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IRRIGATION IN ASIA IN FIGURES

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Foreword

With the advent of the green revolution, high yielding varieties of the major cereals have made it possible for the countries of Asia to sustain a rapidly growing population. Irrigation has been critical in controlling soil moisture, allowing farmers to invest in quality seeds and inputs. Irrigation has expanded rapidly in the last 40 years: in total, the countries presented in this survey have more than 130 million ha of irrigated land, about 50 percent of the world's irrigated land.

The countries of Asia now face new challenges for agricultural production. In many areas the extent of land available for cultivation has reached its limits and intensification is necessary to satisfy the needs of the population. In the most arid areas of the region, mainly in parts of China and India, water is increasingly becoming a limiting factor to agricultural extension. At the same time, problems of land degradation are affecting the agricultural potential of the region.

A good understanding of the major trends and challenges facing irrigated agriculture in Asia is only possible with a complete, up-to-date information base covering all issues related to irrigation in the region.

This publication is the fourth of a series of reports prepared within the framework of FAO's AQUASTAT programme, aimed at providing information on water use and irrigation in the world. The first report covered the African continent. This report presents a description of the situation of water use and irrigation in the countries of the Asian continent not covered by the two previous publications on the Near East and on the countries of the former Soviet Union. It includes country profiles, summary tables, maps, and a regional synopsis emphasizing the sub-regional characteristics of this vast and diverse region.

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The publication has been edited by Julian Plummer and prepared for printing by Lena Steriti and Chrissi Smith Redfern. Figures were prepared by Nick Rubery.

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List of abbreviations

DSSTW	Deep-Set Shallow Tube-well
DTW	Deep Tube-well
FMIS	Farmer Managed Irrigation Scheme
FMTW	Force Mode Tube-well
GDP	Gross Domestic Product
IRWR	Internal Renewable Water Resources
MOP	Manually Operated Pump
NGO	Non-governmental Organization
O&M	Operation and Maintenance
STW	Shallow Tube-well
TRWR	Total Renewable Water Resources
VDSSTW	Very Deep-Set Shallow Tube-eell
WUA	Water Users' Association
WUG	Water Users' Group

UNITS

Volume:
$1\ km^3 = 1 \times 10^9\ m^3 = 1\,000 \times 10^6\ m^3 = 1\,000$ million m^3

Area:
$1\ km^2 = 100$ ha

Power:
$1\ GW = 1 \times 10^3\ MW = 1 \times 10^6\ kW = 1 \times 10^9\ W$
$1\ W = 1\ J/s$

Energy:
$1\ GWh = 1 \times 10^3\ MWh = 1 \times 10^6\ kWh$
$1\ kWh = 3.6 \times 10^6\ J$

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

Presentation of the survey

INTRODUCTION

In 1993, FAO started to develop a programme named AQUASTAT, which is an information system on water use for agriculture and rural development. Its aim is to collect information at country and sub-country level and to make it available, in a standard format, to users interested in global, regional and national perspectives. In 1994-95, the 53 African countries were surveyed, which resulted in FAO Water Report 7 'Irrigation in Africa in Figures'. The present publication is the fourth of a series of regional surveys. It covers the countries of Asia not included in the two previous reports on the Near East (Water Report 9) and on the former Soviet Union (Water Report 15)[1].

The purpose of the survey is twofold:

- to provide a clear picture of the situation of rural water resources management on a country basis, with emphasis on irrigation, and featuring major characteristics, trends, constraints and perspectives;
- to help support continental and regional analyses by providing systematic, up-to-date and reliable information on water for agriculture and rural development, and to serve as a tool for large-scale planning and forecasting.

In order to obtain information that was as reliable as possible, the survey was structured and carried out for each country as follows:

1. Review of literature and existing information on the country and the sub-region.
2. Data collection by means of a detailed questionnaire and with the assistance of national resources persons.
3. Data processing and critical analysis of the information, with the assistance of the AQUASTAT data processing software and selection of the most reliable information.
4. Preparation of a country profile.

Lastly, regional and sub-regional tables and maps and a general summary were prepared. The information was cross-checked where possible.

COUNTRY PROFILES

Each country profile describes the situation regarding water resources and use for agriculture in the country, with special attention to the irrigation and drainage subsectors. Its aim is to emphasize

[1] This report includes the following countries: Bangladesh, Bhutan, Brunei, Cambodia, China, India, Indonesia, Japan, Korea DPR, Republic of Korea, Lao PDR, Malaysia, Maldives, Mongolia, Myanmar, Nepal, Papua New Guinea, the Philippines, Sri Lanka, Thailand and Viet Nam. It does not cover Singapore, Macao and East Timor, although statistics from Indonesia usually include East Timor.

the particularities of each country, as well as the problems encountered in rural water management and irrigation. It also summarizes the trends of irrigation in the countries, as described in the available literature. It was a deliberate choice to try and standardize the country profiles as much as possible. All profiles follow the same pattern, organized in six sections:

- geography and population;
- climate and water resources;
- irrigation and drainage development;
- institutional environment;
- trends in water resources management;
- main sources of information.

Standardized tables are used for all country profiles. Where information is not available, this is indicated by a dash (-). As most of the data are available for a limited number of years only, the most recent reliable data are used in the tables, with an indication of the year to which they refer.

DATA COLLECTION, PROCESSING AND RELIABILITY

The main sources of information were:

- national yearbooks, statistics and reports;
- national water resources and irrigation master plans;
- reports from FAO or other projects;
- international surveys;
- results from surveys made by national or international research centres.

In total, 61 variables were selected and are presented in the tables attached to each country profile. They are grouped into categories corresponding to the profile sections. A detailed definition of each variable is given in the following section.

In most cases, a critical analysis of the information was necessary to ensure consistency between the different data collected for a given country. Where several sources gave different or contradictory figures, preference was always given to information collected at national or sub-national level and, unless proved wrong, to official rather than unofficial sources. In the case of shared water resources, a comparison between countries was made to ensure consistency at river basin level.

Nevertheless, the accuracy and reliability of the information vary greatly between regions, countries and categories of information, as does the year in which the information was gathered. These considerations are discussed in the country profiles.

GLOSSARY OF TERMS

The following is a glossary of the terms used in the tables or in the text of the country profiles, including some considerations about computing methods.

Agricultural water withdrawal (10^6 m^3/year): Annual gross quantity of water withdrawn for agricultural purposes including irrigation and livestock watering. Methods for computing agricultural water withdrawal vary from country to country. The figure was checked for each country against crop water requirements and irrigated areas, and comments were added in the country profiles to explain the figure where necessary. By default, livestock water withdrawal is accounted for in agricultural water withdrawal, although some countries include it in domestic water withdrawal.

Annual crops (ha): Physical area under temporary (annual) crops.

Arable land: The official FAO definition of arable land is ‘land under temporary crops, temporary meadows for mowing or pasture, land under market and kitchen gardens, and land temporarily fallow’ (a description of FAO land use classification is presented in the next section). Data on arable land were obtained from the FAO statistics database.

Area of the country (ha): The total area of the country, including inland water bodies. Data in this category were obtained from the United Nations Statistical Office.

Area salinized by irrigation (ha): Total irrigated area affected by salinization as a result of irrigation. This does not include naturally saline areas.

Average groundwater depletion (10^6 m^3/year): Annual amount of water withdrawn from aquifers and which is not replenished (mining of rechargeable aquifers or extraction from fossil aquifers).

Average precipitation (mm/year and km^3/year): Double average over space and time of water falling on the country in a year.

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

Cultivated area (ha): Area under temporary (annual) and permanent crops. This refers to the physical area actually cultivated and does not include land which is temporarily fallow.

Dependency ratio (%): That part of the total renewable water resources originating outside the country.

Desalinated water (10^6 m^3/year): Installed capacity of desalination plants.

Domestic water withdrawal (10^6 m^3/year): Annual gross quantity of water withdrawn for domestic purposes (mostly cities). It is usually computed as the total amount of water withdrawn by public distribution networks, and may include withdrawal by those industries connected to public networks. In some countries, it may include part of the livestock water use.

Drained area (ha): The area equipped with subsurface or open drains. It can be broken down into drained areas in full or partial control irrigated areas; drained areas in equipped wetland and inland valley bottoms; and other drained areas, equipped for drainage but not equipped for irrigation. Flood recession cropping areas are not considered as being drained.

Equipped wetlands and inland valley bottoms (ha): Cultivated wetlands and inland valley bottoms which have been equipped with water control structures (intake, canals, etc.). Developed mangroves are included in this category.

Flood recession cropping area (ha): Area along rivers where cultivation occurs in the areas exposed as floods recede. The special case of floating rice is included in this category.

Flood protected area (ha): Area of land protected by flood control structures.

Full or partial control irrigation schemes (ha): Areas of irrigation schemes, usually classified as large, medium and small schemes. Criteria used in this classification are given in the tables.

Full or partial control irrigation - equipped area (ha): Physical area of irrigation schemes developed and managed either by government, private estates or farmers, and where a full or partial control of the water is achieved. Gardening is included in this category.

Harvested crops under irrigation (ha): Total harvested irrigated area for the crop for the given year. Areas under double cropping are counted twice. For permanent crops, data generally refer to the total planted area.

Industrial water withdrawal (10^6 m^3/year): Annual gross quantity of water withdrawn for industrial purposes. This sector usually refers to self-supplied industries not connected to any distribution network.

Internal renewable water resources (km^3/year): Average annual flow of rivers and recharge of groundwater generated from endogenous precipitation.

Irrigation potential (ha): Area of land suitable for irrigation development. It includes land already under irrigation. Assumptions made in assessing irrigation potential vary from country to country. In most cases it was computed on the basis of available land and water resources, but economic and environmental considerations may also have been taken into account. Some countries include the possible use of non-conventional sources of water for irrigation. Except in a few cases, no consideration is given to the possible double counting of shared water resources between riparian countries. Wetland and floodplains are usually, but not systematically, included in irrigation potential.

Micro-irrigation (ha): That part of the full or partial control area irrigated by micro-irrigation.

Other cultivated wetland and inland valley bottoms: Parts of wetlands and inland valley bottoms which have not been equipped with water control structures but are used for cropping.

Other water managed areas: Extent of land areas which are not equipped with water control structures but where crop cultivation takes advantage of locally available water resources. It includes non-equipped cultivated wetland or lowland, flood recession cropping areas and areas cultivated with floating rice. It does not include water harvesting areas.

Other water withdrawal (10^6 m^3/year): Annual quantity of water necessary for uses other than agricultural, domestic or industrial purposes. It includes the following sectors: energy, mining, recreation, navigation, fisheries and environment. These sectors are characterized by a very low consumption rate.

Percentage of area irrigated from groundwater (%): That part of the full or partial control area irrigated from wells (shallow wells and deep tube-wells) or springs.

Percentage of area irrigated from non-conventional sources (%): That part of the full or partial control area irrigated from non-conventional sources of water such as (un)treated wastewater, desalinated water or agricultural drainage water.

Percentage of area irrigated from surface water (%): That part of the full or partial control area irrigated from rivers or lakes (reservoirs, pumping or diversion).

Percentage of equipped area actually irrigated (%): That part of the full or partial control area which is actually irrigated. It concerns the actual physical areas. Irrigated land that is cultivated twice a year is counted once. Often, part of the equipped area is not irrigated for various reasons, such as lack of water, absence of farmers, damage, organizational problems, and so forth.

Permanent crops (ha): Area cultivated with crops that occupy the land for long periods and that do not need to be replanted after each harvest. It does not include woodland and forests.

Power irrigated area as percentage of water managed area (%): That part of the water managed area where pumps are used for water supply. It does not include areas where water is pumped with human- or animal-driven water lifting devices.

Produced wastewater (10^6 m^3/year): Annual quantity of wastewater produced in the country. It does not include agricultural drainage water.

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

Re-used treated wastewater (10^6 m^3/year): Annual quantity of treated wastewater which is re-used.

Rural population (%): The figures are UN estimates for 1996.

Safe yield of groundwater: The definition varies between countries and is, wherever possible, confirmed in the country profiles. It may or may not include fossil water.

Spate irrigation area (ha): Area of land equipped for spate irrigation; form of irrigation predominantly found in arid regions where heavy floods of very short duration are diverted on cultivated land.

Sprinkler irrigation (ha): That part of the full or partial control area irrigated by aspersion (sprinkler).

Surface irrigation (ha): That part of the full or partial control area under surface irrigation: furrow, border, basin, including flooded irrigation of rice.

Total (actual) renewable water resources (km^3/year): The sum of internal renewable water resources and incoming flow originating outside the country, taking into consideration the quantity of flows reserved to upstream and downstream countries through formal or informal agreements or treaties and reduction of flow due to upstream withdrawal. This gives the maximum theoretical amount of water actually available for the country (see note on the computation of water resources in the next section).

Total dam capacity (10^6 m^3): The total cumulative capacity of all dams.

Total irrigated grain production (t): The total quantity of cereals harvested annually in the irrigated area.

Total irrigation (ha): Area equipped to provide water to the crops. It includes areas equipped for full and partial control irrigation, spate irrigation areas, and equipped wetland and inland valley bottoms. It does not include other cultivated wetland and inland valley bottoms or flood recession cropping areas. In the text it is also referred to as irrigated area or area under irrigation.

Total number of households in irrigation: Total number of households living directly on earnings from full or partial control irrigation.

Total population (inhabitants): The figures are UN estimates for 1996.

Total water managed area (ha): The sum of full or partial control irrigation equipped areas, spate irrigation areas, equipped wetland, inland valley bottoms, other cultivated wetland and inland valley bottoms (i.e. wetland and inland valley bottoms not equipped with water control structures, but used for cropping) and flood recession cropping areas. It does not include water harvesting areas. A description of the different categories of water management is provided in the next section.

Total water withdrawal (10^6 m^3/year): Annual gross quantity of water withdrawn for agricultural, industrial and domestic purposes. It does not include other withdrawals: energy, mining, recreation, navigation, fisheries and the environment, which are typically non-consumptive uses of water.

Treated wastewater (10^6 m^3/year): Annual quantity of wastewater which is treated.

Water supply coverage (%): The percentage of urban and rural population with access to safe drinking water (criteria may vary between countries).

Water withdrawal (10^6 m^3/year): Gross amount of water extracted from the resources for a given use. It includes consumptive use, conveyance losses and return flow. It includes all the water used for agricultural, domestic and industrial purposes. The use of desalinated and treated wastewater is thus included, although in the strict sense this should be called ‘water use’ rather than ‘water withdrawal’. Desalinated water and treated wastewater are also referred to as non-conventional sources of water.

OTHER DEFINITIONS AND CONVENTIONS

Notwithstanding the detailed description of each variable, some problems persist due to the fact that the literature does not always clearly indicate which definition has been used in computing the figures. The most frequent problems encountered and conventions used in computing the figures are listed below.

Computation of water resources

The following terms have been used in the computation of water resources:

- Internal renewable water resources is the average annual flow of rivers and recharge of groundwater generated from endogenous precipitation. A critical review of the data was made to ensure that double counting of surface water and groundwater (overlap) was avoided.
- Total natural renewable water resources is the sum of internal renewable water resources and natural incoming flow originating outside the country. Special rules are used to take into account the flow of border rivers.

- Natural incoming flow is the average annual amount of water which would flow into the country in natural conditions, i.e. without human influence.
- Total actual renewable water resources is the sum of internal renewable water resources and incoming flow originating outside the country, taking into account the quantity of flow reserved to upstream and downstream countries through formal or informal agreements or treaties and reduction of flow due to upstream withdrawal. It corresponds to the maximum theoretical amount of water actually available for a country at a given moment. The figure may vary with time.
- Manageable water resources, or development potential, refers to that part of the resources which is considered to be available for development under specific economic conditions. This figure considers factors such as flow dependability, floods, extractable groundwater, minimum flow required for non-consumptive uses etc.

Water managed areas and irrigation

Total water managed area is the sum of total irrigation (see definition above), flood recession cropping areas and other cultivated wetland and inland valley bottoms. It does not include water harvesting areas. Schematically, it can be represented as follows:

Total water managed area (ha)				
Irrigation (ha)			Other water managed areas (ha)	
Full and partial control irrigation (ha)	Spate irrigation (ha)	Equipped wetland and inland valley bottom (ha)	Flood recession cropping area (ha)	Other cultivated wetland and inland valley bottom (ha)

In this survey, the distinction between full and partial control irrigation, equipped wetland and inland valley bottoms and other cultivated wetland and inland valley bottoms was often very difficult to make, especially in the case of paddy rice cultivation. In some cases, an arbitrary classification was made, based on the description given in the available literature.

Land use classification

The land use classification used in FAO statistics is as follows:

I. Productive land				
	A. Agricultural land			
		1. Cultivated land		
			a. Cropland	
				Arable land:
				. Land under temporary crops . Land under temporary meadows . Land temporarily fallow . All other arable land
			b. Land under protective cover	
				. Temporary crops . Permanent crops
			c. Land under permanent crops in open air	
		2. Land under permanent meadows and pasture		
				. Cultivated . Naturally grown
	B. Woodland or forests			
II. All other land				

In this survey, irrigated area is expressed as a percentage of cultivated land (annual and permanent crops) rather than of arable land. This makes it possible to include permanent crops which may represent a significant part of the irrigated land in some countries.

General summary

INTRODUCTION

The 21 countries studied in this report have been grouped into five sub-regions showing some kind of homogeneity in their hydro-climatic and socio-economic conditions. For the purposes of this study, these sub-regions are referred to as: Indian subcontinent, Eastern Asia, Far East, Southeast and Islands[1].

CLIMATE, GEOGRAPHY AND POPULATION

The total area of the region is about 20.4 million km², which is 15 percent of the total land area of the world (Tables 1 and 18). China and India together represent about 63 percent of this area.

The total population of the region was estimated in 1996 at 3 030 900 920 inhabitants, about 53 percent of the world's population (Tables 1 and 18). China and India are the most populous and the second most populous countries in the world respectively, together accounting for about 38 percent of the world's population. The annual demographic growth rate in Asia was estimated for the period 1995-96 at 1.5 percent compared to 1.4 percent for the whole world.

TABLE 1
Regional distribution of the population

Sub-region	Area		Population 1996			% of economically active population engaged in agriculture
	km²	% of the region	inhabitants	rural population %	inhabitants per km²	
Indian subcontinent	3 691 680	18.2	1 106 849 000	74	300	62
Eastern Asia	11 285 070	55.3	1 263 255 000	68	112	70
Far East	477 060	2.3	170 665 920	21	358	7
Southeast	1 939 230	9.5	195 114 000	78	101	67
Islands	3 002 930	14.7	295 017 000	58	98	49
Asia	20 395 970	100.0	3 030 900 920	67	149	62
World	133 870 200		5 767 775 000	54	43	47
Asia as % of world	15.24		52.55			

The population of Asia is predominantly rural: about 67 percent of the total, compared to 54 percent for the world as a whole. This percentage rises to 70 percent if Japan and the Republic of Korea are excluded (the two countries where industry predominates and the rural population is only 21 percent). This reflects the importance of agriculture in countries where the contribution of the agricultural sector to the GDP is almost 30 percent, and where the percentage of the economically active population engaged in agriculture is about 62 percent.

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[1] Indian sub-continent: Bangladesh, Bhutan, India, Maldives, Nepal, Sri Lanka
Eastern Asia: China, DPR Korea, Mongoloa
Far East: Japan, Republic of Korea
Southeast: Cambodia, Laos, Myanmar, Thailand, Viet Nam
Islands: Brunei, Indonesia, Malaysia, Papua New Guinea, The Philippines

The population density in the Asian countries was estimated in 1996 at 149 inhabitants/km², compared to an average of 43 inhabitants/km² for the world as a whole. The highest population densities are in Maldives and Bangladesh with 878 and 834 inhabitants/km² respectively, while the lowest densities are in Mongolia and Papua New Guinea with 2 and 10 inhabitants/km² respectively (Table 12).

Indian subcontinent

The Indian subcontinent with an area of 3 961 680 km² represents about 18 percent of the total area of the region. It is made up of India, Bangladesh, Bhutan, Nepal, Sri Lanka and Maldives. The geomorphology of these countries consists of a large portion of floodplains along the Indus and Ganges river basins, some terraces and hilly areas, and the mountainous terrain of the Himalayas, with the world's highest peak (Mount Everest, 8 848 m) located in the Nepal Himalayas.

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

The average annual precipitation in the sub-region is about 1 279 mm, varying from less than 150 mm in the northwest desert of Rajasthan, in India, to more than 10 m in the Khasi hills in northeast India.

The population was estimated in 1996 at 1 106 849 000 inhabitants (74 percent rural). The population density is about 300 inhabitants/km²; Bangladesh and Maldives being the most densely populated countries of the region. The population growth rate in the region varies from 1.15 percent in Sri Lanka to 3.1 percent in Bhutan.

Eastern Asia

The Eastern Asia sub-region includes China, Mongolia and the Democratic People's Republic of Korea (DPR Korea). It extends over an area of 11 285 070 km², which is about 55 percent of the total area covered by this survey and 8.4 percent of the world area. This region is mainly mountainous with about 80 percent of the landmass lying above the mean altitude of 1 000 m above sea level.

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

The average annual precipitation in the sub-region is 597 mm, varying from less than 25 mm in the Tarim and Qaidam basins in China to 1 520 mm in DPR Korea. Among the factors affecting agricultural production in the region are low soil moisture and air humidity in spring and early summer, and frosts in spring and autumn.

The total population was 1 263 255 000 inhabitants in 1996, with China accounting for almost 98 percent of this total. The population density is 112 inhabitants/km², varying from 1.6 inhabitants/km² in DPR Korea to 129 inhabitants/km² in China. The contribution of agriculture to GNP is decreasing mainly due to the industrialization of DPR Korea and China. However, 70 percent of the total economically active population are engaged in agriculture.

Far East

The Far East sub-region includes Japan and the Republic of Korea. The total area is 477 060 km², or 2 percent of the total area of the region. Mountains cover almost 70 percent of the total area. The Fuji Mountain in Japan is the highest point at 3 776 m.

The climate in the region shows four distinct seasons. Winds and the mountainous topography divide the landmass into two typical climatic zones: the Pacific coast zone, marked by the summer monsoon which blows from the Pacific Ocean bringing warmer temperatures and rain, and the continental zone, characterized by the winter monsoon from the Asian continent, which brings freezing temperatures and heavy snowfalls. The average annual precipitation in the region is 1 634 mm; most falling during the summer months from June to September. The region is often struck by typhoons which cause severe crop damage mainly during the summer and early autumn.

In 1996, the total population was estimated at 170 665 920 inhabitants (21 percent rural). The population density is the highest in the region with an average of 358 inhabitants/km² due to the concentration of the population in the urban areas. Typically, farm households are made up of part-time farmers who earn additional income from other jobs. The contribution of the agricultural sector to GDP is very low compared to the other countries of Asia (2 percent in Japan and 6.5 percent in the Republic of Korea).

Southeast

The Southeast sub-region with an area of 1 939 230 km², or 9.5 percent of the total area of the region, is composed of Myanmar and the four riparian countries of the lower Mekong basin (Cambodia, Thailand, Viet Nam and Lao PDR). Mountains and hills are the main physiographical features, covering about two-thirds of the total area, with the highest point situated at 5 800 m above sea level in the extreme north of Myanmar. The extensive plains along the Mekong, Red and Ayeyarwady river are frequently subject to flooding.

The climate is mainly governed by the alternance between the wet season characterized by the southwest monsoon (May to October) with heavy rainfall, and the dry season characterized by the northeast monsoon (November to February) which is relatively cool and dry. About 75 percent of the total rainfall occurs during the wet season. This results in a large difference in the water level in rivers between the wet and the dry seasons: the water level in the Mekong River may differ by up to 20 m between the two seasons. The average annual rainfall in the region is 1 877 mm, ranging from 500 mm in the central dry zone in Myanmar and 650 mm in Phan Rang in Viet Nam to more than 4 000 mm in the mountains of Rakhine in Myanmar and Bac Quang in Viet Nam.

The total population was estimated at 195 114 000 inhabitants (78 percent rural). The population density is 101 inhabitants/km², ranging from 4 inhabitants/km² in Mondul Kiri in northeast Cambodia to 1 085 inhabitants/km² in the Red River Delta in Viet Nam. Agriculture constitute the largest sector in the economy of the region accounting for about 40 percent of GDP and employing more than 67 percent of the total economically active population.

Islands

This sub-region includes the countries of the Indian and North Pacific oceans from Malaysia to Papua New Guinea and characterized by their insular nature. Its land area extends over 3 002 930 km², which is about 15 percent of the total area under survey. The relief is dominated by extensive lowland plains and swamps, which contrast sharply with high mountain ranges, with the highest point situated at 5 030 m above sea level in the volcanic mountains of Indonesia.

The climate of the region is tropical and monsoonal, characterized by the uniformity of temperature (27°C throughout the year) and high humidity (varying from 70 to 80 percent). The region is under the influence of two main air streams: the northeast monsoon, blowing from October to March, and responsible for heavy rainfall, and the southwest monsoon occurring between May and September. Many islands of the region are liable to extensive flooding and typhoon damage during a period extending from June to September. The average rainfall in this region is 2 823 mm, ranging from less than 1 000 mm in Port Moresby to more than 8 000 mm in some mountainous areas in Papua New Guinea.

In 1996, the total population was estimated at 295 017 000 inhabitants (58 percent rural), which represents about 10 percent of the total population of Asia. The annual growth rate varies from 1.7 percent in Indonesia to 4.4 percent in Brunei. The population is unevenly distributed and is mainly concentrated along the coastal areas. The average population density in the region is 98 inhabitants/km². The agricultural sector contributes on average about 20 percent of GDP, and employs almost 49 percent of the total economically active population.

WATER RESOURCES

Compilation of information on water resources shows large methodological discrepancies between countries. This survey distinguishes between internal renewable water resources (IRWR) and total renewable water resources (TRWR). IRWR is that part of a country's water resources which is generated from endogenous precipitation. It is computed by summing surface water flow and groundwater recharge and subtracting their common part. The computation of TRWR is made by summing IRWR and external flow. It is a measure of the maximum theoretical amount of water available to a country without any considerations of a technical, economic or environmental nature. The methodology used in the survey also distinguishes between natural and actual external flow: natural flow is the average annual amount of water which would flow at a given point in a river without any human influence, while actual flow takes into account the reduction of flow due to upstream withdrawal and volumes of water reserved through treaties.

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

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

The information collected from the countries of the region does not make it possible to distinguish between actual and natural flow of the major rivers, i.e. the impact of irrigation and other water withdrawal on the runoff. In this survey, figures were systematically considered as natural flow. This option may lead to a slight underestimation of natural flow in some cases. At least in one case, the Ganges River, the withdrawals in the upstream country (India), are known to affect significantly the volumes of water available to the downstream country (Bangladesh). This has led to the recent signature of a treaty between the two countries on agreed procedures for the management of the river flow. In view of the hydrological regime of the rivers in the region, it can be assumed that runoff in the countries of southeast Asia and the islands is not significantly affected by withdrawals, while the difference between natural and actual flow may be much more important in the arid regions (mostly China).

In terms of shared water resources, the region is characterized, on the one hand by a series of insular countries between which no exchange is possible, and on the other hand by a zone in which shared river basins play a critical role and make the computation of water resources relatively complex (southeast Asia). In several cases, large inconsistencies were noted when comparing the flow at border recorded by neighbouring countries, e.g. the runoff of the main rivers flowing from China to India. The maps of Figures 4 and 5 show the main exchanges between the countries of the sub-region as assessed by this study.

TABLE 2
Regional distribution of internal renewable water resources (IRWR)

Sub-region	Annual precipitation		Internal renewable water resources	
	mm	km³	km³	m³ per inhabitant (1996)
Indian subcontinent	1 279	4 875	1 709	1 544
Eastern Asia	597	6 709	2 914	2 307
Far East	1 634	780	495	2 900
Southeast	1 877	3 640	1 768	9 062
Islands	2 823	8 444	4 707	15 953
Asia	1 194	24 448	11 592	3 825
World	-	110 000	41 022	6 984
Asia as % of world		22	28	

Overall, the region is relatively well endowed with water resources: for a total area representing 15 percent of the world's land surface, it receives 22 percent of its precipitation and produces 28 percent of its water resources. However, as the region is home to 53 percent of the world's population, the amount of water resources per inhabitant is only slightly above half the world's average. Table 2 shows the distribution of water resources among the five sub-regions. The relative aridity of the countries of Eastern Asia is shown by the precipitation which is between two and five times less than the average of the other sub-regions. In terms of water resources per person, a standard indicator of water availability, the groups of the Indian subcontinent, Eastern Asia and the Far East show the lowest figures while Southeast Asia and the Islands have much more water resources per person than the world average.

The figure of 2000 m^3/inhabitant/year is usually used as an indicator of water scarcity: India and China are reaching this limit, while the Republic of Korea is already below it, at 1538 m^3/inhabitant/year and the Maldives have a chronic water scarcity, with 114 m^3/inhabitant/year. Furthermore, in the case of India, 34 percent of the water flows from neighbouring countries, the country's internal water resources being only 1 334 m^3/inhabitant/year (Table 13).

Water withdrawal

Table 3 shows the distribution of water withdrawal by region between the three major sectors of water use: agriculture (irrigation and livestock), communities (domestic water supply) and industry. Water requirements for energy (hydropower), navigation, fisheries, mining, environment and recreation, although they may represent a significant part of the water resources, have a negligible net consumption rate. Furthermore, as most countries do not provide separate figures for those items, they are not included in the computation of the regional water withdrawal. Where available, these figures were included in the specific country profiles.

TABLE 3
Regional distribution of water withdrawal

Subregion	Annual water withdrawal by sector									
	Agricultural		Domestic		Industrial		Total withdrawal			
	km^3	% of total	km^3	% of total	km^3	% of total	km^3	% of Asia	m^3 per inhab.	in % of IRWR
Indian subcontinent	510.7	92	27.2	5	15.5	3	553.4	38	500	32
Eastern Asia	418.3	77	26.8	5	95.0	18	540.1	37	428	19
Far East	73.5	64	23.2	20	18.4	16	115.1	8	674	23
Southeast	82.1	88	3.9	4	7.0	8	93.0	6	476	5
Islands	127.9	90	10.4	7	4.3	3	142.6	10	483	3
Asia	1212.5	84	91.5	6	140.2	10	1444.2	100	476	12
World	2 310.5	71	290.6	9	652.2	20	3 253.3	100	564	8
Asia as % of world	52.5		31.5		21.5		44.4			

For most countries, data on water withdrawal could be obtained from national statistics although large uncertainties remain on computation methods. For six countries (Bhutan, Cambodia, DPR Korea, Lao PDR, Myanmar and Papua New Guinea) data for water withdrawal could not be found in national reports and estimates from the World Resources Institute (1998) were used instead. It should be noted that these are countries where water resources are not a constraint on economic development.

In Asia, almost 84 percent of the water withdrawal is used for agricultural purposes, compared to 71 percent for the world. The Indian subcontinent and Eastern Asia have the highest level of water withdrawal for agriculture with 92 and 77 percent respectively. The two regions together represent about 82 percent of the total irrigated area in Asia. Figures for agricultural water withdrawal expressed in cubic metres per hectare of irrigated land show large discrepancies between countries which cannot be explained solely by differences in climatic conditions. Rather, their difference is to be found in computation methods. Indeed, with a major regional emphasis on flooded rice irrigation, it is particularly difficult to assess agricultural water use. The gross average for the region is 8 900 m^3/ha/year. Figures for China and India, which represent 72 percent of the region's agricultural water withdrawal, are relatively similar: 7 500 and 9 200 m^3/ha of irrigated land respectively. However, other countries show much higher values, as is the case of the Philippines, Malaysia, Japan, Republic of Korea, Nepal and Sri Lanka, where agricultural water withdrawal is between 15 000 and 31 500 m^3/ha/year. More research is needed to obtain homogenous information on agricultural water use among countries.

