This section is largely based on FAO's technical report *World Agriculture: Towards 2015/2030*, the most recent edition of FAO's periodic assessments of likely future developments in world food, nutrition and agriculture. The report provides information on a global basis, with more detailed emphasis on ninety-three developing countries. The section also relies extensively on the data, information and knowledge provided by FAOSTAT, the FAO statistical database, and AQUASTAT, FAO's information system on water and agriculture. The contribution of the International Water Management Institute (IWMI) in the preparation of this section is acknowledged with thanks. National values of key indicators in 251 countries are presented in Table 1. The significance of each indicator is highlighted in the relevant part of the discussion by reference to this table.

Table 1 National values of key indicators on agriculture, food and water

Country	Number of people undernourished 1990–92 (millions)	Number of people undernourished 1997–99 (millions)	Proportion of undernourished in total population 1990–92 (%)[1]	Proportion of undernourished in total population 1997–99 (%)[1]	Cultivated land area in 1998 (1,000 ha)[2]	Irrigated land area in 1998 (1, 000 ha)[2]	Irrigated land as % of cultivated land in 1998	Agricultural water withdrawal in 1998 (km^3/year)	Total renewable water resources (km^3/year)[3]	Agricultural water withdrawal as % of total renewable water resources in 1998
Afghanistan	9.3	12.1	64	58	8 054	2 386	30	22.84	65.00	35
Albania	0.5	0.3	14	10	699	340	49	1.06	41.70	3
Algeria	1.3	1.7	5	6	8 174	560	7	3.94	14.32	28
Angola	6.0	6.3	61	51	3 500	75	2	0.21	184.00	0.1
Antigua and Barbuda	–	–	–	–	8	0	–	0.001	0.05	2
Argentina	0.7	0.4	0	0	27 200	1 561	6	21.52	814.00	3
Armenia	–	1.3	–	35	560	287	51	1.94	10.53	18
Aruba	–	–	–	–	2	0	–	–	–	–
Australia	–	–	0	0	53 786	2 365	4	17.78	492.00	4
Austria	–	–	0	0	1 479	4	0.3	0.02	77.70	0.03
Azerbaijan	–	2.9	–	37	1 972	1 455	74	11.65	30.28	38
Bahamas	–	–	–	–	10	0	–	–	0.02	–
Bahrain	–	–	–	–	4	4	100	0.17	0.12	147
Bangladesh	39.2	44.1	35	33	8 332	3 850	46	70.20	1 210.64	6
Barbados	–	–	–	–	17	1	6	0.02	0.08	24
Belarus	–	0.1	–	0	6 311	115	2	0.84	58.00	1
Belgium – Luxembourg	–	–	0	0	832	40	5	0.11	21.40	0.5
Belize	–	–	–	–	89	3	3	0.03	18.56	0.2
Benin	0.9	0.9	19	15	1 850	12	1	0.19	24.80	1
Bhutan	–	–	–	–	160	40	25	0.40	95.00	0.4
Bolivia	1.7	1.7	25	22	2 203	128	6	1.12	622.53	0.2
Bosnia and Herzegovina	–	0.2	–	4	650	2	0.3	–	37.50	–
Botswana	0.2	0.3	17	23	346	1	0.3	0.06	14.40	0.4
Brazil	19.3	15.9	13	10	65 200	2 870	4	36.12	8 233.00	0.4
Brunei Darussalam	–	–	0	0	7	1	14	–	8.50	–
Bulgaria	0.2	0.9	3	11	4 511	800	18	1.97	21.30	9
Burkina Faso	2.8	2.6	31	24	3 450	25	1	0.69	12.50	5
Burundi	2.8	4.1	48	66	1 100	74	7	0.19	3.60	5
Cambodia	4.3	4.6	43	37	3 807	270	7	4.00	476.11	1
Cameroon	3.4	3.6	29	25	7 160	33	0.5	0.73	285.50	0.3
Canada	–	–	0	0	45 700	720	2	5.41	2 902.00	0.2
Cape Verde	–	–	–	–	41	3	7	0.02	0.30	7
Central African Republic	1.4	1.5	46	43	2 020	0	–	0.001	144.40	0.001
Chad	3.5	2.5	58	34	3 550	20	1	0.19	43.00	0.4
Chile	1.1	0.6	8	4	2 294	1 800	78	7.97	922.00	1
China	192.6	116.3	16	9	135 365	52 878	39	414.76	2 896.00	14

Table 1 *continued*

Country	Number of people undernourished 1990–92 (millions)	Number of people undernourished 1997–99 (millions)	Proportion of undernourished in total population 1990–92 (%)[1]	Proportion of undernourished in total population 1997–99 (%)[1]	Cultivated land area in 1998 (1,000 ha)[2]	Irrigated land area in 1998 (1,000 ha)[2]	Irrigated land as % of cultivated land in 1998	Agricultural water withdrawal in 1998 (km^3/year)	Total renewable water resources (km^3/year)[3]	Agricultural water withdrawal as % of total renewable water resources in 1998
Colombia	6.1	5.3	17	13	4 115	850	21	4.92	2 132.00	0.2
Comoros	–	–	–	–	118	0	–	–	1.20	–
Congo, Dem. Republic of	13.7	31.0	35	64	7 880	11	0.1	0.11	1 283.00	0.01
Congo, Republic of	0.8	0.9	35	32	218	1	0.5	0.004	832.00	0.0005
Costa Rica	0.2	0.2	6	5	505	105	21	1.39	112.40	1
Côte d'Ivoire	2.5	2.4	19	16	7 350	73	1	0.60	81.00	1
Croatia	–	0.7	–	15	1 587	3	0.2	–	105.50	–
Cuba	0.5	1.9	5	17	4 465	870	19	5.64	38.12	15
Cyprus	–	–	0	0	144	40	28	0.17	0.78	22
Czech Republic	–	0.1	–	0	3 337	24	1	0.06	13.15	0.4
Denmark	–	–	0	0	2 374	460	19	0.55	6.00	9
Djibouti	–	–	–	–	1	1	100	0.007	0.30	2
Dominica	–	–	–	–	15	0	–	0	–	–
Dominican Republic	1.9	2.0	27	25	1 550	265	17	2.16	21.00	10
East Timor	–	–	–	–	80	0	–	–	–	–
Ecuador	0.9	0.6	8	5	3 001	865	29	13.96	432.00	3
Egypt	2.6	2.4	5	4	3 300	3 300	100	54.00	58.30	93
El Salvador	0.6	0.7	12	12	810	38	5	0.72	25.25	3
Equatorial Guinea	–	–	–	–	230	0	–	0.001	26.00	0.004
Eritrea	–	2.0	–	57	500	22	4	0.30	6.30	5
Estonia	–	0.1	–	4	1 135	4	0.4	0.008	12.81	0.1
Ethiopia	–	29.6	–	49	10 650	190	2	2.47	110.00	2
Fiji Islands	–	–	–	–	285	3	1	0.05	28.55	0.2
Finland	–	–	0	0	2 170	64	3	0.066	110.00	0.1
France	–	–	0	0	19 517	2 000	10	3.56	203.70	2
French Guiana	–	–	–	–	13	2	15	–	–	–
French Polynesia	–	–	–	–	21	0	–	–	–	–
Gabon	0.1	0.1	11	9	495	15	3	0.05	164.00	0.03
Gambia	0.2	0.2	19	15	200	2	1	0.02	8.00	0.3
Gaza Strip (Palestine)	–	–	–	–	25	12	48	–	0.06	–
Georgia	–	1.0	–	18	1 062	470	44	2.13	63.33	3
Germany	–	–	0	0	12 107	485	4	9.31	154.00	6
Ghana	5.4	2.7	35	15	5 300	11	0.2	0.25	53.20	0.5
Greece	–	–	0	0	3 882	1 422	37	6.12	74.25	8
Greenland	–	–	–	–	0	0	–	–	–	–
Grenada	–	–	–	–	11	0	–	–	–	–

Table 1 *continued*

Guadeloupe	–	–	–	–	26	3	12	–	–	–
Guam	–	–	–	–	12	0	–	–	–	–
Guatemala	1.3	2.3	14	22	1 905	130	7	1.61	111.27	1
Guinea	2.6	2.7	40	34	1 485	95	6	1.36	226.00	1
Guinea–Bissau	–	–	–	–	350	17	5	0.10	31.00	0.3
Guyana	0.1	0.1	19	14	496	150	30	1.60	241.00	1
Haiti	4.5	4.5	63	56	910	75	8	0.93	14.03	7
Honduras	1.1	1.3	23	21	1 875	76	4	0.66	95.93	1
Hungary	0.0	0.1	0	0	5 045	210	4	2.45	104.00	2
Iceland	–	–	0	0	7	0	–	0.0002	170.00	0.0001
India	214.6	225.3	25	23	169 650	57 000	34	556.05	1 896.66	29
Indonesia	16.7	12.0	9	6	30 987	4 815	16	75.60	2 838.00	3
Iran, Islamic Rep. of	2.7	3.5	4	5	18 803	7 562	40	66.78	137.51	49
Iraq	1.2	3.0	7	14	5 540	3 525	64	39.38	75.42	52
Ireland	–	–	0	0	1 088	0	–	0.0002	52.00	0.0004
Israel	–	–	0	0	440	199	45	1.28	1.67	76
Italy	–	–	0	0	11 137	2 698	24	20.00	191.30	10
Jamaica	0.3	0.2	12	8	274	25	9	0.20	9.40	2
Japan	–	–	0	0	4 905	2 679	55	56.03	430.00	13
Jordan	0.1	0.2	3	5	384	75	20	0.76	0.88	86
Kazakhstan	–	1.7	–	11	30 135	2 332	8	28.41	109.61	26
Kenya	11.5	13.4	47	46	4 520	67	1	1.01	30.20	3
Korea, Dem. People's Rep.	3.4	8.8	17	40	2 000	1 460	73	4.96	77.14	6
Korea, Republic of	0.8	0.7	0	0	1 910	1 159	61	8.99	69.70	13
Kuwait	0.5	0.1	23	4	6	6	100	0.20	0.02	1 000
Kyrgyzstan	–	0.5	–	10	1 428	1 072	75	9.45	20.58	46
Lao, PDR	1.2	1.4	29	28	940	168	18	2.59	333.55	1
Latvia	–	0.1	–	4	1 871	20	1	0.04	35.45	0.1
Lebanon	0.1	0.1	0	0	308	120	39	1.06	4.41	24
Lesotho	0.5	0.5	28	25	325	1	0.3	0.01	3.02	0.3
Liberia	0.8	1.0	37	42	390	3	1	0.06	232.00	0.03
Libyan Arab Jamahiriya	0.0	0.0	0	0	2 150	470	22	4.27	0.60	712
Lithuania	–	0.1	–	3	3 004	8	0.3	0.02	24.90	0.1
Macedonia, The Fmr. Yug. Rep.	–	0.1	–	5	635	55	9	–	6.40	–
Madagascar	4.3	6.1	35	40	3 108	1 090	35	14.31	337.00	4
Malawi	4.8	3.8	49	35	2 000	28	1	0.81	17.28	5
Malaysia	0.6	0.4	3	0	7 605	365	5	5.60	580.00	1
Maldives	–	–	–	–	3	0	–	0	0.03	0
Mali	2.2	3.0	25	28	4 650	138	3	6.87	100.00	7
Malta	–	–	–	–	9	2	22	0.01	0.05	20
Martinique	–	–	–	–	23	3	13	–	–	–
Mauritania	0.3	0.3	14	11	500	49	10	1.50	11.40	13
Mauritius	0.1	0.1	6	6	106	20	19	0.37	2.21	17
Mexico	4.3	5.0	5	5	27 300	6 500	24	60.34	457.22	13

Table 1 *continued*

Country	Number of people undernourished 1990–92 (millions)	Number of people undernourished 1997–99 (millions)	Proportion of undernourished in total population 1990–92 (%)[1]	Proportion of undernourished in total population 1997–99 (%)[1]	Cultivated land area in 1998 (1,000 ha)[2]	Irrigated land area in 1998 (1,000 ha)[2]	Irrigated land as % of cultivated land in 1998	Agricultural water withdrawal in 1998 (km^3/year)	Total renewable water resources (km^3/year)[3]	Agricultural water withdrawal as % of total renewable water resources in 1998
Moldova, Republic of	–	0.4	–	10	2 182	307	14	0.76	11.65	7
Mongolia	0.8	1.0	34	42	1 322	84	6	0.23	34.80	1
Morocco	1.4	1.8	5	6	9 976	1 291	13	11.36	29.00	39
Mozambique	9.6	9.5	69	54	3 350	107	3	0.55	216.11	0.3
Myanmar	3.9	3.2	9	7	10 143	1 692	17	27.86	1 045.60	3
Namibia	0.4	0.6	30	33	820	7	1	0.17	17.94	1
Nepal	3.5	5.0	19	23	2 968	1 135	38	9.82	210.20	5
Netherlands	–	–	0	0	941	565	60	2.69	91.00	3
New Caledonia	–	–	–	–	13	0	–	–	–	–
New Zealand	–	–	0	0	3 280	285	9	0.89	327.00	0.3
Nicaragua	1.2	1.4	30	29	2 746	88	3	1.08	196.69	1
Niger	3.3	4.2	42	41	5 000	66	1	2.08	33.65	6
Nigeria	12	7.6	14	7	31 000	233	1	5.51	286.2	2
Norway	–	–	–	–	903	127	14	0.23	382.00	0.1
Oman	–	–	–	–	62	62	100	1.23	0.99	125
Pakistan	26.5	24.4	24	18	21 970	18 000	82	161.84	222.67	73
Panama	0.5	0.4	19	16	655	35	5	0.23	147.98	0.2
Papua New Guinea	0.9	1.2	24	26	670	0	–	0.001	801.00	0
Paraguay	0.8	0.7	18	13	2 285	67	3	0.35	336.00	0.1
Peru	8.9	3.1	41	13	4 170	1 195	29	16.42	1 913.00	1
Philippines	16.0	17.2	26	24	10 000	1 550	16	21.10	479.00	4
Poland	0.3	0.3	0	0	14 379	100	1	1.35	61.60	2
Portugal	–	–	0	0	2 620	650	25	8.81	68.70	13
Puerto Rico	–	–	–	–	81	40	49	–	3.40	–
Qatar	–	–	–	–	13	13	100	0.21	0.05	420
Reunion	–	–	–	–	38	12	32	–	5.00	–
Romania	0.7	0.3	3	0	9,843	2 880	29	14.23	211.85	7
Russian Federation	–	8.1	–	6	127 959	4 663	4	13.83	4 507.25	0.3
Rwanda	2.2	2.6	34	40	1070	4	0.4	0.02	5.20	0.4
Samoa	–	–	–	–	122	0	–	–	–	–
Sao Tome and Principe	–	–	–	–	41	10	24	–	2.18	–
Saudi Arabia	0.3	0.4	0	0	1 620	1 620	100	15.42	2.40	643
Senegal	1.7	2.1	23	24	2 266	71	3	1.43	39.40	4
Seychelles	–	–	–	–	7	0	–	–	–	–
Sierra Leone	1.9	1.7	46	41	540	29	5	0.34	160.00	0.2
Singapore	–	–	–	–	1	0	–	–	–	–

Table 1 *continued*

Slovakia	–	0.1	–	0	1 604	174	11	–	50.10	–
Slovenia	–	0.0	–	0	203	2	1	–	31.87	–
Solomon Islands	–	–	–	–	60	0	–	–	44.70	–
Somalia	4.8	6.0	67	75	1 065	200	19	3.28	13.50	24
South Africa	2.7	3.5	4	5	15 750	1 350	9	10.03	50.00	20
Spain	–	–	0	0	18 516	3 652	20	24.22	111.50	22
Sri Lanka	5.0	4.3	29	23	1 889	651	34	11.74	50.00	23
Saint Helena	–	–	–	–	4	0	–	–	–	–
Saint Kitts Nevis	–	–	–	–	7	0	–	–	0.02	–
Saint Lucia	–	–	–	–	17	3	18	–	–	–
Saint Vincent/Grenadines	–	–	–	–	11	1	9	–	–	–
Sudan	7.9	6.3	31	21	16 900	1 950	12	36.07	64.50	56
Suriname	0.0	0.0	12	11	67	51	76	0.62	122.00	1
Swaziland	0.1	0.1	10	12	180	69	38	0.75	4.51	17
Sweden	–	–	0	0	2 784	115	4	0.26	174.00	0.2
Switzerland	–	–	0	0	439	25	6	0.05	53.50	0.1
Syrian Arab Republic	0.2	0.2	0	0	5 484	1 213	22	18.96	26.26	72
Tajikistan	–	2.8	–	47	864	719	83	10.96	15.98	69
Tanzania, United Republic of	9.1	15.5	34	46	4 650	155	3	1.79	91.00	2
Thailand	16.9	12.9	30	21	18 297	4 749	26	79.29	409.94	19
Togo	0.9	0.7	27	17	2 300	7	0.3	0.08	14.70	0.5
Tonga	–	–	–	–	48	0	–	–	–	–
Trinidad and Tobago	0.1	0.2	12	13	122	3	2	0.02	3.84	0.5
Tunisia	0.1	0.0	0	0	5 100	380	7	2.23	4.56	49
Turkey	0.9	1.2	0	0	26 968	4 380	16	27.11	229.30	12
Turkmenistan	–	0.4	–	9	1 800	1 800	100	24.04	24.72	97
Uganda	4.2	6.2	24	28	6810	9	0.1	0.12	66.00	0.2
Ukraine	–	2.6	–	5	33 821	2 446	7	20.00	139.55	14
United Arab Emirates	0.1	0.1	3	0	74	74	100	1.53	0.15	1 021
United Kingdom	–	–	0	0	6 306	108	2	0.28	147.00	0.2
United States of America	–	–	0	0	179 000	22 300	12	296.87	2 071.00	10
Uruguay	0.2	0.1	6	3	1 307	180	14	3.03	139.00	2
Uzbekistan	–	0.9	–	4	4 850	4 281	88	54.37	50.41	108
Venezuela	2.3	4.8	11	21	3 490	570	16	3.94	1 233.17	0.3
Viet Nam	18.0	14.2	27	19	7 250	3 000	41	48.62	891.21	5
West Bank	–	–	–	–	209	12	6	–	0.75	–
Yemen	4.4	5.7	36	34	1 680	490	29	6.19	4.10	151
Yugoslavia, Fed. Rep. of	–	0.5	–	5	4 047	57	1	–	208.50	–
Zambia	3.6	4.7	43	47	5 279	46	1	1.32	105.20	1
Zimbabwe	4.6	4.8	43	39	3 350	117	3	2.24	20.00	11

– No data available. (1) Values marked as 0 are < 2.5%. (2) Values marked as 0 are < 1,000 ha. (3) Aggregation of data can not be carried out as it would result in double counting of shared water resources.

*Source*FAO estimates.

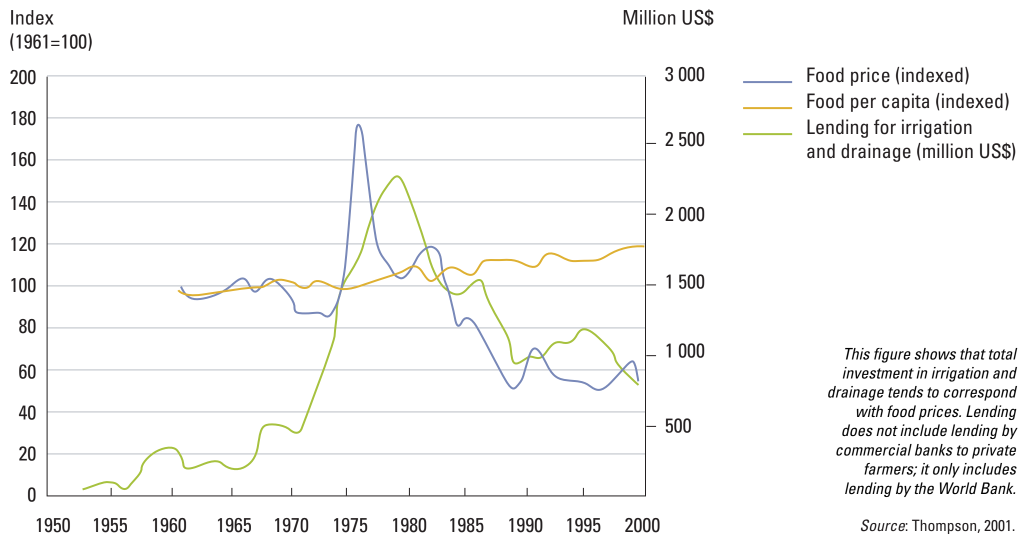
CHAPTER **TWO**

How the world is fed

The world food system: sustained improvement in food availability

Between the early 1960s and the late 1990s, while world population almost doubled, the productive potential of global agriculture met the growth of effective demand. Figure 1 shows that total investment in irrigation and drainage tends to correspond to food prices. But even with the observed decline in food prices, the nutritional status of the world's population continued to improve. Clearly, some of the early investment in agriculture paid off and productivity gains were being made. Irrigation played an important role in ensuring the needed growth in food production. Today, as the food production issue becomes less critical, concern arises over the future for large-scale irrigation in terms of its overall performance and the political and institutional viability of transferring the management of public irrigation schemes to users. The significance of non-structural irrigation and water management reform will grow as world agriculture in general is becoming more responsive to demand. These issues are taken up later in this report.

Figure 1 **Food prices and investment in irrigation and drainage**



This figure shows that total investment in irrigation and drainage tends to correspond with food prices. Lending does not include lending by commercial banks to private farmers; it only includes lending by the World Bank.

Source: Thompson, 2001.

Per capita food consumption, expressed in kcal/person/day, is used as the indicator of food intake. The evolution of per capita food consumption in 1965 and 2030 is given in Table 2, which is based on historical data and on FAO projections for the years 2015 and 2030.

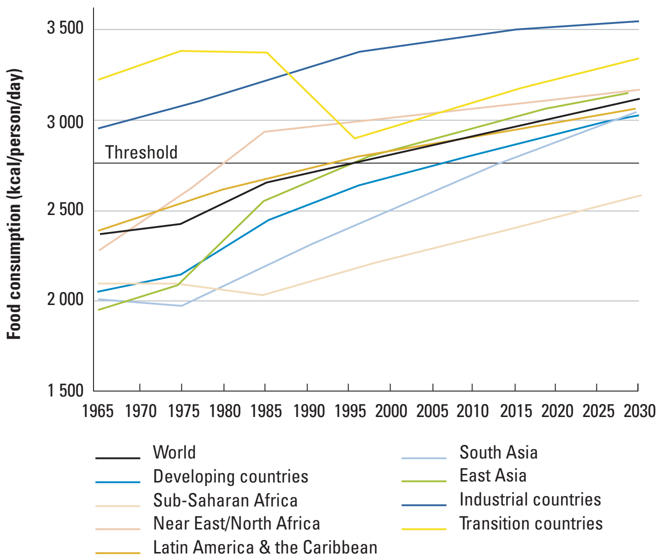
Table 2 Per capita food consumption from 1965 to 2030 (Kcal/person/day)

	1965	1975	1985	1998	2015	2030
World	2 358	2 435	2 655	2 803	2 940	3 050
Developing countries	2 054	2 152	2 450	2 681	2 850	2 980
Sub-Saharan Africa	2 058	2 079	2 057	2 195	2 360	2 540
Near East/North Africa	2 290	2 591	2 953	3 006	3 090	3 170
Latin America/Caribbean	2 393	2 546	2 689	2 826	2 980	3 140
South Asia	2 017	1 986	2 205	2 403	2 700	2 900
East Asia	1 957	2 105	2 559	2 921	3 060	3 190
Industrial countries	2 947	3 065	3 206	3 380	3 440	3 500
Transition countries	3 222	3 385	3 379	2 906	3 060	3 180

There is a global food security situation that is steadily improving, with a consistently increasing global level of food consumption per capita.

Source: FAO, 2002.

Figure 2 Per capita food consumption from 1965 to 2030



This figure shows a global food security situation that is consistently improving, at both global and developing country levels. The threshold of 2,700 kcal is taken as an indicator of the level of satisfaction of food security requirements.

Source: FAO, 2002.

Table 2 and Figure 2 show a global food security situation that is consistently improving, with a steady increase in per capita food consumption at the global level as well as at the level of developing countries. Demand for food tends to saturate at the level of 3500 kcal/person/day. They also clearly show that per capita food consumption in sub-Saharan Africa remained disappointingly low over the last forty-five years although recent improvement trends are expected to continue. It should be noted that gains in overall food consumption are not necessarily translated into commensurate declines in the absolute numbers of undernourished people, in particular when there is high population growth.

The main sources of food supply

The main source of food for the population of the world is agriculture. The term agriculture, as broadly used here, also includes livestock husbandry, managed fisheries (aquaculture) and forestry. The composition of meals changes gradually as demand for food strengthens and lifestyles change. For those that can afford it, many products that are grown out of season or are exotic now appear on their local market. What agriculture produces is driven by consumer demand, and changes in consumer preferences have an influence on the water needed for food production.

It has been estimated that unmanaged natural systems could provide food for 600 million people, one tenth of the current world population (Mazoyer and Roudart, 1998). Thus, about 90 percent of the present world population could not be sustained without agriculture. Yet, while few people live from only fishing, gathering and hunting, these unmanaged, or only loosely managed, natural food systems provide a strategically important contribution to the nutrition of indigenous people as well as to the existence and survival of many displaced, poor and marginal people. Except for marine fisheries, which are monitored, the diffuse reality of food resources directly obtained from natural ecosystems escapes most data collection and is usually not reflected in agricultural and economic statistics.

Therefore, the bulk of global food production (cereals, oils, livestock and fish) is dependent upon a whole range of agricultural systems in which water is a critical factor of production (FAO/ World Bank, 2001).

Major crops

The prominent role of cereals and oil crops

Cereals are by far the most important source of total food consumption as measured in calories. In developing countries, consumption of cereals thirty years ago was 141 kg/person/year, representing 61 percent of total calories. At present it is 173 kg/person/year and provides 56 percent of calories. Thus, cereal use has increased, but less than other components of food intake. The fact that the growth of global demand for cereals is declining reflects diet diversification, as more countries achieve higher levels of nutrition. However, it is expected that cereals will continue to still supply more than 50 percent of the food consumed in the foreseeable future.

To satisfy the cereal demand for a growing population using more cereals per capita, the annual world production of cereals grew by almost a billion tons from 0.94 billion tons in the mid-1960s to 1.89 billion tons in 1998. In the late 1990s, a slowdown in the growth of world consumption of cereals was recorded. It was, however, not caused by production constraints but by slowing demand. The annual world production of cereals is projected by FAO to increase by another billion tons from the 1998 level, to 2.8 billion tons. Within the cereal group, the relative importance of rice is expected to decline slightly, while consumption of wheat will continue to grow in per capita terms.

A large proportion of cereals are not produced for direct human consumption. Thus, of the future increment in cereal production projected by FAO, just under half will be for food, about 44 percent for animal feed, with the balance going to other uses, such as seed, industrial non-food, and waste.

One out of every five calories added to food consumption in developing countries in the last two decades originated in the group of oil crops, which includes palm oil, soybean, sunflower, groundnut, sesame and coconut. In projections towards the future, it is expected that 44 percent of additional calories may come from these products. This projection reflects the prospect, in the majority of developing countries, of only modest further growth in the direct consumption of staples such as cereals, roots and tubers, in favour of non-staples like vegetable oils. The major driving force of the world oil crops economy has been the growth of food demand in the developing countries, but additional demand growth has been experienced in the non-food industrial uses of oil and also in feed for the livestock sector. The future growth of aggregate world demand for, and production of oil crops, is expected to remain well above that of total agriculture. In terms of trade, developing countries have so far been net exporters of oil crops, but this position is likely to change as local consumption increases.

Sources of growth in crop production

There are three sources of growth in crop production:

- arable land expansion;
- increase in cropping intensities (multiple cropping and shorter fallow periods);
- yield growth.

Since the early 1960s, land in agricultural use (arable land and land under permanent crops) in the world has increased by 12 percent to about 1.5 billion ha. This amounts to 11 percent of the globe's land surface. During the same period, the world population nearly doubled from 3.1 billion to over 5.9 billion in 1998. By implication, arable land per person declined by 40 percent, from 0.43 ha in 1962 to 0.26 ha in 1998. As the world food system kept providing enough food for a growing population, a secular decline in the real price of food took place and the global situation of nutrition improved, both in relative terms and in absolute numbers. In the context of low food prices and consequent relatively low value of agricultural land, prime agricultural land is being converted to higher value urban and industrial uses. Also, irrigated land with inadequate or non-existing drainage infrastructure is being gradually lost to salinization that results in lowering yields. Yield increase and intensification have more than compensated for the reduction in per capita land availability.

As an example of growing crop yields, the world average grain yields doubled from 1.4 ton/ha/crop in 1962 to 2.8 ton/ha/crop in 1996. The average cropping intensity probably increased by some 5 percentage points, so that the arable land required to produce a given amount of grain declined by some 56 percent. It is expected that in future 80 percent of increased crop production in developing countries will come from intensification through higher yields, increased multiple cropping and shorter fallow periods. The remaining 20 percent would come from expansion of agricultural land in those developing countries and regions where the potential for expansion exists and where the prevailing farming systems and general demographic and socio-economic conditions favour it.

From 1998 to 2030, arable land in developing countries is projected to increase by 13 percent (120 million ha). The bulk of the projected expansion is expected to take place in sub-Saharan Africa and Latin America, with a smaller part in East Asia. The slowdown in the expansion of arable land is mainly a consequence of the projected slowdown in the growth of crop production.

Livestock: an increasing role

Food production from the livestock sector includes meat (beef, pork, poultry, etc.), dairy products and eggs. In the last few decades, consumption of meat in developing countries has been growing at a rate of about 5 to 6 percent per year, that of milk and dairy products at 3 to 4 percent per year. Much of the growth has been occurring in a small number of countries, including such populous countries as Brazil and China. Many developing nations and whole regions, including sub-Saharan Africa and parts of the Near East/North Africa, where the need to increase protein consumption is the greatest, have not been participating in the buoyancy of the world meat sector. Worldwide, the poultry sector has been expanding fastest, and its share in the total meat output went from 13 percent in the mid-1960s to 28 percent currently. The increasing share of poultry in meat production is expected to continue in the future. The forces that made for the rapid growth of the meat sector in the past are, however, expected to weaken in the future owing to lower population growth and the deceleration of growth that follows the attainment of a fairly high level of consumption. Intensive forms of livestock production have led to a strong demand for cereals used as animal feed and production is rising steadily to meet this demand.