Water withdrawal expressed as a percentage of TRWR, which take into account the incoming or border flows and the existing agreements, is a good indicator of the pressure on water resources. Roughly, it can be considered that pressure on water resources is high when this value is above 25 percent, as is the case for India and the Republic of Korea with 34 and 26 percent respectively. China, Japan, DPR Korea and Sri Lanka also have high values with 18.57, 21.26, 18.36 and 19.54 percent respectively (Table 14). Industrial water withdrawal is particularly important in Eastern Asia (18 percent) and the Far East (16 percent), where the industrial sector is more developed.

The increasing pressure on water resources in north China leads to water scarcity and increased competition for water between agriculture, industries and rapidly growing cities and is usually detrimental to the agricultural sector. The single most important water transfer programme in the region is the Three Gorges project on the Yangtze River, which is intended to transfer 70 km^3/year to north China, mostly to satisfy the increasing water demand of the Beijing area.

Figures for produced and treated wastewater are available only for some countries and are often underestimated. In most countries, treatment plants for wastewater are inexistent. Information on re-used treated wastewater exists only for China and Japan, where the re-used treated wastewater is reserved for the industrial sector. In addition, about 40 million m^3 and 0.37 million m^3 of water are produced by the desalinisation of seawater in Japan and Maldives respectively.

TABLE 4
Wastewater and non-conventional sources of water in selected countries

Country	Year	Produced wastewater (km^3)	Treated wastewater (km^3)	Re-used treated wastewater (km^3)	Desalinated water (km^3)
China	1995	37.29	23.33	13.39	-
India	1988	4.91	0.60	-	-
Japan (*)	1993	32.80	11.37	0.08	0.04
Korea, Rep.	1996	7.95	4.18	-	-
Malaysia	1995	2.69	0.39	-	-
Philippines	1993	0.07	0.01	-	-
Thailand	1995	0.83	0.04	-	-

*Figure for desalinated water is for 1996.

IRRIGATION

Irrigation potential

The irrigation potential for the region was estimated at 235 million ha, taking into account only the countries for which data were available. India and China account for about 76 percent of this total. The methods used to estimate the irrigation potential vary from country to country, which makes comparisons difficult. In addition, there are some contradictions between the figures given for the irrigation potential and the expected situation of the irrigation in the country. In India, for example, the irrigation potential, which is 113.5 million ha, is called ultimate irrigation potential. It corresponds to the gross area which could theoretically be irrigated in a year on the basis of the assumed design cropping pattern and a rainfall probability of 75 percent and represents 2.27 times the area under irrigation in 1993. This figure is a theoretical maximum. Indeed, it is considered that development of irrigation in India is about to reach its limits and that no major extension of irrigated lands is to be expected after the beginning of the twenty-first century.

In China, the figure for irrigation potential is 64 million ha and corresponds to the total area which could be brought under irrigation in the first half of the next century. As much of the additional land proposed for irrigation is located in the arid and semi-arid zones, reaching such a level would require a viable long-term strategy as to how to provide the amount of water necessary to irrigate these lands.

Irrigation development

In most countries of the region irrigation has a long history which is closely linked to the history of rice cultivation. Asia, in general, and the region covered by this survey in particular, represent the bulk of irrigation in the world. The region itself accounts for about 50 percent of the world's irrigation. High population density combined with the tradition of irrigated rice cultivation in all the tropical part of the region are the main factors explaining the importance of irrigation in Asia.

In many countries of the region, irrigation is viewed as an important input to the agricultural production systems. While irrigation development dates back several centuries, the twentieth century, and particularly its second half, has seen a rapid increase in what could be called modern irrigation development (Figure 1) and a majority of the countries have achieved self-sufficiency in cereal crops, mostly rice.

FIGURE 1
Evolution of irrigation in the countries of the region (1961-1996)

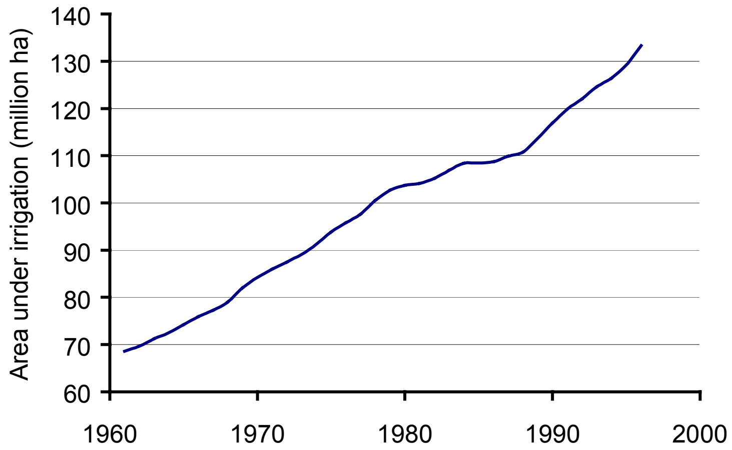


Table 5 presents the regional breakdown of areas under different types of water management.

TABLE 5
Regional distribution of water management methods

Sub-region	Irrigation					Other water managed areas	Total water managed area
	Full or partial control	Spate irrigation	Total irrigation	in % of total	in % of cultivated		
Indian subcontinent	55 595 113	-	55 595 113	43	36	-	55 55 113
Eastern Asia	54 460 500	27 000	554 487 500	42	55	-	54 487 500
Far East	4 016 874	-	40 116 874	3	60	-	4 0116 874
Southeast	9 983 995	-	9 983 995	7	25	352 500	10 336 495
Islands	6 341 522	-	6 341 522	5	13	3 841 450	10 182 972
Asia	130 398 004	27 000	130 425 004	100	37	4 193 950	134 618 954

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

In total, 37 percent of the land under cultivation in the region is irrigated (Tables 5 and 15). This is the highest level compared to the other major regions of the world. DPR Korea has the highest level, with 73 percent of cultivated land under irrigation, followed by Japan with 65 percent and China with 55 percent. Bangladesh, Nepal, Republic of Korea and Viet Nam have more than 40 percent of cultivated land under irrigation. Other tropical countries of south Asia and the Islands have an average between 20 and 25 percent of their cultivated land under irrigation.

Scheme classifications also vary widely among countries. Classifications are made according to scheme size, type of management, or institutional set-up. Several countries make the distinction between schemes designed for wet season crops and schemes designed for dry season crops (Lao PDR, Philippines, and Bangladesh).

While most wet season rice irrigation is fully gravity irrigation (cascades from plot to plot), dry season cropping may require pumping in places. This is the case in Lao PDR where, due to the pumping costs, dry season rice cropping has not proved economic unless a very bad harvest has been recorded in the previous wet season. In the tropical zone, wet season irrigation is almost only paddy rice. It is usually considered as supplementary irrigation to an already abundant precipitation. During the dry season, a much larger diversity of crops are grown on irrigated fields. In Cambodia, Indonesia, Malaysia and Mongolia, a kind of flood control irrigation is practised with flood water being used to inundate paddy fields which are then cultivated with rice. In total, such practice concerns an area of about 1.2 percent of the total irrigated land in the region.

Irrigation techniques

Surface irrigation is by far the most widespread irrigation technique in the region. It includes all paddy rice cultivation and most of the other crops. In most countries, sprinkler or drip irrigation systems are reported to exist on very small, experimental plots. Table 6 presents the information on sprinkler and micro-irrigation for the countries for which this information was available.

TABLE 6
Irrigation techniques

Country	Irrigation techniques					
	Surface		Sprinkler		Micro-irrigation	
	ha	%	ha	%	ha	%
India	49 330 000	98.5	700 000	1.4	71 000	0.1
Japan	2 830 079	90.5	243 000	7.8	55 000	1.7
Mongolia	13 900	24.3	43 400	75.7	-	-

Mongolia is the only country where sprinkler irrigation represents a significant part of the area under irrigation as large schemes were systematically equipped with sprinkler irrigation in the 1980s.

Origin of irrigation water

Surface water is the major source of irrigation water in the region, except for Bangladesh and India where groundwater is widely used (Table 16). Irrigation systems are generally grouped as:

- systems supplied through surface reservoirs;
- pumping from rivers;
- pumping from groundwater.

The percentage of power irrigated area is more important in Bangladesh, China and India, with 83, 54 and 53 percent respectively, while in Bhutan and Myanmar the corresponding figures are only 2 and 3 percent respectively (Table 7).

Irrigated crops

Information on irrigated crops is scarce and incomplete. In many countries, no distinction is made between areas of irrigated and rainfed crops. Rice represents about 45 percent of all irrigated crop areas in the region and 59 percent of the rice is irrigated (Table 8). However, its regional distribution shows major trends: in the countries of the Far East, Southeast Asia and the Islands, rice represents systematically more than 90 percent of irrigated crops, as is also the case for Bhutan, Nepal and Sri Lanka. In these countries, the remaining 10 percent consists of some dry season cereals, vegetables or industrial crops. Irrigation has played an important role in rice production in the second part of the twentieth century, and by the end of the 1980s many countries of the region had achieved self-sufficiency in rice.

TABLE 7
Power irrigated area as percentage of total irrigation

Country	Year	Irrigated area in ha	% of power irrigated area
Bangladesh	1995	3 751 045	83
China	1993	53 943 200	54
India	1993	3 000 000	53
Viet Nam	1994	3 300 000	26
Korea, Rep.	1996	888 795	18
Lao PDR	1995	155 394	15
Philippines	1993	1 550 000	11
Thailand	1995	5 003 724	6
Myanmar	1995	1 555 416	3
Bhutan	1995	38 734	2

By contrast, India, China and DPR Korea have a much more balanced distribution of irrigated crops with rice representing only about one-third to one half of the total irrigated crop area. This reflects the cold or arid context of large parts of these countries. In India, the percentage of land under irrigated wheat is slightly higher than that under irrigated rice (31 percent against 30 percent), the rest being shared between a large variety of crops. Data for irrigated crops in China were not available but it can be estimated that it is shared evenly between rice, wheat and other crops; rice being the single most important irrigated crop. However, in India only 47 percent of the total harvested area for paddy rice is irrigated, while more that 92 percent of the harvested paddy rice in China is irrigated (Table 8).

TABLE 8
Harvested area of paddy rice

Country	Year	Harvested area of paddy in hectares			Irrigated paddy rice in % of total paddy
		Irrigated	Rainfed	Total	
Bhutan	1990	27 400	0	27 400	100
Japan	1994	2 200 000	12 000	2 212 000	99
Viet Nam	1997	6 820 700	200 000	7 020 700	97
China	1995	28 465 000	2 642 000	31 107 000	92
Korea, Rep.	1996	888 795	160 192	1 048 987	85
Brunei	1997	375	75	450	83
Malaysia	1994	433 553	265 071	698 624	62
India	1993	19 633 000	22 380 500	42 013 500	47
Philippines	1992	1 442 678	1 794 322	3 237 000	45
Bangladesh	1994	2 683 554	7 235 746	9 919 300	27
Myanmar	1995	1 591 687	4 441 013	6 032 700	26
Lao PDR	1994	160 272	450 688	610 960	26
Cambodia	1993	313 000	1 510 625	1 823 625	17
Sri Lanka	1994	661 700	5 081 175	5 742 875	12
Subtotal		65 321 714	46 173 407	111 495 121	59

Rate of use of irrigated land

More or less reliable and complete information on irrigated cropping pattern is available for ten countries. Table 9 compares the total area of irrigated crops with the area equipped for irrigation. Cropping intensity varies from 72 percent in Bhutan, to 132 percent in India and Malaysia with an average of 127 percent. Care should be taken, however, when comparing figures for different countries. In Bhutan, for instance, irrigation figures refer only to summer crops.

In Bangladesh (84 percent), irrigation is considered only for dry season cropping. The average irrigated cropping intensity for these ten countries is 127 percent.

TABLE 9
Intensification of irrigated land, in ten countries

Country	Area under irrigation ha	Irrigated crops ha	Intensification %
Bangladesh	3 75 041	3 167 756	84
Bhutan	39 734	27 900	72
India	50 101 000	66 144 000	132
Sri Lanka	570 000	666 700	120
Korea, Rep.	888 795	978 795	110
Cambodia	390 461	313 000	80
Lao PDR	155 394	162 692	105
Myanmar	1 555 416	1 911 162	123
Malaysia	362 600	477 606	132
Philippines	1 550 000	1 492 676	96
Total (10 countries)	59 363 445	75 362 287	127

Drainage, flood control and environmental issues

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

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

In these areas, drainage and flood control are also very much related. In Bangladesh, on average, 22 percent of the country is flooded every year and 50 percent of water development expenditures are spent on flood control and drainage. In Myanmar, in the Ayeyarwady Delta, drainage and flood control structures are also linked: in 1995 a total of 193 000 ha were reported to be equipped for surface drainage which is considered as a form of flood protection. Drainage covers 1 million ha in north and central Viet Nam, mostly in the Red River Delta. Flood protected areas in China represent 32.69 million ha. The extreme case of agriculture under flood conditions is floating rice, which is reported in Cambodia, but can probably be found in other countries of the sub-region.

Data on drainage infrastructure associated to irrigation in arid and semi-arid areas concern mostly northern China, India and Mongolia. In China as a whole (no distinction can be made between arid and humid areas), it was estimated in 1996 that 24.58 million ha were subject to waterlogging, of which 20.28 million ha were equipped with drainage. In India, drainage works have been undertaken on about 5.8 million ha (12 percent of the irrigated area), but investment in drainage works associated with irrigation schemes has been widely neglected and drainage systems are usually in very poor maintenance condition. No data were available from Mongolia.

A specific case of drainage is reported for Malaysia when 940 000 ha are drained, of which 600 000 ha for oil palm cultivation.

In arid and semi-arid areas of northern China, waterlogging, salinity and alkalinization are considered serious constraints on agricultural development in irrigated land. Saline/alkaline cultivated land in China covers 7.73 million ha (5.51 million ha of which have been improved). In India, waterlogging due to irrigation covers an area of about 2.46 million ha; 3.06 million ha are affected by salinity and 0.24 million ha by alkalinity problems. Salinization is also reported in the central dry zones of Myanmar, where major groundwater pumping irrigation schemes are located.

Although total water withdrawal remains limited compared to water resources in Southeast Asia (about 5 percent), the large amounts of water diverted, mostly for agriculture, in those countries, have an environmental impact which may assume important proportions locally. Intrusion of saltwater in deltas is a concern in Myanmar, Viet Nam and parts of India. Excessive groundwater exploitation around Bangkok, in Thailand, creates land subsidence and exacerbates already existing flood problems. In several countries, competition for water is becoming increasingly important, with direct implications for agriculture. This point is discussed in the next section.

Water-borne diseases

Information on water-borne diseases is difficult to obtain and probably very incomplete. Cambodia, Philippines and Thailand have detailed statistics on the subject, which are summarized in Table 10.

TABLE 10
Water-borne diseases in some countries of the region

Countries	Number of inhabitants affected	
	Total	% of population
Cambodia	500 000	4.9
Philippines	782 000	1.1
Thailand	1 040 000	1.8

Trends in irrigation and drainage

Although quite subjective by nature, some clear trends can be observed across the countries of the region. The most frequently mentioned issue relates to the recognition of the failure to develop adequate operation and maintenance (O&M) mechanisms to ensure the sustainability of the irrigation schemes (mostly large, public schemes). Irrigation management transfer or increased participation of users in the management of the schemes is seen by most countries as the solution to this sustainability problem. This is achieved through the development or improvement of water users associations (WUAs) and is a priority in India, Bangladesh, Bhutan, Cambodia, Nepal and the Republic of Korea where WUAs are a reality. In the Philippines, Lao PDR and China, gradual programmes of irrigation management transfer are at different stages of completion, while Mongolia plans to introduce WUAs in the near future.

Financial sustainability requires a revision of measurement, computation and recovery mechanisms related to water fees. In countries such as China, Lao PDR, Thailand, the policy is now to adjust water fees so that they cover at least the cost of O&M.

The strengthening of WUAs is also linked to the need expressed in several countries to improve the overall performance and water use efficiency of irrigation schemes. Intensification and improved performance are indicated as objectives of irrigation policies for India, Bangladesh and Malaysia. Diversification (from rice) is a policy of Japan and Malaysia, while Lao PDR Malaysia, Mongolia, Myanmar and Viet Nam are attempting to promote a more market-oriented irrigated agriculture, free cropping and extension of cash crops.

Countries are also studying ways to modernize their irrigation as for instance in Japan, Malaysia and Mongolia.

As the older public schemes reach the age of 30-40 years in most countries, the issue of rehabilitation, which is related to those of operation and maintenance and modernization, is becoming increasingly important. While for some countries (such as Lao PDR, Myanmar, Philippines, Viet Nam and parts of India) the extension of irrigated land still represents an important part of irrigation programmes, in most countries rehabilitation programmes are taking on increasing importance. The increased land and water scarcity and low expected return of future expansion of irrigation in these countries are often factors explaining the growing importance of rehabilitation in irrigation programmes.

Indeed, water scarcity is another major issue mentioned in several country reports such as for China, Japan, Philippines or India. Increased competition for water between sectors already affects agriculture in China, India, Malaysia, Thailand and the Republic of Korea and the trend is towards an intensification of the problem due mainly to the rapid growth of the domestic and industrial sectors in these countries. Major interbasin transfer programmes are reported in China and Thailand. Water scarcity and the interdependency between water use sectors are pushing countries to develop integrated water resources management programmes, as in Malaysia, Myanmar, Viet Nam and Thailand.

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

Competition for land is acute in Japan (where urban encroachment on agricultural land also has implications for water distribution in irrigated areas), in DPR Korea and in the Philippines. In Thailand, the transfer of populations from high density to low density areas has encountered serious socio-economic problems.

While irrigation has been instrumental in achieving self-sufficiency in staple crop production in recent decades in most countries of the region, some countries such as Indonesia and the Philippines still indicate self-sufficiency as a major target of their irrigation development programmes; this mainly to keep pace with rising populations. In Malaysia, however, the national policy is to decrease self-sufficiency in rice from 80 to 65 percent in 2010, due to the high cost of rice production. In Japan, rice irrigation has been on a downward trend for the last 20 years due to overproduction in the 1970s.

Summary tables

TABLE 11
Land use and irrigation potential in Asia

Country	Area of the country	Cultivable area **	Cultivated area					Irrigation potential	
			Year	Annual	Permanent	Total	% of cultivable area**	ha**	% of cultivable area**
	ha	ha		ha	ha	ha			
	(1)	(2)		(3)	(4)	(5) = (3)+(4)	(6) = 100*(5)/(2)	(7)	(8) = 100 * (7)/(2)
Bangladesh	14 400 000	8 774 000	1994	7 351 000	392 000	7 743 000	88	7 550 000	86
Bhutan	4 700 000	-	1995	152 016	17 092	169 108	-	-	-
Brunei	577 000	13 000	1995	3 000	4 000	7 000	54	-	-
Cambodia	18 104 000	4 626 000	1993	1 966 000	146 000	2 112 000	46	606.364	13
China*	959 803 000	129 972 000	1995	92 084 000	3 767 000	95 851 000	74	64 000 000	50
India	328 759 000	183 956 000	1993	134 910 000	7 599 000	142 509 000	77	113 512 000	62
Indonesia	190 457 000	-	1995	21 743 000	13 836 000	35 579 000	-	10 865 000	-
Japan	37 780 000	4 994 000	1996	4 384 000	392 000	4 776 000	96	-	-
Korea, DPR	12 054 000	2 410 800	1994	1 700 000	300 000	2 000 000	83	-	-
Korea, Rep.	9 926 000	-	1996	1 747 037	198 443	1 945 480	-	1 945 480	-
Lao PDR	23 680 000	2 000 000	1994	674 410	45 000	719 410	36	600 000	30
Malaysia	32 975 000	14 174 688	1996	445 700	4 650 118	5 095 818	36	413 700	3
Maldives	30 000	-	1996	1 000	2 000	3 000	-	-	-
Mongolia	156 650 000	1 800 000	1992	664 000	700	664 700	37	518 000	29
Myanmar	67 658 000	18 270 000	1995	9 571 000	570 000	10 141 000	56	10 500 000	57
Nepal	14 718 000	3 955 100	1994	2 598 742	43 000	2 641 742	67	2 177 800	55
Papua New Guinea	46 284 000	12 500 000	1995	60 000	480 000	540 000	4	360 000	3
Philippines	30 000 000	-	1991	5 332 770	4 172 540	9 505 310	-	3 126 000	-
Sri Lanka	6 561 000	-	1995	887 000	1 000 000	1 887 000	-	570 000	-
Thailand	51 312 000	26 790 000	1995	17 085 000	3 360 000	20 445 000	76	12 245 000	46
Viet Nam	33 169 000	7 086 000	1995	5 509 000	1 248 000	6 757 000	95	6 000 000	85
Total	2 039 597 000	420 721 588	-	308 868 675	42 222 893	351 091 568	72	234 989 344	55

Total irrigation potential may include double counting of shared water resources
* Irrigation potential estimated for the year 2050
** Total cultivable area and total irrigation potential are calculated for the countries for which data are available.

TABLE 12
Population of Asia

Country	Area of the country km²	Cultivated area ha	Population (1996)					% of econ. active pop. engaged in agriculture
			Total			Rural		
			Inhabitants	Inhabitants per km²	Inhabitants per ha of cultivated area	Inhabitants	% of total	
	(1)	(2)	(3)	(4)=(3)/(1)	(5)=(3)/(2)	(6)	(7)=100*(6)/(3)	(8)
Bangladesh	144 000	7 743 000	120 073 000	834	16	97 259 130	81	61
Bhutan	47 000	169 108	1 812 000	39	11	1 685 160	93	94
Brunei	5 770	7 000	300 000	52	43	126 000	42	2
Cambodia	181 040	2 112 000	10 273 000	57	5	8 115 670	79	73
China	9 508 030	95 851 000	1 238 274 000	129	13	848 217 690	69	71
India	3 287 590	142 509 000	944 580 000	287	7	689 543 400	73	61
Indonesia	1 904 570	35 579 000	200 453 000	305	6	127 488 108	64	49
Japan	377 800	4 776 000	125 351 000	332	26	27 577 220	22	5
Korea, DPR	120 540	2 000 000	22 466 000	186	11	8 761 740	39	33
Korea, Rep.	99 260	1 945 480	45 314 920	457	23	7 703 536	17	11
Lao PDR	236 800	719 410	5 035 000	21	7	3 927 300	78	77
Malaysia	329 750	5 095 818	20 581 000	62	4	9 364 355	46	22
Maldives	300	3 000	263 000	878	88	191 990	73	29
Mongolia	1 566 500	664 700	2 515 000	2	4	955 700	38	28
Myanmar	676 580	10 141 000	45 922 000	68	5	33 982 280	74	72
Nepal	147 180	2 641 742	22 021 000	150	8	18 938 060	86	93
Papua New Guinea	462 840	540 000	4 400 000	10	8	3 696 000	84	77
Philippines	300 000	9 505 310	69 283 000	231	7	31 177 350	45	42
Sri Lanka	65 610	1 887 000	18 100 000	276	10	13 937 000	77	46
Thailand	513 120	20 445 000	58 703 000	114	3	46 962 400	80	55
Viet Nam	331 690	6 757 000	75 181 000	227	11	59 392 990	79	69
Total	20 395 970	351 091 568	3 030 900 920	149	9	2 039 003 079	67	62

TABLE 13
Renewable water resources in Asia

Country	Population (1996)	Precipitation (mm)	Annual renewable water resources					Dependency ratio %
			Internal		External	Total		
			million m^3	m^3 per inhab. 1996	million m^3	million m^3	m^3 per inhab. 1996	
	(1)	(2)	(3)	(4)=(3)*10^6 /(1)	(5)	(6)=(3)+(5)	(7)=(6)*10^6/(1)	(8)
Bangladesh	120 073 000	2 320	105 000	874	1 105 644	1 210 644	10 083	91.3
Bhutan	1 812 000	4 000	95 000	52 428	0	95 000	52 428	0.0
Brunei	300 000	2 654	8 500	28 333	0	8 500	28 333	0.0
Cambodia	10 273 000	1 463	120 570	11 737	355 540	476 110	46 346	74.7
China	1 238 274 000	648	2 812 400	2 271	17 169	2 829 569	2 285	0.6
India	944 580 000	1 170	1 260 540	1 334	647 220	1 907 760	2 020	33.9
Indonesia	200 453 000	2 700	2 838 000	14 158	0	2 838 000	14 158	0.0
Japan	125 351 000	1 728	430 000	3 430	0	430 000	3 430	0.0
Korea, DPR	22 466 000	1 054	67 000	2 982	10 135	77 135	3 433	13.1
Korea, Rep.	45 314 920	1 274	64 850	1 431	4 850	69 700	1 538	7.0
Lao PDR	5 035 000	1 600	190 420	37 782	143 130	331 550	66 181	42.9
Malaysia	20 581 000	3 000	580 000	28 183	0	580 000	28 183	0.0
Maldives	263 000	1 883	30	114	0	30	114	0.0
Mongolia	2 515 000	251	34 800	13 837	0	34 800	13 837	0.0
Myanmar	45 922 000	2 341	880 600	19 176	165 001	1 045 601	22 769	15.8
Nepal	22 021 000	1 500	198 200	9 000	12 000	210 200	9 545	5.7
Papua New Guinea	4 400 000	3 500	801 000	182 045	0	801 000	182 045	0.0
Philippines	69 283 000	2 373	479 000	6 914	0	479 000	6 914	0.0
Sri Lanka	18 100 000	2 000	50 000	2 762	0	50 000	2 762	0.0
Thailand	58 703 000	1 485	210 000	3 577	199 944	409 944	6 983	48.8
Viet Nam	75 181 000	1 960	366 500	4 875	524 710	891 210	11 854	58.9
Total	3 030 900 920	1 194	11 592 410	3 825				

TABLE 14
Water withdrawal in Asia

Country	Annual water withdrawal										
	Year	Agricultural		Domestic		Industrial		Total			
		million m^3	% of total	million m^3	% of total	million m^3	% of total	million m^3	m^3 per inhab. (1996)	% of intern. renewable water res.	% of total renewable water res.
		(1)	(2)=(1)*100/(7)	(3)	(4)	(5)	(6)	(7)=(1)+(3)+(5)	(8)=(7)*10^6 / (1) of T.13	(9)=(7)*100/ (3) of T.13	(10)=(7)*100/(6) of T.13
Bangladesh	1990	12 600.00	86	1 704.32	12	332.16	2	14 636.48	122	13.94	1.21
Bhutan	1987	10.80	54	7.20	36	2.00	10	20.00	11	0.02	0.02
Brunei	1994	-	-	-	-	-	-	91.60	305	1.08	1.08
Cambodia	1987	489.00	94	26.00	5	5.00	1	520.00	51	0.43	0.11
China	1993	407 774.00	77	25 165.00	5	92 550.00	18	525 459.00	424	18.68	18.57
India	1990	460 000.00	82	25 000.00	5	15 000.00	3	500 000.00	529	39.67	26.21
Indonesia	1990	69 241.00	93	4 729.00	6	376.00	1	74 346.00	371	2.62	2.62
Japan	1992	58 600.00	64	17 000.00	19	15 800.00	17	91 400.00	729	21.26	21.26
Korea, DPR	1987	10 336.80	73	1 557.60	11	2 265.60	16	14 160.00	630	21.13	18.36
Korea, Rep.	1994	14 877.00	63	6 209.00	26	2 582.00	11	23 668.00	522	36.50	33.96
Lao PDR	1987	812.00	82	79.00	8	99.00	10	990.00	196	0.52	0.30
Malaysia	1995	9 750.00	77	1 342.00	10	1 641.00	13	12 733.00	619	2.20	2.20
Maldives	1987	0.00	0	3.32	98	0.05	2	3.37	13	11.23	11.23
Mongolia	1993	227.04	53	85.36	20	115.72	27	428.12	170	1.23	1.23
Myanmar	1987	3 564.00	90	277.20	7	118.80	3	3 960.00	86	0.45	0.38
Nepal	1994	28 702.00	99	246.00	1	5.00	0	28 953.00	1 315	14.61	13.77
Papua New Guinea	1987	49.00	49	29.00	29	22.00	22	100.00	23	0.01	0.01
Philippines	1995	48 857.00	88	4 269.00	8	2 296.00	4	55 422.00	780	11.57	11.57
Sri Lanka	1990	9 380.00	96	195.00	2	195.00	2	9 770.00	540	19.54	19.54
Thailand	1990	30 200.00	91	1 496.00	5	1 436.00	4	33 132.00	564	15.78	8.08
Viet Nam	1990	47 000.00	86	2 000.00	4	5 330.00	10	54 330.00	723	14.82	6.10
Total		1 212 469.64	84	91 420.00	6	140 171.33	10	1 444 152.97	476	12.46	

TABLE 15
Agricultural water management in Asia

Country	Irrigation							Other water management areas [(2)]	Total water managed areas
	Year	Full/partial control	Spate irrigation	Total	% of cultivated area	% of irrigation potential[(1)]	% of equipped area actually irrigated		
		ha	ha	ha				ha	ha
		(1)	(2)	(3) = (1) + (2)	(4)=100*(3)/ (5) of T.11	(5)=100*(3)/ (7) of T.11	(6)	(7)	(8) = (3) + (7)
Bangladesh	1995	3 751 045	-	3 751 045	48	50	-	-	3 751 045
Bhutan	1995	38 734	-	38 734	23	-	94	-	38 734
Brunei	1995	1 000	-	1 000	14	-	100	-	1 000
Cambodia	1993	269 461	-	269 461	13	44	90	121 000	390 461
China	1993	52 943 200	-	52 943 200	55	83	89	-	52 943 200
India	1993	50 101 000	-	50 101 000	35	44	-	-	50 101 000
Indonesia	1996	4 427 922	-	4 427 922	12	41	-	3 841 450	8 269 372
Japan	1993	3 128 079	-	3 128 079	65	-	100	-	3 128 079
Korea, DPR	1995	1 460 000	-	1 460 000	73	-	-	-	1 460 000
Korea, Rep.	1996	888 795	-	888 795	46	46	-	-	888 795
Lao PDR	1995	155 394	-	155 394	22	26	96	231 500	386 894
Malaysia	1994	362 600	-	362 600	7	88	100	-	362 600
Mongolia	1993	57 300	27 000	84 300	13	16	61	-	84 300
Myanmar	1995	1 555 416	-	1 555 416	15	15	100	-	1 555 416
Nepal	1994	1 134 334	-	1 134 334	43	52	-	-	1 134 334
Philippines	1993	1 550 000	-	1 550 000	26	43	95	-	1 550 000
Sri Lanka	1995	570 000	-	570 000	30	100	-	-	570 000
Thailand	1995	5 003 724	-	5 003 724	24	41	91	-	5 003 724
Viet Nam	1994	3 000 000	-	3 000 000	44	50	70	-	3 000 000
Total	-	130 398 004	27 000	130 425 004	37	54	-	4 193 950	134 618 954
% of water managed	-	96.87	0.02	96.89	-	-	-	3.11	100.00

Note: Maldives and Papua New Guinea do not have irrigation
[(1)]Regional percentage of irrigation potential calculated for the countries for which irrigation potential data are available.
[(2)]Includes cultivated wetland (Indonesia), non irrigated lowland paddy (Lao PDR) and recession cropping areas (floating rice; Cambodia). Cultivated lowland are reported in several other countries but no statistics are available

TABLE 16
Origin of irrigation water in Asia

Country	Year	Total irrigation	Origin of irrigation water **				Country
			Surface water		Groundwater		
		ha	ha	%	ha	%	
		(1)	(2)	(3)=100*(2)/(1)	(4)	(5)=(4)*100/(1)	
Bangladesh	1995	3 751 045	1 158 579	30.8	2 592 466	69.2	Bangladesh
Bhutan	1995	38 7734	38 734	100.0	0	0.0	Bhutan
Brunei	1995	1 000	1 000	100.0	0	0.0	Brunei
Cambodia	1993	269 461	269 461	100.0	0	0.0	Cambodia
China	1993	52 943 200	-	-	-	-	China
India(*)	1993	50 101 000	20 327 000	40.5	26 538 000	53.0	India
Indonesia	1996	4 427 922	4 383 713	99.0	44 209	1.0	Indonesia
Japan	1993	3 128 079	3 128 079	100.0	500 000	16	Japan
Korea, DPR	1995	1 460 000	1 255 600	86.0	204 400	14.0	Korea, DPR
Korea, Rep.	1996	888 795	844 355	94.9	44 440	5.1	Korea, Rep.
Lao PDR	1995	155 394	155 344	100.0	0	0.0	Lao PDR
Malaysia	1994	362 600	335 350	92.0	27 250	8.0	Malaysia
Mongolia	1993	84 300	-	-	-	-	Mongolia
Myanmar	1995	1 555 416	1 500 241	96.5	55 175	3.5	Myanmar
Nepal(*)	1994	1 134 334	837 913	73.9	140 195	12.4	Nepal
Philippines	1993	1 550 000	1 397 872	90.2	152 128	9.8	Philippines
Sri Lanka	1995	570 000	569 000	99.8	1 000	0.2	Sri Lanka
Thailand	1995	5 003 724	4991 724	99.8	12 000	0.2	Thailand
Viet Nam	1994	3 000 000	-	-	-	-	Viet Nam
Total **	-	130 425 004	41 193 965	57.6	30 311 263	42.4	

Note: Maldives and Papua New Guinea do not have irrigation

* In India, 3 236 000 ha are classified as irrigated from "undefined sources" and do not appear in this table. In Nepal, the source of water is not known for 156 226 ha which do not appear in this table

** Totals for origin of irrigation water refer to 16 countries only.

TABLE 17
Salinization and drainage in Asia

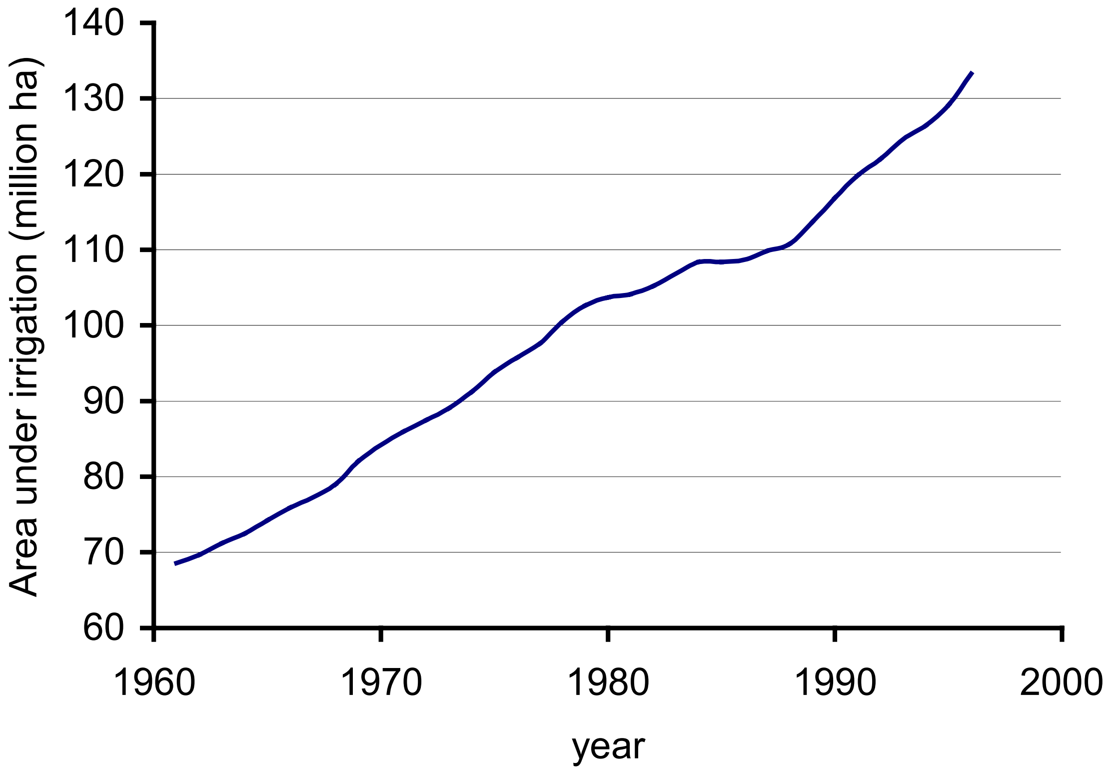
Country	Total irrigation		Area salinized by irrigation			Drained area in ha			
	year	ha	year	ha	% of irrigated area	year	Surface	Subsurface	Total
		(1)		(2)	(3)=(2)*100/(1)		(4)	(5)	(6)=(4)+(5)
Bangladesh	1995	3 751 045	1991	100 000	2.7	1993	1 501 400	0	1 501 400
Bhutan	1995	38 734	-	-	-	-	-	-	-
Brunei	1995	1 000	-	-	-	-	-	-	-
Cambodia	1993	269 461	-	-	-	-	-	-	-
China	1993	52 943 200	-	-	-	1995	-	-	20 065 000
India	1993	50 101 000	1991	3 300 000	6.6	1991	-	-	5 800 000
Indonesia	1996	4 427 922	-	-	-	-	-	-	-
Japan	1993	3 128 079	-	-	-	-	-	-	-
Korea, DPR	1995	1 460 000	-	-	-	-	-	-	-
Korea, Rep.	1996	888 795	-	-	-	1996	1 037 637	1 500	1 039 137
Lao PDR	1995	155 394	-	-	-	-	-	-	-
Malaysia	1994	362 600	1994	0	0.0	1994	-	-	960 600
Mongolia	1993	84 300	-	-	-	-	-	-	-
Myanmar	1995	1 555 416	-	-	-	1994	193 363	0	193 363
Nepal	1994	1 134 334	-	-	-	-	-	-	-
Philippines	1993	1 550 000	-	-	-	1993	-	-	1 470 691
Sri Lanka	1995	570 000	-	-	-	-	-	-	-
Thailand	1995	5 003 724	-	-	-	-	-	-	-
Viet Nam	1994	3 000 000	-	-	-	1994	-	-	1 000 000

Note: Maldives and Papua New Guinea do not have irrigation and drainage
(1) Drained areas: for some countries, no breakdown between surface and sub-surface drainage is available

TABLE 18
Asia compared to the world

Variable	Unit	World	Asia	Asia in % of the world
Total area	km^2	133 870 200	20 395 970	15
Total population 1996	inhabitants	5 767 775 000	3 030 900 920	53
Population growth 1995-96	%/year	1.4	1.5	
Population density	inhab./km^2	43	149	
Rural population	%	54	67	
Economically active population engaged in agriculture	%	47	62	
Precipitation	km^3/year	110 000	24 359	22
Renewable water resources				
Total	km^3/year	41 022	11 592	28
Per inhabitant 1996	m^3/year	6 918	3 825	
Water withdrawal				
- agricultural	km^3/year	2 310	1 212	53
- % of total	%	71	84	
- domestic	km^3/year	291	91	32
- % of total	%	9	6	
- industrial	km^3/year	652	140	22
- % of total	%	20	10	
Total water withdrawal	km^3/year	3 253	1 444	44
- in % of renewable water resources	%	8	12	
- per inhabitant 1996	m^3/year	564	476	
Irrigation	ha	266 073 634	130 425 004	49

Figures


Area under irrigation (million ha)
140
130
120
110
100
90
80
70
60
1960
1970
1980
1990
2000
year

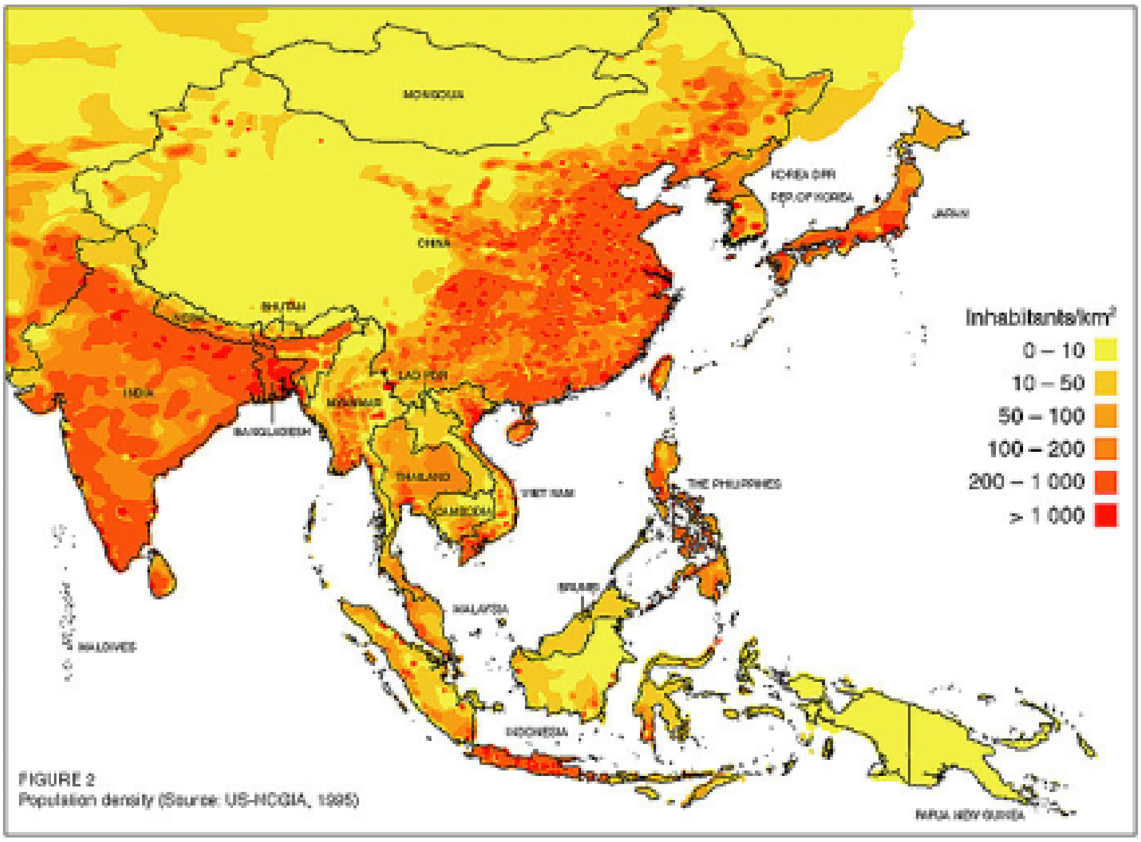


FIGURE 2
Population density (Source: US-NCGIA, 1995)

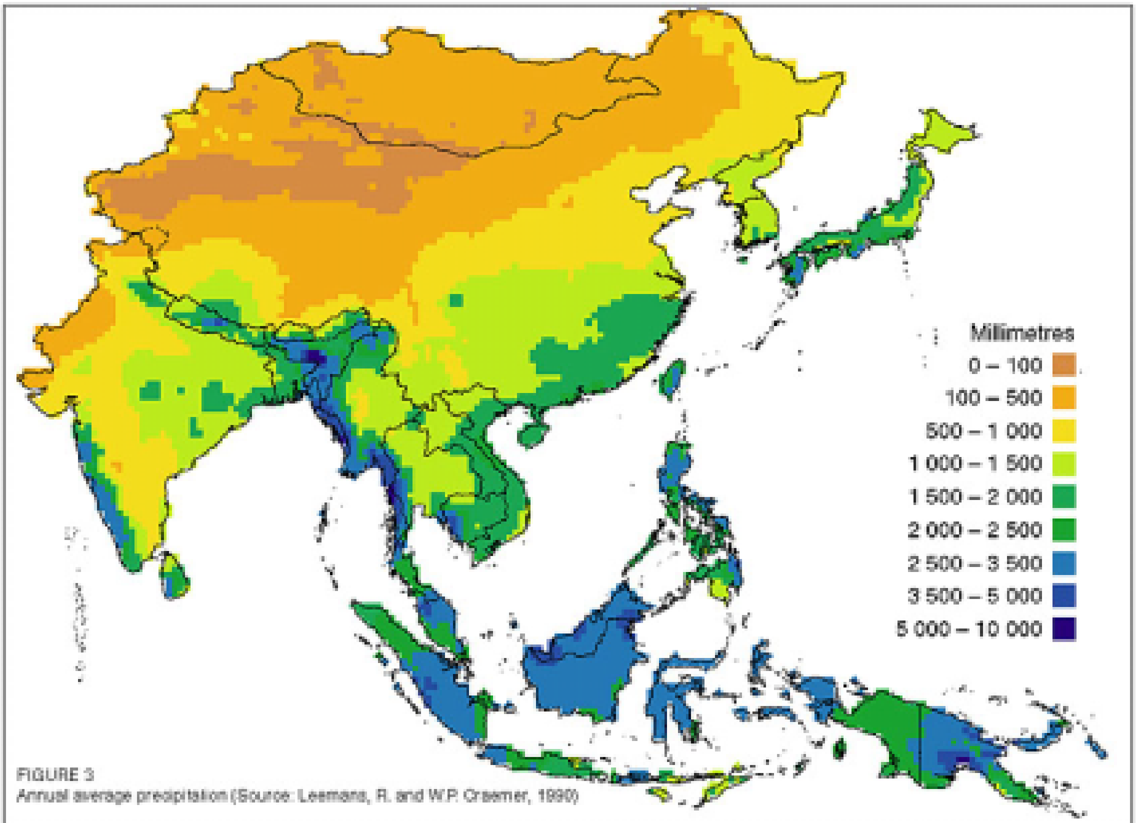


FIGURE 3
Annual average precipitation (Source: Leemans, R. and W.P. Cramer, 1990)

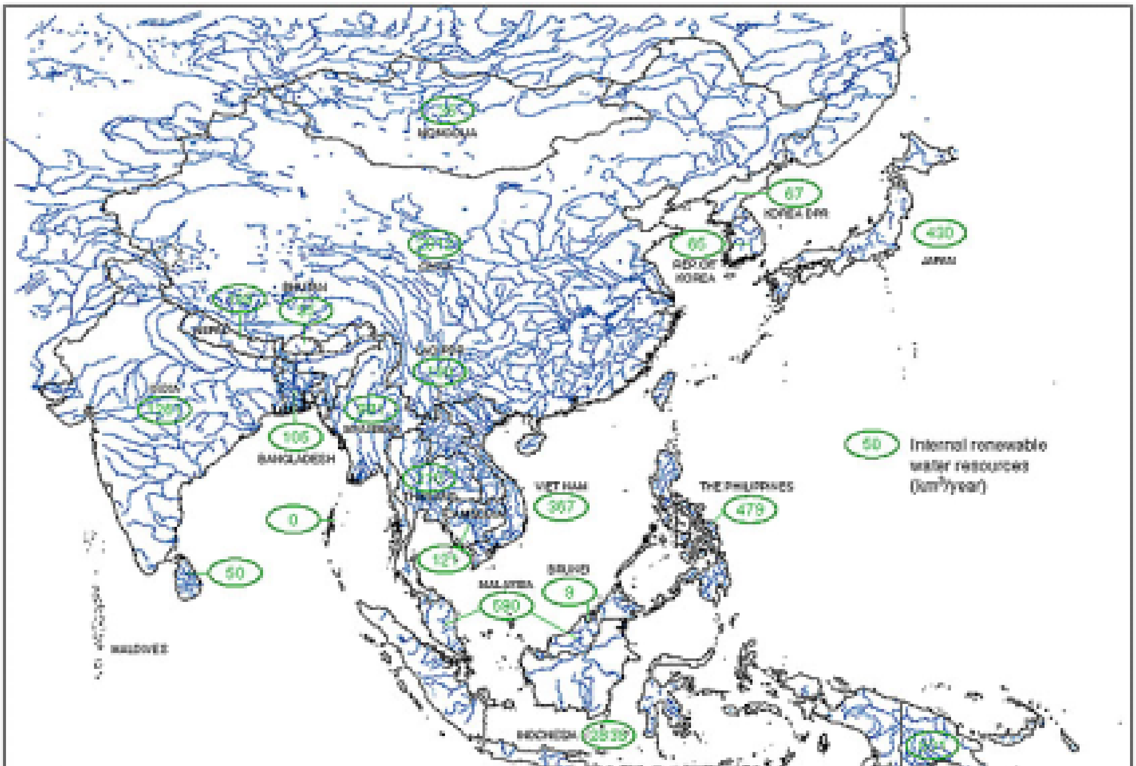


FIGURE 4
Internal renewable water resources

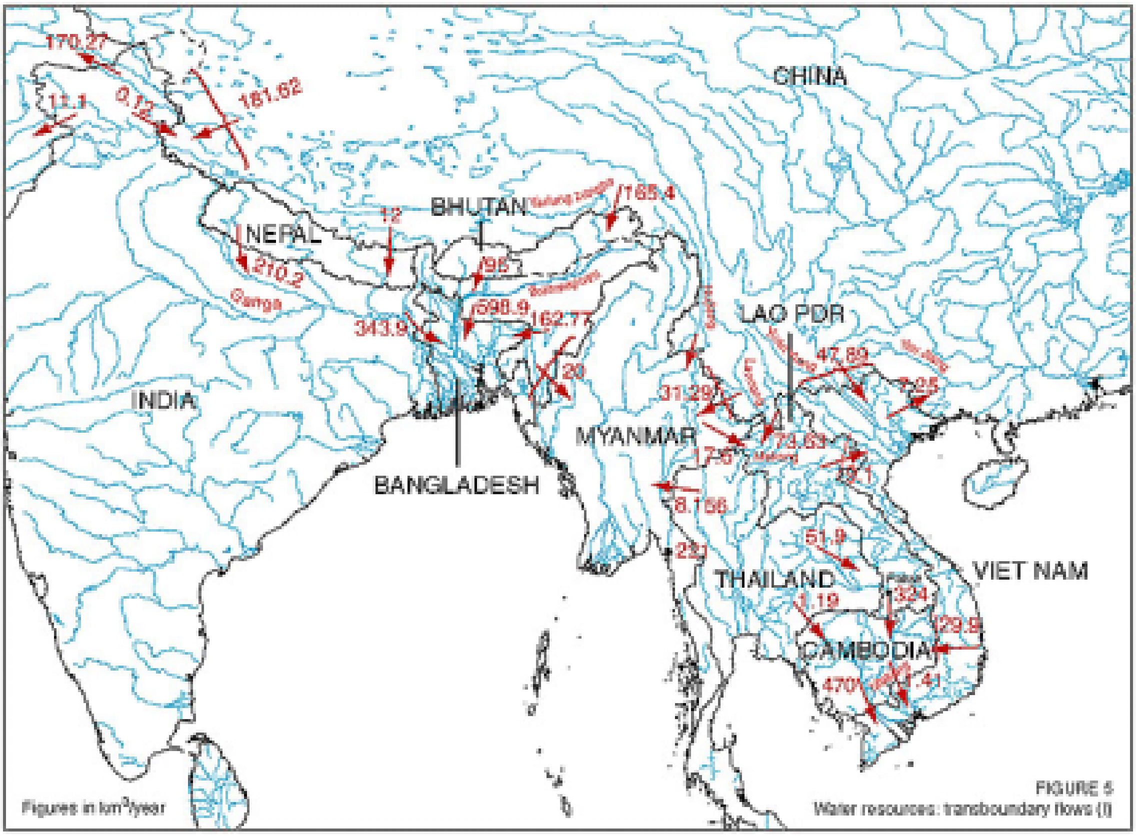


FIGURE 5
Water resources: transboundary flows (I)