Fisheries and the growing importance of aquaculture

Average world per capita consumption of fish was at about 16.3 kg per year in 1999, with large differences ranging from countries with virtually no fish consumption to countries that reach over 100 kg per year. Per capita consumption could grow to 19 to 20 kg by 2030, raising total fish use to 150-160 million tons. Of the total world fisheries and aquaculture production in 2000 (130 million tons), some 74 percent (97 million tons) was available for direct human consumption as food fish. The remainder was reduced into fishmeal and fish oil for use in animal feeding (livestock and aquaculture) or for industrial purposes. Marine capture fisheries production, excluding aquaculture was in the range of 80 to 85 million tons per year in the 1990s. The long-term yearly sustainable yield of marine capture fisheries is estimated at no more than around 100 million tons per year; over-fishing of some species in certain parts of the worlds threatens the resource base. Achieving and sustaining these levels assumes more efficient utilization of stocks, healthier ecosystems and better conservation of critical habitats. Inland catches (excluding aquaculture) were recorded at about 7 to 8 million tons per year. However, a recent in-depth study of inland fisheries revealed that actual catches may be double this amount. It is important to note that fishery resources in many inland water bodies such as rivers and lakes are under increasing environmental threats resulting from continued trends of increasing aquatic pollution, habitat degradation, water abstraction, and other human-made pressures.

The bulk in the future increase of fish supply will have to come from aquaculture, which has been growing at a rate of 10 percent per year during the 1990s and increased its share in world fish supplies to about 27 percent. Most aquaculture development was in Asia (some 70 percent of world aquaculture production is in China). At present, aquaculture production amounts to 35 million tons, of which 21 million inland and 14 million marine. Over 90 percent of total aquaculture food fish production in 1995 came from developing countries, compared with 51 percent of terrestrial animal meat production. Fish exports from developing countries have been growing rapidly and now far exceed earnings from commodities such as coffee, cocoa, bananas or rubber. Strong growth may continue for some time, but constraints such as lack of feed stuffs and suitable sites, diseases and environmental constraints are becoming more binding. Major factors affecting both the sustainability of capture fisheries and the expansion of aquaculture will be improved management in the sector and a better understanding of aquatic ecosystems, as well as prevention and better management of environmental impacts affecting fishery resources and aquatic biodiversity.

Food trade

Developing countries are increasing their imports

At the global level, food production equals consumption. For individual countries and clusters of countries, production and consumption differ depending on agricultural trade. In general, the growth rates of food production in the developing countries have been below growth rates of demand, and food imports of these countries have been growing faster than their agricultural exports. For example, the net cereal imports of developing countries increased from 39 million tons in the mid-1970s to 103 million tons in 1998. Notwithstanding lower growth in the demand for cereals in the future, the dependence of developing countries on cereal imports is expected to continue to grow owing to limited potential in these countries to increase production. One production constraint is scarcity of water resources for irrigation, but inadequate access to credit and markets, and poor agricultural policy and management have also hampered production increases. The course towards a widening net trade deficit of the developing countries continues in the projections to the future: net food imports are expected to rise fairly rapidly to 198 million tons in 2015 and 265 million tons in 2030. This compares to a projected cereal production in developing countries of the order of 1,650 million tons in 2030.

Few countries pursue a policy of 100 percent food self-sufficiency, and few countries depend on imports for more than 20 percent of their food demand. A number of countries with a chronic trade balance deficit and high population growth already have difficulty in raising the foreign exchange needed to satisfy the growing demand for food imports. While in the past such a foreign exchange situation would have called for an increase in import taxes, and encouragement for local food production to supply the local market, the structural adjustment programmes and market liberalization policies implemented in the 1980s and 1990s have precluded the adoption of national policies leading in the direction of food self-sufficiency (Stiglitz, 2002). Yet, farmers in many developing countries with weak infrastructure and no access to capital and technology cannot face competition from the international market. This is particularly the case when their production competes with that of the heavily subsidized agriculture of industrial countries where the productivity of labour can be 1 000 times higher than theirs (Mazoyer and Roudart, 1997).

The concept of virtual water

The term "virtual water" was coined in the 1990s in support of a trade and water policy point: for the food security of arid countries, where water is needed for domestic use and in support of the services and industrial sector, it is not necessary to use water for local food production, because the easier and economically more attractive alternative is to import food, in particular the inexpensive cereal base of the national diet. Thus, using a hydrologic perspective, trade in food was called trade in virtual water that is the water consumed to produce an agricultural commodity. For example, a crop such as wheat consumes about 1 000 to 1 500 litres of water to produce one kilogram of cereal. For poultry with a feed/meat conversion factor of 4:1, the virtual water content would be 6 000 litres per kg of poultry meat. For cattle, with a conversion factor of 10:1, the virtual water content of one kg of beef would be 15 000 litres. Table 3 in the following section gives examples of specific water needs for the production of a unit of a selection of agricultural commodities. The amount of virtual water imported by a country is a measure of the degree to which the country depends on the international market for its food supply.

Manipulation of the virtual water concept is subject to some caveats, one of which is that the water actually used by a crop may have stemmed partially or totally from rain, which is free of cost, whereas piped water definitely has a cost. In the case of meat, one has to keep in mind that free-roaming animals are efficient collectors of virtual water: in arid areas, the pasture they consumed grew on rainfall that usually would have no other use.

CHAPTER **THREE**

The use of water in agriculture

Water for food production

For vegetative growth and development, plants require, within reach of their roots, water of adequate quality, in appropriate quantity and at the right time. Most of the water a plant absorbs performs the function of raising dissolved nutrients from the soil to the aerial organs, from where it is released to the atmosphere by transpiration: agricultural water use is intrinsically consumptive. Crops have specific water requirements, and these vary depending on local climatic conditions. Whereas an indicative figure for producing one kilogram of wheat is about 1000 litres of water that is returned to the atmosphere, paddy rice may require twice this amount. The production of meat requires between six and twenty times more water than for cereals, depending on the feed/meat conversion factor. Specific values for the water equivalent of a selection of food products are given in Table 3. Water required for human food intake can be derived from these specific values in a grossly approximate way, depending on the size and composition of the meals (see Box 1).

Table 3 **Water requirement equivalent of main food products**

Product	Unit	Equivalent water in m^3 per unit
Cattle	head	4 000
Sheep and goats	head	500
Fresh beef	kg	15
Fresh lamb	kg	10
Fresh poultry	kg	6
Cereals	kg	1.5
Citrus fruits	kg	1
Palm oil	kg	2
Pulses, roots and tubers	kg	1

This table gives examples of water required per unit of major food products, including livestock, which consume the most water per unit. Cereals, oil crops, and pulses, roots and tubers consume far less water.

Source: FAO, 1997a.

BOX 1 **ASSESSING FRESHWATER NEEDS FOR GLOBAL FOOD PRODUCTION**

The amount of water involved in food production is significant, and most of it is provided directly by rainfall. A rough calculation of global water needs for food production can be based on the specific water requirements to produce food for one person. Depending on the composition of meals and allowing for post-harvest losses, the present average food ingest of 2 800 kcal/person/day may require roughly 1 000 m^3 per year to be produced. Thus, with a world population of 6 billion, water needed to produce the necessary food is 6 000 km^3 (excluding any conveyance losses associated with irrigation systems). Most water used by agriculture stems from rainfall stored in the soil profile and only about 15 percent of water for crops is provided through irrigation. Irrigation therefore needs 900 km^3 of water per year for food crops (to which some water must be added for non-food crops). On average, about 40 percent of water withdrawn from rivers, lakes and aquifers for agriculture effectively contribute to crop production, the remainder being lost to evaporation, deep infiltration or the growth of weeds. Consequently, the current global water withdrawals for irrigation are estimated to be about 2 000 to 2 500 km^3 per year.

Food production: the dominant role of rainfed agriculture

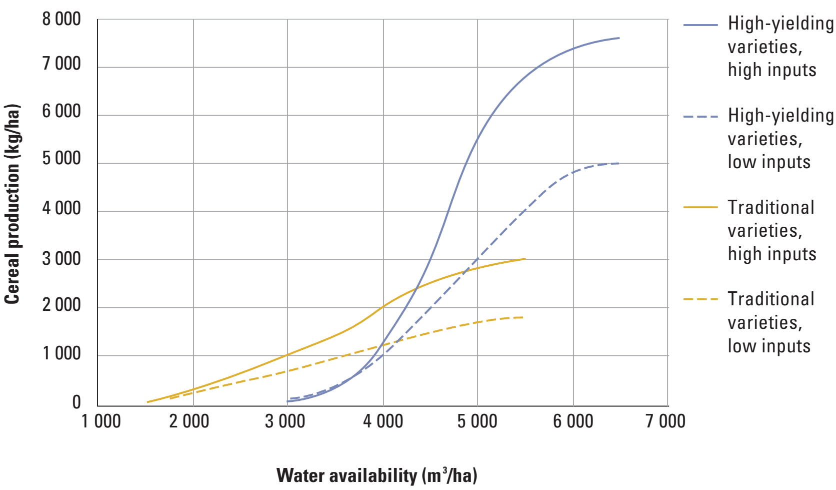
Non-irrigated (rainfed) agriculture depends entirely on rainfall stored in the soil profile. This form of agriculture is possible only in regions where rainfall distribution ensures continuing availability of soil moisture during the critical growing periods for the crops. Non-irrigated agriculture accounts for some 60 percent of production in the developing countries. In rainfed agriculture, land management can have a significant impact on crop yields: proper land preparation leading surface runoff to infiltrate close to the roots improves the conservation of moisture in the soil. Various forms of rainwater harvesting can help to retain water *in situ*. Rainwater harvesting not only provides more water for the crop but can also add to groundwater recharge and help to reduce soil erosion. Other methods are based on collecting water from the local catchment and either relying on storage within the soil profile or else local storage behind bunds or ponds and other structures for use during dry periods. Recently, conservation agriculture practices such as conservation tillage have proven to be effective in improving soil moisture conservation.

The potential to improve non-irrigated yields is restricted where rainfall is subject to large seasonal and interannual variations. With a high risk of yield reductions or complete loss of crop from dry spells and droughts, farmers are reluctant to invest in inputs such as plant nutrients, high-yielding seeds and pest management. For resource-poor farmers in semi-arid regions, the overriding requirement is to harvest sufficient food stuff to ensure nutrition of the household through to the next harvest. This objective may be reached with robust, drought-resistant varieties associated with low yields. Genetic engineering has not yet delivered high-yield drought-resistant varieties, a difficult task to achieve because, for most crop plants, drought resistance is associated with low yields.

Role of irrigation in food production

In irrigated agriculture, water taken up by crops is partly or totally provided through human intervention. Irrigation water is withdrawn from a water source (river, lake or aquifer) and led to the field through an appropriate conveyance infrastructure. To satisfy their water requirements, irrigated crops benefit from both more or less unreliable natural rainfall, and from irrigation water. Irrigation provides a powerful management tool against the vagaries of rainfall and makes it economically attractive to grow high-yield seed varieties and to apply adequate plant nutrition as well as pest control and other inputs, thus giving room for a boost in yields. Figure 3 illustrates the typical yield response of a cereal crop to water availability and the synergy between irrigation, crop variety and inputs. Irrigation is crucial to the world's food supplies. In 1998, irrigated land made up about one-fifth of the total arable area in developing countries but produced two-fifths of all crops and close to three-fifths of cereal production.

Figure 3 **Typical response to water for cereal crops**

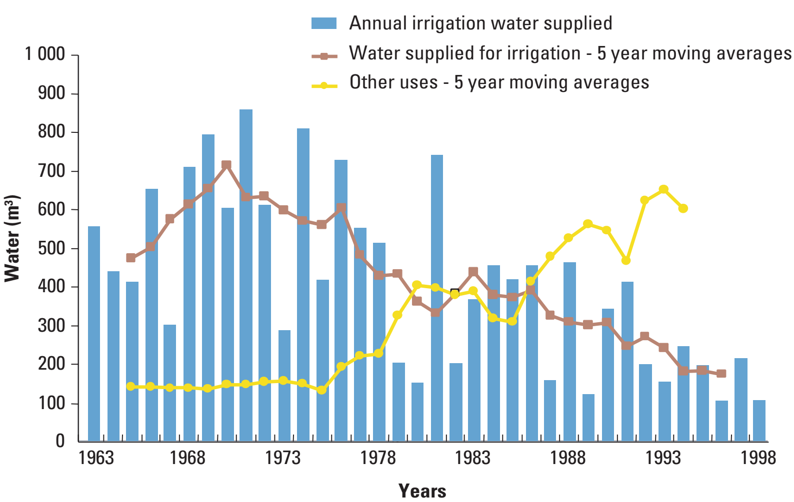


The graph shows the yield response of crops to water availability. High yielding varieties produce more than rainfed varieties only when provided with adequate amount of water.

Source: Smith *et al.*, 2001.

The developed countries account for a quarter of the world's irrigated area (67 million ha). Their annual growth of irrigated area reached a peak of 3 percent in the 1970s and dropped to only 0.2 percent in the 1990s. The population of this group of countries is growing only slowly and therefore a very slow growth in their demand and production of agricultural commodities is foreseen. The focus of irrigation development is consequently expected to be concentrated on the group of developing countries where demographic growth is strong. Increasing competition from the higher valued industrial and domestic sector results in a decrease in the amount of overall water allocated to irrigation. Figure 4 illustrates the case for the Zhanghe irrigation system in China.

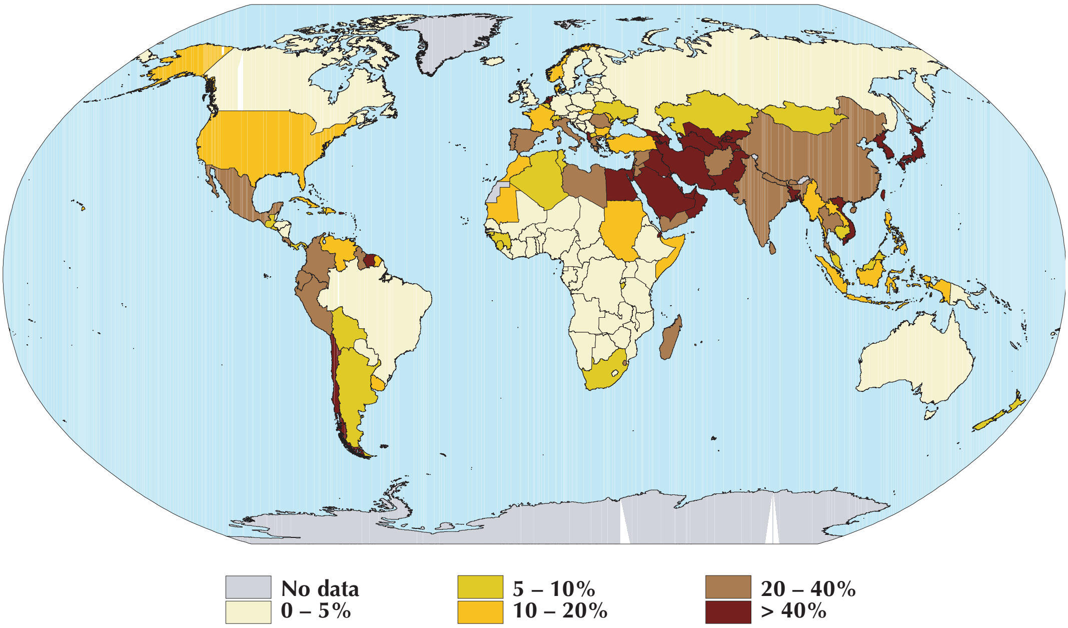
Figure 4 **Competing uses of water in the Zhanghe irrigation district, China**



This figure illustrates that increasing competition and demand from the industrial and domestic sectors result in the decrease of irrigation's share of water use.