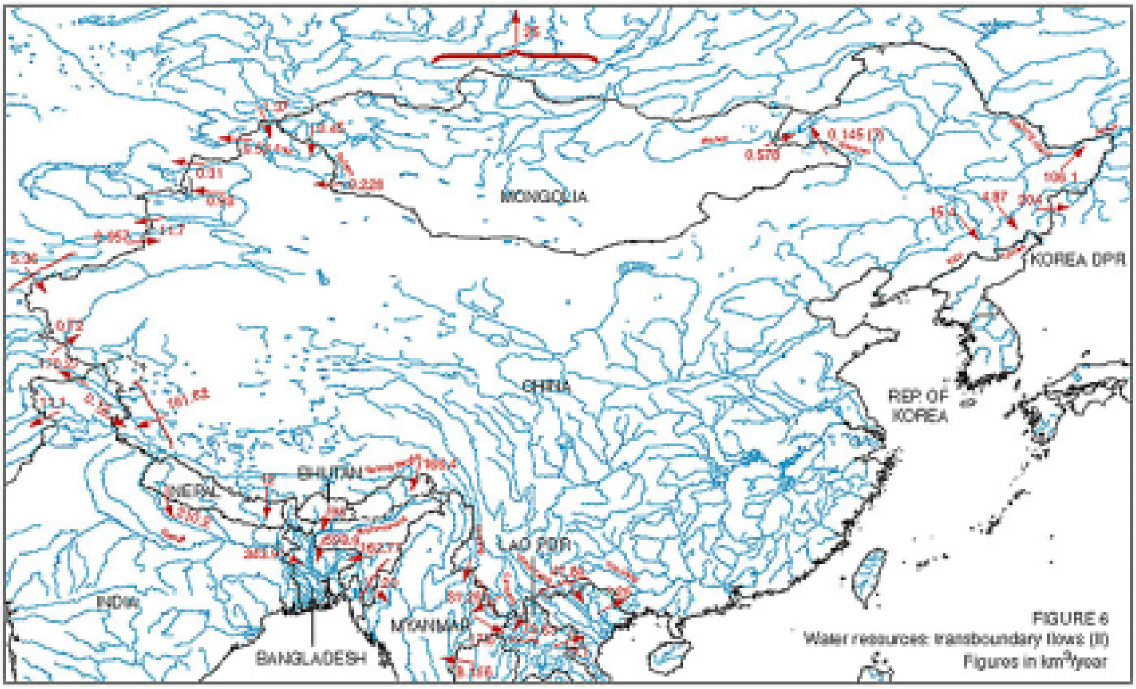


FIGURE 6
Water resources: transboundary flows (II)
Figures in km³/year

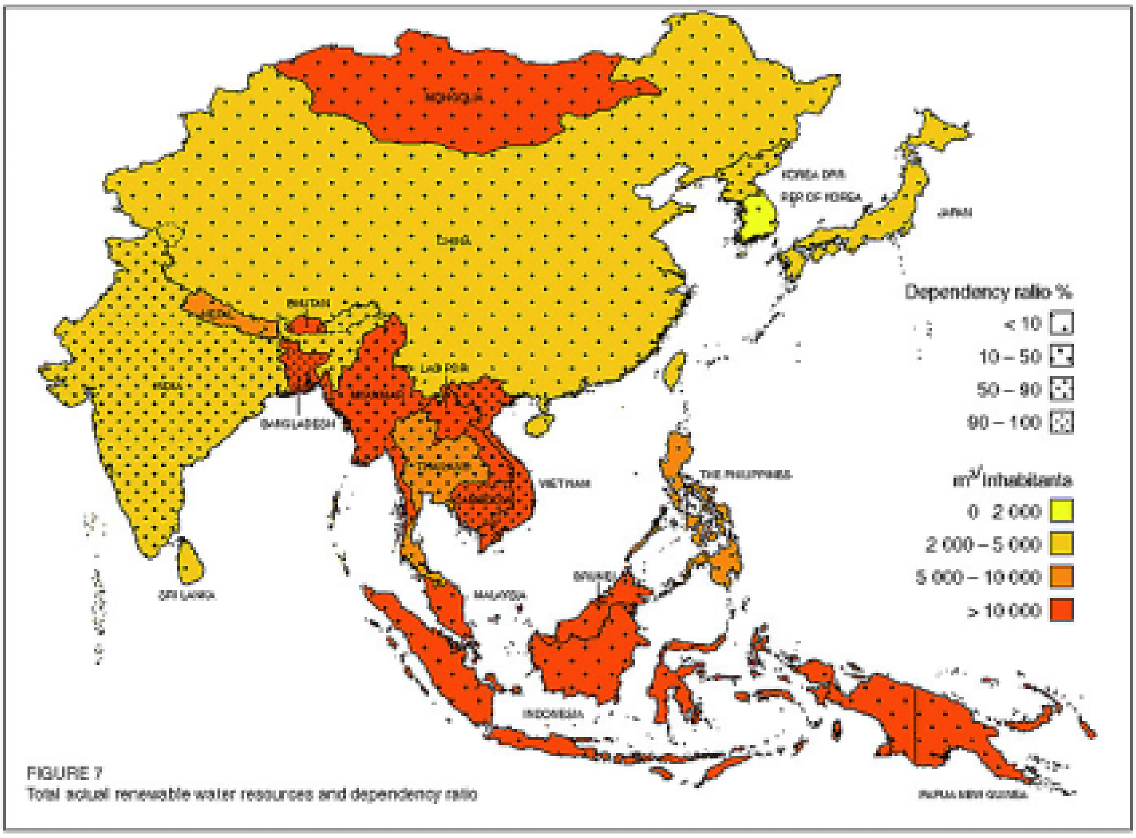


FIGURE 7
Total actual renewable water resources and dependency ratio

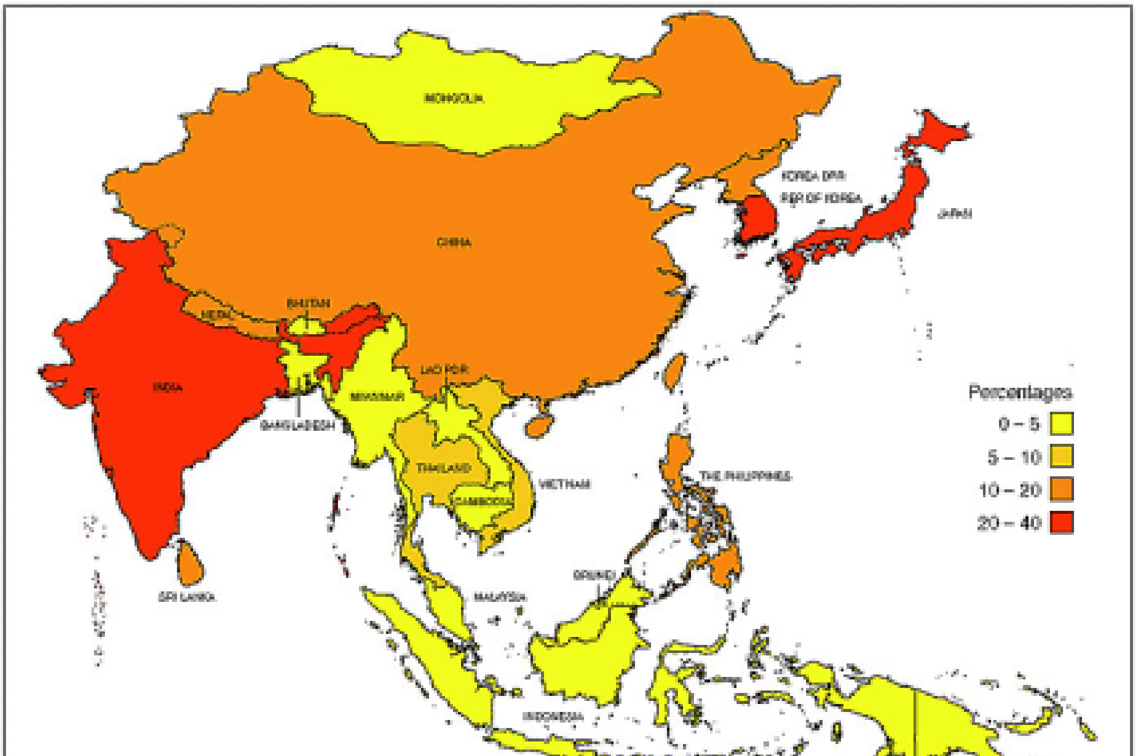


FIGURE 8
Water withdrawal as a percentage of total renewable water resources

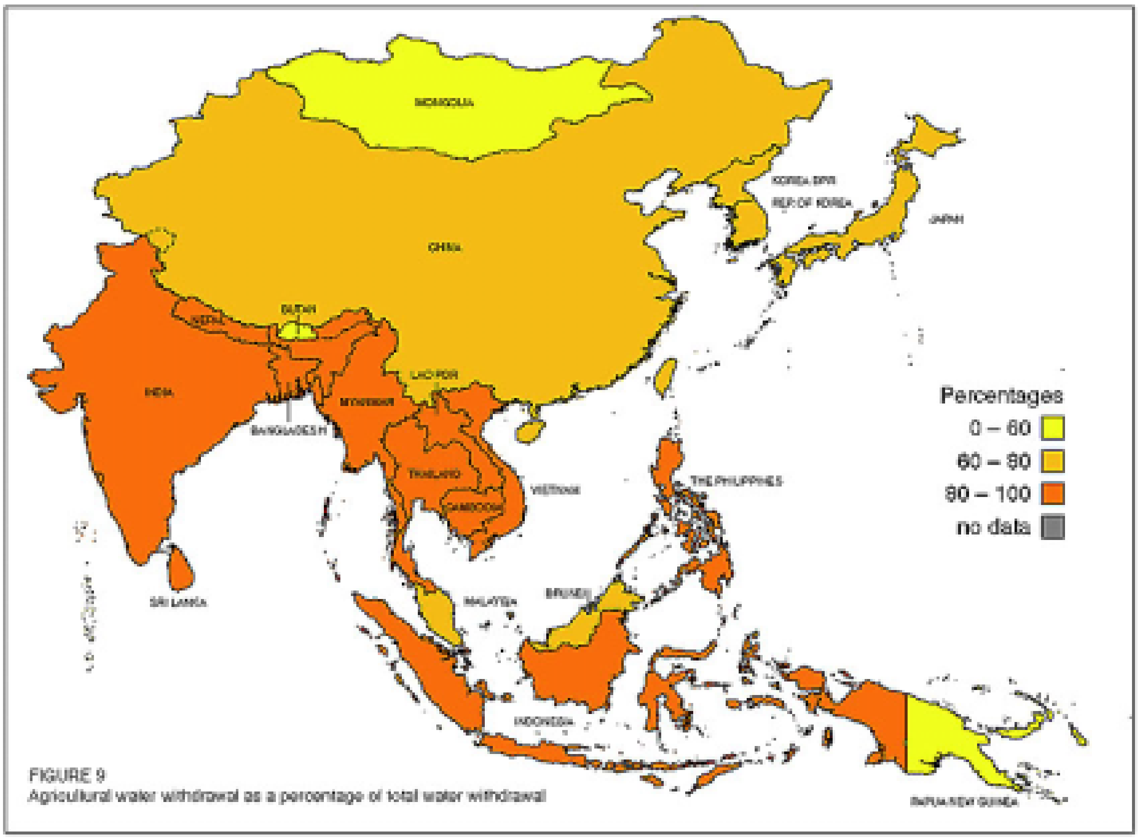


FIGURE 9
Agricultural water withdrawal as a percentage of total water withdrawal

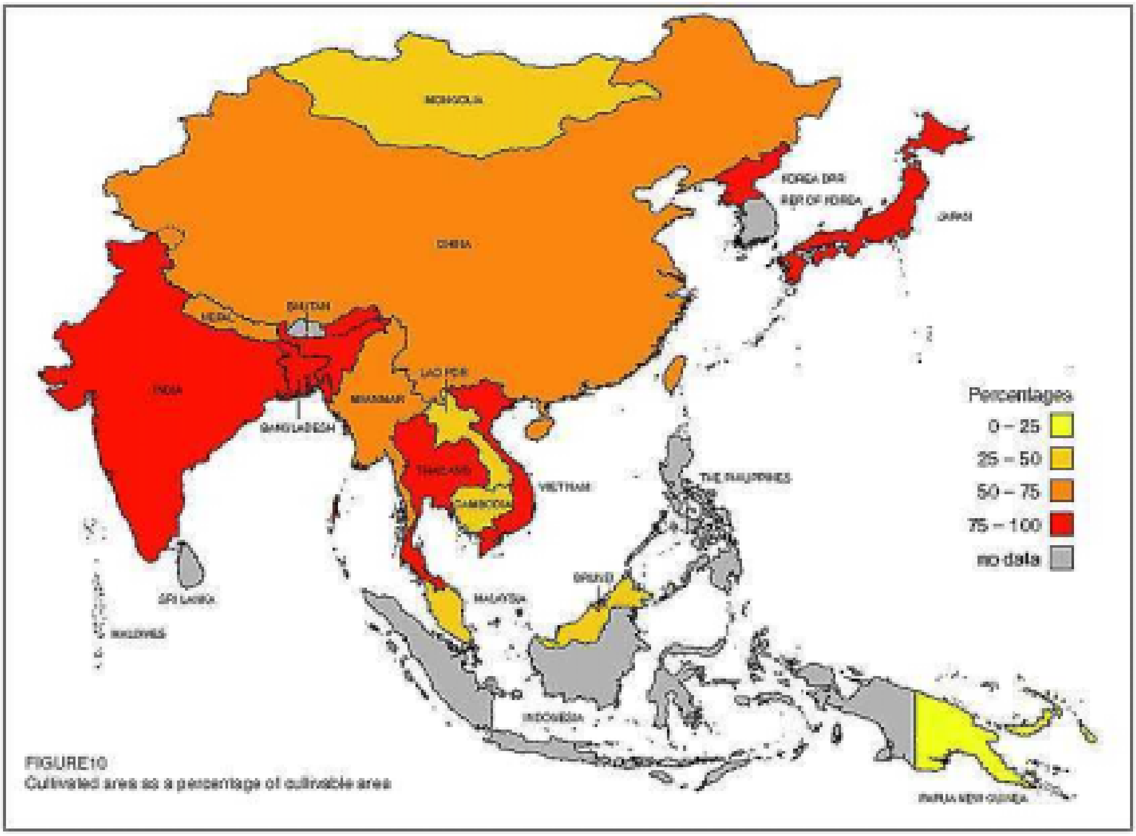


FIGURE10
Cultivated area as a percentage of cultivable area

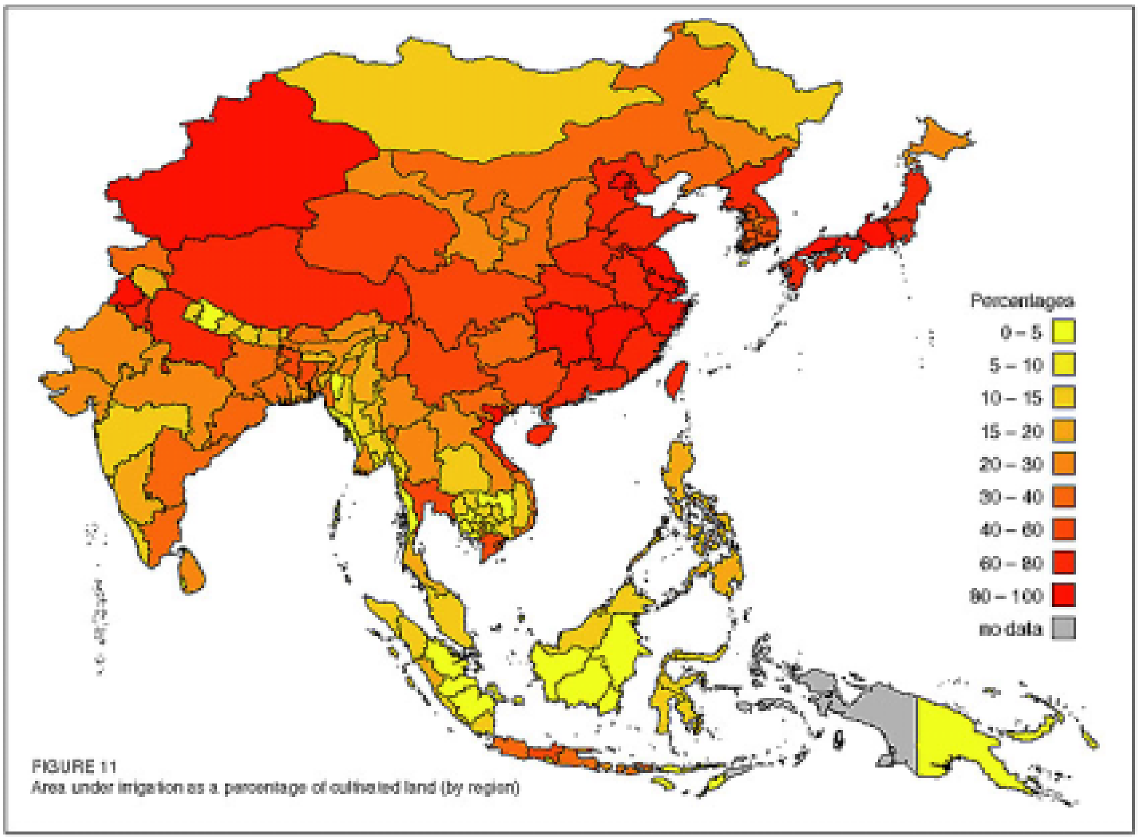


FIGURE 11
Area under irrigation as a percentage of cultivated land (by region)

Country profiles

Bangladesh

GEOGRAPHY AND POPULATION

Bangladesh is located in southern Asia, in the northeast of the Indian subcontinent, and covers a total area of 144 000 km². It has a common border in the west, north and east with India, a short border with Myanmar in the southeast, and is bounded by the Bay of Bengal in the south. Administratively, the country is divided into 6 divisions, 64 districts and 490 thanas. There are four metropolitan areas including the capital city, Dacca.

The country is flat with some uplands in the northeast and southeast. A great plain lies almost at sea level along the southern part of the country and rises gradually towards the north. The land elevation in the plain varies from 0 to 90 m above sea level. The maximum elevation is 1230 m above sea level at Keocradang in the Rangamati hill district. The geomorphology of the country consists of a large portion of floodplains (79.1 percent), some terraces (8.3 percent) and hilly areas (12.6 percent).

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	14 400 000	ha
Cultivable area	1994	8 774 000	ha
Cultivated area	1994	7 743 000	ha
- annual crops	1994	7 351 000	ha
- permanent crops	1994	392 000	ha
Population:			
Total population	1996	120 073 000	inhabitants
Population density	1996	834	inhab/km²
Rural population	1996	81	%
Economically active population engaged in agriculture	1996	61	%
Water supply coverage:			
Urban population	1990	39	%
Rural population	1990	89	%

The total cultivable area is estimated at 8 774 000 ha, which is about 61 percent of the total area. In 1994, the total cultivated area amounted to 7 743 000 ha, of which 392 000 ha under permanent crops. Of the area cultivated under annual crops, about 19 percent was single cropping, 59 percent double cropping and the remaining 22 percent triple cropping. In 1994, due to double and triple cropping, the total area of crops amounted to about 13.5 million ha, giving an average intensity of 154 percent. Subsistence farming practices characterize agriculture in Bangladesh. Cereals, occupying nearly 11 million ha or 76 percent of the total area in 1994, are the most important annual crops, with rice alone representing more than 10 million ha. Other annual crops are pulses, oilseeds, jute and sugar cane. The average holding per farm household was 0.9 ha in 1983. Nearly 24 percent of farm households own less than 0.2 ha and another 46 percent own up to 1.0 ha.

In 1996, the population of Bangladesh was estimated at 120 073 000 inhabitants (81 percent rural) with an annual growth rate of 1.88 percent. Bangladesh is one of the most densely populated countries in the world with about 834 inhabitants/km². The agriculture sector continues to play an important role in the economy of the country. It accounts for about 30 percent of GDP and 61 percent of overall employment, 57 percent of the labour force being directly engaged in farming activities.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		2320	mm/year
		334.2	km^3/year
Internal renewable water resources		105	km^3/year
Total renewable water resources	1985	1210.6	km^3/year
Dependency ratio		91.3	%
Total renewable water resources per inhabitant	1996	10 083	m^3/year
Total dam capacity	1991	20 296	10^6 m^3
Water withdrawal:			
- agricultural	1990	12 600.00	10^6 m^3/year
- domestic	1990	1 704.32	10^6 m^3/year
- industrial	1990	332.16	10^6 m^3/year
Total water withdrawal		14 636.48	10^6 m^3/year
per inhabitant	1996	122	m^3/year
as % of total renewable water resources		1.2	%
Other water withdrawal	1990	10 000	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

CLIMATE AND WATER RESOURCES

Climate

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

The mean annual temperature is about 25°C, with extremes of 4 and 43°C. Ground frosts can occur in the hills. Humidity ranges between 60 percent in the dry season and 98 percent during the monsoon.

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

River basins and water resources

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

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

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

Out of the 230 water courses in the country, 57 are transboundary rivers coming essentially from India and about 93 percent of the catchment areas of the rivers are located outside the country. On average, 1 105.612 km^3 of water cross the borders of Bangladesh annually, 85 percent of it between June and October. Around 54 percent (598.908 km^3) is contributed by the Brahmaputra, 31 percent (343.932 km^3) by the Ganges and nearly 15 percent (162.772 km^3) by the tributaries of the Meghna and other minor rivers.

Because of the great disparity between the monsoon floods and the low flow during the dry season, the manageable surface water resources are considered as equal to 80 percent of the dependable flow in March. Surface water resources are used extensively for dry season irrigation.

The internal renewable surface water resources are estimated at 105 km^3/year. This includes 84 km^3 of surface water and about 21 km^3 of groundwater resources produced within the country, although part of the groundwater comes from the infiltration of surface water with an external origin. The total renewable water resources are therefore estimated at 1 210.6 km^3

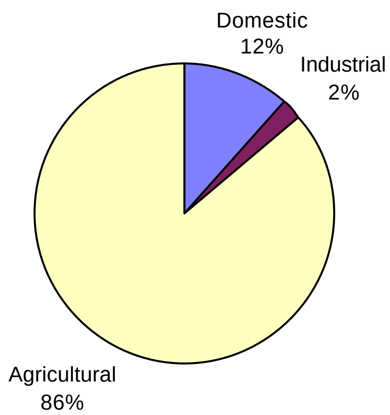
India controls the flow of the Ganges River through a dam completed in 1974 at Farraka, 18 km from the border with Bangladesh. This dam was a source of tension between the two countries, with Bangladesh asserting that the dam held back too much water during the dry season and released too much water during monsoon rains. A treaty was signed in December 1996 under which Bangladesh is ensured a fair share of the flow reaching the dam during the dry season.

Dams and lakes

In 1991, the total dam capacity was estimated at 20.30 km^3. In addition, there are three barrages across the Teesta, Tangon and Manu rivers which are used as diversion structures for irrigation purposes only.

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

FIGURE 1
Water withdrawal
Total: 14.64 km^3 in 1990



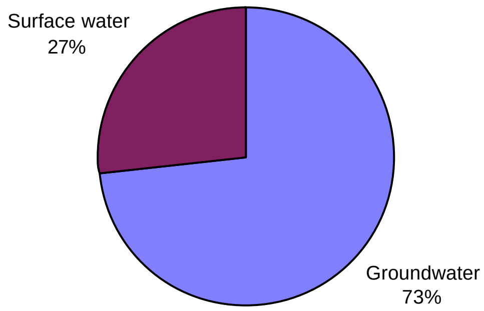
Water withdrawal

In 1990, the total water withdrawal for agricultural, domestic and industrial purposes was estimated at about 14.64 km^3, of which about 86 percent for agriculture (Figure 1). Other water uses, including navigation and fisheries, were estimated at 10 km^3. Approximately 73 percent of the total water withdrawal comes from groundwater (Figure 2).

Arsenic contamination

In recent years, great concern has been expressed about the occurrence of arsenic in groundwater based drinking water supplies at levels well above WHO standards. The phenomenon is concentrated in the upper aquifer (10-120 m) and is widespread in the southwest and the Meghna estuary area, affecting up to 75 percent of all wells in some areas.

FIGURE 2
Water supply by source



IRRIGATION AND DRAINAGE DEVELOPMENT

In Bangladesh, the expansion of minor irrigation (small-scale irrigation) is a vital component of the Government's agriculture strategy. Irrigation through major canals (large-scale irrigation) covers only 6 percent of the total irrigated area, the remainder being classed as minor irrigation consisting of low lift pumps (LLPs: power operated centrifugal pumps drawing water from rivers, creeks and ponds), shallow tube-wells (STWs: with a motorized suction mode pumping unit), deep tube-wells (DTWs: with a power operated force mode pumping unit), manually operated pumps (MOPs: extracting water from a shallow tube-well) and traditional systems. At the end of the dry season, the water level falls beyond the suction limit of the centrifugal pump. In these situations, it is possible to draw water by placing the STW in a pit. An STW in a pit is called a deep-set shallow tube-well (DSSTW) or a very deep-set shallow tube-well (VDSSTW). Where static water levels fall further (over 10.7 m), a submersible or vertical turbine (FMTW: force mode tube-well) is needed.

Between 1950 and 1987, public tube-wells, regulations governing private installations and public monopolies in the supply of pumps, motors and other equipment were a constraint on the development of irrigation. Since 1972, the emphasis has been on minor irrigation through low lift pumps and tube-wells (STWs, DTWs and FMTWs).

From 1979 to 1984, there was a liberalized expansion of minor irrigation, mainly with STWs in the private sector. In 1982, about 1.5 million ha were under food crop irrigation. The rate of minor irrigation development slowed from 39 000 STWs in 1984 to less than 5 000 in 1986. This was due to a number of reasons: private sector STW sales were limited; there was official concern over reported declines in groundwater levels where STWs operated; an embargo on all diesel engines was imposed (1985); and engines were standardized (Figure 3).

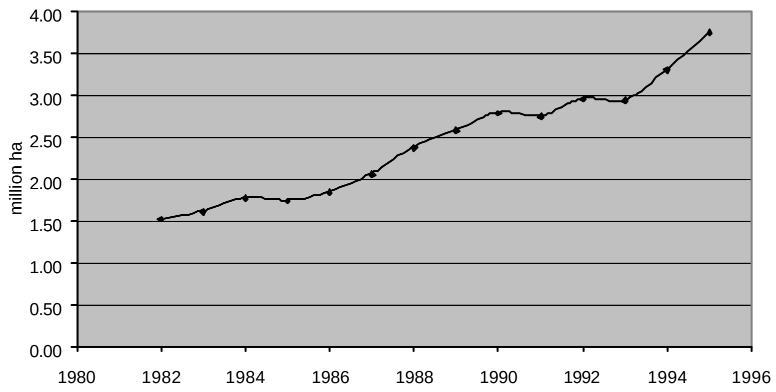
In 1991, the National Minor Irrigation Development Project (NMIDP) was established in response to the needs of farmers and the requirement for increased private sector investment in minor irrigation technologies. The project activity mainly concentrated on VDSSTW and FMTW technology, whereas irrigation by STW was mainly controlled by the private sector.

In 1994, 665 VDSSTWs and 32 FMTWs had been constructed by farmers as a result of the promotional action of the project. However, there has been a general reduction in the area irrigated by wells as a consequence of aquifer drawdown, and there has been an increase in salinity intrusion particularly along the coastal areas in the southwest of the country. The area salinized by irrigation was estimated at 100 000 ha in 1991.

TABLE 3
Irrigation and drainage

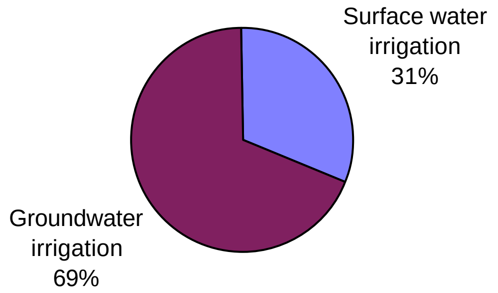
Irrigation potential	1991	7 550 000 ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1995	3 751 045 ha
- surface irrigation		- ha
- sprinkler irrigation		- ha
- micro-irrigation		- ha
% of area irrigated from groundwater	1995	69 %
% of area irrigated from surface water	1995	31 %
% of equipped area actually irrigated		- %
2. Spate irrigation		- ha
Total irrigation (1+2)	**1995**	**3 751 045 ha**
- as % of cultivated area		48 %
- power irrigated area as % of irrigated area	1995	83 %
3. Other water management area		- ha
Total water managed area (1+2+3)	**1995**	**3 751 045 ha**
- as % of cultivated area		48 %
- increase over last 10 years	1995	59 %
- power water managed area as % of water managed area	1995	83 %
Full or partial control irrigation schemes:		
Large-scale schemes (major irrigation)	1995	355 000 ha
Small-scale schemes (area under DTW, STW & LLP projects)	1995	3 396 045 ha
Total number of households in irrigation	1992	5 000 000
Irrigated crops:		
Total irrigated grain production	1994	26 244 600 t
as % of total grain production	1994	47 %
Harvested crops under irrigation	**1994**	**3 256 889 ha**
- permanent crops: total	1994	89 132 ha
- annual crops: total	1994	3 167 757 ha
. cereals	1994	2 956 180 ha
. pulses	1994	2 889 ha
. oilseeds	1994	15 175 ha
. potatoes	1994	87 110 ha
. other	1994	106 403 ha
Drainage - environment:		
Drained area	1993	1 501 400 ha
- drained area in full or partial control irrigated areas	1993	118 400 ha
- drained area in equipped wetland and i.v.b.	1993	1 383 000 ha
- other drained area		- ha
- area with subsurface drains		- ha
- area with surface drains	1993	1 501 400 ha
Drained area as % of cultivated area		19 %
Power drained area as % of total drained area		- %
Flood protected areas	1990	4 200 000 ha
Area salinized by irrigation	1991	100 000 ha
Population affected by water-borne diseases		- inhabitants

FIGURE 3
Growth in irrigation since 1982



Currently, the irrigation potential is estimated at 7 550 000 ha, of which about 3 751 045 ha had been brought under irrigation by 1995. Irrigation through major canals covers only 9.5 percent of the total area, the remainder being classified as minor irrigation (Figure 4).

FIGURE 4
Type of irrigation
Total: 3.75 million ha in 1995



Irrigation by type of water control in 1995

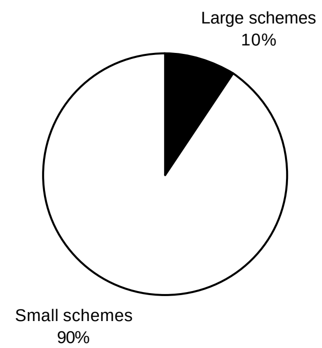
In 1995, the total area equipped for full/partial irrigation covered by large irrigation schemes (major irrigation) was estimated at 355 000 ha. Small irrigation schemes covered a total area of 3 396 045 ha (Figure 5).

Type of water control	Irrigated area in ha	% of total
Surface water		
Gravity flow	355 000	9.5
LLP (including floating pump)	577 216	15.4
Traditional (manual pumping)	226 363	6.1
Subtotal	1 158 579	31
Groundwater		
STW, DSSTW and VDSSTW	2 004 500	53.4
DTW and FMTW	537 865	14.3
Unmechanized (HTW)	50 101	1.3
Subtotal	2 592 466	69
Total	3 751 045	100

LLP: low lift pump; DTW: deep tube-well; STW: shallow tube-well; HTW: hand tube-well; FMTW: force mode tube-well; DSSTW: deep-set shallow tube-well; VDSSTW: very deep-set shallow tube-well.

In 1992, the average cost of irrigation development was estimated at US$522/ha for large schemes, and US$48.43/ha for small schemes. The average cost for O&M was estimated at US$10.52/ha/year.

FIGURE 5
Irrigation schemes
Total: 3.75 million ha in 1995



At present, irrigation is practised for boro rice (71 percent) and wheat (9 percent), which together occupy 80 percent of the irrigated land. Irrigation is mainly used in the dry season. Supplementary irrigation could appreciably increase transplanted aman rice production. The total harvested irrigated area is thus estimated at 3 256 889 ha, which does not include wet season crops on areas equipped for full or partial control irrigation. The irrigated paddy yield was moderately high at 4.4 t/ha. In 1994, total HYV boro rice production amounted to 6.2 million t. The total irrigated grain production amounted to 12.4 million t, which represented about 47 percent of the total grain production.

Because of its low-lying topography, about 22 percent of the area of the country is flooded each year. Flood control and drainage are used to reduce the depth of flooding or eliminate, through 'controlled flooding', high and untimely floods in order to provide greater security for crop production.

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

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

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

In 1993, the total area of wetlands was 3 140 000 ha, of which 1 545 000 ha were cultivated and 1 383 000 ha were drained through surface drains. In addition, the irrigated areas equipped for drainage represented about 118 400 ha. In 1992, the average cost of drainage development was US$192/ha.

Different types of floods occur in Bangladesh. Of the total cropped area, about 1.32 million ha are severely flood-prone and 5.05 million ha are moderately flood-prone. The flood protected area in 1990 was estimated at 4 200 000 ha.

INSTITUTIONAL ENVIRONMENT

Public sector involvement in irrigation in Bangladesh is shared between the Ministry of Agriculture (MOA) and the Ministry of Local Government, Rural Development and Co-operatives (LGRD), with jurisdiction over minor irrigation, and the Ministry of Water Resources (MOWR), with jurisdiction over all other forms of water management.

The MOA is mainly concerned with agricultural policy development, planning and monitoring. Project delivery is the responsibility of its various agencies, the most important being the Bangladesh Agricultural Development Corporation (BADC). In the past, the BADC had been directly involved in input supply. It is now withdrawing from all commercial operations relating to minor irrigation, leaving them to the private sector. The Department of Agriculture Extension demonstrates and extends information to farmers on crops, varieties and agronomic practices for irrigated agriculture.

The Water Resources Planning Organisation (WARPO), under the Ministry of Water Resources, has a mandate to ensure coordination of all relevant ministries through the National Water Council and to plan all aspects of water development including major and minor irrigation, navigation, fisheries and domestic water supply.

The Bangladesh Water Development Board (BWDB) is responsible for the planning, implementation and operation of small, medium and large-scale flood control, drainage and irrigation schemes.

Two other types of institutions are involved in irrigation: the nationalized banks, and several private cooperatives managed by government. The banks are supposed to make loans to farmers for the purchase of minor irrigation equipment. The Bangladesh Rural Development Board (BRDB) guides the development of two-thirds of the national cooperative system.

The country is divided into five regions for water management purposes.

TRENDS IN WATER RESOURCES MANAGEMENT

Water management and flood protection occupy a critical position in any perception of planning for the development of the country. The strategy of the Government is divided into two parts: the short-term period extending over five years, and the long-term period. A combination of short and medium-term strategies involving both the public and private sector includes:

- maximum utilization of existing facilities through command area development and effective O&M of existing projects;
- de-siltation of rivers and channels;
- adoption of an integrated basin/sub-basin approach in the design of new flood control drainage (FCD) and flood control drainage and irrigation (FCDI) projects in order to avoid interference with natural flood flows;
- adoption of conjunctive use of water resources in planning further development;
- greater emphasis on the participation of beneficiaries in the planning and design of new projects so as to encourage ownership, particularly with respect to O&M.

Irrigation targets 1995-2010 (000 ha)

Irrigation	Target for 2000	Target for 2010
Surface water		
Gravity flow	466	785
LLP including floating pump	1 250	1 500
Traditional	230	200
Groundwater		
DTW	600	600
STW	2 200	2 200
HTW	20	30
FMTW	100	300
DSSTW	90	225
VDSSTW	38	110
Total	4 959	7 050

Indicative targets have been set for irrigation, as shown in the table.

Public sector involvement will remain an important aspect of future development, particularly with respect to:

- the development of suitable on-farm water management packages to improve water use efficiencies and the dissemination of such information through the extension service (the present water distribution efficiency of STW and DTW is 60 percent);
- the organization of a comprehensive monitoring system of different groundwater zones to ensure that water abstractions remain consistent with recharge;
- characterization of the aquifer and tests for improved well design and development;
- improved design efficiency of pumping units;
- promotion of effective extension services on the selection, repair and maintenance of irrigation facilities and demonstrations of integrated irrigation and mechanization technologies in intensive and diversified farming systems.

Due to the lowering of the groundwater levels in the dry season, the share of DSSTWs, VDSSTWs and FMTWs is expected to increase. DTW technology will disappear as farmers prefer to arrange irrigation on an individual basis or though small group of farmers. DSSTWs, VDSSTWs and FMTWs will cover 45 percent of the irrigated area in Bangladesh by 2025.

In addition, based on past experience, the National Water Management Plan (NWMP) currently being prepared emphasizes environmental protection and improved data management.

Following the signing of the Ganges Water Treaty in December 1996, planning has now started on developing projects to use water from the river, initially for the relief of the environmental problems in the southwest and ultimately for the expansion of surface water irrigation based on the rejuvenation of the rivers of the southwest and on abstraction by low lift pumps.

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Bhutan

GEOGRAPHY AND POPULATION

Bhutan is a Himalayan landlocked country with a total area of 47 000 km^2. For administrative purposes, it is divided into 20 dzongkhag (districts). The country is almost entirely mountainous, with flat land limited to the broader river valleys and along the foothills bordering the Indian subcontinent. Altitudes range from 7 500 m at the summit of Kula Kangri on the northern border to about 200 m at the Indian border in the south. Bhutan has three major landform features: the southern foothills, the inner Himalayas and the higher Himalayas.

Owing to the extremely rugged mountainous terrain, only 3.6 percent of the total area, or 169 108 ha, is cultivated, of which 17 092 ha are under permanent crops. There is little room for expansion of acreage under agricultural production.

In 1996, the total population was estimated at 1.81 million by the United Nations, although the latest official estimates give a figure of 600 000 inhabitants for 1990. About 93 percent of the total population is rural. The current population growth rate is estimated at 3.1 percent, which is one of the highest in the region. With an average of 38 inhabitants/km^2, the population density is relatively modest by regional standards. However, when expressed in terms of hectares of cultivated area, the population density is one of the highest in the world. The population is unevenly distributed with the highest population densities at the lower altitudes. About 95 percent of the population lives in the southern subtropical zone or in the central mid-mountainous zone, mainly in the relatively gentle sloping areas of the river valleys.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	4 700 000	ha
Cultivable area		-	ha
Cultivated area	1995	169 108	ha
- annual crops	1995	152 016	ha
- permanent crops	1995	17 092	ha
Population:			
Total population	1996	1 812 000	inhabitants
Population density	1996	38	inhab/km^2
Rural population	1996	93	%
Economically active population engaged in agriculture	1996	94	%
Water supply coverage:			
Urban population	1990	25	%
Rural population	1990	50	%

The agriculture sector accounted for 38.6 percent of GDP in 1993. In 1996, around 94 percent of the labour force was engaged in the agriculture sector. In 1993, hydropower made up 8 percent of GDP (25 percent of export earnings).

CLIMATE AND WATER RESOURCES

Climate

Bhutan has perhaps the greatest diversity of climate of any country of its size in the world, ranging from hot and humid subtropical conditions in the south to the perpetual ice and snow of the High Himalayas.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		4 000	mm/year
		188 000	km^3/year
Internal renewable water resources		95	km^3/year
Total renewable water resources	1995	95	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	52 428	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1987	10.8	10^6 m^3/year
- domestic	1987	7.2	10^6 m^3/year
- industrial	1987	2	10^6 m^3/year
Total water withdrawal		20	10^6 m^3/year
per inhabitant	1996	11	m^3/year
as % of total renewable water resources		0.02	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

The main climatic factor is the southwest monsoon which lasts from mid-June to September, bringing with it some 60-90 percent of the annual precipitation, depending upon the region. Precipitation ranges from 2 500 mm/year (even 5 000 mm/year in localized areas) in the south to 500-1 000 mm/year in the inner valleys, and to less than 500 mm/year above 4000 m. Average precipitation is roughly estimated around 4 000 mm/year. In the dry season, rainfall is erratic and limited, and the peak demand for supplementary irrigation would be in April and May.

Nearly every valley in Bhutan has a swiftly flowing river or stream, fed either by the perennial snows, the summer monsoon or both.

River basins

Except for a small river in the extreme north of the country which flows north, all rivers flow south to India. The river basins are oriented north-south and are, from west to east, the Jadalkha, Torsa, Raidak, Sankosh, Mao Khola/Aie, Manas and eastern river basins, this last basin being composed of the Bada and Dhansiri rivers. Only the Torsa River has its primary source outside Bhutan, in India. Although it has not been measured, this inflow is negligible in comparison to the internal renewable water resources which are estimated at 95 km^3/year. Because of the mountainous character of the country, the groundwater resources in Bhutan are probably limited and are drained by the surface water network. They cannot in any case be considered as an additional resource.

Lakes and dams

The only dam in the country is the Chukha hydropower dam. Some dams could be constructed in the near future for hydropower purposes. There is no wastewater treatment in Bhutan, but two wastewater collection and treatment projects are being implemented in the cities of Thimphu and Phuntsoling.

Most rivers are deeply incised into the landscape, a fact which greatly limits the possibilities for run-of-the-river irrigation. On the other hand, Bhutan has a large potential for hydropower development, which is presently estimated at an exploitable 12 000 MW out of a theoretical capacity of 20 000 MW. The total power generation capacity in 1994 was 344 MW, of which 325 MW from the Chukha hydropower plant. Hydroelectricity represents 96 percent of the country’s electricity generating capacity and 99.9 percent of its electricity generation.

About 87 percent of the electricity generated within Bhutan is exported to India. A number of hydropower projects are now under construction or negotiation.

Water withdrawal

The total water withdrawal was estimated at 20 million m^3 in 1987 (Figure 1), which is a minimal fraction of the resources (0.02 percent).

FIGURE 1
Water withdrawal
Total: 0.02 km^3 in 1987

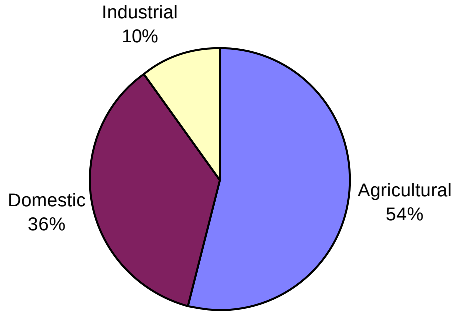
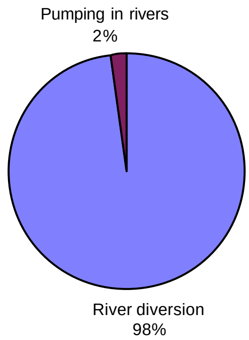


FIGURE 2
Origin of irrigation water
Total area: 38 734 ha in 1995



IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigated agriculture in Bhutan can be almost equated to paddy cultivation which takes place during the summer-autumn period. Indeed, wherever irrigation water is available on arable lands below 2 600 m, farmers have traditionally chosen to grow rice.

Irrigation systems in Bhutan are typically less than 100 ha in extent. Only two large-scale systems have been developed by the Government in recent years: the Taklai Irrigation scheme (1 350 ha) and the Geylegphug Lift Irrigation scheme (800 ha), though neither of them is in operation. However, the Taklai scheme is being rehabilitated and will be in operation soon. There is little possibility of further development of large schemes due to the geographical conditions. Two types of small-scale schemes can be found:

- valley bottom schemes, located on relatively gently sloping terraces beside the major rivers. Water is usually reliably provided by purely gravity fed channels from secondary rivers;
- hill schemes, located at higher elevations, on more steeply sloping land where tertiary streams and rivers are the sources of water.

It is estimated that there may be 1 500-1 800 irrigation schemes in the country. River diversion is the source of water for all Bhutanese schemes, except in the Geylegphug lift irrigation scheme (Figure 2). Generally, the diversion structures are not permanent, and in a large number of rehabilitated schemes part of the project consists of improving the intake structure to make it permanent.