Source: Molden, unpublished.

Map 1 Area equipped for irrigation as percentage of cultivated land by country (1998)

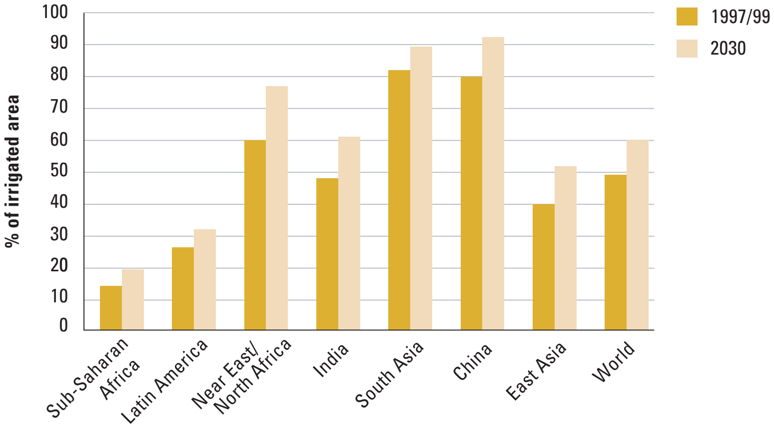


Source: FAOSTAT, 2002.

Map 1 shows irrigated land as percentage of arable land in developing countries. A high proportion of irrigated land is usually found in countries and regions with an arid or semi-arid climate. However, low proportions of irrigated land in sub-Saharan Africa point also to underdeveloped irrigation infrastructure. Data and projections of irrigated land compared to irrigation potential in developing countries are shown in Figure 5. The irrigation potential figure already takes into account the availability of water. The graph shows that a sizeable part of irrigation potential is already used in the Near East/North Africa region (where water is the limiting factor) and in Asia (where land is often the limiting factor), whereas a large potential is still unused in sub-Saharan Africa and in Latin America.

According to FAO forecasts, the share of irrigation in world crop production is expected to increase in the next decades. In particular in developing countries, the area equipped for irrigation is expected to have expanded by 20 percent (40 million ha) by 2030. This means that 20 percent of total land with irrigation potential but not yet equipped will be brought under irrigation, and that 60 percent of all land with irrigation potential (402 million ha) will be in use by 2030. The net increase in irrigated land (40 million ha, 0.6 percent per year) projected to 2030 is less than half the increase over the preceding 36 years (99 million ha, 1.9 percent per year). The projected slowdown in irrigation development reflects the projected lower growth rate of food demand, combined with

Figure 5 **Irrigated area as proportion of irrigation potential in developing countries**



This figure shows that a vast share of the irrigation potential is already being useg in Asia and in the Near East but there remains a large potential still untapped in sub-Saharan Africa and Latin America.

Source: FAO, 2002.

the increasing scarcity of suitable areas for irrigation and of water resources in some countries, as well as the rising cost of irrigation investment. The first selection of economically attractive irrigation projects has already been implemented, and prices for agricultural commodities have not risen to encourage investment in a second selection of more expensive irrigation projects.

Most of the expansion in irrigated land is achieved by converting land in use in rainfed agriculture or land with rainfed production potential but not yet in use into irrigated land. The expansion of irrigation is projected to be strongest in South Asia, East Asia and Near East/North Africa. These regions have limited or no potential for expansion of non-irrigated agriculture. Arable land expansion will nevertheless remain an important factor in crop production growth in many countries in sub-Saharan Africa, Latin America and some countries in East Asia, although to a much smaller extent than in the past. The growth in wheat and rice production in the developing countries will increasingly come from gains in yield, while expansion of harvested land will continue to be a major contributor to the growth in production of maize.

Future investments in irrigation

In many developing countries, investments in irrigated infrastructures have represented a significant share of the overall agricultural budget during the second half of the twentieth century. The unit cost of irrigation development varies with countries and types of irrigated infrastructures, ranging typically from US$1 000 to US$10 000 per hectare, with extreme cases reaching US$25 000 per hectare (these costs do not include the cost of water storage as the cost of dam construction varies on a case-by-case basis). The lowest investment costs in irrigation are in Asia, which has the bulk of irrigation and where scale economies are possible. The most expensive irrigation schemes are found in sub-Saharan Africa, where irrigation systems are usually smaller and developing land and water resources is costly.

In the future, the estimates of expansion in land under irrigation will represent an annual investment of about US$5 billion, but most investment in irrigation, between US$10 and 12 billion per year, will certainly come from the needed rehabilitation and modernization of aging irrigated schemes built during the years 1960-1980. In the 1990s, annual investment in storage for irrigation was estimated at about US$12 billion (WCD, 2000). In the future, the contrasting effects of reduced demand for irrigation expansion and increased unit cost of water storage will result in an annual investment estimated between US$4 and 7 billion in the next thirty years.

Typically, investment figures in irrigation do not include that part of the investment provided by the farmer in land improvement and on-farm irrigation that can represent up to 50 percent of the overall investment. In total, it is estimated that annual investment in irrigated agriculture will therefore range between US$25 and 30 billion, about 15 percent of annual expected investments in the water sector.

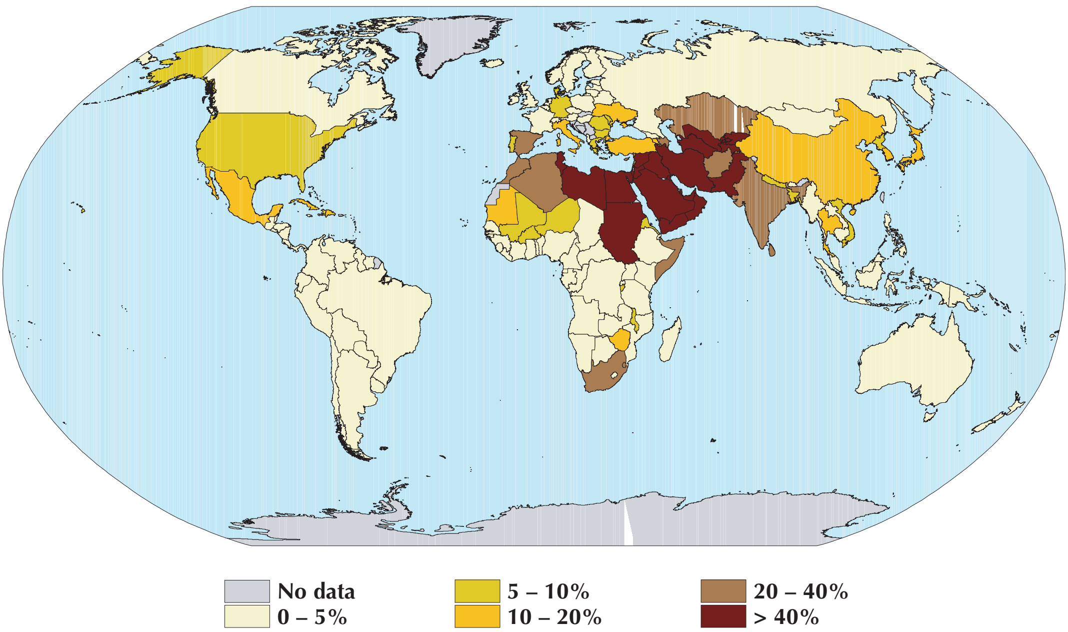
Water use efficiency

Assessing the impact of irrigation on available water resources requires an estimate of total abstraction for the purpose of irrigation from rivers, lakes and aquifers. The volume extracted is considerably greater than the consumptive use for irrigation because of conveyance losses from the withdrawal site to the plant root zone. Water use efficiency is an indicator often used to express the level of performance of irrigation systems from the source to the crop: it is the ratio between estimated plant requirements and the actual water withdrawal.

On average, it is estimated that overall water use efficiency of irrigation in developing countries is about 38 percent. Map 2 shows the importance of agriculture in the countries' water balance, and Figure 6 shows the expected growth in water abstraction for irrigation from 1998 to 2030. The predictions are based on assumptions about possible improvements in irrigation efficiency in each region. These assumptions take into account that, from the farmer's perspective, wherever water is abundant and its cost low, the incentives to save water are limited. Conversely, if farmers can profitably irrigate more land using their allocation in an optimum way, irrigation efficiency may reach higher levels.

Improving irrigation efficiency is a slow and difficult process that depends in large part on the local water scarcity situation. It may be expensive and requires willingness, know-how and action at various levels. Table 4 shows current and expected water use efficiency for developing countries in 1998 and 2030, as estimated by FAO. The investment and management decisions leading to higher irrigation efficiency are taken and involve irrigation system management and the system-dependent farmers. National water policy may encourage water savings in water-scarce areas by providing incentives and effectively enforcing penalties. When upstream managers cannot ensure conveyance efficiency, there may be no incentives for water users to make efficiency gains. With groundwater, this caveat may not apply since the incentive is generally internalized by the users, and in many cases groundwater users show much greater efficiency than those depending on surface resources. Box 2 provides an overview of different aspects of potential improvements in agricultural water use efficiency.

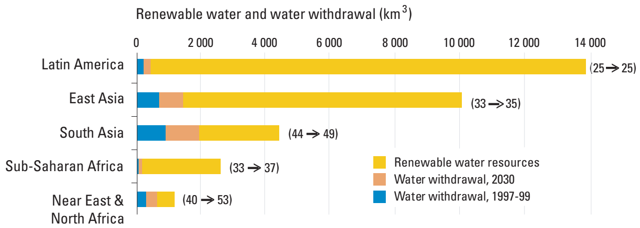
Map 2 **Agricultural water withdrawals as percentage of renewable water resources (1998)**



The importance of agriculture in countries' water balance is shown here. Whereas agricultural water withdrawals account for little of the total renewable water resources in the majority of countries, certain regions, such as north-east Africa and western Asia, are notable in that their agricultural withdrawals add up to more than 40 percent of their total water resources. In parts of the Near and Middle East, agriculture water withdrawal represents more than total resources.

Source: AQUASTAT, 2002.

Figure 6 Irrigation and water resources: current (1999) and predicted (2030) withdrawals



In brackets: movement in irrigation efficiency from 1997-99 to 2030.

This figure shows the expected growth in water abstraction for irrigation for the period 1999 to 2030. There is a potential increase in all regions, most notably in south Asia, whereas the sub-Saharan Africa region is predicted to maintain its very low level of irrigation water withdrawals.

Source: FAO data and projections.

Table 4 Water use efficiency in 1998 and 2030 (predicted) in 93 developing countries

	Sub-Saharan Africa	Latin America	Near East & North Africa	South Asia	East Asia	All countries
Water use efficiency in irrigation (%)						
1998	33	25	40	44	33	38
2030	37	25	53	49	35	42
Irrigation water withdrawal as a percentage of renewable water resources (%)						
1998	2	1	53	36	8	8
2030	3	2	58	41	8	9

Source: FAO, 2002.

BOX 2 POTENTIAL FOR IMPROVEMENTS IN AGRICULTURAL WATER USE EFFICIENCY

Global water strategies tend to focus on the need to increase agricultural water use efficiency, reduce wastage and free large amounts of water for other, more productive uses as well as sustaining the environmental services of rivers and lakes. While there is scope for improved use of water in agriculture, these improvements can only be made slowly and are limited by several considerations. First, there are large areas of irrigated agriculture located in humid tropics where water is not scarce and where improved efficiency would not result in any gain in water productivity. Second, water use efficiency is usually computed at the level of the farm or irrigation scheme, but most of the water that is not used by the crops returns to the hydrological system and can be used further downstream. In these conditions, any improvement in water use efficiency at field level translates into limited improvement in overall efficiency at the level of the river basin. Finally, different cropping systems have different potential for improvement in water use efficiency. Typically, tree crops and vegetables are well adapted to the use of localized, highly efficient irrigation technologies, while such equipments are not adapted to cereal or other crops.

Future water withdrawals for irrigation

Irrigation water withdrawal in developing countries is expected to grow by about 14 percent from the current 2 130 km^3 per year to 2 420 km^3 in 2030. This finding is consistent with the one given in Box 1 earlier but it is based specifically on individual assessments for each developing country. Harvested irrigated area (the cumulated area of all crops during a year) is expected to increase by 33 percent from 257 million ha in 1998 to 341 million ha in 2030. The disproportionate increase in harvested area is explained by expected improvements in irrigation efficiency, which will result in a reduction in gross irrigation water abstraction per ha of crop. A small part of the reduction is due to changes in cropping patterns in China, where consumer preference is causing a shift from rice to wheat production.

While some countries have reached extreme levels of water use for agriculture, irrigation still represents a relatively small part of total water resources of the developing countries. The projected increase in water withdrawal will not significantly alter the overall picture. At the local level, however, there are already severe water shortages, in particular in the Near East / North Africa region and in large parts of Asia.

Of the ninety-three developing countries surveyed by FAO, ten are already using more than 40 percent of their renewable water resources for irrigation, a threshold used to flag the level at which countries are usually forced to make difficult choices between their agricultural and urban water supply sectors. Another eight countries were using more than 20 percent, a threshold that can be used to indicate impending water scarcity. By 2030 South Asia will have reached the 40 percent level, and the Near East and North Africa not less than 58 percent. However, the proportion of renewable water resources allocated to irrigation in sub-Saharan Africa, Latin America and East Asia in 2030 is likely to remain far below the critical threshold.

The special role of groundwater

Water contained in shallow underground aquifers has played a significant role in developing and diversifying agricultural production. This is understandable from a resource management perspective: when groundwater is accessible it offers a primary buffer against the vagaries of climate and surface water delivery. But its advantages are also quite subtle. Access to groundwater can occasion a large degree of distributive equity, and for many farmers, groundwater has proved to be a perfect delivery system. Because groundwater is on demand and just-in-time, farmers have sometimes made private investments in groundwater technology as a substitute for unreliable or inequitable surface irrigation services. In many senses, groundwater has been used by farmers to break out of conventional command and control irrigation administration. Some of the management challenges posed by large surface irrigation schemes are avoided, but the aggregate impact of a large number of individual users can be damaging, and moderating the 'race to the pump-house' has proved difficult. However, as groundwater pumping involves a direct cost to the farmer, the incentives to use groundwater efficiently are high. These incentives do not apply so effectively where energy costs are subsidized; such distortion has arguably accelerated groundwater depletion in parts of India and Pakistan.

The technical principles involved in sustainable groundwater and aquifer management are well known but practical implementation of groundwater management has encountered serious difficulties. This is largely due to groundwater's traditional legal status as part of land property and the competing interests of farmers withdrawing water from common-property aquifers (Burke and Moench, 2000). Abstraction can result in water levels declining beyond the economic reach of pumping technology; this may penalize poorer farmers and result in areas being taken out of agricultural production. When near the sea, or in proximity to saline groundwater, over-pumped aquifers are prone to saline intrusion. Groundwater quality is also threatened by the application of fertilizers, herbicides and pesticides that percolate into aquifers. These 'non-point' sources of pollution from agricultural activity often take time to become apparent, but their effects can be long-lasting, particularly in the case of persistent organic pollutants.

Fossil groundwater, that is, groundwater contained in aquifers that are not actively recharged, represent a valuable but exhaustible resource. Thus, for example, the large sedimentary aquifers of North Africa and the Middle East, decoupled from contemporary recharge, have already been exploited for large-scale agricultural development in a process of planned depletion. The degree to which further abstractions occur will be limited in some cases by the economic limits to pumping, and promoted where strong economic demand from agriculture or urban water supply becomes effective (Schiffle, 1998). Two countries, Libyan Arab Jamahiriya and Saudi Arabia, are already using considerably more water for irrigation than their annual renewable resources, by drawing on fossil groundwater reserves. Several other countries rely to a limited extent on fossil groundwater for irrigation. Where such groundwater reserves have a high strategic value in terms of water security, the depletion of such reserves to irrigate is questionable.

BOX 3 FOOD SECURITY AND ITS INDICATORS

Food security is defined by FAO as physical, social and economic access for all people to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life. Its converse, food insecurity, applies when people live with hunger and fear of starvation. Food security requires that:

- sufficient quantities of food of appropriate quality be available – a production issue;
- individuals and households have access to appropriate foods – a poverty issue; and
- nourishment is taken under good conditions, including regular meals, safe food, clean water and adequate sanitation – a public health issue.

The individual state of health is also relevant for food security as disease-stricken people are hampered or unable to contribute to their own and their household's food security. By the same token, undernourished people are much more prone to disease.

For regional and global assessments, per capita food intake per day in kilocalories is used as the indicator for food security. This indicator is derived from agricultural production and trade statistics. At the national level, a per capita food intake of less than 2,200 kcal/day is taken as indicative of a very poor level of food security, with a large proportion of the population affected by malnutrition. A level of more than 2,700 kcal/day indicates that only a small proportion of people will be affected by undernourishment. As people are enabled to access food, per capita food intake increases rapidly but levels off in the mid-3,000s. It must be stressed that per capita food intake in terms of kilocalories is only an indicator of food security: adequate nutrition requires, in addition to calories, a balanced diversity of food including all necessary nutrients.

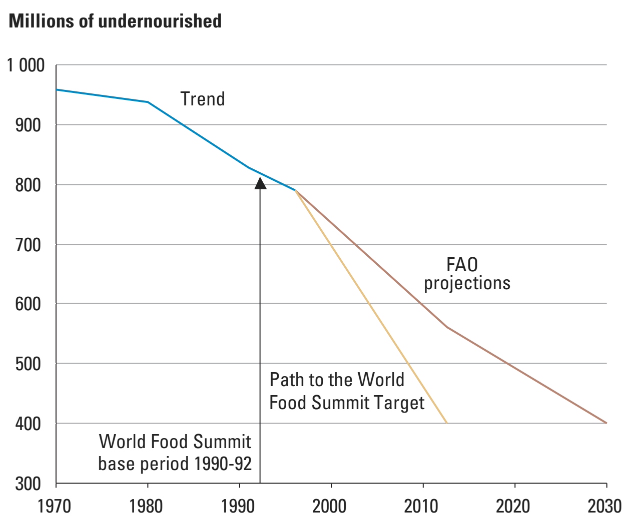
CHAPTER **FOUR**

Ensuring access to food for all

The markets fail to provide food for all

Since the 1960s, market food prices have been low while food production satisfied market demand. However, FAO's estimates indicate that in 1998 there were 815 million undernourished people in the world: 777 million in the developing countries, 27 million in countries in transition and 11 million in the industrialized countries. The world is capable of producing sufficient food to feed its population until 2030 and beyond (actually, a growing part of cereal production is already dedicated to animal feed). The 1996 World Food Summit set a target of reducing the number of undernourished people to 400 million by 2015. FAO projections indicate that this target may not be achieved before 2030. The normative target and the projection of the current course of events are illustrated in Figure 7.

Figure 7 **Progress towards the World Food Summit target**



FAO projections of attainment of the World Summit food security goal are clearly at odds with the targeted goal. According to FAO estimates, the World Summit goal would not be achieved before 2030, fifteen years behind schedule.

Source: FAO, 2002.

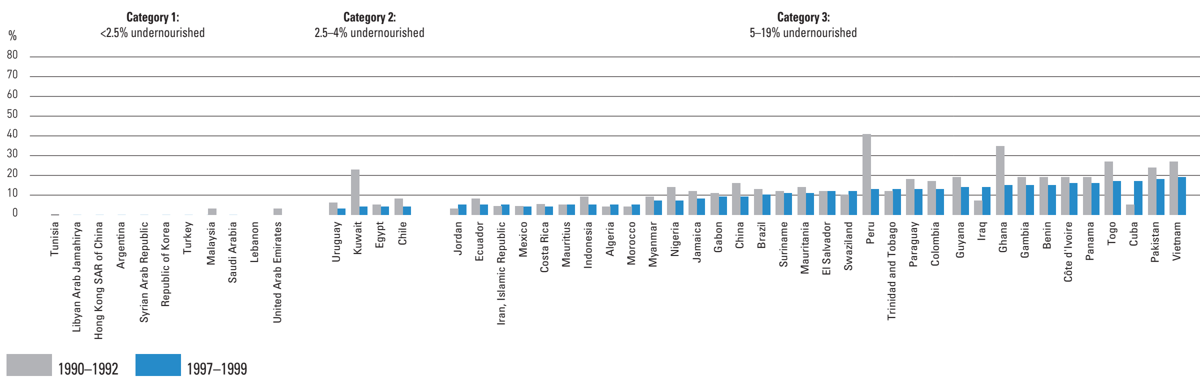
The plight of undernourished people needs to be addressed through pro-active implementation of food-security programmes. Necessary policy adjustment should be tailored to ensure that people can apply their initiative and ingenuity to access food and establish a livelihood. Food security programmes should identify the most vulnerable categories of population and consider their assets and constraints in order to emerge from poverty. FAO has developed specific indicators for this purpose (see Box 3). A first level of support is emergency assistance to households that have been hit by natural, man-made or individual disasters. Households weakened by hunger and disease need to be restored to the necessary strength for being able to apply themselves to construction of a viable livelihood. At this point, people may need punctual support to realize their plans. External support may take a variety of forms, from provision of seeds and tools to capacity building and infrastructure development. Many poverty alleviation activities bear some relation with water. The role of irrigation is discussed further on.

The undernourished: where, who, and why?

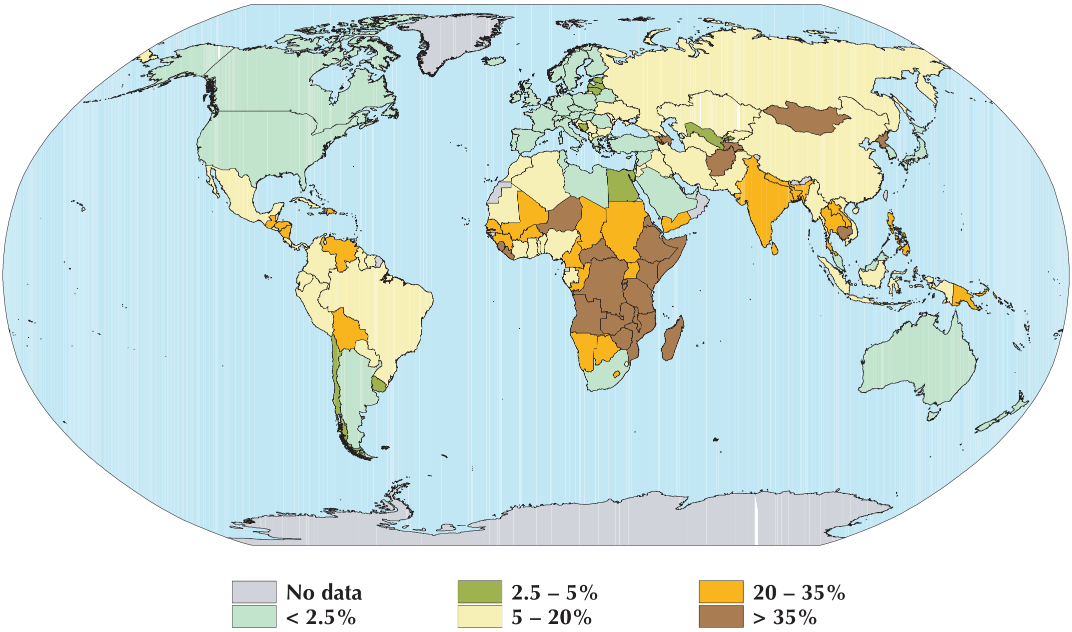
Figure 8 and map 3 identify the countries with the highest prevalence of undernourished people. Many of these countries have been stricken by war and natural disasters, including extended periods of drought. Within the countries, large numbers of undernourished people live in environmentally degraded rural areas and in urban slums. During the 1990s, the number of undernourished people fell steeply in East Asia. In South Asia, although the proportion fell, the total number remained almost constant. In sub-Saharan Africa, the proportion remained virtually unchanged, which meant that the number of undernourished people rose steeply. Food security action has therefore a special focus on sub-Saharan Africa.

Many undernourished people are refugees who have lost their physical and social assets in displacement caused by war or natural disaster. The cause of displacement can also be unmitigated externalities stemming, for example, from urban development and consequent water pollution, as well as construction of dams and consequent flooding of the land. Some national macro-policies have failed to recognize the importance of agriculture and have also contributed to the forces pushing

Figure 8 **Proportion of undernourished people in developing countries, 1990–1992 and 1997–1999**

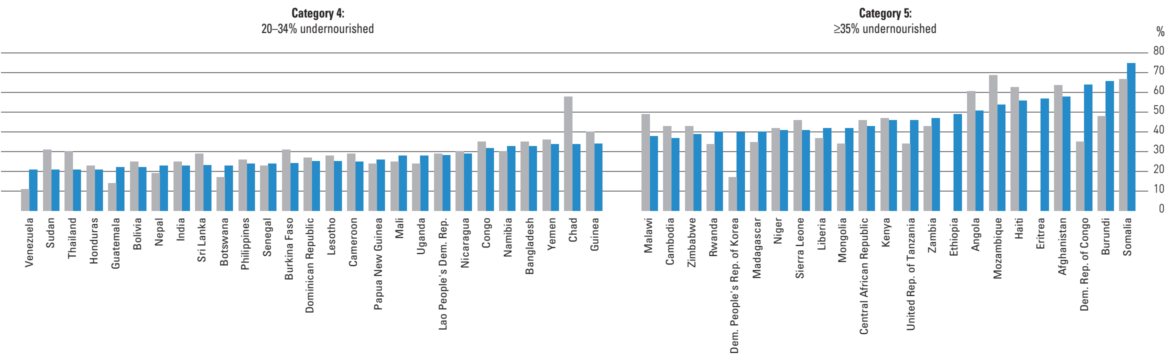


Map 3 **Percentage of undernourished people by country (1998)**



This map shows large regional disparities in the proportion of undernourished people throughout the world, and illustrates the typical division between developed and underdeveloped countries. Whereas western Europe and North America have reasonable food security levels, much of Africa, and large parts of Latin America and Asia do not enjoy the same luxury.

Source: FAO, 2001b.



This graph indicates the levels of malnutrition in developing countries between 1990-92 and 1997-99. While a majority of countries have reduced their level of malnutrition, there are still many cases of worsening situations.

Source: FAO, 2001b.

rural people into poverty. In rural areas, the people most affected include smallholders, landless labourers, traditional herders, fishermen and generally marginalized groups such as refugees, indigenous peoples and female-headed households. Children are particularly vulnerable to the full impact of hunger, which can lead to permanent impairment of physical and mental development.

Undernourishment is a characteristic feature of poverty. Poverty includes deprivation of health, education, nutrition, safety, and legal and political rights. Hunger is a symptom of poverty and also one of its causes. These dimensions of deprivation interact with and reinforce each other. Hunger is a condition produced by human action, or lack of human action to correct it. For example, in the early 1990s nearly 80 percent of all malnourished children lived in developing countries that produced food surpluses. Lack of access to water to provide basic health services and support reliable food production is often a primary cause of undernourishment. To eradicate hunger, abundant food production is a requirement, but in addition existing food needs to be accessible to all.

The role of irrigation in alleviating poverty and improving food security

There is a positive, albeit complex, link between water services for irrigation and other farm use, poverty alleviation and food security (IFAD, 2001; FAO, 2001a; FAO/World Bank, 2001). Many of the rural poor work directly in agriculture, as smallholders, farm labourers or herders. The overall impact can be remarkable: in India, for example, in unirrigated districts 69 percent of people are poor, while in irrigated districts, only 26 percent are poor (World Bank, 1991). Their income can be boosted by pro-poor measures, such as ensuring fair access to land, water and other assets and inputs, and to services, including education and health. Relevant reforms of agricultural policy and practices can strengthen these measures.

The availability of water confers opportunities to individuals and communities to boost food production, both in quantity and diversity, to satisfy their own needs and also to generate income from surpluses. Irrigation has a land-augmenting effect and can therefore mean the difference between extreme poverty and the satisfaction of the household's basic needs. It is generally recognized that in order to have an impact on food security, irrigation projects need to be integrated with an entire range of complementary measures, ranging from credit, marketing and agricultural extension advice to improvement of communications, health and education infrastructure (see Box 4 for an example from Senegal). Land tenure may also represent a major constraint: irrigation schemes controlled by absentee landowners and serving distant markets, even when highly efficient, may fail to improve local food security when both commodities and benefits are exported.

Irrigation projects are as diverse as the local situations in which they are implemented. Generally, small-scale irrigation projects including projects based on shallow groundwater pumping provide

BOX 4 WATER AND FOOD SECURITY IN THE SENEGAL RIVER BASIN

Parts of the Senegal River basin in Senegal and Mauritania are entirely situated in the arid Sahelian zone with, in the lower valley and the delta, a total annual rainfall that rarely exceeds 400 mm. Thus, when used in the low-lying areas, the rain-dependent crops of the plateau and flood-recession crops barely meet the food needs of farming families. During periods of drought like those of the 1970s, local populations are drastically affected; for this reason one of the four fundamental tasks for the Organization for the Development of the Senegal River (OMVS) at its founding in 1972 was 'to create food self-sufficiency for populations in the Senegal River basin and, by extension, for the subregion.' To this end the goal set was to develop 375 000 hectares out of a potential irrigable area of 823 000 hectares, by combined operation of the Manantali and Diama dams. The crops targeted for irrigation were rice and wheat, to be added to sorghum, maize and market gardening – the traditional rain-dependent and recession crops. With respect to this goal, a total of some 100 000 hectares has so far been developed. However, a 1996 study by the International Institute for Environment and Development (IIED) indicated that no single type of farming could guarantee the survival of the family unit and that crop diversification was essential. The study also pointed out the major issues in optimizing flood plain development as part of the fight for food security. These geographical areas are vital for agriculture, fishing, livestock pasture and forest regeneration. This is why, after the dams were filled in 1986 and 1987, OMVS decided to simultaneously expand the irrigated areas by delivering artificial flooding that would guarantee between 50 000 hectares and 100 000 hectares of recession crops and ensure 63 000 ha of pasture and wooded areas for 2.7 million cattle and 4.5 million sheep and goats. Fishing is also an economically and socially important activity in the Senegal River basin. With annual catches estimated at between 26 000 and 47 000 tons, it represents a substantial income for the populations concerned. The storage lakes of the Diama and Manantali dams – 11.5 million m^3 spread over 500 km^2 – have attracted large fishing communities since the dams became operational. The programmes begun by OMVS thus contribute to achieving food security in the area. For this aim to be met as quickly as possible, the OMVS High Commission sees a need, on the one hand, for increased technical, institutional and financial means so as to accelerate development and ensure sound management, and on the other hand, for technical improvements permitting more intensive farming, higher yields and a close association between farming, fishing, livestock-raising, forestry and the water economy.