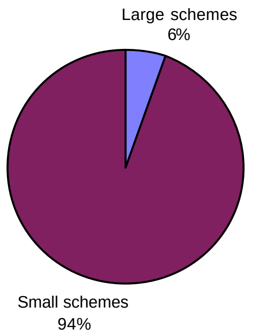
The irrigated areas are called wetland in the local classification. This means that they have been terraced for basin irrigation. These areas were estimated at 27 020 ha by an agronomic survey, but a study based on a remote sensing approach gave a figure of at least 38 734 ha in 1995 (Figure 3).

In summer, almost all wetland is under paddy cultivation. Double cropping of paddy is limited to the lowest altitudes where the winter temperatures allow its cultivation. Where paddy cannot be cultivated, wheat, buckwheat, mustard and potato are cropped on wetland areas during the winter season. The wetland areas can be cropped during the winter season, though watering of these winter crops is generally limited to one irrigation at the time of land preparation. The table lists the irrigated crops on the 27 020 ha of wetland which were known before the re-estimate.

TABLE 3
Irrigation and drainage

Irrigation potential		-	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1995	38 734	ha
- surface irrigation	1995	38 734	ha
- sprinkler irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater	1995	0	%
% of area irrigated from surface water	1995	100	%
% of equipped area actually irrigated	1995	94	%
2. Spate irrigation	1995	0	ha
Total irrigation (1+2)	**1995**	**38 734**	**ha**
- as % of cultivated area		23	%
- power irrigated area as % of irrigated area	1995	2	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1995**	**38 734**	**ha**
- as % of cultivated area		23	%
- increase over last 10 years		-	%
- power water managed area as % of water managed area	1995	2	%
Full or partial control irrigation schemes:			
Large-scale schemes (> 50 ha)	1990	2 150	ha
Medium-scale schemes		-	ha
Small-scale schemes (< 50 ha)	1990	36 584	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
. rice	1990	27 400	ha
. potatoes	1990	500	ha
Drainage - environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas	1995	100	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

FIGURE 3
Type of schemes
Total area: 38 734 ha in 1995



Crops on irrigated areas

Crop	Summer	Winter irrigated	Winter not irrigated
Paddy	27 020 ha	380 ha	-
Maize	-	-	1 600 ha
Wheat and barley	-	4 900 ha	
Buckwheat and millet	-	-	1 400 ha
Mustard	-	-	400 ha
Potato	-	500 ha	-
Others	-	-	200 ha
Total	27 020 ha	9 380 ha	

To a limited extent, farmers have started to irrigate horticultural crops, including orchards, using hose pipes and surface irrigation methods.

Irrigation schemes can be classified according to their origin:

- indigenous irrigation systems, which have evolved with little or no government assistance. No technical assistance has been provided, and the maximum involvement of government may have been the provision of a few bags of cement;
- assisted farmer-initiated irrigation systems, which have been constructed by the beneficiaries, but which have received technical and other government assistance on one or more occasions to restore or improve the system;
- government initiated irrigation systems, which have been constructed under the government assistance programme.

All three categories of schemes are managed by farmers. The level of government assistance had, until recently, little or no bearing on the development of WUGs. Government assistance for strengthening local organizations and formalizing them into WUAs started only after the adoption of the national irrigation policy in 1992.

Irrigation canals have an acute sedimentation problem. Sedimentation is generally caused by sand accumulation from subsidiary sources and runoff into irrigation canals during heavy monsoon rains. Generally, sand and silt traps are constructed and periodically flushed to alleviate this problem.

The average cost of irrigation development varies widely depending upon the region. The National Irrigation Policy states that the maximum capital investment per hectare for the main canal development should be US$630 and US$950 for renovation schemes and new schemes respectively, while it should be US$160/ha for the development of the distribution system.

As most of the schemes are terraces, no drainage network has been constructed.

INSTITUTIONAL ENVIRONMENT

There is no institution specifically responsible for water resources. Because of the high hydropower potential, the Department of Power has recently been given responsibility for hydrological and meteorological data collection.

The Irrigation Agency consists of irrigation offices at three levels:

- central level: the Irrigation Section of the Research, Extension and Irrigation Division under the Ministry of Agriculture, which is responsible for the coordination of all sector activities, including policy formulation, monitoring and evaluation;
- regional level: the Project Facilitation Offices, which provide technical, logistic, communication and accounting support for two IFAD financed projects covering three and six districts of Bhutan;
- district level: the District (Dzongkhag) Irrigation Offices, which are fully responsible for the planning and implementation of all irrigation facilities in their district.

A National Environmental Commission has received the mandate to formulate a strategy to ensure that all aspects of the utilization of natural resources and the possible pollution of the environment are taken into consideration in development policies as well as in concrete development projects.

The Land Law (1979) allows all types of agricultural land to be converted to wetland but prohibits wetland from being changed to other forms of land use. This was consistent with the Government's policy at the time, which aimed to achieve complete self-sufficiency in rice. Land is privately registered in accordance with the Land Law which sets the maximum limit a person can own at 10 ha (except for orchard and pasture where there is no limit). All non-registered land is considered forest land, owned by the Government and subject to the Forest Act.

A national irrigation policy was adopted in 1992. It focuses mainly on the management aspects of irrigation and particularly on the importance of the strengthening local organizations and formalizing them in WUAs.

TRENDS IN WATER RESOURCES MANAGEMENT

Until the 1970s, all irrigation schemes had been constructed and maintained by the beneficiaries themselves. With the start of the Government's irrigation development programme in the late 1960s and early 1970s, many schemes were built or improved with external assistance while management remained in the hands of the water users. With the new irrigation policy adopted in 1992, government assistance to the irrigation sector has been redefined, with three basic principles: meaningful farmer participation, support to WUAs, and multidisciplinary teamwork. The emphasis is on scheme renovation rather than new irrigation development, and the whole process of public intervention has been carefully and precisely elaborated in view of the three principles (11 steps from farmers' requests and preliminary investigations to monitoring through to the end of construction).

After two years of implementation, the irrigation policy has been discussed in view of the forthcoming 8th Five Year Plan (1997-2002), which states the crucial role of irrigation for rice production with a view to achieving at least 70 percent of self-sufficiency in all major grains by 2002, and for crop diversification and intensification with a view to increasing Bhutan's revenue base and to raising rural incomes.

Three immediate objectives have been set:

- to raise the productivity of existing rice-based irrigation schemes through sustainable improvements in water delivery and management;
- to increase rural incomes by diversifying the range of irrigated crops on wetland as well as dryland;
- to rationalize the irrigation assistance programme with a view to increasing the role of water users and the private sector, and to reduce recurrent government investments in irrigation schemes.

A revision, improvement and expansion of the national irrigation policy will thus be necessary, and are planned within the framework of a proposed irrigation programme strengthening project.

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Brunei

GEOGRAPHY AND POPULATION

Brunei lies in southeast Asia, on the northwest coast of the island of Borneo. It is bordered on the landward side by Sarawak, one of the two eastern states of Malaysia. The country consists of two enclaves separated from each other by the valley of the Limbang River in Sarawak. Brunei is divided into four districts with a total area of 5 770 km².

The districts of Brunei-Muara, Tutong and Belait, which form the larger western portion, are dominated by hilly lowlands, swampy plains and alluvial valleys. Mountainous terrain abounds in the eastern district of Temburong. The highest elevation of the country is 1850 m (Bukit Pagon).

The cultivable area is estimated at 13 000 ha, which is about 2.5 percent of the total land area. In 1995, the cultivated area was estimated at 7 000 ha, about 54 percent of the cultivable area. About 4 000 ha consisted of permanent crops, the remaining 3 000 ha being under annual cultivation. The main crops include rice, cassava, bananas and pineapples.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	577 000	ha
Cultivable area	1994	13 000	ha
Cultivated area	1995	7 000	ha
- annual crops	1995	3 000	ha
- permanent crops	1995	4 000	ha
Population:			
Total population	1996	300 000	inhabitants
Population density	1996	52	inhab/km²
Rural population	1996	42	%
Economically active population engaged in agriculture	1996	1.6	%
Water supply coverage:			
Urban population	1990	100	%
Rural population	1990	97	%

Brunei has a population of 300 000 inhabitants (1996 estimate), of which about 42 percent is rural. The annual population growth rate is estimated at 4.4 percent. The district of Brunei-Muara, which includes the capital, Bandar Seri Begawan, has the largest population with 201 100 inhabitants, while Temburong district in the east is sparsely populated with a total of 8 700 inhabitants. The average population density in the country is 52 inhabitants/km².

In Brunei, agriculture accounts for less than 3 percent of GDP and the country imports 80 percent of its food. In 1996, out of an economically active population of 127 000, only 2 000, or less than 2 percent, were engaged in the agriculture.

CLIMATE AND WATER RESOURCES

Climate

Brunei has a tropical climate characterized by high rainfall and temperature throughout the year. Climatic variations follow the influence of the monsoon winds. The northeast monsoon blows from December to March, while the southeast monsoon occurs around June to October.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		2654	mm/year
		15.3	km^3/year
Internal renewable water resources		8.5	km^3/year
Total renewable water resources	1998	8.5	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	28 333	m^3/year
Total dam capacity	1995	45	10^6 m^3
Water withdrawal:			
- agricultural		-	10^6 m^3/year
- domestic		-	10^6 m^3/year
- industrial		-	10^6 m^3/year
Total water withdrawal	1994	91.6	10^6 m^3/year
per inhabitant	1996	305	m^3/year
as % of total renewable water resources		1.1	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

The total rainfall was 2654 mm in 1994. There area two rainy seasons: from September to January and from May to July. The average precipitation in the nearby city of Kota Kinabalu (Sabah, Malaysia) is 2691 mm and this could be considered as a reasonable estimate for the average precipitation in Brunei.

The temperature is relatively uniform throughout the year, with an annual average of 27.9°C, ranging from 23.8 to 32.1°C. The drought months of March and April are the warmest. Due to high temperature and rainfall, humidity is high throughout the year with an average of 82 percent.

Water resources

There are four main river basins in Brunei: Temburong, Belait, Tutong and Brunei. The Temburong, the smallest of the rivers, drains a catchment area of about 430 km^2.

The Belait is the largest basin, with an area of 2700 km^2. The lower catchment comprises an extensive area of peat swamp forest. The river narrows at the town of Kuala Belait and a sandbar restricts the discharge of water to the South China Sea. Some areas in the upper catchment have been cleared for agriculture.

The Tutong basin, which is about 1 300 km^2, has a complex estuary system formed between two sand spits. Subject to fairly high tidal influence, its lower catchment is mainly floodplain. The upper catchment is jungle with patches of agriculture.

The Brunei River flows into Brunei Bay. The upper reaches of the river are a major freshwater source particularly for the western part of the country.

By analogy with the rest of the island of Borneo, the runoff coefficient is estimated at 1.5 m/year corresponding to a surface flow of 8.5 km^3. Limited reserves of groundwater have been identified in the Sungai Liang and Seria areas of the Belait district and in the Berakas area of the Brunei-Muara district. The estimated safe yield is 17.3 million m^3/year. Also by analogy with the rest of the island of Borneo, the total groundwater resources are estimated at 0.1 km^3/year, all being drained by the rivers.

Lakes and dams

Brunei has two dams with a total storage capacity of 45 013 000 m³. The Tasek reservoir used for water supply has a total capacity of 13 000 m³ and a catchment area of 2.8 km². The Benutan dam, an impounded reservoir used to regulate the Sungai Tutong River, has a total storage capacity of 45 000 000 m³ and a catchment area of 28.6 km².

There is at present no hydropower dam though one suitable site has been located within the National Forest Reserve of Temburong.

Water withdrawal

In 1994, the total water withdrawal was estimated at 91.59 million m³. Urban water supply is entirely from surface water. The major use of water in industrial processes is for the liquefied natural gas industry which abstracts and treats its own water from the Sungai Belait River. Other industrial uses are on a smaller scale for timber/sawmills, dairy farms, soft-drink manufacture and workshops which account for an estimated 25 percent of overall water demand.

Initially, groundwater abstraction was undertaken in the 1950s for use by the oil and gas industries. This has been replaced by surface water sources. Groundwater abstraction, which accounts for 0.5 percent of the total water supply, is currently limited to the local bottled water industry.

IRRIGATION AND DRAINAGE DEVELOPMENT

All irrigation facilities were equipped in 1980. There are only minor irrigation schemes (up to 0.9 ha). Irrigated agriculture represents 1000 ha, and all irrigation is surface irrigation. The existing infrastructure and facilities are being upgraded in rural areas, but the irrigated area has remained unchanged since 1980.

The major irrigated crops are rice, vegetables and fruits. The figures for rice show that the country is able to meet only 3.6 percent of the total demand of 27 500 t/year. Lack of labour is the main constraint on agricultural development in the country.

TRENDS IN WATER RESOURCES MANAGEMENT

The water demand for 2000 will be 105 million m³, and will basically depend on the growth of the population and expected increase in per caput consumption as a result of increased urbanization.

Efforts are being made to diversify the economy away from a heavy dependence on oil and gas towards a more independent agriculture sector. The first of the Government’s four major objectives in agriculture is to enhance domestic production of paddy, vegetables, poultry and livestock. The Government is trying to stimulate greater interest in agriculture through the establishment of model farms, and by providing training, advice and support.

TABLE 3
Irrigation and drainage

Irrigation potential		-	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1995	1 000	ha
- surface irrigation	1995	1 000	ha
- sprinkler irrigation	1995	0	ha
- micro-irrigation	1995	0	ha
% of area irrigated from groundwater	1995	0	%
% of area irrigated from surface water	1995	100	%
% of equipped area actually irrigated	1995	100	%
2. Spate irrigation	1995	0	ha
Total irrigation (1+2)	**1995**	**1 000**	**ha**
- as % of cultivated area		14.3	%
- power irrigated area as % of irrigated area		-	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1995**	**1 000**	**ha**
- as % of cultivated area		14.3	%
- increase over last 10 years		-	%
- power water managed area as % of water managed area		-	%
Full or partial control irrigation schemes:			
Small-scale schemes (0.9 ha)	1995	1 000	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production	1997	1 000	t
as % of total grain production	1997	100	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
. rice	1997	375	ha
. wheat		-	ha
. barley		-	ha
. vegetables		-	ha
. other		-	ha
Drainage - environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

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Cambodia

GEOGRAPHY AND POPULATION

Cambodia is situated in southeast Asia on the coast of the Gulf of Thailand and has a total area of 181 040 km^2. It is bordered by Thailand in the west, Lao PDR in the north and Viet Nam in the east. These countries share the lower Mekong basin with Cambodia. Water surfaces, including Lake Tonle Sap, occupy approximately 2.2 percent of the total area of the country. The country is divided into 21 provinces for administrative purposes.

Physiographically, the country comprises an undulating plateau in its eastern part, a continuous flat plain (the Lake Tonle Sap lowland) interrupted only by isolated hills (Phnoms) and the Mekong River in the central part of the country, and by the Cardamone mountains in the southwest of the country.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	18 104 000	ha
Cultivable area	1994	4 626 000	ha
Cultivated area	1993	2 112 000	ha
- annual crops	1993	1 966 000	ha
- permanent crops	1993	146 000	ha
Population:			
Total population	1996	10 273 000	inhabitants
Population density	1996	57	inhab/km^2
Rural population	1996	79	%
Economically active population engaged in agriculture	1996	73	%
Water supply coverage:			
Urban population	1992	40	%
Rural population	1992	15	%

The cultivable area is estimated at 4.626 million ha, or 25 percent of the total area. The total cultivated area has been estimated by a recent remote sensing survey at 3914 400 ha, or 21.6 percent of the total area, though this may be an overestimate. Indeed, there is a mosaic of about 1 million ha of crops and secondary vegetal formation or trees, where the area actually cropped and harvested does not exceed 150 000 ha. Moreover, many paddy fields with palm trees are considered as cultivated although they are not actually farmed every year. More realistic estimates give a total cultivated area of about 2.1 million ha for 1993, of which 1 844 000 ha of cultivated rice (1 685 000 ha harvested), 122 000 ha of other annual crops, and 146 000 ha of permanent crops (mainly palm trees, coconut and rubber).

The total population was estimated at 10.3 million in 1996 (79 percent rural). The population density is 57 inhabitants/km^2, varying from 4 inhabitants/km^2 in Mondul Kiri in the northeast to 236 inhabitants/km^2 in Kandal in the southeast. The population growth rate was 2.5 percent in 1994. About 73 percent of the active population is currently engaged in agriculture, and agriculture accounted for 45 percent of GDP in 1994.

CLIMATE AND WATER RESOURCES

Climate

Cambodia has a wet monsoon climate. The wet season starts in May and ends in October. The rainfall pattern is bi-modal with peaks in June and September/October.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		1 463	mm/year
		264.8	km^3/year
Internal renewable water resources		120.57	km^3/year
Total renewable water resources	1995	476.11	km^3/year
Dependency ratio		74.7	%
Total renewable water resources per inhabitant	1996	46 346	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1987	489	10^6 m^3/year
- domestic	1987	26	10^6 m^3/year
- industrial	1987	5	10^6 m^3/year
Total water withdrawal		520	10^6 m^3/year
per inhabitant	1996	51	m^3/year
as % of total renewable water resources		0.1	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater	1994	0.2	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

In August, a short period of drought may damage wet season rice which is not irrigated. In Phnom Penh, the monthly rainfall ranges from 5 mm in January to 255 mm in October. The average annual rainfall is estimated at 1463 mm but varies from about 1000 mm in Svay Check in the western province of Banteay Meanchey to nearly 4700 mm in Bokor in the southern province of Kampot. The mean annual evaporation varies from 1 000 to 2 300 mm/year. April is the warmest month of the year with a maximum temperature of 36°C, while January is the coldest with 21°C.

River basin: the Tonle Sap/Mekong system

Cambodia has a unique hydrological system. The Mekong River and Lake Tonle Sap are connected by the Tonle Sap River which twice a year reverses its direction of flow. From July to the end of October, when the level of the Mekong is high, water flows into the Tonle Sap River, which fills Lake Tonle Sap, thereby increasing the size of the lake from 2600 km^2 to about 10 500 km^2 at its maximum. The storage capacity of Lake Tonle Sap is estimated at 72 km^3. In early November, when the level of the Mekong decreases, the Tonle Sap River reverses its flow, and water flows from Lake Tonle Sap to the Mekong River and thence to the Mekong Delta.

About 86 percent of Cambodia's territory (156 000 km^2) is included in the Mekong River basin, the remaining 14 percent draining directly towards the Gulf of Thailand. Cambodia was a member of the Mekong River Committee between 1957 and 1975. On 5 April 1995, Cambodia, Lao PDR, Thailand and Viet Nam signed an agreement for the development of the Mekong River. Under the agreement, the Mekong River Committee became the Mekong River Commission.

The average annual discharge of the Mekong River entering Cambodia is estimated to be close to the discharge at Paksé (324.45 km^3/year) in Lao PDR, some 120 km upstream from the border with Cambodia. Other inflows to the Mekong-Tonle Sap system from outside the country amount to 29.9 km^3 from Viet Nam and 1.2 km^3 from Thailand. On average, 471.4 km^3/year flow out of the country in the Mekong channels and tributaries to Viet Nam.

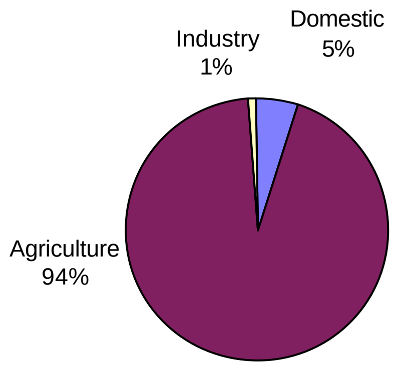
The internal renewable surface water resources (IRSWR) have been computed as the difference between outflow and inflow, i.e. 115.9 km^3. This figure does not include the unknown discharge of small rivers to the Gulf of Thailand and is thus probably an underestimate. Groundwater resources are estimated at 17.6 km^3, most of which (an estimated 13 km^3/year) is drained by the rivers and cannot be considered as additional water resources. The total renewable water resources of Cambodia are therefore estimated at 476.110 km^3/year.

The quality of groundwater is generally satisfactory, although high iron concentrations and increased salinity levels have been encountered in some provinces (Svay Rieng, Prey Veng and Takeo).

Lakes and dams

The capacity of the existing dams is very low and has not been estimated. Only one small dam (Ochum, in the northeastern province of Ratanakiri) is used as a hydropower station with an installed capacity of 1 MW. The Kirirom power plant, which was installed in 1968 in Kompong Speu province with a capacity of 10 MW, has not been in operation since 1970 due to war damage. A number of dams with high storage capacity are planned for the near future.

FIGURE 1
Water withdrawal
Total: 520 million m^3 in 1987



Water withdrawal

Water withdrawal was estimated at 520 million m^3 in 1987 (Figure 1), of which 94 percent for agricultural purposes.

The total population with access to water supply was estimated at 19 percent in 1992. At that time, it was estimated that only 7 000 wells had been constructed (by international organizations) out of the 30 000 needed.

A 1995 survey assessed the quality of water supply, wastewater and sanitation in the main towns of Cambodia. Most of the systems combined sewage and drainage water, and have not been maintained over the past two decades. As a result, they are now in a poor condition and not functioning properly. Drainage water often mixes with drinking water with obvious health implications; floods are frequent during the rainy season as the sewers clog rapidly. In Battambang, in the west of the country, about 13 000 people are served by a water sewage system. The average treated sewage flows are estimated at 157 000 m^3/year.

IRRIGATION AND DRAINAGE DEVELOPMENT

Cambodia's history of hydraulic control goes back to before the Angkor period (tenth century). The famous Angkor Wat irrigation system was based on four reservoirs, built between the tenth and thirteenth centuries, and stored some 100-150 million m^3 of water to irrigate approximately 14 000 ha.

Modern irrigation systems were first developed in the period 1950-53. Many of the structures built during that period functioned until 1975. Most of these structures, such as the ‘colmatage’ canals, have become non-functional as a result of the network of irrigation/drainage systems built during the period 1975-79. Since then, most attempts to rehabilitate these newer schemes have failed (Figure 2).

TABLE 3
Irrigation and drainage

Irrigation potential	1993	606 364	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1993	269 461	ha
- surface irrigation	1993	269 461	ha
- sprinkler irrigation	1993	0	ha
- micro-irrigation	1993	0	ha
% of area irrigated from groundwater	1993	0	%
% of area irrigated from surface water	1993	100	%
% of equipped area actually irrigated	1993	89.7	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1993**	**269 461**	**ha**
- as % of cultivated area		13	%
- power irrigated area as % of irrigated area		-	%
3. Other water management area	1993	121 000	ha
Total water managed area (1+2+3)	**1993**	**390 461**	**ha**
- as % of cultivated area		18	%
- increase over last 10 years		-	%
- power water managed area as % of water managed area		-	%
Full or partial control irrigation schemes:			
Large-scale schemes (> 500 ha)	1993	181 466	ha
Medium-scale schemes (100 to 500 ha)	1993	77 824	ha
Small-scale schemes (<100 ha)	1993	17 093	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
. rice	1993	313 000	ha
. other		-	ha
Drainage - environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases	1994	507 000	inhabitants

FIGURE 2
Evolution of cropped area in f/p control irrigation schemes during the wet season

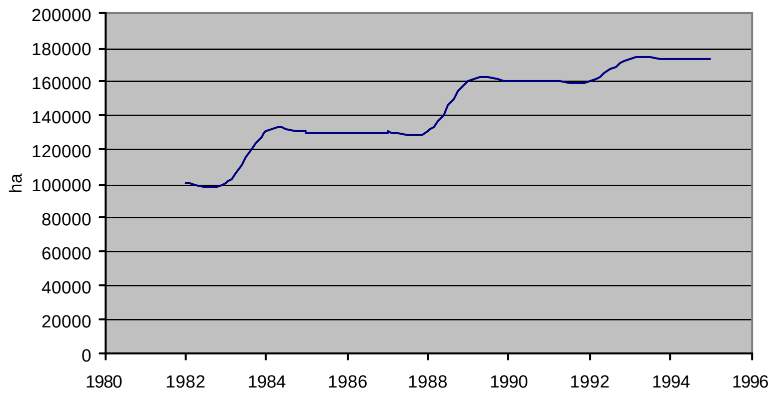
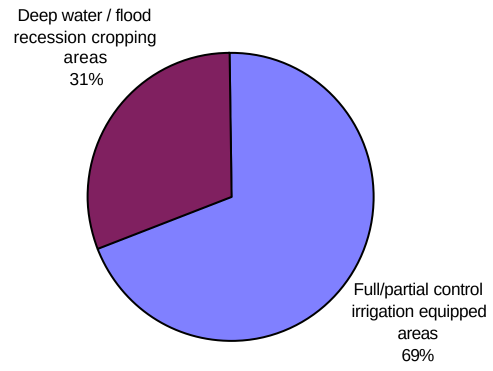


FIGURE 3
Water managed areas
Total: 390 461 in 1993

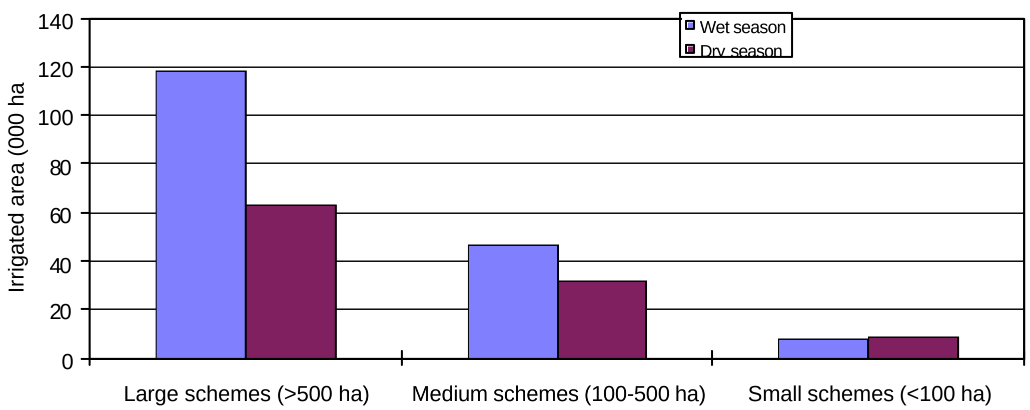


Irrigation potential has never been estimated in terms of physical area which could be irrigated considering water and land resources. However, an assessment has been made of the total potential cropped area if existing and past irrigation systems were rehabilitated and improved. The total area would be 419 344 ha in the wet season and 187 020 ha in the dry season.

Water managed areas were estimated to be 390 461 ha in 1993, of which 69 percent were equipped with full/partial control irrigation, and 31 percent were flood recession cropping areas (Figure 3).

Some 841 full/partial control irrigation schemes have been recorded in a recent inventory, covering a total area of 269 461 ha. Only 176 of these schemes were reported to be fully operational, while 115 schemes covering 27 638 ha were equipped but not operating.

FIGURE 4
Areas irrigated (full or partial control)
Total: 172 727 ha in wet season, 103 656 ha in dry season in 1993



The operating full/partial control irrigation schemes can be divided into four main categories (Figure 4):

- River, lake or stream diversion by gravity. These systems are used for wet season supplementary irrigation as there are no storage facilities. Offtakes are generally uncontrolled, although in some cases, water level control is provided by diversion weirs.
- Water pumping from rivers. These systems can provide water for both the wet and dry seasons. Pump stations have been provided by the Government.

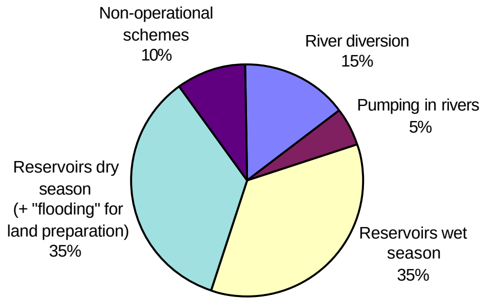
- Reservoirs storing water from runoff, streams or rivers for wet season supplementary irrigation. Water is abstracted from the reservoir by gravity or mobile pumps provided by farmers.
- Reservoirs storing flood waters from the Tonle Sap/Bassac/Mekong system and released by gravity or mobile pumps for a dry season recession crop only. These areas also benefit from natural flooding for land preparation. The crop is transplanted as the floodwater recedes and irrigated during the growing season with water stored in nearby reservoirs. This system takes advantage of the large range of water levels in the Tonle Sap/Bassac/Mekong system to fill the reservoirs during the flood to a level sufficient to give gravity command of the paddy fields. Although they are equipped for full/partial control irrigation, these areas are often termed flood recession areas as they use natural flooding at the beginning of the season for land preparation and the filling of the reservoirs.

The cropped area in these full/partial control irrigation schemes is estimated at 172 727 ha during the wet season and 103 656 ha in the dry season. Double cropping is practised only on small areas (estimated at 6 922 ha).

Another classification, used by the Department of Hydrology, defines three irrigation systems (Figure 5):

- Large-scale projects, where water is supplied from a multipurpose dam (generally irrigation and hydropower). The annual irrigated area for these schemes is estimated at 118 225 ha in the wet season and 63 241 ha in the dry season.
- Medium-scale projects, with an irrigated area of 100 ha or more, where water is supplied by single-purpose dams or 'colmatage' canals. The 'colmatage' system uses dikes and sluices to provide controlled annual inundation. Intake and drainage are controlled, allowing a fertile layer of silt to settle on the fields. The annual irrigated area for these schemes is estimated at 46 599 ha in the wet season and 31 225 ha in the dry season.
- Small-scale projects, with an area of less than 100 ha. The annual irrigated area for these schemes is estimated at 7 903 ha in the wet season and 9 190 ha in the dry season.

FIGURE 5
Areas equipped for full/partial control irrigation: origin of water
Total: 276 383 ha in 1993



There are about 121 000 ha of floating rice, mainly in the provinces bordering Lake Tonle Sap: Battambang, Banteay Meanchey, Pursat, Siem Reap, Kompong Thom and Kampong Cham. This general category consists of two subcategories:

- floating rice, with a straw length up to 4 m;
- deep water rice, with a straw length of 1-2 m.

Both subcategories are adapted to continuous, unregulated flooding. The rice varieties have a rapid elongation with increase in water depth, and submergence tolerance to flash floods. In this country profile, these 121 000 ha are considered as deep-water/flood recession cropping areas.

A recent survey has estimated that the development of one hectare irrigated by pumping would require an investment coast of US$2 800, and US$85/year for O&M, while the respective figures for a hectare irrigated from a reservoir would be US$3 600-4 300 and US$40-65/year.

The major crop in Cambodia is rice, with a total harvested area of 1.84 million ha in 1993. This figure comprises irrigated rice, floating rice, but also upland rice (about 24 000 ha in 1993) and rainfed rice which is cultivated in the lowland during the wet season and which covers most of the rice-cropped area in Cambodia. The average rice yield is estimated at 1.39 t/ha under rainfed conditions and 2.07 t/ha under irrigated conditions.

A recent FAO survey indicates that a number of areas appear suitable for groundwater exploitation, though there are still uncertainties about water quantity and quality. The lack of data, particularly on water quality, is a cause for concern as there are reports on iron toxicity from Svay Rieng province, close to the border with Viet Nam, as well as increased tidal saline incursion from the Mekong River in May-June.

Two of the most common water related diseases linked to the development of irrigation are malaria and schistosomiasis. Malaria is already a serious problem throughout the country as a consequence of the natural ecosystem. Estimates of about 500 000 cases of malaria per year are common. Each year, 5 000-10 000 persons die from malaria. Schistosomiasis was reported in the Kratie area in 1993. Dengue haemorrhagic fever has recently become an important cause of child morbidity in Cambodia. In 1990, about 7 000 cases resulting in 340 deaths were recorded.

INSTITUTIONAL ENVIRONMENT

The public institutions involved in the water sector are:

- The General Directorate of Irrigation, Meteorology and Hydrology of the Ministry of Agriculture, Forestry and Fisheries, with:

  - the Department of Water Management, which is responsible for the O&M of all irrigation infrastructure in Cambodia, including the operation and repair of pumps. The office also undertakes rural water supply, including well drilling;

  - the Department of Engineering, which is responsible for the design and construction of hydraulic structures;

  - the Department of Hydrology, which carries out the installation and maintenance of a network of hydrological stations, and collects and processes data;

  - the Department of Meteorology, which is in charge of meteorological data collection and forecasting;

  - the Department of Research, Training and Extension.