Source: Prepared for the World Water Assessment Programme (WWAP), by the Organization for the Development of the Senegal River (OMVS), 2002.

a manageable framework that can give control to the local poor and avoid leaking resources to the non-poor. Large-scale irrigation, as may be determined by the need to carry out large-scale engineering works to harness water and convey it to the fields, can also be made to work for the poor provided that the benefits can be shared equitably, and investment, operation and maintenance costs are efficiently covered.

Managing agricultural risk for sustainable livelihoods

Community-managed small-scale irrigation systems, by improving yields and cropping intensities, have proved effective in alleviating rural poverty and eradicating food insecurity. Marketing of agricultural produce, both locally and at more distant places when adequate transport and communication infrastructure is available, can make a significant contribution to the income of farmers. Bank deposits and credits, as well as crop insurance, can be used to finance agricultural operations and buffer against climatic risk. However, banking services usually are not accessible to people who have no collateral assets. Many rural credit systems may also not accommodate pay-back over a period of years – the time needed to realize the benefits from investment in irrigation technology. However, non-conventional credit systems based on trust and social solidarity can support poor farmers. Improvement in poor people's food commodity storage facilities reduces post-harvest losses and can save significant amounts of food, thus contributing to food security. Similarly, where technically and financially possible, storing water in surface reservoirs and aquifers is a strategic means for managing agricultural risk. Water in the reservoir or the aquifer is, in a way, equivalent to money in the bank.

Irrigation contributes to creating off-farm employment

Irrigation, supported through inputs such as high-yielding varieties, nutrients and pest management, together with a more extended agricultural season, higher cropping intensity and a more diverse assortment of crops, can generate rural employment in other non-agricultural services. The productivity boost provided by irrigated agriculture results in increased and sustained rural employment, thereby reducing the hardships experienced by rural populations that might otherwise drift to urban areas under economic pressure. Growth in the incomes of farmers and farm labourers creates increased demand for basic non-farm products and services in rural areas. These goods and services are often difficult to trade over long distances. They tend to be produced and provided locally, usually with labour-intensive methods, and so have great potential to create employment and alleviate poverty. Studies in many countries have shown multipliers ranging from two (in Malaysia, India and the United States) to six (in Australia, World Bank, 2002).

The contribution of fisheries and aquaculture to food security

Fish has a very good nutrient profile and is an excellent source of high-quality animal protein and of highly-digestible energy. Refugees and displaced people facing food insecurity may turn to fishing for survival, where this possibility exists. Staple-food fish, often low-valued fish species, is in high demand in most developing countries, because of its affordability.

Inland fish production provides significant contributions to animal protein supplies in many rural areas. In some regions freshwater fish represent an essential, often irreplaceable source of cheap high-quality animal protein, crucial to a well-balanced diet in marginally food-secure communities.

Most inland fish produce is consumed locally, marketed domestically, and often contributes to the subsistence and livelihood of poor people. The degree of participation in fishing and fish farming is high in many rural communities. Fish production is often undertaken in addition to agricultural or other activities. Yields from inland capture fisheries, especially subsistence fisheries, can be very significant, even though they are often greatly under-reported. Yields from inland capture fisheries are highest in Asia in terms of total volumes, but are also important in sub-Saharan Africa. Fishery enhancement techniques, especially stocking of natural and artificial water bodies, are making a major contribution to the total catch (FAO, 2000).

Rural aquaculture contributes to the alleviation of poverty directly through small-scale household farming of aquatic organisms for domestic consumption and income. It also contributes indirectly through employment of the poor as service providers to aquaculture or as workers on aquatic farms. Poor rural and urban consumers can greatly benefit from low-cost fish provided by aquaculture. For aquaculture to be effective in alleviating poverty, it should focus on low-cost products favoured by the poor, and emphasis should be placed on aquatic species feeding low in the food chain. The potential exists for aquaculture production for local markets and consumers. Combined rice-fish systems are possible and carry high benefits because they provide cereals and protein at the same time. These systems have also been shown to have beneficial effects on the malaria situation, where mosquito vectors breed in rice fields and where the selected fish species feed on the mosquito larvae. This is the case in parts of Indonesia, for example (see Box 5).

BOX 5 **RICE-FISH FARMING IN LAOS**

Lao People's Democratic Republic has extensive water resources in the form of rivers, lakes and wetlands. Fisheries and the collection of aquatic animals during the rainy season are important activities in the country and fish forms an important part of the national diet. Rice cultivation is widespread in rainfed, irrigated and terraced fields. Rice is mostly cultivated on a one-crop-per-year basis, but in irrigated areas two crops per year are possible. In upland rainfed fields, bunds are often raised to increase water depth for fish cultivation. In some cases, a small channel is constructed to facilitate fish capture. In the Mekong River plain, rice-fish farming is practiced in rainfed rice fields where soils are relatively impermeable as well as in irrigated rice fields, which offer ideal conditions for fish cultivation. As elsewhere, there is little reliable data available concerning production levels from rice-fish farming but productions of 125 to 240 kg/hectare/year have been reported for upland rice-fish production systems. Carp, tilapia and other species cultured in this system are mostly for consumption in the farmer's home. While rice-fish farming is popular with farmers, there are some constraints that need to be addressed through proper support. Integrated pest management practices should be applied to reduce pesticide use. Furthermore, fingerlings need to be made available more easily and farmers' access to credit should be improved.

Source: Dixon *et al.*, 2001.

Forestry and food security

A large number of forest products contribute to food security: FAO estimates that about 1.6 billion people in the world rely to a certain extent on forest resources for their livelihoods. For most rural people in the world, firewood provides the fuel for cooking food, and so its availability is an integral part of food security. The bio-energy sector generates employment and income in developing countries.

Most forests and tree plantations subsist on rainwater, or may develop around irrigation schemes. Some tree species can use large amounts of water drawn from water storage in the soil profile and in shallow aquifers. Trees in forests and outside of forests provide significant benefits to poor people and contribute to food security. The benefits from water used by forests are largely seen in terms of wood and non-wood products, as well as in protecting the environment, reducing soil degradation, and preserving biodiversity.

CHAPTER **FIVE**

Trends in irrigation-water management

Adapting institutional arrangements

The institutional arrangements governing irrigation-water appropriation and use have been established over the centuries in various countries under different environmental and social circumstances. Adapting to new pressures that call for higher water productivity and increased user participation and liability in cost recovery has proved difficult. With increasing competition for water, both within the irrigated subsector (between farmers) and with other economic sectors – principally municipalities, industry and hydropower - irrigation institutions are often not adequately equipped to adapt to changing circumstances and expectations. The competing demands from municipalities, industry and the energy sector are forcing transfers from agriculture to other, higher value, uses. Figure 4 earlier showed an example of this process at work in one district in China.

Irrigated agriculture has played a pivotal role in keeping up with global food demands in the twentieth century, but into the twenty-first century there is continued evidence of lacklustre performance in the public sector alongside a frustrated private sector. In many cases, distorted markets, ill-conceived incentives and institutional rigidity plague the irrigation subsector. Producers are seeking financial returns against tight margins for food commodities, subsidies for rainfed agriculture and varying degrees of competition for raw water from other sectors, and are also expected to maintain environmental integrity.

One troubling aspect is the continued expectation that the physical endowments of land and water equate to a ‘potential' that needs to be realized, without parallel analysis of economic, financial, institutional and environmental constraints and without a realistic market analysis. This has conditioned the approach that many governments continue to take in implementing irrigation and water policies, irrigation institutions and in allocating public-sector budgets. There has been a dominance of supply-led approaches predicated upon large-scale irrigation infrastructure and governments have shown determination in continuing to play a role in operating public infrastructure for the supply of irrigation services. In many instances, there is a sharp discontinuity in policy, institutional capacity, investment between the provision of irrigation services and the promotion of agricultural systems. This applies to many of the key developing economies. It could be argued that if irrigated agriculture has its failures, it is in a large part because it has focused essentially on providing water and not enough on the productivity of the agricultural systems and their responsiveness to agricultural markets.

Increasing private investment in irrigation

Investment in large irrigation projects increased in the 1970s and then fell by more than 50 percent in the 1980s. It further declined in the 1990s. Most of the water-related infrastructure projects over the past forty to fifty years were financed by the governmental sector with significant intervention by the international development banks. Development costs for new irrigation lands have increased markedly in recent years; for example, costs have been increasing by more than 50 percent in the Philippines, 40 percent in Thailand and have nearly tripled in Sri Lanka. With declining crop prices, it is difficult to justify new irrigation development. Financial capability is lacking for new infrastructure as well as for modernizing present structure and ensuring system sustainability.

Recently there has been an increase in the private-sector financing of large water-sector infrastructure, and small-scale irrigation systems. According to the World Bank, 15 percent of the infrastructure is currently being financed through private funds, and this is part of a growing trend. Groundwater development has proved a particularly attractive target for private investment because of the private level of control it offers.

Reforming irrigation: modernization and empowerment

During the green revolution of the 1960s and 1970s, making irrigation water available to farmers had a high priority. Governments had surface irrigation systems established and managed through public sector agencies. Some large-scale systems were poorly designed, with insufficient provision for drainage and consequent soil degradation. System management often failed to respond to the needs of users, in particular of smallholders and sectors carrying low social and political weight. Water-use fees were not collected or not applied to proper system operation and maintenance. Large rehabilitation needs emerged and as governments and international lending institutions found it difficult to raise funds for this purpose, it became clear that the economic and social context of large-scale irrigation needed to be reformed.

Reforming efforts focused on transferring responsibility for operating and maintaining irrigation systems to the farmers, organized in water-user associations. This highlighted the need for building and developing managerial capacity among stakeholders, while confining irrigation-system administration to the role of water-service provider. Empowerment alone may not be sufficient unless deficiencies in design and operation and/or upgrade of infrastructures are addressed. Irrigation modernization is a process of change from supply-oriented to service-oriented irrigation. It involves institutional, organizational and technological changes and transforms a traditional irrigation scheme from protective to productive irrigation. The modernization and transfer of some management responsibilities of government-held irrigation systems to water-user associations and service-providing companies have been carried out in several countries such as Mexico, China and Turkey and has proved beneficial in certain cases. However, governments have tended to be only half-hearted when enacting complementary policies and institutional reforms that are necessary to provide the appropriate environment for effective operation of the new irrigation management entities. The process of empowering marginalized stakeholders, including smallholders, and evicting political influence from irrigation management, is as yet not completed. Irrigation management transfer is complicated because of a number of factors. Firstly there is a need to promote poor stakeholders into equity with non-poor stakeholders and reconcile conflict between upstream and downstream users. Secondly, the transaction costs of water-user associations may be higher than under properly working 'command and control' management establishments. Finally, the apportionment of financial and operation risk and liability is difficult to make when a large-scale infrastructure is transferred to user associations or service companies not prepared for such responsibilities.

Equity in the roles of men and women in irrigation

Gender equity is a case in point. Women are among the main stakeholders in poverty alleviation, in food production in irrigated and non-irrigated agriculture, and in ensuring and dispensing nutrition at the household level. A majority of the poor, estimated at 70 percent, are rural people, and rural poverty has become feminized as men of productive age migrate away from impoverished rural areas to the more promising urban environment, or are forcibly recruited by warring factions, leaving behind the women, the elderly, the sick and the children. In rural areas endemically stricken by conflicts, whatever little infrastructure there was collapses or is wantonly destroyed and insecurity prevails, increasing the burden on women. Households headed by women are recognized among the poorest of the poor. Against a biased view that 'women do not irrigate', women are now recognized as actively involved in irrigation, often demonstrating high levels of skill (see Box 8).

BOX 6 **LAND OWNERSHIP AND ECONOMIC INDEPENDENCE**

A recent study in Dakiri, Burkina Faso, shows that allocating smaller plots to men and women separately instead of allocating larger plots to household heads has produced both higher yields and social benefits. When both men and women have irrigated plots, the productivity of irrigated land and labour is higher than in households where only men have plots. Women are equally good or even better irrigation farmers than men, and those who have obtained irrigated plots are proud of their increased ability to contribute to the needs of their households. Women prefer to contribute to their households by working on their own plots rather than providing additional labour to their spouse's or to the collective plots. As they become economically less dependent upon their husbands, they can help support their relatives and increase their own opportunities for individual accumulation of wealth in the form of livestock. The effects of having an individual plot significantly improve the bargaining position of a woman within a household and are a source of pride in the household and the community.

Source: OECD/DAC, 1998.

Improving water-use productivity in agriculture

Improving water-use productivity is often understood in terms of obtaining as many kilograms of crop as possible per m^3 of water – 'more crop for the drop'. Financially astute farmers may prefer to target a maximum income per m^3 – 'more dollars for the drop', while community leaders and politicians could be looking for maximum employment and widespread income generated through the crop and its derivatives – 'more jobs for the drop'. In a broad sense, increasing productivity in agriculture involves deriving more benefit, or achieving more welfare, for every unit of water withdrawn from natural water bodies.

Technology permits accurate water application in the optimum quantity and timing for crop development. Drip irrigation for example can respond to existing soil moisture conditions by leading the required quantity of water to the root zone of the plant. Laser-supported land-levelling devices allow accurate bounded field irrigation. When such techniques are applied in water-scarce regions with high-value outputs their application results in profit for the farmer. The application of advanced technology is dependent on a level of investment and capacity as well as on an economic incentive to make it worthwhile. Most irrigation in the world was initially established to take advantage of otherwise-unused water. It should not be surprising that water-use efficiency makes only slow progress wherever water is cheap, either because it has no other uses and therefore a low opportunity value, or because it is subsidized. Actually improving efficiency can be a slow and laborious process that requires system modernization, therefore upgrading the technological environment and the knowledge and capacity of irrigation operators.

From the perspective of a national economy, a key goal for water-use productivity is to improve net economic returns per dollar invested in water use, favouring investment in the urban and industrial sectors. However, such a view may not adequately recognize the social and environmental benefits derived from agriculture.

Diversifying crops

Crop diversification, made possible by irrigation, has a beneficial influence on local food security in remote rural areas by supporting a longer growing season and providing a healthier, more diversified diet including fresh produce. At a medium scale, crop diversification strengthens the rural economy and reduces the uncertainty associated with the market vagaries that affect monocultures. In 1990 in Asia for example, cereals, pulses and other crops accounted for 66 percent, 8 percent and 26 percent of the total cropped area. By 1997, this had changed to 56 percent, 7 percent and 37 percent. Per capita cereal production nevertheless increased owing to higher yields. Irrigation systems designed for cereal cultivation often do not have sufficient regulation and the effective water control structures required for crop diversification.

Diversification also calls for higher levels of management capacity, as it is not enough to produce a variety of crops: in addition to being produced, these have to be marketed. Policy and economic factors such as market incentives and availability of labour influence the crop choice of farmers. Availability of low-cost pumping technology has supported the expansion, under private initiative and finance, of diversified cropping systems.