- The Mekong Secretariat: the River Mekong, whose lower basin covers large areas of Cambodia, Lao PDR, Thailand and Viet Nam, is a major regional resource. In 1957, the Mekong River Committee was established under the auspices of the United Nations to coordinate the efforts of these countries in developing the resource. In principle, all proposals to utilize the waters of the Lower Mekong Basin require the unanimous approval of the country representatives on the now renamed Mekong River Commission.

An informal 'water resources law task force' has been established through the Irrigation Sector Meeting of the interested parties. As part of this process, an adviser to the Ministry of

Agriculture, Forestry and Fisheries (MAFF) has compiled a draft law on the water resources of Cambodia, which was due to be submitted in 1996.

Domestic water supply is the responsibility of several institutions: the Department of Hydrology, the Ministry of Public Works and the Ministry of Rural Development.

TRENDS IN WATER RESOURCES MANAGEMENT

Under the National Socio-Economic Development Plan, 1996-2000, water supply and wastewater treatment have been set as priorities by the Government.

While precise comprehensive data on access to water supply are not available, it is estimated that some 1.75 million people (19 percent of the population) have access to clean drinking water. This is about 40 percent of the urban population and 15 percent of the rural population.

Similarly, precise comprehensive data on the provision of environmental sanitation are not available. Access to sanitation is limited to an estimated 1.24 million people (13 percent of the population); about 53 percent of the urban population (mostly in Phnom Penh) and 6 percent of the rural population.

It is estimated that providing a safe water supply to 65 percent of the rural population by 2000 would require a capital investment of nearly US$31 million, or an average of about US$6 million/year.

The target is to provide an additional 1.5 million rural people with access to environmental sanitation facilities in the period 1996-2000. This is based on a realistic assessment of the Government's absorptive capacity, its ability to implement programmes and the prospects for external funding to the sector. It would increase the coverage of rural sanitation from 6 percent to about 22 percent by 2000.

In the recent past, sedimentation of Lake Tonle Sap has given cause for concern. This concern is mainly due to the Mekong silt load, and to deforestation in the upper reaches of the Tonle Sap watershed. In the absence of reliable data on hydrology and sediments in this area, many scenarios have been developed. The most pessimistic ones forecast a drying up of the lake in a ten-year period, while other studies estimate that the lake would take 600 years to dry up. All these estimates reveal a need for reliable hydrological data. What is agreed by all concerned is the negative effect of sedimentation on the environment, particularly on fish.

As new irrigation scheme development has a low economic internal rate of return (1-6 percent), the rehabilitation of existing schemes has been set as a priority by the Government. Priority is given to small-scale schemes, as large-scale schemes have serious O&M problems. The estimated potential of irrigated agriculture production is high for small-scale irrigation schemes with active community participation and in combination with other agricultural technology packages, especially balanced fertilizer use. Indeed, soil fertility is a major problem in Cambodia and production increase with irrigation alone would remain relatively limited.

In the Mekong Delta, the development of groundwater irrigation might be a valid alternative to the present water managed systems (in certain areas with sufficient and easily accessible groundwater reserves) whose efficiency depends heavily on the level fluctuations of the Mekong River. Recently, sprinkler and micro-irrigation have been introduced on very small areas in Cambodia.

Another priority is the development of well-designed flood control devices in conjunction with irrigation facilities to enable drainage in times of flooding, and irrigation in the dry season. Another priority is the construction of several dams, mainly for hydropower purposes. Investigations have been carried out by the Mekong River Commission. Two of these dams (Sambor and Stung Treng), with a total estimated cost of US$11 907 million would have a power capacity of 4 208 MW. The environmental costs would include 31 700 ha of agricultural land and 75 300 ha of forests flooded, and more than 14 000 people having to be resettled.

Another project has been prepared for regulating the level of Lake Tonle Sap and for hydroelectricity generation (140 MW of capacity) at an estimated cost of US$435 million.

The Asian Development Bank is investigating the feasibility of building dams on the Stung Chinit (a tributary of the Tonle Sap River), and on the Se Kong and Se San rivers, both in the province of Ratanakiri in northeast Cambodia.

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China

GEOGRAPHY AND POPULATION

China is located in the southeast of the Eurasian landmass, bounded by the Pacific Ocean in the southeast. The average altitude in China ranges from over 4 000 m in the west to less than 100 m in the east. The total area of China is about 9 598 030 km² and consists of mountains (33 percent), plateaux (26 percent), basins (19 percent), plains (12 percent) and hills (10 percent). For administrative purposes, China is divided into 23 provinces, 3 municipalities and 5 autonomous regions, in addition to the special administrative region of Hong Kong.

There are about 129.4 million ha of cultivable land, which is 13.5 percent of the total area. In 1995, the cultivated area was 95 851 000 ha, of which 3 767 000 ha were under permanent crops. In addition, there were about 400 million ha of prairie and 262.89 million ha of forested land. In 1996, the total sown area was 152 381 000 ha, of which grain crops (mainly rice, wheat and corn) represented 74 percent.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	959 803 000	ha
Cultivable area	1995	129 372 000	ha
Cultivated area	1995	95 851 000	ha
- annual crops	1995	92 084 000	ha
- permanent crops	1995	3 767 000	ha
Population:			
Total population	1996	1 238 274 000	inhabitants
Population density	1996	129	inhab/km²
Rural population	1996	68.5	%
Economically active population engaged in agriculture	1996	71	%
Water supply coverage:			
Urban population	1995	93	%
Rural population	1996	68	%

The population was 1 238 274 000 inhabitants in 1996, of which 68.5 percent lived in rural villages. The annual population growth declined from 1.66 percent in 1987 to 1.04 percent in 1996. The average population density is 129 inhabitants/km², varying from less than 10 inhabitants/km² in the west to 670 inhabitants/km² in the east, and 2 042 inhabitants/km² in Shanghai. The share of agriculture in GNP declined from 28.4 percent in 1978 to 21.2 percent in 1993. In 1996, the agriculture sector employed 71 percent of the economically active population, and it contributed about 20 percent of GDP in 1997.

CLIMATE AND WATER RESOURCES

Climate

Vast areas of east China and most of south China are affected by the east Asia monsoon climate. Mountains and plateaux prevent the monsoon from penetrating deeply into the northwest of the continent. The result is low precipitation. In winter, the mainland is generally under the influence of dry cold air masses from Siberia.

The mean annual precipitation is 648 mm. In the coastal areas of the southeast and in some regions of the southwest, the mean annual precipitation exceeds 2 000 mm. It exceeds 1 000 mm to the south of the middle and lower reaches of the Yangtze River; is between 400 and 800 mm in the Huaihe River basin, in the northern plains, northeast and central China, is

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		648	mm/year
		6 189	km^3/year
Internal renewable water resources		2 812.4	km^3/year
Total renewable water resources	1995	2829.6	km^3/year
Dependency ratio		0.6	%
Total renewable water resources per inhabitant	1996	2 285	m^3/year
Total dam capacity	1995	480 000	10^6 m^3
Water withdrawal:			
- agricultural	1993	407 744	10^6 m^3/year
- domestic	1993	25 165	10^6 m^3/year
- industrial	1993	92 550	10^6 m^3/year
Total water withdrawal		525 459	10^6 m^3/year
per inhabitant	1996	424	m^3/year
as % of total renewable water resources		18.6	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional water sources:			
Wastewater:			
- produced wastewater	1995	37 285.08	10^6 m^3/year
- treated wastewater	1995	23 329.88	10^6 m^3/year
- reused treated wastewater	1995	13 389.57	10^6 m^3/year

less than 400 mm in parts of northeast China and most of the hinterland in the northwest; and is less than 25 mm in the Tarim and the Qaidam basins. Precipitations are more significant in the summer months (from April/May to July/August in the south, and from June to September in the north).

Water resources

Rivers

The average annual river runoff generated over the country is 2 711.5 km^3, corresponding to a depth of 284 mm. Precipitation makes up 98 percent of total river runoff, the remaining 2 percent coming from melting glaciers.

In total, there are more than 50 000 rivers with a basin area of over 100 km², 1 500 of them with a basin exceeding 1 000 km². Rivers can be classified in two categories: those discharging into seas (outflowing rivers), and the inland rivers which run to depressions in the interior. The table below lists the length, drainage area and average discharge of the major rivers in China.

Main rivers in China

River	Length (km)	Drainage area (km²)	Average annual runoff (km³)
Changjiang (Yangtze)	6 300	1 808 500	951.3
Huang He (Yellow)	5 464	752 443	66.1
Heilongjiang (Amur) *	3 420	896 756 **	117.0
Songhua (Sungari)	2 308	557 180	76.2
Xijiang (Pearl) *	2 210	442 100	333.8
Yarlung Zangbo	2 057	240 480	165.0
Tarim	2 046	194 210	35.0
Lancangjiang *	1 826	167 486	74.0
Nujiang *	1 659	137 818	69.0
Liao He	1 390	228 960	14.8
Hai He	1 090	263 631	28.8 ***
Huai He	1 000	269 283	62.2
Ertix (Irtysh)	633	57 290	10.0
Luan He	877	44 100	6.0
Minjiang	541	60 992	58.6
Total		6 121 229	2 067.8

* Length and drainage area within the country; ** including the Songhua River basin; *** including the Luan He.

The total drainage area of the outflowing rivers covers 65.2 percent of the country's territory, of which 58.2 percent drain into the Pacific Ocean, 6.4 percent to the Indian Ocean and 0.5 percent to the Arctic Ocean; while that of that inland rivers covers 34.8 percent of the country's total area. The mean annual volume of water flowing into the sea is 1 724.3 km³.

Volume of water flowing out of the country

The volume of water flowing out of the country is estimated at 719 km^3/year. This represents 26 percent of the total natural river runoff of the country (including the inflow from other countries).

The lower reaches of some rivers enter neighbouring countries: to the north, the Heilongjiang River (Amur River) enters the Russian Federation before it empties into the Sea of Okhotsk; the Ertix River joins the Ob River in Kazakhstan; the Ili River discharges into Lake Balkhash in Kazakhstan; the Suifen River flows through the Russian Federation to the sea at Vladivostok; to the southwest, the Yuanjiang, Lixianjiang, Panlongjiang rivers are the upper reaches of the Red River in Viet Nam; the Lancangjiang River becomes the Mekong River after it enters Lao PDR; the Nujiang River becomes the Salween River after it enters Myanmar; the Yalung Zangbo River is called the Brahmaputra River after it enters India; the Langqen Zangbo and Sengge Zangbo rivers of west Tibet and the Qipuqiapu River of Xinjiang are the upper reaches of the Indus River flowing through India and Pakistan into the Indian Ocean. The mean annual runoff of these rivers is given in the table below.

Rivers flowing out of the country

Region	River	Destination	Mean annual runoff volume flowing out of the country (km³)	
Heilongjiang	Suifen and Amur	Russian Federation	119.04	
Southwest	Yarlung Zangbo	India and Bhutan	165.400	
	Rivers in south and west Tibet	India	181.620	
		Nepal	12.000	
	Nujiang	Myanmar	68.740	
	Lancang	Lao PDR and Myanmar	73.630	
	Yuanjiang	Viet Nam	44.100	*
	Rivers in west Yunan	Myanmar	31.290	
Inland rivers	Emin	Kazakhstan	0.310	
	Ili	Kazakhstan	11.700	
	Rivers on west slope of Barluke mountain	Kyrgyz Republic	0.558	
	Aksu	Kazakhstan	0.927	
	Ertix (attached)	Kazakhstan	9.530	
Total			718.845	

* According to Chinese data the outflow to Viet Nam would be 47.89 km³/year.

Border rivers

The main course of the Heilongjiang River (Amur) and its upstream tributaries (the Ergun and Wusuli rivers) flow along the border between China and the Russian Federation. After it receives the flow of the Songhua River (10.9 km³/year), the Amur River flows into the Russian Federation. The total flow of the Amur and Songhua rivers (117 km³/year) is considered as flowing out of China. The Tumen and Yalu rivers flow along the boundary between China and DPR Korea. However, the corresponding flow is not considered as outflowing as these rivers do not leave Chinese territory. The table below lists the catchment areas and mean discharges of the border rivers.

Border rivers

Region	River	Catchment area on China side (km²)	Bordering country	River discharge along borders with nearby countries km³/year
Heilongjiang	Heilongjiang*	891 093	Russian Fed.	106.1
Liaohe	Yalu	32 466	DPR Korea	15.4
	Tumen	22 861	DPR Korea	4.9
Total		946 420		126.4

* Including the Erguma and Wusuli rivers.

Volume of water flowing into the country from neighbouring countries

There are 12 main rivers that enter China from six neighbouring countries (Mongolia, Pakistan, India, Kazakhstan, the Kyrgyz Republic and Viet Nam). The mean annual volume of water entering the country is 17.2 km³, of which 4.2 percent in the Heilongjiang basin, 52.9 percent in inland rivers, 0.7 percent in rivers in the southwest, and 42.2 percent in the Pearl River basin. The table below presents data on rivers entering China.

Rivers entering China

Region	River	Annual volume of water entering China (km³)	Country from which the rivers enters China
Heilongjiang	Herlen	0.578	Mongolia
	Wursun	0.145	Mongolia
Inland rivers*	Kara Ertix	0.450	Mongolia
	Haba	1.370	Kazakhstan
	Bulgan	0.228	Mongolia
	Tekes	0.957	Kazakhstan
	Kunmalike	3.580	Kyrgyz Republic
	Guokeshar	1.220	Kyrgyz Republic
	Kizi	0.556	Kyrgyz Republic
	Keleqing	0.718	Pakistan
Southwest	Ruxu Zangbo	0.117	India
Pearl River basin	Upper reaches of the Zuojiang	7.250	Viet Nam
Total		17.169	

* Including the Ertix River.

Glaciers

The total area of glaciers in China is about 58 651 km² extending over six northwestern and southwestern provinces or autonomous regions (Gansu, Qingha, Xinjiang, Tibet, Sichuan and Yunnan). The country's glacier storage is around 5 100 km³ in total. The amount of mean annual glacier meltwater is about 56 km³.

Groundwater resources

he average annual groundwater resources for the whole country are estimated at 828.8 km³. That part which reaches the rivers as base flow or comes from river seepage is estimated at 727.85 km³.

Total renewable water resources

The internal renewable water resources (IRWR) of China are summarized in the table below. The total renewable water resources are computed by adding the total external inflow (17.169 km³/year) to the IRWR, i.e. 2 829.6 km³/year.

Internal renewable water resources of China by catchment area

Major catchment area	Area km²	Gross mean annual precipitation 10^9 m³	Mean annual surface water 10^9 m³	Mean annual ground-water 10^9 m³	Overlap 10^9 m³	Gross mean annual water resources 10^9 m³	Mean annual yield modulus 10^9 m³/km²
Heilongjiang River	903 418	447.60	116.59	43.07	24.48	135.18	149.63
Liaohe River	345 027	190.10	48.70	19.42	10.45	57.67	167.10
Haihe-Luanhe rivers	318 161	178.10	28.78	26.51	13.18	42.11	132.40
Yellow River	794 712	369.08	66.14	40.58	32.36	74.36	93.60
Huaihe River	329 211	283.00	74.13	39.31	17.34	96.10	291.90
Yangtze River	1 808 500	1 936.00	951.30	246.42	236.38	961.34	531.57
Pearl River	580 641	896.70	468.50	111.55	109.24	470.81	810.85
Rivers in Zheijang, Fuijan and Taiwan	239 803	421.60	255.70	61.31	57.84	259.17	1 080.76
Rivers in south-west China	851 406	934.60	585.31	154.38	154.38	585.31	687.46
Inland rivers	3 321 713	511.30	106.37	81.97	68.27	120.07	36.15
Ertix River	52 730	20.80	10.00	4.25	3.93	10.32	195.71
Total	9 545 322	6 188.88	2 711.52	828.77	727.85	2 812.44	294.64

Lakes and dams

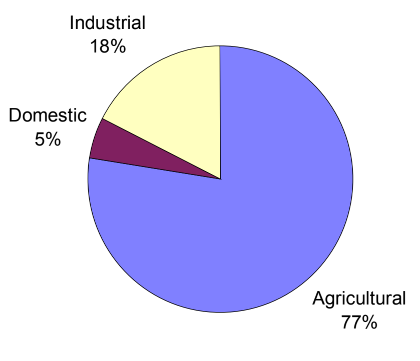
There are about 2 300 lakes (excluding seasonal ones) in China with a total storage of 708.8 km³, of which the freshwater portion is 31.9 percent (226.1 km³). There are five major lake districts as listed in the following table.

Lake district	Area (km²)	Storage (km³)	Freshwater storage (km³)
Qinghai-Tibet plateau	36 889	518.2	103.50
Eastern plains	21 641	71.1	71.10
Mongolia Xinjiang plateau	9 411	69.7	2.35
Northeast plains and mountains	2 366	19.0	18.85
Yunnan-Guizhou plateau	1 108	28.8	28.80
Others	372	2.0	1.50
Total	71 787	708.8	226.10

At the end of 1995, the number of artificial reservoirs was 84 775 with a total capacity of 480 km³. Of these, 387 are classed as large reservoirs with a total capacity of 349 km³; 2 593 are medium reservoirs with a total capacity of 72 km³; and 81 795 are small reservoirs with a total capacity of 59 km³.

China has a gross theoretical hydropower potential of 5 932 TWh/year (779 GW) and a technically feasible potential of 1925 TWh/year (383 GW). The economically feasible potential evaluated in 1993 was 1 261 TWh/year (292 GW). Of the 220 GW total power plant capacity at the end of 1995, hydroelectric plants accounted for 53 868 MW, while the generation from hydroplants in 1994/95 was 167.2 TWh.

FIGURE 1
Water withdrawal
Total: 525.46 km³ in 1993



Water withdrawal

The total water withdrawal was 525.5 km³ in 1993, of which 385 km³ for irrigation, 22.66 km³ for rural domestic uses and livestock, 25.17 km³ for urban domestic and public uses, and 92.55 km³ for industrial water use (Figure 1).

TABLE 3
Irrigation and drainage

Irrigation potential		**64 000 000**	**ha**
Irrigation:			
1. Full or partial control irrigation: equipped area	1996	52 943 200	ha
- surface irrigation		-	ha
- sprinkler irrigation and micro-irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater		-	%
% of area irrigated from surface water		-	%
% of equipped area actually irrigated	1995	91.0	%
2. Spate irrigation area	1996	0	ha
Total irrigation (1+2)	**1996**	**52 943 200**	**ha**
- as % of cultivated area		55	%
- power irrigated area as % of irrigated area	1996	55	%
3. Other water management area	1996	0	ha
Total water managed area (1+2+3)	**1996**	**52 943 200**	**ha**
- as % of cultivated area		55	%
- increase over last 10 years	1995	5	%
- power irrigated area as % of water managed area	1995	55	%
Full or partial control irrigation schemes: (*)			
Large-scale schemes (> 20 000 ha)	1995	8 757 620	ha
Medium-scale schemes (667-20 000 ha)	1995	13 741 280	ha
Small-scale schemes (< 667 ha)	1995	27 913 980	ha
Total number of households in irrigation	1995	-	
Irrigated crops:			
Total irrigated grain production	1993	456 490 000	tons
as % of total grain production	1993	67	%
Harvested crops under irrigation (full or partial control)		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
. wheat		-	ha
. rice		-	ha
. coarse cereals		-	ha
. sugar cane		-	ha
. other		-	ha
Drainage - environment:			
Drained area	1995	20 065 000	ha
- drained areas in full or partial control irrigated areas	1995	15 861 610	ha
- drained areas in equipped wetland and i.v.b		-	ha
- other drained areas		-	ha
- total drained area with subsurface drains		-	ha
- total drained area with surface drains		-	ha
Drained area as % of cultivated area		21	%
Power drained area as % of total drained area		21	%
Flood protected area	1996	32 686 000	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

(*) Figures for the breakdown by scheme correspond to the irrigated farmland and do not take in account the irrigated area in Taiwan and Hong Kong.

The total water demand for 2000 is estimated at 593 km³, with 7 percent for domestic and municipal use, 21 percent for industry, and 72 percent for irrigation.

In 1995, the total amount of wastewater produced was 37.29 km³, of which 23.33 km³ was treated. The re-used treated volume was 13.39 km³.

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation and drainage in China have a long history. The first canals dug to divert water and wells drilled to lift water for irrigation agriculture were constructed four thousand years ago.

Since the founding of the People's Republic of China in 1949, irrigation and drainage have experienced a period of vigorous development. From 1958 to 1985, about 64 368 million yuan were spent on irrigation and drainage projects. The irrigated area for farmland increased from 16 million ha in 1949 to 51 million ha in 1996 (Figure 2).

FIGURE 2
Growth of irrigation in farmland areas since 1975 (mainland China, excluding Hong Kong)

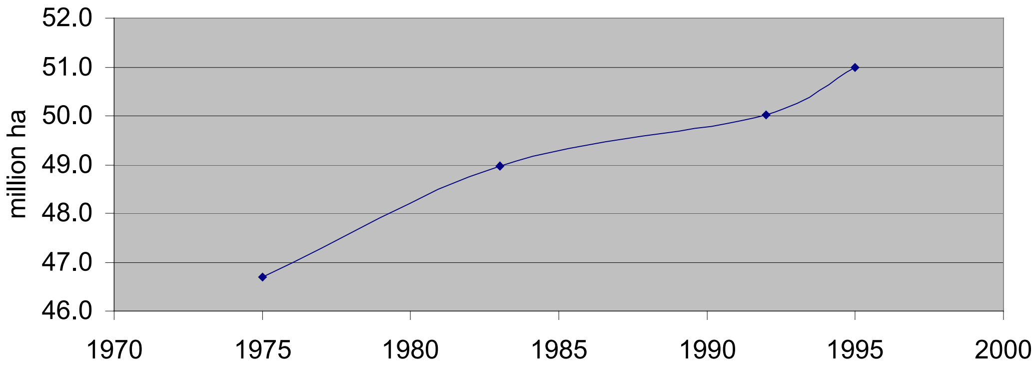
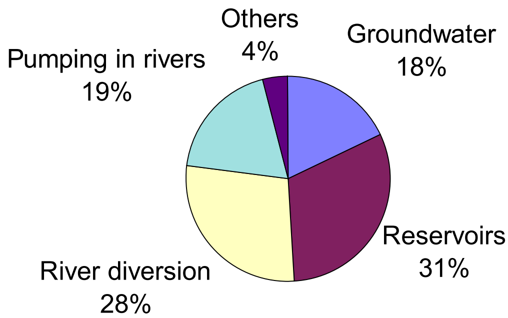


FIGURE 3
Origins of irrigation water
Total: 48 million ha in 1990



After 1949, in order to promote agricultural production, pump irrigation and drainage were developed rapidly. In north China, insufficient surface water resources have meant that since 1950 the Government has had to rely on groundwater for the development of irrigation projects in the Hebei, Henan and Shandong provinces. In 1985, the area irrigated through tube-wells in the country was 11.13 million ha. In 1989, the pump irrigated area reached 26.87 million ha.

Sprinkler irrigation was introduced in China in the early 1950s. The first sprinkler irrigation project was constructed in Shanghai in 1954. Sprinkler irrigation and localized irrigation were considerably developed in the late 1970s. In 1976, the area of sprinkler irrigation was about 67 000 ha. It increased until 1980, but large areas were then abandoned due to the poor quality of equipment and poor management. In 1989, 106 530 ha of farmland had developed water conservation techniques for irrigation, of which 95 140 ha for sprinkler irrigation, 7 370 ha for trickle irrigation and 4 020 ha for mist irrigation (trickle and mist are two types of localized irrigation).

The irrigated farmland area (area regularly ploughed for growing agricultural crops) in China was about 48 million ha in 1990, of which 21.3 million ha for paddy field, 17.3 million ha for grain, and 9.3 million ha for cash crops and vegetables. In 1994, land under irrigation in mainland China (excluding Hong Kong) covered 53 221 440 ha, of which 49 938 070 ha of irrigated farmland, 1 209 000 ha of orchards, 864 050 ha of forests, 770 600 ha of pastures and 439 720 ha of other irrigated land. The irrigated areas are classed by water source as follows: from reservoirs and ponds, 31 percent; through river diversion, 28 percent; pump lifting irrigation, 19 percent; from tube-wells, 18 percent; other, 4 percent (Figure 3).

The territory of China can be divided into three irrigation zones:

- The zone of perennial irrigation, where precipitation is less than 400 mm and irrigation is necessary for agriculture. It covers mainly the northwest regions and part of the middle reaches of the Huanghe River.

- The zone where precipitation ranges from 400 to 1 000 mm, strongly influenced by the monsoon, with a consequently uneven precipitation distribution. Irrigation here is necessary to secure production. This zone includes the Hangh Huai Hai plain and northeast China.
- The zone of supplementary irrigation, where annual precipitation exceeds 1 000 mm. Irrigation is still necessary for paddy (especially to improve cropping intensity), and supplementary irrigation is sometimes required for upland crops. This zone covers the middle and lower reaches of the Changjiang River, the Zhujiang and Minjiang rivers and part of southwest China.

In terms of scheme size, the irrigation areas of China are divided into three categories. Large irrigation districts cover areas over 20 000 ha; medium districts cover areas between 667 and 20 000 ha; and small districts are under 667 ha. The large and medium irrigation districts are generally administrated by special governmental organizations. The small ones are usually farmer managed. Some small ponds, wells and pumping stations are owned by individuals. There are 173 large-scale irrigation districts (8.76 million ha) and 5 389 medium-scale irrigation districts (13.74 million ha) (Figure 4).

FIGURE 4
Types of irrigation schemes in farmland areas (mainland China, excluding Hong Kong)
Total: 50.41 million ha in 1995

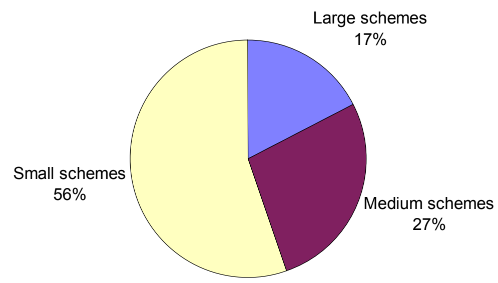
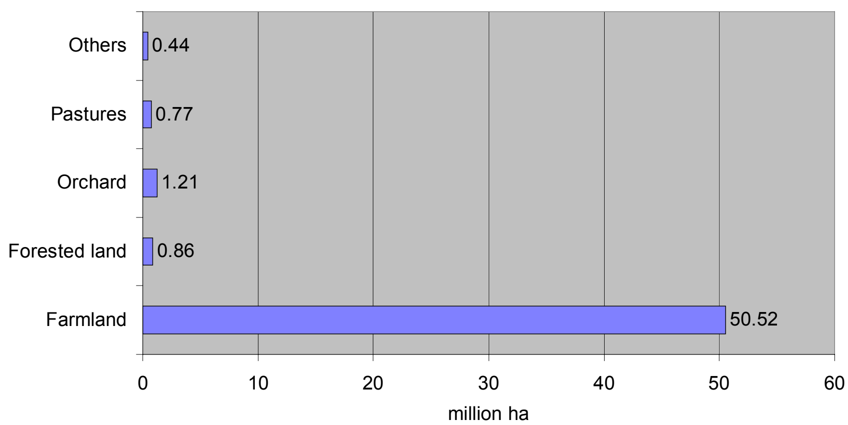


FIGURE 5
Area under irrigation
Total: 53.8 million ha in 1994



The Ministry of Water Resources estimates the maximum possible area which might be brought under irrigation in the first half of the next century at 64 million ha. Nevertheless, as much of the land proposed for irrigation is located in arid and semi-arid zones, a long-term viable strategy has to be formulated as to how to provide additional water resources to irrigate these lands. The total area equipped for irrigation, including farmland, orchards and pastures, was 52 943 200 ha in 1996 (Figure 5 shows the distribution of irrigated crops for 1994). The irrigated area represents 55 percent of the total cultivated area. The area actually irrigated in 1995 was 48.2 million ha, of which tube-well irrigation represented 12.79 million ha.

Until 1995, the total installed capacity of water lifting machines for irrigation and drainage was 68 240 MW. The pumping irrigation and drainage area amounted to 33.27 million ha, of which the pumping irrigation area was 29.07 million ha.

Surface irrigation is the method practised (mainly for rice, wheat, millet, vegetables, corn and cotton) on about 99 percent of the total equipped irrigated area. The remaining 1 percent is under sprinkler and localized irrigation. Since the 1970s, sprinkler irrigation and micro-irrigation (mainly for fruit trees, vegetables and tea) have been introduced.

In 1993, the total sown area was 147.74 million ha and the total grain production was 456.5 million t. The main grain crops are rice, wheat and corn, which make up 84 percent of total grain production. About two-thirds of grain production comes from irrigation. According to a nationwide survey in the early 1980s, the average paddy rice yield of irrigated farmland was 7.3 t/ha and the average yield of non-irrigated paddy rice was 2.1 t/ha. In 1995, the International Rice Commission estimated an average yield of 6 t/ha for irrigated paddy rice.

In 1996, the area subject to waterlogging was 24.58 million ha, of which 20.28 million ha were controlled through drainage. In 1995, the power drained area was 4.2 million ha. Saline-alkaline cultivated areas cover 7.73 million ha, of which 5.51 million ha have been improved or reclaimed. The total cultivated area protected from floods is 32.69 million ha. In northern China in particular, waterlogging, salinization and alkalization have been the main constraints on agricultural production. In this region, there are about 6.70 million ha of low-yielding farmland prone to waterlogging (out of a total of 18.09 million ha of farmland), and 33 500 ha of saline-alkaline soils.

Under government regulations, all water users must pay water charges. Since 1985, the water charge has, in principle, been calculated on the basis of the cost of the water supply. The water charge for agriculture is usually lower than that for industry. It is calculated either according to the quantity of water supplied, the beneficial area, or a mixture of basic water charge plus a metered water charge. Where shortages occur, a rational water allocation system is practised and dissuasive charges are applied to extra volumes of water. On average, water charges for irrigation varied between 150 and 300 yuan/ha (US$17.96 and 35.92/ha) in 1995. The average cost for sprinkler irrigation development was 6 000 yuan/ha (US$720/ha), and that for micro-irrigation was 18 000 yuan/ha (US$2 200/ha) in 1995.

INSTITUTIONAL ENVIRONMENT

The main institutions involved in water resources management are:

- the Ministry of Water Resources (MWR), responsible for water resources survey and assessment, rural water planning and development, and management and protection of water resources. The Ministry of Water Resources directly supervises the Water Resources and Hydroelectric Power Construction Corporation, and administers 13 higher education institutions and 7 regional basin commissions;
- he Local Water Resources Management Department, responsible for water administration at provincial level. Each province has a Water Resource Bureau responsible for planning, survey, design, construction, operation and management of irrigation, drainage, flood control works, and rural hydro-electricity. Water resources bureaux at the prefecture and county levels are directly responsible for the construction and maintenance of main and secondary canals, associated irrigation and flood control structures, and medium-sized reservoirs.

Townships and villages share responsibility for constructing and maintaining branch canals, ancillary works, and small reservoirs;

- the Ministry of Geology and Mineral Resources cooperates with the MWR in the management of groundwater resources;
- the State Environmental Protection Bureau deals with the protection of water resources;
- he Ministry of Agriculture is responsible for state farm water conservation, construction and management;
- the Ministry of Construction is responsible for urban water conservancy including groundwater exploitation and protection.

China's water law was enacted in 1988 and establishes principles, general guidelines, and technical standards for water resources management.

In China, small-scale irrigation and drainage works are built and managed by the farmers themselves. The on-farm engineering facilities below the level of tertiary canals in large-scale irrigation districts are also built and managed by farmers themselves. The 'representative conference of irrigation districts' is a form of WUA, allowing for farmers' participation in the management of the irrigation schemes.

TRENDS IN WATER RESOURCES MANAGEMENT

The further development of irrigation in China faces a number of problems:

- The whole country is facing increasing water shortages, especially in north China.
- Most irrigation projects constructed in the 1950s and 1960s can no longer be operated effectively. This results in a continuous decline in irrigation benefits and has a direct impact on the stability of agricultural development and on the economy.
- The policy of low water fees and free water delivery services practised in irrigation and drainage projects in the past has led to a situation where the funds needed for their regular maintenance and rehabilitation have not been available.

In order to achieve the goals stipulated by the Govenrnent in the 9th Five Year Plan, irrigation should increase by 3.3 million ha and grain production capacity should increase by 40-50 million t in the period 1995-2000. To achieve these objectives, the Government has decided to allocate part of the basic national construction fund for agriculture to the rehabilitation of the irrigation works. The main projects will rehabilitate the key structures in the irrigation districts, control canal seepage, and erect new management facilities. The costs of the rehabilitation and modernization of irrigation projects will be borne by the central, provincial, prefecture and county governments.

In 1985, the Government issued a new rule requiring water charges to be collected according to the cost of water delivery. At present, water charges are on average between a half to two-thirds of the water delivery costs. It is expected that cost recovery will be accelerated in the near future, with regional variations to take account of farmers' ability to pay.

WUAs are recommended by international organizations such as the World Bank. Pilot projects in Hunan and Hubei provinces are currently testing the capacity of WUAs to manage and administer irrigation schemes autonomously. If successful, these approaches may be extended to the rest of the country.

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India

GEOGRAPHY AND POPULATION

India is located in southern Asia and has a total area of 3 287 590 km^2. It is the world's largest peninsula and the seventh largest country in the world. It is bordered in the northwest by Pakistan, in the north by China, Nepal and Bhutan, and in the northeast by Myanmar and Bangladesh. In the south, it has some 5 600 km of coastline on the Arabian Sea, Indian Ocean and Bay of Bengal. The peninsula can be divided into three main regions: peninsular India, located south of the Vindhya and Satpura mountain ranges; the plains of the Indus (northwest) and Ganges (north and northeast) rivers; and the mountainous terrain of the Himalayas. In addition, the Lakshadweep Islands in the Arabian Sea and the Andaman Islands and Nicobar Islands in the Bay of Bengal are part of the territory of India. For administrative purposes, India is divided into 25 states and 7 union territories.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	328 759 000	ha
Cultivable area	1995	183 956 000	ha
Cultivated area	1993	142 509 000	ha
- annual crops	1993	134 910 000	ha
- permanent crops	1993	7 599 000	ha
Population:			
Total population	1996	944 580 000	inhabitants
Population density	1996	287	inhab/km^2
Rural population	1996	73	%
Economically active population engaged in agriculture	1996	61	%
Water supply coverage:			
Urban population	1996	85	%
Rural population	1996	82	%

The total cultivable area is estimated at 183.95 million ha, or about 56 percent of the total area. The total cultivated area was estimated at 142.5 million ha in 1995. In the recent past, the evolution of cultivated area has presented two distinct phases. From 1950 to 1970, the cultivated area rose by 18 percent/year, while the cropping intensity increased from 111 to 118 percent. From 1970 to 1990, the cultivated area rose by 2 percent/year while the cropping intensity increased to 130 percent. The major cereals grown in India are bajra (spiked millet), barley, jowar (great millet), common millet, maize, ragi, rice and wheat. The average cereal yield increased from 522 kg/ha in 1950 to 1 457 kg/ha in 1992, i.e. an average annual growth rate of 2.5 percent. The average farm size is estimated at 1.57 ha, and the table below presents the distribution of landholdings in 1990-91.

Distribution of landholdings

Landholding	Criteria	Average size	% of total number of holdings	% of total area
Marginal	< 1ha	0.40 ha	59.0	14.9
Small	1-2 ha	1.44 ha	19.0	17.3
Semi-medium	2-4 ha	2.76 ha	13.2	23.2
Medium	4-10 ha	5.90 ha	7.20	27.2
Large	> 10 ha	17.33 ha	1.60	17.4
All holdings		1.576 ha	100	100

Source: Ministry of Agriculture (1996).

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		1 170 mm/year
		4 000 km^3/year
Internal renewable water resources		1260.54 km^3/year
Total renewable water resources	1990	1907.76 km^3/year
Dependency ratio		33.9 %
Total renewable water resources per inhabitant	1996	2 020 m^3/year
Total dam capacity	1996	250 000 10^6 m^3
Water withdrawal:		
- agricultural	1990	460 000 10^6 m^3/year
- domestic	1990	25 000 10^6 m^3/year
- industrial	1990	15 000 10^6 m^3/year
Total water withdrawal		500 000 10^6 m^3/year
per inhabitant	1996	529 m^3/year
as % of total renewable water resources		26 %
Other water withdrawal	1990	52 000 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater	1988	4 910 10^6 m^3/year
- treated wastewater	1988	600 10^6 m^3/year
- re-used treated wastewater		- 10^6 m^3/year

India is the second most populous country in the world, with a total population estimated at 944.58 million inhabitants in 1996 (73 percent rural). The average density is estimated at 287 inhabitants/km^2, but varies from fewer than 50 inhabitants/km^2 in Jammu and Kashmir (northern state between Pakistan and China), Arunachal Pradesh (northeastern state near China) and Mizoram (eastern state between Bangladesh and Myanmar) to more than 500 inhabitants/km^2 in Uttar Pradesh, Bihar and West Bengal (northern states in the Ganges Valley), and Kerala and Tamil Nadu (states in the extreme south of the country). The average annual population growth rate is estimated at 2.1 percent. Agriculture contributed about 29 percent of GDP in 1992-93. It employs more than 65 percent of the labour force and is the primary source of livelihood in rural areas.

CLIMATE AND WATER RESOURCES

Climate

India has a typical monsoon climate. In this region, surface winds undergo a complete reversal from January to July, and cause two types of monsoon. In winter, dry and cold air from land in the northern latitudes flows southwest (northeast monsoon), while in summer, warm and humid air originates over the ocean and flows in the opposite direction (southwest monsoon), accounting for some 70-95 percent of the annual rainfall. The average rainfall is estimated at 1 170 mm over the country, but varies significantly from place to place. In the northwest desert of Rajasthan, the average annual rainfall is lower than 150 mm/year. In the broad belt extending from Madhya Maharashtra to Tamil Nadu, through parts of Andhra Pradesh and Karnataka, the average annual rainfall is generally lower than 500 mm/year. At the other extreme, more than 10 m of rain fall on the Khasi hills in the northeast of the country in a short period of four months. On the west coast, in Assam, Meghalaya, Arunachal Pradesh (states located in the northeast) and in sub-Himalayan West Bengal the average annual rainfall is about 2 500 mm.

Except in the northwest of India, the interannual variability of rainfall is relatively low. The main areas affected by severe droughts are Rajasthan, Gujarat, Saurashtra and Kutch.

The year can be divided into four seasons:

- the winter or northeast monsoon from January to February;

- the hot season from March to May;
- the summer or southwest monsoon from June to September;
- the post-monsoon season from October to December.

Temperature variations are also marked. During the post-monsoon and winter seasons from November to February, the temperature decreases from south to north due to the effect of continental winds over most of the country. From March to May, the temperature increases to some 40°C in the northwest. With the advent of the southwest monsoon in June, there is a rapid fall in the maximum daily temperature, which then remains stable until November. The temperature conditions are suitable for year-round crop production in the whole of India except at higher elevations in the Himalayas.

River basins

The rivers of India can be classified into the following four groups:

- the Himalayan rivers, which are formed by melting snow and glaciers and therefore have a continuous flow throughout the year. As this region receives very heavy rainfall during the monsoon period, the rivers swell and cause frequent floods;
- the rivers of the Deccan plateau, which are rainfed and fluctuate in volume, many of them being non-perennial;
- the coastal rivers, which, especially on the west coast, are short in length with limited catchment areas, most of them being non-perennial;
- the rivers of the inland drainage basin in western Rajasthan, which are ephemeral, drain towards the silt lakes such as the Sambhar, or are lost in the sands.

For planning purposes, the country is divided into 20 river units, 14 of which are major river basins, while the remaining 99 river basins have been grouped into 6 river units, as presented in the table (page 94).

Rivers flowing from or to neighbouring countries

Several important river systems originate in upstream countries and then flow to other countries: the Indus River originates in China and flows to Pakistan; the Ganges-Brahmaputra river system originates partly in China, Nepal and Bhutan, and flows to Bangladesh; some minor rivers drain into Myanmar and Bangladesh.

Water resources

The two main sources of water in India are rainfall and the snowmelt of glaciers in the Himalayas. Although reliable data on snow cover in India are not available, it is estimated that some 5 000 glaciers cover about 43 000 km^2 in the Himalayas with a total volume of locked water estimated at 3 870 km^3. Considering that about 10 000 km^2 are located in Indian territory, the total water yield from snowmelt contributing to the river runoff in India may be of the order of 200 km^3/year. Although snow and glaciers are poor producers of fresh water, they are good distributors as they yield at the time of need, in the hot season. Indeed, about 80 percent of the flow of rivers in India occurs during the four to five months of the southwest monsoon season.

The total surface flow, including regenerating flow from groundwater and the flow from neighbouring countries, is estimated at 1 869 km^3/year, of which only 690 km^3 are considered as utilizable in view of the constraints of the present technology for water storage and inter-state issues. A significant part (647.2 km^3/year) of these estimated water resources comes from neighbouring countries: 210.2 km^3/year from Nepal, 347 km^3/year from China (Chinese data) and 90 km^3/year from Bhutan. An important part of the surface water resources leaves the

Internal surface water resources - average annual runoff

	River basin unit	Location	Draining into	Catchment area (km²)	Average annual runoff (km³)	Utilizable surface water (km³)
1	Ganges-Brahmaputra-Meghna - Ganges - Brahmaputra(2) - Barak(3)	Northeast	Bangladesh	861 452(1) 193 413(1) 41 723(1)	525.02* 537.24* 48.36	250.0 24.0 -
2	West flowing rivers from Tadri to Kanyakumari	Southwest coast	Arabian Sea	56 177	113.53	24.3
3	Godavari	Central	Bay of Bengal	312 812	110.54	76.3
4	West flowing rivers from Tapi to Tadri	Central-west coast	Arabian Sea	55 940	87.41	11.9
5	Krishna	Central	Bay of Bengal	258 948	78.12	58.0
6	Indus	Northwest	Pakistan	321 289(1)	73.31*	46.0
7	Mahanadi	Central-east	Bay of Bengal	141 589	66.88*	50.0
8	Narmada(5)	Central-west	Arabian Sea	98 796	45.64	34.5
9	Minor rivers of the northeast	Extreme northeast	Myanmar and Bangladesh	36 302(1)	31.00*	-
10	Brahmani-Baitarani	Northeast	Bay of Bengal	51 822	28.48	18.3
11	East flowing rivers between Mahanadi & Pennar	Central-east coast	Bay of Bengal	86 643	22.52	13.1
12	Cauvery(4)	South	Bay of Bengal	81 155	21.36	19.0
13	East flowing rivers between Kanyakumari and Pennar	Southeast coast	Bay of Bengal	100 139	16.46	16.7
14	West flowing rivers of Kutsh and Saurashtra	Northwest coast	Arabian Sea	321 851	15.10	15.0
15	Tapi	Central-west	Arabian Sea	65 145	14.88	14.5
16	Subernarekha	Northeast	Bay of Bengal	29 196	12.37	6.8
17	Mahi	Northwest	Arabian Sea	34 842	11.02	3.1
18	Pennar	Southeast	Bay of Bengal	55 213	6.32	6.9
19	Sabarmati	Northwest	Arabian Sea	21 674	3.81	1.9
20	Rajasthan inland basin	Northwest	-	-	negl	-
	Total			**3 227 121**	**1 869.35**	**690.3**

Source: Central Water Commission (1993), p 12. and, Central Water Commission (1996), p 15.
* Earlier estimates reproduced from Central Water Commission (1988).
Notes: (1) Area in India territory. (2) The potential indicated for the Brahmaputra is the average annual flow at Jogighopa situated 85 km upstream of the India-Bangladesh border. The area drained by the tributaries such as the Champamati, Guarang, Sankosh, Torsa, Jaldhaka and Tista joining the Brahmaputra downstream of Jogighopa is not accounted for in this assessment. (3) The potential of the Barak and others was determined on the basis of the average annual flow at Badarpurghat (catchment area: 25 070 km²) given in a Brahmaputra Board report on the Barak sub-basin. (4) The assessment for Cauvery was made by the Cauvery Fact Finding Committee in 1972 based on 38 years' flow data at Lower Anicat on Coleroon. An area of nearly 8 000 km² in the delta is not accounted for in this assessment. (5) The potential of the Narmada basin was determined on the basis of catchment area proportion form the potential assessed at Garudeshwar (catchment area: 89 345 km²) as given in the report on Narmada. Water Disputes Tribunal Decision (1978).

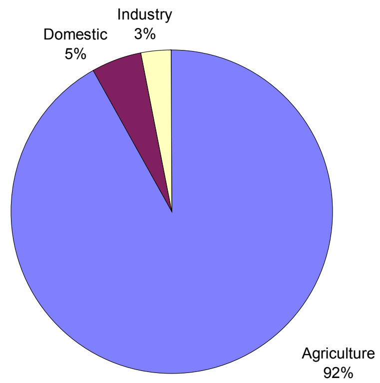
country before it reaches the sea: 20 km^3/year to Myanmar, 181.37 km^3/year to Pakistan (Pakistani information) and 1 105.6 km^3/year to Bangladesh.

The Central Water Commission estimates the groundwater resources at 418.5 km^3/year. Part of this amount, estimated at 380 km^3/year, constitutes the base flow of the rivers. The total renewable water resources of India are therefore estimated at 1 907.8 km^3/year.

Under the Indus Water Treaty (1960) between India and Pakistan, all the waters of the eastern rivers, i.e. the Sutlej, Beas and Ravi rivers taken together, shall be available for the unrestricted use of India. All the waters, while flowing in Pakistan, of any tributary which in its natural course joins the Sutlej main or the Ravi main after these rivers have crossed into Pakistan shall be available for the unrestricted use of Pakistan. This flow reserved by treaty is estimated at 11.1 km^3/year.

India controls the flow of the Ganges River through a dam completed in 1974 at Farraka, 18 km from the border with Bangladesh. This dam was a source of tension between the two countries, with Bangladesh asserting that the dam held back too much water during the dry season and released too much water during monsoon rains. A treaty was signed in December 1996, under which Bangladesh is ensured a fair share of the flow reaching the dam during the dry season.

FIGURE 1
Water withdrawal
Total: 500 km3 in 1990



Dams and hydropower

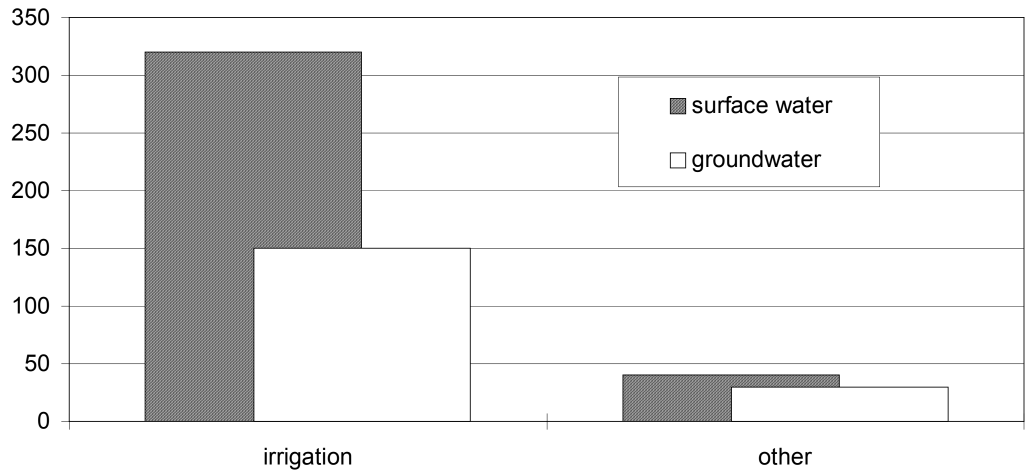
The total water storage capacity constructed up to 1996 was of the order of 250 km^3, including 72.25 km^3 from projects under construction. Seven dams have a reservoir capacity exceeding 8 km^3. They are the Nagarjuna Sagar dam on the Krishna River (11.56 km^3), the Rihand dam on the Rihand River (10.6 km^3), the Bhakra dam on the Sutlej River (9.62 km^3), the Srisailam dam on the Krishna River (8.72 km^3), the Hirakud dam on the Mahanadi River (8.1 km^3), the Pong (Beas) dam on the Beas River (8.57 km^3) and the Ukai dam on the Tapti River (8.5 km^3).

The gross theoretical hydropower potential has been estimated at 140 000 MW as installed capacity, or 84 044 MW at 60 percent power load factor, of which 75 percent in the Himalayan rivers. According to provisional estimates, the installed capacity was 21 645 MW in April 1997, generating about 25 percent of the total electricity produced in India.

Water withdrawal

In 1990, the total water withdrawal was estimated at 500 km^3 (27 percent of the country's actual renewable water resources), of which 91.6 percent for irrigation purposes (Figure 1). Some 19 km^3 are used for energy purposes, and some 33 km^3 are reserved for environmental and other purposes. The surface water withdrawal was 362 km^3, while the amount coming from groundwater was estimated at 190 km^3.

FIGURE 2
Origin of water withdrawn
Total: 540 km3 in 1985



Wastewater and desalination

Wastewater production was estimated at 25.408 km^3 in 1996. Statistics on wastewater treatment in 1988 are also available for the major cities of India, where about 0.98 km^3 of wastewater was collected, of which 0.60 km^3 was treated (primary and secondary treatments).

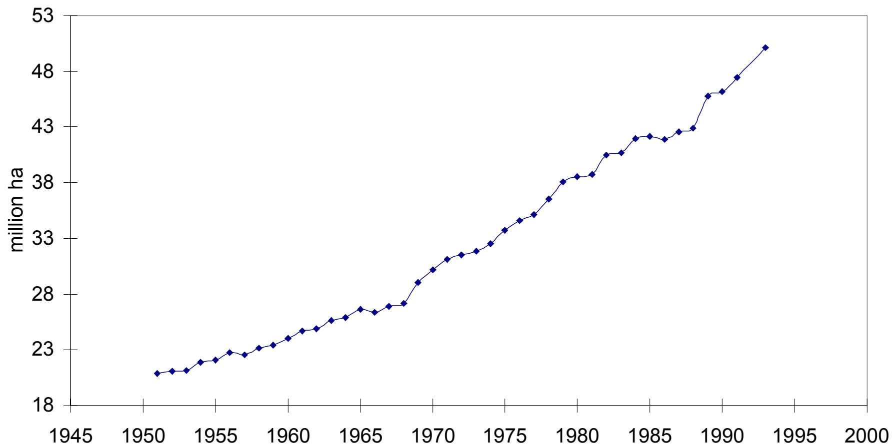
Desalination of seawater is carried out in India on a limited scale. In 1996, some 550 000 m^3 of seawater were desalinated in the Lakshadweep Islands, mainly through electrodialysis and reverse osmosis. Solar stills are also installed on the peninsula, as in Gujarat in the northwest.

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation history

Traces of irrigation structures dating back 3 700 years have been found in the state of Maharashtra. During the Mauriyan era (2 600-2 200 years ago), it is reported that farmers had to pay taxes for irrigation water from neighbouring rivers. The Grand Anicut (Canal) in Tamil Nadu was begun 1 800 years ago and its basic design is still used today. In 1800, some 800 000 ha were irrigated in India. Following major famines at the end of the nineteenth century, major irrigation canals were built, and in 1900 the Indian peninsula (including Bangladesh and Pakistan) had some 13 million ha under irrigation. In 1947, India had about 22 million ha under irrigation. High priority has been given to irrigation with nearly 10 percent of all planned outlays since 1950 being invested in irrigated agriculture. This has resulted in about 0.6 million ha of new irrigated schemes being developed every year. About US$1 500 million are invested every year in irrigation programmes in India. Figure 3 shows the evolution of the irrigated area from 1950 to 1993.

FIGURE 3
Evolution of irrigated area



Irrigation potential

According to the Indian definition, irrigation potential (called ultimate irrigation potential) is estimated at 113.5 million ha. This figure corresponds to the gross area which could theoretically be irrigated in a year on the basis of the assumed design cropping pattern and a rainfall probability of 75 percent. This figure is generally divided into 58.5 million ha for major and medium irrigation schemes, and 55 million ha for minor schemes, of which 40 million ha use groundwater and 15 million ha use surface water (Figure 4). These estimates do not include

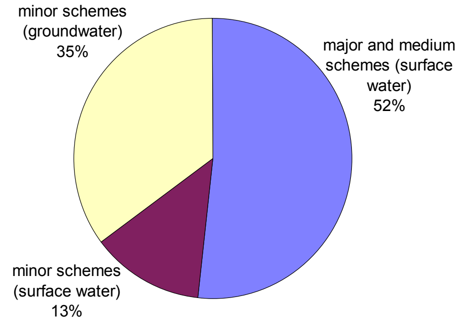
TABLE 3
Irrigation and drainage

Irrigation potential		1993	113 512 000 ha
Irrigation:			
1. Full or partial control irrigation: equipped area		1993	50 101 000 ha
- surface irrigation			- ha
- sprinkler irrigation		1996	700 000 ha
- micro-irrigation		1992	71 000 ha
% of area irrigated from groundwater		1993	53.0 %
% of area irrigated from surface water		1993	40.5 %
% of area irrigated from undefined sources		1993	6.5 %
% of equipped area actually irrigated			- %
2. Spate irrigation			- ha
Total irrigation (1+2)		**1993**	**50 101 000 ha**
- as % of cultivated area			35 %
- power irrigated area as % of irrigated area		1993	53 %
3. Other water management area			- ha
Total water managed area (1+2+3)		**1993**	**50 101 000 ha**
- as % of cultivated area			35 %
- increase over last 10 years		1993	23 %
- power water managed area as % of water managed area		1993	53 %
Full or partial control irrigation schemes:			
Large-scale schemes	> 10 000 ha	1993	17 084 000 ha
Medium-scale schemes	between 2 000 and 10 000 ha	1993	(*) ha
Small-scale schemes	< 2 000ha	1993	33 017 000 ha
Total number of households in irrigation		1981	39 963 000
Irrigated crops:			
Total irrigated grain production		1993	105 250 000 t
as % of total grain production		1993	56 %
Harvested crops under irrigation		**1993**	**66 144 000 ha**
- permanent crops: total			- ha
- annual crops: total			- ha
. wheat		1993	20 654 000 ha
. rice		1993	19 633 000 ha
. coarse cereals		1993	3 555 000 ha
. pulses		1993	2 441 000 ha
. sugar cane		1993	3 614 000 ha
. other		1993	16 247 000 ha
Drainage - environment:			
Drained area		1991	5 800 000 ha
- drained area in full or partial control irrigated areas			- ha
- drained area in equipped wetland and i.v.b.			- ha
- other drained area			- ha
- area with subsurface drains			- ha
- area with surface drains			- ha
Drained area as % of cultivated area			- %
Power drained area as % of total drained area			- %
Flood protected areas		1993	14 400 000 ha
Area salinized by irrigation		1991	3 300 000 ha
Population affected by water-borne diseases		1994	4 958 inhabitants

(*) included under the area of large schemes

additional waters which could be used for irrigation if major interbasin transfer of water were undertaken. This project, known as the National Perspective Project, would increase the irrigation potential up to 148.5 million ha, 10 million ha being obtained by an increased use of groundwater, and 25 million ha by surface water. However, interbasin transfers of water would be expensive and require water-sharing cooperation between states.

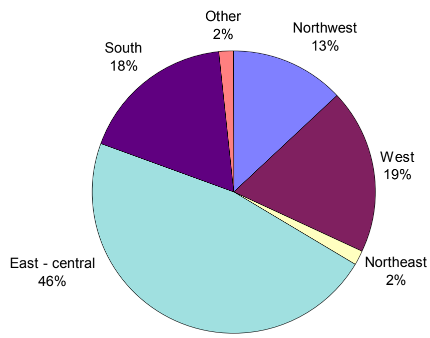
FIGURE 4
Ultimate irrigation potential: source of water
(113.5 million ha)



Irrigation

The area equipped for irrigation is estimated at 50.1 million ha (1993). The breakdown by state shows that irrigation is mainly concentrated in the north of the country, along the Indus and Ganges rivers: Uttar Pradesh (22 percent of the irrigated area), Rajasthan (9 percent) Madhya Pradesh (9 percent) and Punjab (8 percent) (Figure 5). Another classification by origin of water is in common use with the Indian authorities. It differentiates irrigation from canals (34 percent, of which 97 percent are government canals), from tanks (6.5 percent), from groundwater (53 percent, the majority being tube-wells, generally privately owned and managed) and other or undefined sources (6.5 percent) (Figures 6 and 7).

FIGURE 5
Irrigated areas by region
Total: 50 101 000 ha in 1993



The development of tube-well irrigation, supported by investment in electrification and credit provision, has been the main driving force behind irrigation expansion and productivity improvements over the past few decades, particularly in the northwest. Private groundwater irrigation with shallow wells serving 3-4 ha currently appears to be the most cost-effective investment, partly because of government subsidies.

Irrigation by state and by source

N	State	Region *	Ultimate irrigation potential (ha)	Irrigated area: total (ha)	from canals (%)	from tanks (%)	from ground-water (%)	from other sources (%)
1	Andhra Pradesh	S	9 200 000	4 029 000	43	18	35	4
2	Arunachal Pradesh	NE	260 000	36 000	-	-	-	100
3	Assam	NE	2 670 000	572 000	63	-	-	37
4	Bihar	E	12 400 000	3 344 000	28	4	51	17
5	Goa	O	82 000	23 000	35	-	65	-
6	Gujarat	W	4 750 000	2 642 000	21	1	78	0
7	Haryana	NW	4 550 000	2 628 000	52	0	47	1
8	Himachal Pradesh	O	335 000	99 000	9	1	6	84
9	Jammu/Kashmir	O	800 000	311 000	93	1	1	5
10	Karnataka	S	4 600 000	2 194 000	41	12	33	14
11	Kerala	O	2 100 000	335 000	32	14	20	34
12	Madhya Pradesh	E	10 200 000	4 775 000	35	4	49	12
13	Maharashtra	W	7 300 000	2 470 000	23	15	55	7
14	Manipur	NE	240 000	65 000	-	-	-	100
15	Meghalaya	NE	120 000	45 000	-	-	-	100
16	Mizoram	NE	70 000	8 000	-	-	-	100
17	Nagaland	NE	90 000	60 000	-	-	-	100
18	Orissa	E	5 900 000	2 070 000	45	15	40	-
19	Punjab	NW	6 550 000	3 861 000	35	-	62	3
20	Rajasthan	W	5 150 000	4 471 000	32	4	63	1
21	Sikkim	O	42 000	16 000	-	-	-	100
22	Tamil Nadu	S	3 900 000	2 698 000	32	23	44	1
23	Tripura	NE	215 000	50 000	58	16	22	4
24	Uttar Pradesh	E	25 700 000	11 322 000	29	1	67	3
25	West Bengal	E	6 100 000	1 911 000	38	14	37	11
26	Union Territories	O	188 000	66 000	23	-	74	3
	Total		**113 512 000**	**50 101 000**	34	6.5	53.0	6.5

* S: south, E: east-central, W: west, NW: northwest, NE: northeast, O: other.

Irrigation schemes can be divided into thre categories:

- major irrigation projects, with a command area in excess of 10 000 ha;

FIGURE 6
Irrigated areas: source of water
Total: 50 101 000 ha in 1993

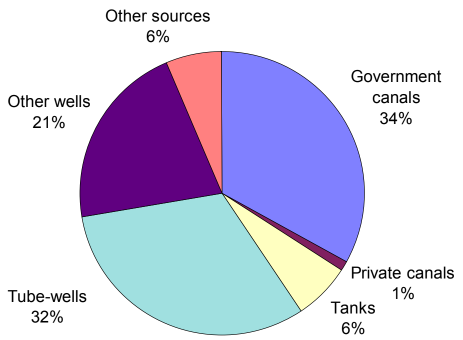
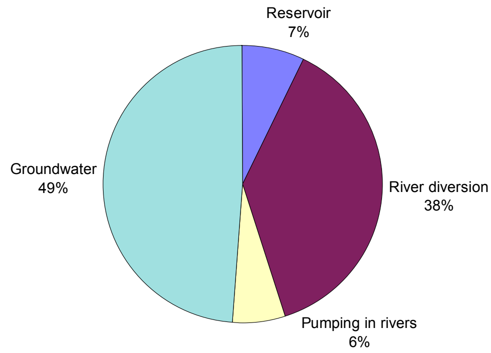
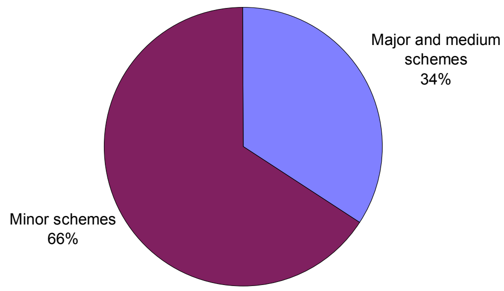


FIGURE 7
Irrigated areas: origin of water
Total: 42 200 000 ha in 1986



- medium schemes, with a command area between 2 000 and 10 000 ha;
- minor schemes, with a command area of 2 000 ha or less (Figure 8).

FIGURE 8
Typology of full/partial control irrigation schemes



The emphasis in irrigation development was initially on run-of-the-river schemes. Subsequently, the need was felt for storage projects for either single or multiple purposes. Minor irrigation projects generally have both surface water and groundwater as sources, while major and medium projects exploit surface water resources. In new major irrigation works, social and environmental costs (resettlement of displaced people, loss of biodiversity in submerged areas, etc.) are taken into consideration in a more systematic way than in the past. A case in point is the Sardar Sarovar dam on the Narmada River, built without external financial assistance due to resettlement terms considered too stringent by the national authorities.

Irrigation management

The main types of irrigation schemes in India are:

- the warabandi system in semi-arid and arid northwest India where irrigation water is rationed strictly in proportion to farm area and supplied on a predetermined rotational schedule. Farmers decide on crops according to the expected water supply. Infrastructure and operational procedures are relatively simple;
- the shejpali systems of western and parts of central and southern India where farmers obtain official sanction for proposed cropping patterns and are then entitled to irrigation supplies according to crop needs. Designed at a time when irrigation water was plentiful relative to demand, most shejpali systems are now experiencing difficulties;

- the localization systems in parts of southern India which focus on locational control of cropping patterns. Low-lying areas are zoned for ‘wet’ crops (primarily rice and sugar cane), while higher areas are limited to irrigated ‘dry’ crops and more restricted water supplies. Such systems break down as head-end farmers in ‘dry’ zones take more than their theoretical allocation;
- traditional field-to-field irrigation systems used mainly for rice in parts of eastern India and some delta schemes in the south. Continuous irrigation flows are provided, passing from field to field, generally without watercourses or field channels. Operating rules have often evolved and been agreed through local tradition, and where water is abundant, yields can be good. However, crop choice and cropping patterns are limited.

A broad distinction can be made between supply-based, or crop-to-water, systems that distribute water according to predetermined procedures and require the farmer to respond accordingly in terms of cropping patterns and areas (such as warabandi), and demand-based, or water-to-crop, systems that attempt to meet crop water needs (such as shejpali). In supply-based systems, the role of the irrigation department tends to be simpler than under demand-based systems that require the department to respond to changing farmers’ needs with more complex and flexible infrastructures and more intensive management.