CHAPTER **SIX**

Agricultural water use, environment and health

Environmental aspects

Agriculture may have distinct negative externalities in terms of water quantity and quality. Pasture and crops take up 37 percent of the Earth's land area. Agriculture is the largest water user and the main source of nitrate pollution of ground and surface waters, as well as the principal source of ammonia pollution. It is also a major contributor to the phosphate pollution of waterways and of release to the atmosphere of the greenhouse gases methane and nitrous oxide. Land degradation, Stalinization, over-abstraction of groundwater and the reduction of genetic diversity in crop and livestock affect the basis of agriculture's own future. The vanishing Aral Sea is a clear example of the irreversible impacts of excessive withdrawals. The irrigation sector is coming under increasing public scrutiny as amenity and ecosystem values are lost while the expected economic and social benefits of irrigation systems are not fully realized. Competition between urban dwellers and agriculture is also a growing issue and may worsen environmental pressure. In developed countries, environmental concerns have been a key driver for modernizing irrigation systems.

Reclamation of wetlands has historically made a major contribution to agricultural growth. Because of the presence of water during a large part of the year and in view of the relative fertility of their soils, many wetlands have a good potential for agricultural use. However, this use leads to serious environmental damage, which has been recognized by the adoption of the Convention on Wetlands (Ramsar, 1971) to protect wetlands. The developing countries still have some 300 million ha of wetlands that may be suitable for crop production but only a relatively small percentage is currently used to this end. Where no alternative additional land resources are available to exploit, wetlands will inevitably be converted to crop production. This is the case in many parts of sub-Saharan Africa, where the nutritional situation is bad and wetlands represent an attractive opportunity for agricultural development.

Unwise use of wetlands may result in environmental degradation. Draining of wetlands has often been carried out under the wrong assumption that wetlands are useless and worthless. Sustainable use of wetlands can be achieved by selecting crops adapted to wetland conditions, using appropriate water and soil management technologies and planning wetland development and management carefully within the global framework of the watershed area. Wetlands of particular international or national importance on account of their significance in terms of ecology, botany, zoology or biodiversity should be protected from any agricultural use and from the influences of agricultural activities in upstream areas.

Water pollution, habitat degradation and massive water withdrawals can deprive fishing communities of their livelihood and push them into food insecurity. The resulting environmental impacts affecting fishery resources in inland waters can be devastating. Even in estuarine and coastal zones at the lower end of river basins, fishery resources are impacted by pollution, habitat degradation and upstream water withdrawal and use. It is increasingly recognized that agriculture also has positive externalities, including environmental services and products. The multifunctional nature of agriculture is increasingly acknowledged and encouraged, so that farmers are seen not only as commodity-producers but also appreciated as self-employed citizens, stewards of the landscape and stakeholders in vibrant communities. Trade-offs between food security and the environment can be further reduced through already available or emerging technologies and land-management practices. By using more sustainable production methods, the negative impacts of agriculture on the environment can be attenuated. Agriculture can play an important role in reversing negative impacts by, for example, environmentally sound water use, biological treatment of waste, enhancing the infiltration of water to reduce flood runoff, preserving agricultural and natural biodiversity, and storing carbon in soils.

Water-quality deterioration

With rising demands for water, quality concerns over water have risen rapidly. Pollutant loads have increased enormously, and at the same time the amounts of water available for dilution are decreasing. The situation is particularly alarming in developing nations while, in developed countries, the enforcement of water quality measures has resulted in improved water-quality conditions for most rivers. Water quality poses a serious threat to the sustainability and the safety of food produced by intensive farming systems upon which global food security has become increasingly dependent. Security and stability in food supplies in this century will be closely linked to success in water quality control. Organic matter, if free of pathogens, can actually be beneficial to irrigated agriculture (see Box 7), but water contamination with hazardous chemicals makes it unusable for food production.

It is estimated that poor drainage and irrigation practices have led to waterlogging and salinization of about 10 percent of the world's irrigated lands, thereby reducing productivity. In particular, mobilization of resident salts is a widely-occurring phenomenon in irrigated river basins in arid regions. Waterlogging and salinization in large-scale irrigation projects are often the result of unavailable drainage infrastructure that was not included in the engineering design to make projects look economically more attractive. These problems are generally associated with large-scale irrigation development under arid and semi-arid conditions, as in the Indus, the Tigris-Euphrates and the Nile river basins. The solutions to these problems are known but their implementation is costly.

BOX 7 USE OF WASTEWATER FOR IRRIGATION

The cost of disposing of urban wastewater is all too often externalized against the aquatic environment and downstream users in rivers, estuaries and coastal zones and hardly, if ever, appears in the benefit and cost accounts. However, wastewater is recognized as a resource, particularly in water-scarce regions. If the polluter actually pays, wastewater is free or has only a low cost, is reliable in time and close to urban markets. In addition to direct benefits to farmers who would otherwise have little or no water for irrigation, wastewater improves soil fertility and reduces water contamination downstream. The total land irrigated with raw or partially diluted wastewater is estimated at 20 million hectares in fifty countries, somewhat below 10 percent of total irrigated land in developing countries. For irrigation use, wastewater should be subject to primary and secondary treatment, but in poor countries that is often not the case and raw sewage is applied. Disadvantages and risks related to use of insufficiently treated wastewater concern the exposure of irrigation workers and food consumers to bacterial, amoebic, viral and nematode parasites as well as organic, chemical and heavy metal contaminants. In a context of prevailing poverty, such water is used in the informal, unregulated sector, but sanitary concerns preclude the export of the products and, at least partially, the access to local food markets. Governments and the development community promote efforts to lead wastewater reuse into sustainable channels, but countries and municipalities short of resources are slow in facing the cost of water treatment. Given water scarcity and the relatively high cost of obtaining potable freshwater for municipal uses, the use of treated wastewater in the urban context is projected to increase in the future.

Health and irrigation

The key irrigation-related vector-borne diseases are malaria, schistosomiasis and Japanese encephalitis. Irrigation development has in the past sometimes been accompanied by adverse impacts on the health status of local communities. The principal causes for these impacts are rooted in ecosystem changes that created conditions conducive to the transmission of vector-borne diseases, and drinking water supply and sanitation conditions leading to gastrointestinal conditions. The attribution of the burden of each of these diseases to irrigation, or components thereof in specific settings is complex. Only where irrigation is introduced in an arid region where the diseases previously did not occur, is the association between the resulting dramatic landscape changes and the explosive rise of disease incidence and prevalence clear-cut. In most cases, there is a complex mixture of contextual determinants of the diseases combined with a number of confounding factors. For example, in parts of Africa south of the Sahara, the transmission of malaria is so intense throughout the year that the additional risk factors from irrigation development will not add to the disease burden. Schistosomiasis, rightly equated with irrigation in Africa, is also determined by human behaviour and by the state of sanitation.

Many vector-borne disease problems in irrigated areas can be traced to absent or inadequate drainage. The various forms of surface irrigation all impose increased vector-borne disease hazards, while overhead irrigation and drip irrigation are virtually free of such hazards. Crop selection can be important. In that sense, flooded rice and sugarcane are crops that carry increased vector-borne disease risk. Irrigated agriculture often requires additional chemical inputs for crop protection, and the application of pesticides can disrupt the ecosystem balance favouring certain disease vectors; it can also contribute to an accelerated development of resistance to insecticide in disease vector species.

There are many opportunities in the planning, design and operation of irrigation schemes to incorporate health safeguards: hydraulic structures, for instance, can be designed so they provide less or no habitat for vector breeding. Improved water-management practices such as alternate wetting and drying of irrigated rice fields, rotational drying of parallel irrigation canals, flushing of canals with pools of standing water and clearing canals of aquatic weeks can reduce vector breeding. Moreover, the very infrastructural development that usually accompanies irrigation development and the economic development that follows in its wake imply improvements in access to health services and increased buying power to purchase drugs, mosquito nets and other preventative and protective tools and products.

Until the 1980s, a drinking-water-supply component was often overlooked in the context of irrigation development. While this situation has improved, the two types of water use are occasionally at odds. Highly increased chemical inputs may pollute groundwater and local communities have been known to revert to canal water because the quality of water from their pumps had deteriorated. Easy access to large quantities of water in irrigation canals for domestic needs other than drinking will contribute positively to overall hygiene. There are also important overlaps between operation and maintenance tasks for irrigation and drainage schemes and for drinking water supply and sanitation services that would allow important economies of scale to be achieved. A study carried out in three African countries (see Box 8) for instance, showed that small dams and wells acted as catalysts for change, initiating actions that generated income and allowed people to diversify diets, afford health services and better cope with hungry periods of the year.

BOX 8 **INTEGRATING IRRIGATION, NUTRITION AND HEALTH**

FAO assessed the impact of three small-scale irrigation projects on the health and welfare of villagers in Burkina Faso, Mali and the United Republic of Tanzania. The assessment showed that small dams and wells acted as catalysts for change, initiating actions that generated income and allowed people to better cope with the hungry periods of the year, diversify diets and afford health services. These projects encouraged production, processing and preparation of a variety of indigenous foods, nutrition education and the participation of women's groups. In all three cases, irrigation increased food production or income by enough to provide one additional meal per day, even during the 'hungry season' before the harvest (FAO, 2001b). In the arid countries of Asia, there are often large areas where groundwater is brackish and people have to obtain water from irrigation canals for all uses, including domestic. A study by the International Water Management Institute in Pakistan showed that safe use of canal irrigation water is possible if households have a large water storage tank in their house and have a continuous water supply for sanitation and hygiene. The results also showed that children from households having a large storage capacity for water in the house had much lower prevalence of stunted growth than children from families lacking such a storage facility. Increasing the quantity of irrigation water available for domestic use and providing toilet facilities are the most important interventions to reduce the burden of diarrhoeal disease and malnutrition.

CHAPTER **SEVEN**

Conclusions

Agriculture will remain the dominant user of water at the global level. In many countries, in particular those situated in the arid and semi-arid regions of the world, this dependency can be expected to intensify. Water appropriation by agriculture experienced strong growth with the Green Revolution. The contribution of irrigated agriculture to food production is substantial but the rate of growth will be lower than in the past. Both irrigated and non-irrigated agriculture still have scope for increasing productivity, including water productivity. Arguably, the expansion of irrigated agriculture protected people on the nutritional fringe from premature death, and preserved tracts of land under forest and wetlands from encroachment by hard-pressed farmers. However, pressures to encroach on such lands persist.

Within the current demographic context, the global food security is slowly improving and towards 2050, the increased world population could enjoy access to food for all. The fact that close to 800 million people are at present ravaged by chronic undernourishment in developing countries is not due to a lack of capacity of the world to produce the required food, but to global and national social, economic and political contexts that permit, and sometimes cause, unacceptable levels of poverty to perpetuate. Malnutrition is being alleviated, albeit slowly, and as the share of food slips lower in household budgets, the prospects for agriculture to internalize its costs may improve. Water still has a large unmet potential to help alleviate poverty and undernourishment. In taking this direction, agricultural-water management will continue to require better integration with rural household water uses, and to make more positive contributions in environmental management. Food for all could be achieved much earlier than present projections indicate, provided that the necessary policies are backed with the necessary resources. The economic, social and environmental cost of continued food insecurity for hundreds of millions of people is high.

Agriculture can use water more efficiently than present practices indicate. Technology for efficient transport of water from the site of abstraction to the field, and for delivering it to the crop plants with a minimum of losses, is available and is being progressively applied where water is scarce. Irrigation-water-use efficiency increases when the right policy and market incentives are in place. As competition for limited water resources and pressure to internalize environmental impacts intensify in a number of countries, agriculture and, in particular, irrigation comes under growing pressure to review and adapt its policies and institutions, including the water rights and allocation system. Under such circumstances as in the Near East/North Africa region, current water efficiency is relatively high and projected to further increase. Data show an aggregate low-water-use efficiency in the water-rich Latin America region, and it is not seen as increasing significantly in the future because no other large-scale users compete with agriculture; locally, however, wherever water is scarce, high efficiency is also obtained in that region. Agriculture can also increase the use of recycled water and of water stemming from non-conventional sources.

References

Alcamo, J., Döll, P., Henrichs, T., Lehner, B., Kaspar, F., Rösch, T., Siebert, T. Forthcoming. 'WaterGAP: Development and Application of a Global Model for Water Withdrawals and Availability'. *Hydrological Sciences Journal*.

Burke, J.-J. and Moench, M. 2000. *Groundwater and Society, Resources, Tensions and Opportunities: Themes in Groundwater Management for the 21st Century*. New York, United Nations.

Dixon, J., Gulliver, A., Gibbon, D. 2001. *Farming Systems and Poverty: Improving Farmer Livelihoods in a Changing World.* Washington DC, Food and Agriculture Organization / World Bank.

Döll, P.; Kaspar, F., Lehner, B. Forthcoming. 'A. Global Hydrological Model for Deriving Water Availability Indicators: Model Tuning and Validation'. *Journal of Hydrology*.

Döll, P. and Siebert, S. 2002. 'Global Modelling of Irrigation Water Requirements'. *Water Resources Research*, Vol. 38, No. 4, 8.1–8.10, DOI 10.1029/2001WR000355.

FAO. 2002. *World Agriculture: Towards 2015/2030, an FAO Study*. Rome.

FAO. 2001a. *Crops and Drops: Making the Best Use of Water for Agriculture.* Rome.

FAO. 2001b. *The State of Food Insecurity in the World.* (Annual report issued also in 1999 and 2000; see web link for the ongoing series of annual reports.) Rome.

FAO. 2000a. *The State of World Fisheries and Aquaculture 2000.* Rome.

FAO. 2000b. *World Agriculture towards 2015/2030, Summary Report.* Rome.

FAO. 1999. 'Integrating Fisheries and Agriculture for Enhanced Food Security'. In: *The State of Food and Agriculture in 1998*. Rome.

FAO. 1997a. *Water Resources of the Near East Region: A Review.* Rome.

FAO. 1997b. 'Irrigation Potential in Africa: A Basin Approach'. In: *FAO Land and Water Bulletin,* Vol. 4. Rome.

FAO. 1995. 'Irrigation in Africa in Figures'. In: *FAO Water Report No 7.* Rome.

FAO/World Bank. 2001. *Farming System and Poverty: Improving Farmers' Livelihoods in a Changing World.* Rome.

IFAD (International Fund for Agricultural Development). 2001. *Rural Poverty Report 2001: The Challenge of Ending Rural Poverty*. Oxford, Oxford University Press.

IHE (Institute for Infrastructural, Hydraulic and Environmental Engineering). 2000. *A Vision of Water for Food and Rural Development.* Publication for the Second World Water Forum, The Hague.

IUCN (World Conservation Union). 2000. *A Vision for Water and Nature.* Publication for the Second World Water Forum, The Hague.

Mazoyer, M. and Roudart, L. 1998. 1997. 'Développement des inégalités agricoles dans le monde et crise des paysanneries comparativement désavantagées'. In: *Land Reform, 1997/1*. Food and Agriculture Organization, Rome.

Molden, D., Amarasinghe, U., Bhattarai, M., Wang, Jinxia, Makin, I. 2002. Water and food security: Background paper for the World Water Development Report. *Comprehensive Assessment Research Paper 2* (draft). Colombo, Sri Lanka, Comprehensive Assessment Secretariat

OECD/DAC (Organization for Economic Cooperation and Development/Development Assistance Committee). 1998. *Guidelines for Gender Equality and Women's Empowerment in Development Cooperation*. Paris.

Pitman, G.K. 2002. *Bridging Troubled Waters: Assessing the World Bank Water Resources Strategy.* A World Bank Operations Evaluation Study. Washington DC, World Bank. Ramsar Convention on Wetlands. 1971. Ramsar, Iran.

Schiffle, M. 1998. *Economics of Groundwater Management in Arid Countries*. London, Frank Cass.

Smith, M., Fereres, E., Kassam, A. 2001. 'Crop Water Productivity Under Deficient Water Supply'. Paper presented on the occasion of the Expert Meeting on Crop Water Productivity Under Deficient Water Supply, 3–5 December 2001, Rome, Italy.

Stiglitz, J. 2002. *Globalization and its Discontents.* New York, W. W. Norton.

Thompson, R.-L. 2001. 'The World Bank Strategy to Rural Development with Special Reference to the Role of Irrigation and Drainage'. Keynote address on the occasion of the 52nd IEC meeting of the International Commission on Irrigation and Drainage, 16–21 September 2001, Seoul.

Vassolo, S. and Döll, P. 2002. 'Development of a Global Data Set for Industrial Water Use'. Unpublished manuscript. University of Kassel, Centre for Environmental Systems Research.

WCD (World Commission on Dams). 2000. *Dams and Development: A New Framework for Decision-Making.* London, Earthscan Publications.

World Bank. 2002. *Water Resources Sector Strategy* (draft). Washington DC.

World Bank. 1991. *India Irrigation Sector Review*, Vols. 1 and 2. Washington DC.

ANNEX **ONE**

The right to adequate food and the right to water

The legal basis of the right to adequate food and the right to water

The right to adequate food and the right to water are human rights. Their most prominent legal basis is Art. 11 of the International Covenant on Economic, Social and Cultural Rights that enshrines the right of everyone to an adequate standard of living for himself and his family, including adequate food, clothing and housing. The Covenant is legally binding upon those 146 States that ratified it. As the right to adequate food and the right to water are also recognized in a large number of other binding and non-binding legal instruments they are arguably part of customary international law as well.

The compliance of State Parties with the Covenant is monitored by the Committee on Economic, Social and Cultural Rights, the treaty body of the Covenant consisting of 18 independent experts. The Committee adopts "General Comments" constituting authoritative interpretations of the provisions of the Covenant to clarify the normative content of the rights, States parties' and other actors' obligations, violations and implementation of the rights at the national level.

The right to adequate food

In 1999 the Committee adopted General Comment 12 on the right to adequate food. It is the right of everyone to have physical and economic access to adequate food or the means for its procurement. Its core content implies the availability of food in a quantity and quality sufficient to satisfy the dietary needs of individuals, free from adverse substances, and acceptable within a given culture and the accessibility of such food in ways that are sustainable and do not interfere with the enjoyment of other human rights.

Availability refers to the possibilities of either feeding oneself directly from productive land or other natural resources, or having means for its procurement through well functioning distribution, processing and market systems. Accessibility encompasses both economic and physical accessibility.

Sustainable access to water resources for agriculture must be ensured in order to realize the right to food.[1] Attention should be given to ensuring that disadvantaged and marginalized farmers, including women farmers, have equitable access to water and water management systems,

[1] This aspect of the right to adequate food is dealt with mainly in the introduction to General Comment 15 on the Right to water.

including sustainable rain harvesting and irrigation technology. As the Covenant also provides that "a people may not be deprived of its own means of subsistence" (Art. 1 (2)) it must also be ensured that there is adequate access to water for subsistence farming and for securing the livelihoods of indigenous peoples.

The right to water

In 2002 the Committee adopted General Comment 15 on the right to water (Art. 11 and 12 of the Covenant). General Comment 15 was the first document that fleshed out in detail the right's content and clearly stated that the right to water emanated from and was indispensable for an adequate standard of living as it is one of the most fundamental conditions for survival. The right to water entitles everyone to sufficient, safe, acceptable, physically accessible and affordable water for personal and domestic use. Availability implies that the water supply for each person must be sufficient and continuous for drinking, personal sanitation, washing of clothes, food preparation, personal and household hygiene. It must be free from micro-organisms, chemical substances and radiological hazards that constitute a threat to a person's health. Water and water facilities and services have to be physically and economically accessible to everyone without discrimination.

Water is also necessary to realize a number of other rights. Water use to ensure environmental hygiene is covered by the right to health. Water necessary for the enjoyment of certain cultural practices is protected by the right to take part in cultural life. The right to gain a living by work encompasses water for securing livelihoods. Finally, as mentioned above, water to produce food is necessary to realize the right to adequate food. In case of competing uses priority in allocation must be given to the right to water for personal and domestic use as well as to the prevention of starvation and disease.

States' obligations

The right to adequate food and the right to water pose on States obligations of progressive realization as well as immediate obligations. The principle obligation of States with respect to the right to adequate food and the right to water is the obligation to take steps to achieve progressively the full realization of both rights. States must move as expeditiously and effectively as possible within the limits of the maximum of their available resources towards this goal. While full realization might take time, steps must be taken immediately. Also of immediate effect is the obligation to ensure that the rights can be exercised on a non-discriminatory basis.

States must *respect, protect* and *fulfil* the right to adequate food and the right to water. The obligation to *respect* requires that *states* refrain from interfering directly or indirectly with the enjoyment of the rights. They must refrain from engaging in any practice or activity that denies or limits access to food or water or interferes arbitrarily with existing arrangements, e.g. by unlawful excessive abstraction of water by the state. The obligation to *protect* requires states to take measures to ensure that *third parties* such as individuals, groups, corporations or other entities do not interfere in any way with the enjoyment of the rights, e.g., by adopting the necessary, effective and enforced legislative and other measures to control and restrain third parties' activities such as pollution control measures. The obligation to *fulfil* means that States must take positive measures to facilitate individuals' enjoyment of their rights through the development of strategies, policies and legislative measures, to promote the rights by appropriate education concerning for example the protection of water resources and methods to minimize its waste and, finally, to provide for the fulfilment of the rights directly in those cases in which individuals are unable for reasons beyond their control to realize the rights themselves (e.g. orphaned children).

Outlook

Although a large number of individuals all over the world continue to be denied their rights to adequate food and water, some encouraging developments are taking place. More and more countries and international agencies adopt rights-based policies and approaches that incorporate, for example in food security strategies, mechanisms of accountability, the principles of non-discrimination, equality and participation and the interdependence of rights. An increasing number of states explicitly or implicitly recognize the two rights in their constitutions or legal frameworks and endeavour to implement the rights comprehensively through the development of new sets of measures. Some have made the rights justiciable. Furthermore, FAO and UN Member States are currently developing within the framework of an Intergovernmental Working Group established by the FAO Council in October 2002 a set of Voluntary Guidelines for the progressive realization of the right to adequate food in the context of national food security.

References

Committee on Economic, Social and Cultural Rights, General Comment No. 12. 1999. The Right to Adequate Food, E/C.12/1999/5 (12 May 1999), available at: http://www.unhchr.ch/tbs/doc.nsf/(symbol)/E.C.12.1999.5,+CESCR+General+comment+12.En?OpenDocument

Committee on Economic, Social and Cultural Rights, General Comment No. 15. 2002. The Right to Water, E/C.12/2002/11 (26 November 2002), available at: http://www.unhchr.ch/tbs/doc.nsf/(Symbol)/E.C.12.2002.11.En?Opendocument

Links

Food and Agricultural Organization (FAO), Right to Food Page of the Legal Office
http://www.fao.org/Legal/rtf/rtf-e.htm

Information on the right to food links to official documents and international instruments, to FAO publications, to other organizations and initiatives dealing with the right to food.

Food and Agricultural Organization (FAO), The Intergovernmental Working Group (IGWG) for the elaboration of a set of Voluntary Guidelines to support the progressive realization of the right to adequate food in the context of national food security
http://www.fao.org/righttofood/en/index.html

Official documents, submissions and information about the sessions of the IGWG.

ANNEX **TWO**

Related global assessment publications

This annotated list covers some of the more recent global reports in water and development issues related to food and agriculture.

FAO (Food and Agriculture Organization). Annual publication. *The State of Food and Agriculture*. Rome.
FAO's annual report on current developments and issues in world agriculture. The Organization monitors the global agricultural situation as well as the overall economic environment surrounding world agriculture. The 2002 report calls for increased international financial flows towards agriculture and rural areas. It also examines one of the possible new mechanisms for this financing: the Clean Development Mechanism (CDM) deriving from the Kyoto Protocol to the United Nations Framework Convention on Climate Change. Particular attention is paid to the potential use of the CDM as an instrument for both enhancing carbon sequestration through land use changes and for reducing rural poverty. *[Main challenge area: Securing the food supply]*

FAO (Food and Agriculture Organization). Annual publication. *The State of Food and Agriculture. 2000. World Agriculture: Towards 2015/2030.* Rome.
A summary of FAO projections and messages intended for the general reader. The projections cover supply and demand for the major agricultural commodities and sectors, including fisheries and forestry. This analysis forms the basis for a more detailed examination of other factors, such as nutrition and undernourishment, and the implications for international trade. The report also investigates the implications of future supply and demand for the natural resource base and discusses how technology can contribute to a more sustainable development. *[Main challenge area: Securing the food supply]*

Leisinge, K.-M., Schmitt, K., Pandya-Lorch, R. 2002. *Six Billion and Counting: Population Growth and Food Security in the 21st Century*. Baltimore, United States, Johns Hopkins University Press, International Food Policy Research Institute.
More people will inevitably mean greater demand for food, water, education, health care, sanitary infrastructure and jobs, as well as greater pressure on the environment. There must come a point when population growth threatens global food security and the Earth's finite natural resources. But what specific threats does population growth present now and in the coming decades? How can the world achieve sustainable development in the face of an ever-growing population? This book deals with these questions. *[Main challenge area: Securing the food supply]*

Pardey, P.-G., Beintema, N.-M. 2001. ***Slow Magic. Agricultural R&D a Century After Mendel.*** **Washington DC, International Food Policy Research Institute, Agricultural Science and Technology Indicators Initiative.**
This report assembles and assesses new and updated evidence regarding investments in agricultural R&D by public and private agencies, contrasting developments in rich and poor countries. It tracks trends in agricultural R&D over the past several decades. *[Main challenge area: Securing the food supply]*

Pinstrup-Andersen, P., Pandya-Lorch, R., Rosegrant, M.-W. 1999. ***World Food Prospects: Critical Issues for The Early Twenty-First Century.*** **Washington DC, Food Policy Report, International Food Policy Research Institute**.
This report provides a summary of the most recent results from the International Food Policy Research Institute projections of the future world food situation. It then identifies and discusses six recent developments and emerging issues that will influence the prospects for global food security. It also discusses new evidence on the opportunities offered by agro-ecological approaches, the potential role of modern biotechnology and the relevance of new information technology and precision farming for small farmers in developing countries. *[Main challenge area: Securing the food supply]*

Rosegrant, M.-W., Paisner, M.-S., Meijer, S., Witcover, J. 2001. ***2020 Global Food Outlook: Trends, Alternatives, and Choices. A Vision for Food, Agriculture, and the Environment Initiative.*** **Washington DC, International Food Policy Research Institute.**
This report shows how, and how much, certain policy decisions and social changes will affect the world's future food security. It projects the likely food situation in 2020 if the world continues on more or less its present course, and it then shows how alternative choices could produce a different future. *[Main challenge area: Securing the food supply]*

UNDP/UNEP/World Bank/WRI (United Nations Development Programme/United Nations Environment Programme/World Bank/World Resources Institute). 2000. ***World Resources 2000–2001 – People and Ecosystems: The Fraying Web of Life.*** **Washington DC.**
This book is a comprehensive guide to the global environment. This edition provides an assessment of five of the world's major ecosystems: agro-, coastal and marine, forest, freshwater and grassland ecosystems. *[Main challenge area: Protecting ecosystems]*

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2001. Biennial publication. *World Science Report.* Paris.

This report provides information on the more important technical development of the last two years with a discussion of the main issues raised in this area by some of the most eminent world specialists. The last release of the report (1998) includes chapters looking at how science is helping to safeguard our two most basic commodities – food and water – in a context of rapid demographic growth and environmental stress. *[Main challenge area: Ensuring the knowledge base]*

UNESCO (United Nations Educational, Scientific and Cultural Organization). 2001. Biennial publication. *World Social Science Report.* Paris.

First released in 1999, the report takes stock of the social sciences as they are, and looks forward to their continuing development in the coming decades. It is divided into two parts. The first, *A Global Picture*, provides an overview of the history (since the eighteenth century), future prospects and current organization, financing and resources of the social sciences. The second takes up three central issues: science and technology in society, development and the environment. A final section reviews two areas of contact between the natural and social-cognitive science and the evolutionary study of human behaviour. *[Main challenge area: Ensuring the knowledge base]*

UN-Habitat. 2001. *The State of the World's Cities Report 2001.* Nairobi.

The State of the World's Cities Report 2001 is a first in-depth attempt to monitor, analyse and report on the realities faced by urban populations around the world. The report was produced by UN Habitat to coincide with the Istanbul + 5 Special Session of the United Nations General Assembly. Its central message is that people's processes and initiatives and enabling governing structures must unite to form broad-based partnerships that will promote justice, equity and sustainability in cities. *[Main challenge areas: Water and cities, Meeting basic needs]*

ANNEX **THREE**

Some useful Web sites

Food and Agriculture Organization (FAO), AQUASTAT

http://www.fao.org/ag/agl/aglw/aquastat/main/

Provides data on the state of water resources across the world, including an online database on water and agriculture, GIS, maps, etc.

Food and Agriculture Organization (FAO), FAOSTAT

http://apps.fao.org/

Time series records covering production, trade, food balance sheets, fertilizer and pesticides, land use and irrigation, forest and fishery products, population, agricultural machinery, etc.

Food and Agriculture Organization (FAO), Fisheries Global Information System (FIGIS)

http://www.fao.org/fi/figis/tseries/index.jsp

Global fishery statistics on production, capture production, aquaculture production, fishery commodity production and trade, and fishing fleets.

Food and Agriculture Organization (FAO), Food Insecurity

http://www.fao.org/SOF/sofi/

Provides information on the state of food insecurity in the world and on global and national efforts.

International Water Management Institute (IWMI), Water for Agriculture

http://www.cgiar.org/iwmi/agriculture/

Provides information on issues related to water for agriculture: research activities, list of publications and links. This site is part of a larger site that houses information on a plethora of water management-related topics, such as the environment, health, etc.

Food and Agriculture Organization (FAO), WAICENT

http://www.fao.org/Waicent/

FAO's information portal: this is a programme for improving access to documents, statistics, maps and multimedia resources.

Producing our daily food requires one thousand times more water than we use to drink and one hundred times more than we use to meet our basic personal needs. Rainfed agriculture alone cannot ensure global food supply, and up to 70 percent of the water we take from rivers and aquifers goes into irrigated agriculture. Agriculture is the major source of food and by far the largest consumer of water on the globe.

What is the role of water in the world's food production? What are the contributions to food production from rainfed and irrigated agriculture and from fisheries? How can more food be produced with the same amount of water? What role does the market play? How does food security connect to poverty and water use? This report discusses these and many other questions using up-to-date information and state-of-the-art knowledge.

The United Nations World Water Development Report and its various thematic components provide a periodic review of the world's freshwater resources and the way we steward them. Chapter 8 of the Report is re-issued here as *Agriculture, food and water*.

Agriculture, food *and* water

ISBN 92-5-104943-2

9 789251 049433

TC/M/Y4683E/1/5.03/1100