The first WUAs were established in the 1980s, and some 4 403 WUAs had been formed by March 1997 managing an irrigated area of about 397 100 ha under major and medium irrigation schemes. For minor irrigation schemes (mostly tube-wells), some 10 400 WUAs had been formed managing an irrigated area of about 50 000 ha.

The aims of the WUAs are: to promote and secure distribution of water among users; to ensure adequate maintenance of the irrigation systems; to improve efficiency and economic utilization of water; to optimize agricultural production; to protect the environment; and to ensure ecological balance by involving the farmers and inculcating a sense of ownership of the irrigation systems in accordance with the water budget and operational plan. The WUAs are formed and work on the basis of executive instructions/guidelines laid down by each state government. There is no central legislation or legal instrument in this regard. However, the only state which has passed legislation exclusively for farmer participation in the management of irrigation systems is Andhra Pradesh.

In many states, especially in the north (Uttar Pradesh, Punjab and Haryana), the conjunctive use of surface and groundwater has been practised through canal systems and tube-wells or dug-wells to increase the yield and general efficiency of the water system. Water from the tube-wells, which are installed along the side of the existing canals, is added into the canals for utilization in the canal command areas. This practice helps prevent waterlogging but requires the adoption of good management techniques by farmers.

The average overall water use efficiency in canal irrigation systems is estimated at 38-40 percent.

In India, there is considerable diversity in the systems of levying irrigation charges (water rates). Except in Assam and the northeast states which do not levy irrigation rates, all states charge directly or indirectly for the use of irrigation from public sources. In Andhra Pradesh and Tamil Nadu there is no separate water rate for areas under old irrigation systems (including minor surface irrigation systems). Land irrigation by these systems is classed as wetlands for land revenue purposes. Being more productive, wetlands are charged at a much higher rate than drylands are. Within wetlands, there is a further differentiation by quality of soil and irrigation source. The difference between dry and wet assessment can be constructed as a water charge determined on the basis of productivity impact as assessed at the time of the revenue settlement. The last such settlement was determined more than 50 years ago and there has been no revision in the base rates of land revenue since. However, for second and third crops raised on wetlands using public irrigation sources, both states collect a water levy called irrigation cess. For systems constructed since 1947, they charge separate water rates for irrigation from public systems.

In all the other states, lands irrigated by public systems are charged separate water rates. As a rule, these rates are levied on the area actually irrigated; they are invariably differentiated by season and crop. In many states, the rates are further differentiated by categories of irrigation projects to allow for differences in the quality of irrigation as reflected in the quantum, duration and assurance of water supplies. For example, Bihar distinguishes between perennial and non-perennial canals, and between sources which are assured and those which are not. Even more elaborate classifications are used in Orissa and Utter Pradesh. Within this general pattern, there are some notable variations in particular states. Thus, Orissa charges a basic water rate on all lands within the cultivable command area of a project for the supply of water, whether used or not, for the staple cereal crop of the area (generally paddy), and individual water rates for non-staple crops. Bihar makes a distinction between long lease, seasonal lease and single watering. Maharashtra and Madhya Pradesh make a distinction between demand rate and agreement rate.

Water rates are uniform throughout the state in Andhra Pradesh, Gujarat, Kerala, Madhya Pradesh and West Bengal. However, in Bihar, Haryana, Maharashtra, Punjab, Rajasthan, Tamil Nadu, Tripura and Uttar Pradesh rates vary within the state from region to region or project to project.

The water rates are higher for storage systems than for flow diversion schemes. Similarly, the rates for canal lift irrigation are generally higher (double) than flow irrigation when water lifting is undertaken by the government bodies. Where lifting arrangements are made by the individual farmers, then the rate is lower than the flow rate, as in Punjab, Haryana, Madhya Pradesh and Maharashtra.

Thus, a number of parameters are involved in setting the water rates in different states, such as:

- recovery of cost of water:
  O&M cost only as in Gujarat and Manipur,
  O&M cost plus interest charges at the rate of 1 percent for irrigation purposes;
- capacity of irrigators to pay based on:
  gross earning, or
  net benefit of irrigation;
- water requirements of crops;
- sources of water supply;
- classification of land;
- linkage with land revenue system;
- combination of various elements stated above.

The 10th Finance Commission has adopted a norm of Rs300 (about US$8.5) per hectare as the O&M charge for major and medium irrigation works. This norm is to be increased by 30 percent for hill states (hilly terrain). Similarly, for minor irrigation which includes tube-wells, the commission has adopted a norm of Rs150 (about US$4.2) per hectare; again increased by 30 percent in hill states.

Irrigation techniques

The development of sprinkler and drip irrigation in recent years has been considerable, mainly due to the pressing demand for water from other sectors, a fact which has encouraged governments and farmers to find water saving techniques for agriculture.

Sprinkler irrigation was not widely used in India before the 1980s. Although no statistics are available on the total area under sprinkler irrigation, more than 200 000 sprinkler sets were sold between 1985 and 1996 (about 65 000 for 1995-96) according to the National Committee on the Use of Plastics in Agriculture. The annual growth rate of the sprinkler irrigated area in India is about 25 percent. This area can be estimated at about 0.7 million ha in 1996. The cost of installation of sprinkler irrigation depends upon a number of factors such as type of crop, the distance of the water shore, spacing, and nature of terrain. The approximate capital cost (excluding pump cost) ranges from Rs16 000 to Rs20 000 (US$450-560) per hectare.

Drip irrigation is expanding rapidly in India. This can be partly explained by the subsidies offered by the Government to adopt drip systems. From about 1 000 ha in 1985, the area under drip irrigation increased to 70 860 ha in 1991, mainly in Maharashtra (32 924 ha), Andhra Pradesh (11 585 ha) and Karnataka (11 412 ha). The drip irrigated crops are mainly orchards (39 140 ha), whose main crops are grapes (12 000 ha), bananas (6 500 ha) pomegranates (5 440 ha) and mangoes (4 750 ha). Drip irrigation is also used for sugar cane (3 900 ha) and coconut (2 600 ha). The average cost of drip irrigation development ranges from US$750 to 2 000 (Rs15 000-40 000) per hectare, but a farmer can receive a subsidy up to Rs15 000 (US$750).

Crops

Irrigation development has enabled crops to be grown all year round. The expansion of irrigation has not only directly enabled yield increases, it has also been the essential prerequisite for the expansion of the use of chemical fertilizers and wheat and rice HYVs. About 56 percent of total agricultural production comes from irrigated agriculture, which is approximately 35 percent of the net sown area. Furthermore, the spread of irrigation has also enabled crop diversification.

The total harvested area was estimated at 66.14 million ha in 1993, which means an average cropping intensity of 1.32 on the irrigated area.

Crop yields have increased substantially, and irrigated crops produce much more than rainfed crops (Figure 9). However, irrigated crop yields are still low relative to yields under irrigation in other countries. This is mainly due to poor water management on the majority of the surface command areas. Irrigation is mainly provided on wheat (84 percent of the total area sown with wheat is irrigated), rice (47 percent) and sugar cane (88 percent). Cotton (33 percent), pulses (10 percent) and coarse cereals (10 percent) are also irrigated to a lesser extent. Trends show that irrigation has been used mainly for wheat (3 million ha irrigated in 1950; 20 million ha in 1990) and rice (10 million ha in 1950, 20 million ha in 1993), while coarse cereals and maize have not benefited much from irrigation (Figure 10).

Drainage and salinization

Drainage works have been undertaken on about 5.8 million ha, which is 12 percent of the irrigated area. The average cost for drainage is estimated at US$280/ha (Rs10 000/ha). However, in the case of reclamation of soil affected by alkalinity, the cost is estimated at the rate of US$560/ha (Rs20 000/ha). Investment in drainage has been widely neglected, and where

FIGURE 9
Influence of irrigation on crop yields

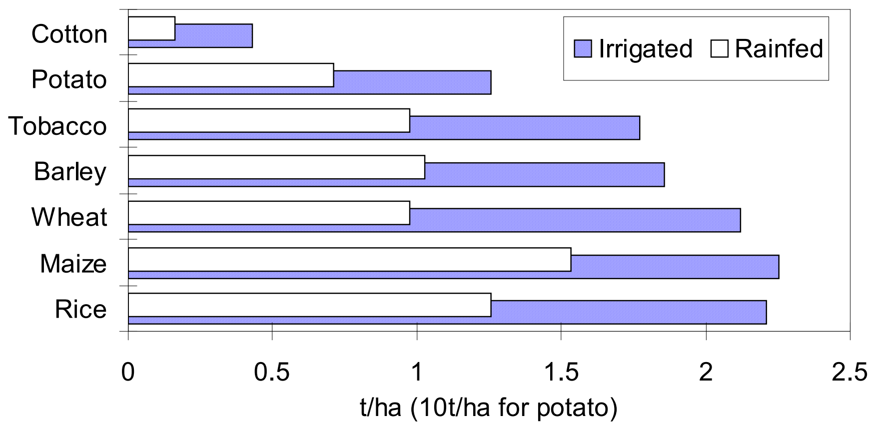
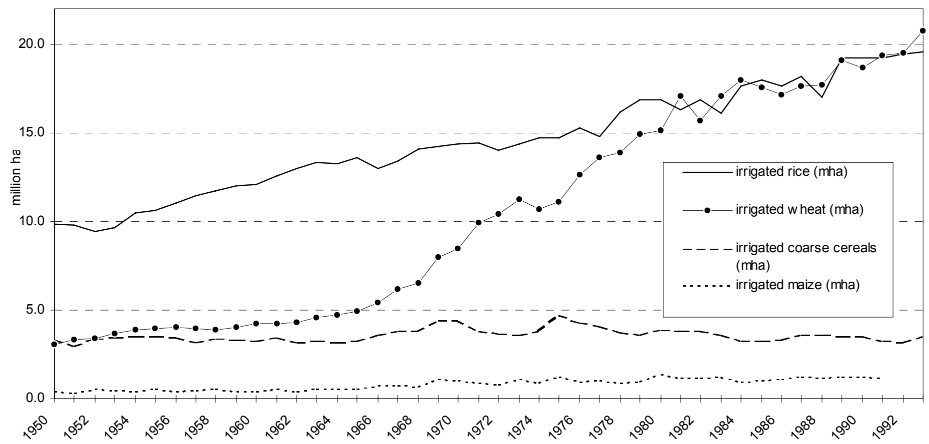


FIGURE 10
Evolution of irrigated areas by crop



such investment has been made, poor maintenance has caused many drainage systems to become silted up. In the eastern Ganges plain, investment in surface drainage would probably have a larger productive impact, and at a lower cost, than investment in surface irrigation.

The total area subject to waterlogging was estimated at 6 million ha in 1976, including both rainfed and irrigated areas. This is thought to be a substantial underestimate though precise data are lacking. Some 2.46 million ha of irrigated land are estimated to be affected by waterlogging. Furthermore, it is estimated that out of the total irrigated area about 3.06 million ha are affected by salinity and about 0.24 million ha by alkalinity. Based on the extrapolation of data on individual schemes, it is estimated that on average irrigation induces salinization/waterlogging on some 10 percent (i.e. 5.8 million ha for the whole of India) of the command area (net irrigated area). Parts of northwest India and Uttar Pradesh are affected by a build up of saline groundwater. Measures to counter waterlogging and salinity are being taken by constructing field channels and drains, and by encouraging the combined use of surface water and groundwater.

According to the National Commission on Floods, the area subject to flooding is estimated at about 40 million ha. About 80 percent of this area, or 32 million ha, could be provided with reasonable protection. The total area provided with reasonable protection as at March 1993 was 14.4 million ha.

Water-borne diseases have continued increasing over the years in spite of government efforts to combat them. States such as Punjab, Haryana, Andhra Pradesh and Uttar Pradesh have now become endemic for malaria on account of the high water table, waterlogging and seepage in the canal catchment area. There are also numerous cases of filariasis.

INSTITUTIONAL ENVIRONMENT

Indian irrigation is dominated by the public sector. The scale of most schemes has necessitated government funding; the O&M of most schemes also requires public sector involvement. Government management extends to the chak level (plots of about 40 ha), and has entailed a large network of grassroots irrigation officials. The collection of water charges also involves a substantial government apparatus. India relies much less than many other countries on non-governmental bodies for scheme management, although farmers' organizations are encouraged to take over the O&M of small irrigation schemes.

Under the Indian Constitution, water is the responsibility of the states. Thus the federal states are primarily responsible for the planning, implementation, funding and management of water resources development. This responsibility in each state is borne by the Irrigation and Water Supply Department. The Inter-State Water Disputes Act of 1956 provides a framework for the resolution of possible conflicts.

At central level (responsible for water policy in the union territories), there are three main institutions involved in water resources management:

- the Ministry of Water Resources, which is responsible for laying down policy guidelines and programmes for the development and regulation of the country's water resources. The ministry's technical arm, the Central Water Commission, provides general infrastructural, technical and research support for water resources development at state level. The Central Water Commission is also responsible for the assessment of water resources;
- the Planning Commission, which is responsible for the allocation of financial resources required for various programmes and schemes of water resources development to the states as well as to the Ministry of Water Resources. It is also actively involved in policy formulation related to water resources development at the national level;
- the Ministry of Agriculture, which promotes irrigated agriculture through its Department of Agriculture and Cooperation.

The Central Pollution Control Board is in charge of water quality monitoring, and the preparation and implementation of action plans to solve pollution problems.

Following the agreement of 19 September 1960 between India and Pakistan, there is a joint commission for the Indus basin. Similar arrangements exist between Nepal and India for the exploitation of the Kosi River (1954, 1966) and the Gandak River (1959). Although an India-

Bangladesh commission was set up for the regulation of the Ganges River, it has never been operational.

TRENDS IN WATER RESOURCES MANAGEMENT

Water resources management planning should be seen in a context of foodgrain availability. Foodgrain production increased in the 1950s and 1960s due to increases in the cultivated area, and due to a tremendous expansion in irrigation and the use of HYVs from the mid-1960s onwards. Irrigation has also helped reduce interannual fluctuations in agriculture output and India's vulnerability to drought. One of the goals of Indian policy is now to find ways of maintaining the same level of foodgrain availability per inhabitant in a context of population increase. The development of irrigation schemes will reach its limits at the beginning of the next century. Total water demand will equal water availability by 2025, but industrial and domestic water demand are expected to rise drastically at the expense of the agriculture sector which will have to produce more with less water. Therefore, water saving techniques and improved water use efficiency, which averaged about 40 percent in 1996, are indispensable. Emphasis has therefore been placed on improving irrigation performance.

India adopted a national water policy in 1987 for the planning and development of water resources to be governed by national perspectives. It emphasizes the need for river basin planning. Water allocation priority has been given to drinking water, followed by irrigation, hydropower, navigation and industrial or other uses. As water resources development is a state responsibility, all the states are required to develop their state water policy within the framework of the national water policy and, accordingly, set up a master plan for water resources development. However, by 1996, not much progress had been achieved by the states in this regard, and the impact of the national water policy is still limited by the lack of institutional mechanisms to plan, coordinate and implement water development across state boundaries and among users.

Water quality is a major issue in India. Although in their upper reaches most rivers are of good quality, the importance of water use for cities, agriculture and industries, and the lack of wastewater treatment plants in the middle and lower reaches of almost all rivers cause a major degradation of surface water quality. Groundwater is also affected by domestic, industrial and agricultural pollutants. The overexploitation of groundwater can also lead to seawater intrusion. For example, there is an inland advance of the saline-freshwater interface in the Chingelput district of Tamil Nadu, where a well field along the Korttalaiyar River supplies water to the city of Madras.

In 1992, the Central Pollution Control Board completed water quality studies in all major river basins. The pollution control action plan of the Ganges River basin was formulated in 1984 and has been enforced by the Ganges Project Directorate, under the Central Ganges Authority, to oversee pollution control and the consequent cleaning of the Ganges River. The water quality in the middle stretch of the Ganges River, which had deteriorated to class C and D (the worst class is E, the best A), was restored to class B in 1990 after the implementation of the action plan. A similar programme for the Yamuna River is in the pipeline, and a national river action plan is being drawn up to clean the heavily polluted stretches of the major rivers of the country.

India has the second largest irrigated area in the world, but due to the rapid expansion of irrigation with its emphasis on new construction, irrigation performance and the sector's increasing management needs have not received adequate attention. The development impact of irrigation has been well below its potential, and deficiencies in implementation have accumulated over time. A study by the World Bank (1991) mentions four points for concern:

- Irrigation productivity is low. The non-optimal distribution of water results in low yields and cropping intensity and reduced opportunities for diversifying agriculture as do deficiencies in agricultural extension, limited research on irrigation technology, insufficient piloting of innovations, poor project design and preparation, and deteriorating infrastructure.
- The sustainability of irrigation investment is put in doubt by a decline in the maintenance of infrastructure and in the quality of construction. Rehabilitation requirements represent an increasing part of construction investment and environmental problems are mounting.
- A sharp financial deterioration of the sector poses a threat. Lack of control of expenditure and works in the past decade have resulted in unproductive staff growth and wastage.
- The domination of the sector by public authorities does not leave much room for private initiative, nor does it enable responsibilities to be allocated in the most effective way.

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Indonesia

GEOGRAPHY AND POPULATION

Indonesia is a tropical archipelago country of more than 13 600 islands. The country extends over an area of about 1 904 570 km². The major islands are Sumatra, Java, Nusa Tenggara, Kalimantan, Sulawesi, Maluku and Irian Jaya. Most of the major islands have a mountain range running their whole length. The mountains are of volcanic origin and in some cases still active. The elevations of the islands range from 0 to 5 030 m above sea level. For administrative purposes the country is divided into 26 provinces. The capital is Jakarta.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1996	190 457 000	ha
Cultivable area		-	ha
Cultivated area	1995	35 579 000	ha
- annual crops	1995	21 743 000	ha
- permanent crops	1995	13 836 000	ha
Population:			
Total population	1996	200 453 000	inhabitants
Population density	1996	105	inhab/km^2
Rural population	1996	63.6	%
Economically active population engaged in agriculture	1996	49	%
Water supply coverage:			
Urban population	1990	35	%
Rural population	1990	33	%

The land area is about 1.81 million km² with a coastline exceeding 84 000 km. In 1995, the total cultivated area was estimated to be 35 579 000 ha. Of the cultivated area, 13 836 000 ha were under permanent crops such as rubber, coconut, coffee, cocoa and palm oil. Annual crops such as paddy, maize, soybean, sugar cane and tobacco were grown on 21 743 000 ha. Farmholdings in Indonesia are relatively small: 34 percent are less than 0.25 ha and a further 25 percent are between 0.25 and 0.5 ha.

In 1996, the total population was about 200 million inhabitants (63.6 percent rural), with a growth rate of 1.7 percent. The average population density was 105 inhabitants/km². The population is unevenly distributed with about 60 percent living on the island of Java, which has an average population density of over 800 inhabitants/km². Another 20 percent of the population lives on the island of Sumatra, with a population density of 77 inhabitants/km². Agricultural crop production and livestock contribute approximately 18 percent of GDP. The agriculture sector provides employment for 49 percent of the population.

CLIMATE AND WATER RESOURCES

Climate

There are two seasons, the dry season and the wet season. The dry season lasts from March to August and the wet season from September to March with the heaviest rainfall usually from November to February. The average annual rainfall for the major islands is presented below.

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		2 700 mm/year
		5 142 km^3/year
Internal renewable water resources		2 838 km^3/year
Total renewable water resources	1990	2 838 km^3/year
Dependency ratio		0 %
Total renewable water resources per inhabitant	1996	14 158 m^3/year
Total dam capacity	1995	15 803 10^6 m^3
Water withdrawal:		
- agricultural	1990	69 241 10^6 m^3/year
- domestic	1990	4 729 10^6 m^3/year
- industrial	1990	376 10^6 m^3/year
Total water withdrawal		74 346 10^6 m^3/year
per inhabitant	1996	371 m^3/year
as % of total renewable water resources		2.6 %
Other water withdrawal		- 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater		- 10^6 m^3/year
- treated wastewater		- 10^6 m^3/year
- re-used treated wastewater		- 10^6 m^3/year

The temperature ranges from 21° to 33°C, but at higher altitudes the climate is cooler. Humidity is between 60 and 80 percent.

Average annual rainfall

Island	mm/year
Sumatra	2 600
Java	2 600
Nusa Tenggara	1 500
Kalimantan	2 800
Sulawesi	2 100
Maluku	2 200
Irian Jaya	3 200

Source: Adapted from Ministry of Public Works data (1993).

River basins and water resources

Indonesia has over 5 590 rivers. The catchment areas and annual average river runoff by major island are presented in the following table.

Annual average river runoff

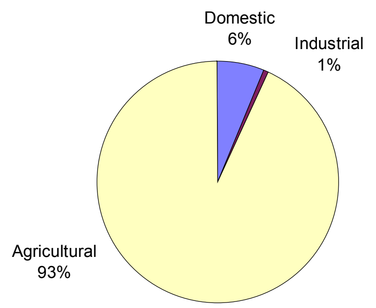
Island	Catchment area (km^2)	Annual average river runoff	
		(m^3/s)	(km^3/year)
Sumatra	409 000	19 710	622
Java	139 000	6 950	220
Nusa Tenggara	88 500	1 550	49
Kalimantan	539 500	28 000	883
Sulawesi	191 000	5 930	187
Maluku	75 000	2 320	73
Irian Jaya	422 000	24 090	759
Indonesia	1 864 000	88 550	2 793

Source: Adapted from Ministry of Public Works data (1993).

The groundwater resources are estimated at 455 km^3/year, although most (an estimated 90 percent) return as base flow to the rivers. The groundwater potential in Indonesia is, therefore, limited and can meet only part of the urban and rural needs for water supply, while providing irrigation water for very limited areas in the eastern part of Indonesia. In some places, overexploitation of groundwater has led to critical problems. In Jakarta, total groundwater abstraction in 1993 was 32.6 million m^3. Groundwater abstraction has caused saline groundwater to reach about 10 km inland from the coastline and led to land subsidence at a rate of 2-34 cm/year in east Jakarta.

Although water resources are abundant, the seasonal and spatial variation in the rainfall pattern and lack of adequate storage create competition and conflicts among users. The annual renewable water resources are estimated to be about 2 838 km³. Municipal and industrial wastewater is discharged virtually untreated into the waterways causing rapid deterioration in the quality of river water.

FIGURE 1
Water withdrawal
Total: 74.34 km³ in 1990



Lakes and dams

Most of the lakes in Indonesia are of volcanic origin. Lake Toba is the largest volcanic lake in the world with an average surface area of 1 100 km² and an average volume of 1 258 km³. In 1995, there were 82 dams. The large dam capacity was 15.83 km³. The gross theoretical hydropower potential in Indonesia is estimated at 3 388 GWh/year. In 1991, the total installed power capacity was 2 061 MW and hydropower accounted for 16.27 percent of the electricity generated.

Water withdrawal

In 1990, water withdrawals were 69.24 km³ for agriculture, 4.73 km³ for domestic and municipal water supply and 0.38 km³ for industrial use (Figure 1). As the nation has started to implement development programmes in order to meet the sharply increasing needs for irrigation, safe drinking water, industrial water, energy, etc., the demand on water resources has increased rapidly. It is estimated that between 1990 and 2020, the demand will increase by about 220 percent. More than 50 percent of all irrigation water is consumed in Java.

In 1990, 35 percent of the urban population and 33 percent of the rural population had access to water supply.

IRRIGATION AND DRAINAGE DEVELOPMENT

The development of community irrigation systems started more than two thousand years ago. Modern irrigation systems were introduced in the middle of the nineteenth century. The first water resources development project which incorporated multi-sectorial water allocation was the Jatiluhur project in west Java. This project, proposed in 1948, is the largest in Indonesia. It allocates water for irrigation, hydropower and domestic water supply to Jakarta.

In 1969, with the launching of the five year development plan called Repelita, the Government started a major programme in irrigation development which included: rehabilitation of existing irrigation works; expansion of service areas in existing schemes; construction of new irrigation systems; upgrading of semi-technical irrigation systems to technical level; introduction of special maintenance to upgrade the physical infrastructure; implementation of efficient O&M for launching sustainable O&M programmes; a credit programme; and strengthening of WUAs.

In the first twenty-five years of development, spanning five Repelitas (1969-1993), termed 'Pembangunan Jangka Panjang I' (PJP I), or first phase of long-term development, water resources policies were directed to support the development of different sectors with the primary emphasis being on agriculture. During PJP I, about 1.44 million ha were provided with new irrigation systems, whilst 3.36 million ha of existing irrigation systems were either rehabilitated or upgraded through special maintenance. The success of this development is demonstrated by the country having achieved food self-sufficiency, particularly in rice, since

TABLE 3
Irrigation and drainage

Irrigation potential		1993	10 865 000 ha
Irrigation:			
1. Full or partial control irrigation: equipped area		1996	4 427 922 ha
- surface irrigation		1996	4 427 922 ha
- sprinkler irrigation			- ha
- micro-irrigation			- ha
% of area irrigated from groundwater		1995	1 %
% of area irrigated from surface water		1995	99 %
% of equipped area actually irrigated			- %
2. Spate irrigation		1996	- ha
Total irrigation (1+2)		**1996**	**4 427 922 ha**
- as % of cultivated area			12.4 %
- power irrigated area as % of irrigated area			- %
3. Other water management area			3 341 450 ha
Total water managed area (1+2+3)		**1996**	**8 269 372 ha**
- as % of cultivated area			23.2 %
- increase over last 10 years (**)		1996	11 %
- power water managed area as % of water managed area			- %
Full or partial control irrigation schemes:			
Technical	see text	1996	3 328 016 ha
Semi-technical	- do -	1996	1 099 906 ha
Simple and village managed (*)	- do -	1996	2 658 690 ha
Total number of households in irrigation			-
Irrigated crops:			
Total irrigated grain production			- t
as % of total grain production			- %
Harvested crops under irrigation			**- ha**
- permanent crops: total			- ha
- annual crops: total			- ha
Drainage - environment:			
Drained area			- ha
- drained area in full or partial control irrigated areas			- ha
- drained area in equipped wetland and i.v.b.			- ha
- other drained area			- ha
- area with subsurface drains			- ha
- area with surface drains			- ha
Drained area as % of cultivated area			- %
Power drained area as % of total drained area			- %
Flood protected areas			- ha
Area salinized by irrigation			- ha
Population affected by water-borne diseases			- inhabitants

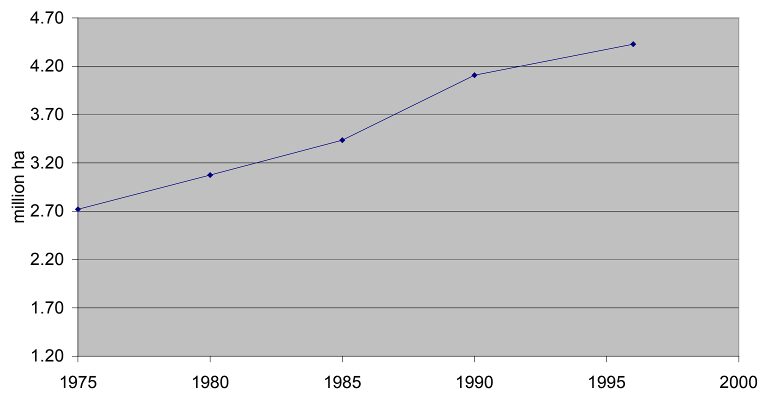
* 2 658 690 ha may not be equipped and cannot be considered as full/partial control schemes.

1984. Another result of Indonesia's development was the reduction of poverty from 44 percent of the population (54 million people) in 1969 to 13 percent (26 million people) in 1993.

The country has now embarked on the second twenty-five-year development period (1994-2019), termed PJP II, which started in April 1993 with Repelita VI. Here the emphasis is on sustainable development and management of water resources. Water resources have now been elevated to a full sector level and policies are directed to promoting a more effective and efficient management of water resources in an integrated manner. Greater emphasis is placed on sustaining self-sufficiency in rice and on the O&M of water resources infrastructure. In addition, the Government is implementing a crash programme in Repelita VI to improve 1.0 million ha of village irrigation systems and to develop a 600 000-ha rice estate by swamp reclamation in central Kalimantan.

The irrigation potential of the country is estimated at 10.86 million ha. In 1996, the total land area equipped for full or partial control irrigation was 4.43 million ha. In addition, there were 0.70 million ha of "simple" irrigation and 1.96 million ha of village managed schemes. It should be noted, however, that large discrepancies are observed among sources of information, leading to important uncertainties about the areas under irrigation. It was reported that, in 1995, 638 reservoirs, 10 770 weirs, 1 017 barrages, 1 192 pumping stations and 6 792 intakes were used to supply water to an area of 4 600 000 ha. Moreover, in 1995, irrigation from groundwater reportedly covered an area of 44 209 ha, of which 36 784 ha were served by 834 units of deep tube-wells, 4 204 ha by 363 units of intermediate tube-wells and 14 807 ha by 471 units of shallow tube-wells. Of the cultivated land, 23.5 percent have some kind of water management.

FIGURE 2
Growth in irrigation since 1975 (technical and semi-technical schemes)



In Indonesia, fields under water management are classed in four types: technical, semi-technical, simple and village managed. Usually the first three types belong to the public works system.

Technical systems: in 1996, they served an area of 3 328 016 ha. They are characterized by permanent canals, control structures, measuring devices and government control of water distribution down to tertiary level.

Semi-technical systems: in 1996, they served an area of 1 099 906 ha. They are characterized by permanent canals, few control or measuring devices, and government control of generally only the source and the main canal.

Simple systems: in 1996, they served an area of 697 194 ha. They are characterized by few permanent control or distribution structures and may be managed by farmers.

Village managed irrigation systems: in 1996, they served an area of 1 961 496 ha. These systems are developed and managed spontaneously by farmers.

In 1995, the total area of irrigation schemes serving areas of less than 500 ha was 2 175 019 ha; of which 854 214 ha were government managed and 1 320 805 ha were farmer managed.

The main objective of irrigation development in Indonesia is to expand the cultivation of rice paddy, the staple food in Indonesia. The major crops cultivated under control irrigation are paddy and palawija (dry season crops, e.g. corn, soybean, etc.). In 1996, the total harvested wetland paddy area was 10.2 million ha, including irrigated and rainfed lowland. In 1994, the average yield for irrigated paddy in Java was 5.4 t/ha and Java contributed 60 percent of Indonesia's rice production. In 1992, the average cost of developing a surface irrigation scheme was US$3 645/ha while the average O&M cost of a surface irrigation system was US$8.4/ha/year.

Indonesia has an estimated 39.0 million ha of coastal and inland swamps. The extent of arable swampland has not been assessed in detail but is estimated to be 7.5 million ha. In 1996, the tidal and non-tidal swamp area used for irrigation (mainly for rice) was about 1.18 million ha. The table gives a summary of water managed areas by type.

Distribution of water managed areas by type (1996)

Irrigation		4 427 922
- Technical	3 328 016	
- Semi-technical	1 099 906	
Cultivated wetland		3 841 450
- simple schemes	697 194	
- village management	1 961 496	
- cultivated swamps	1 182 760	
Total		**8 269 372**

INSTITUTIONAL ENVIRONMENT

The 1945 constitution declared national water and land resources to be controlled by the State and that they should be utilized in an equitable manner for the benefit of the people. The responsibilities for the development and management of water resources and irrigation schemes are specified in laws, presidential instructions and government regulations. The most important are:

- Presidential Instruction No. 1 (1969), on the management of irrigation water and maintenance of irrigation networks;
- law on water resources development No. 11 (1974);
- government regulations on:
  beneficiaries contribution for maintenance cost of water resources facilities No. 6 (1981),
  water management No. 6 (1982),
  irrigation, No. 23 (1982),
  rivers (1991) and swamps (1991);
- decree of the Minister of Mining and Energy concerning underground water resources management (1983).

Numerous institutions are presently involved in water resources management. Their tasks and responsibilities are clearly stated in national legislation:

- The Ministry of Public Works, with its Directorate General of Water Resources Development, is responsible for planning, design, construction, equipment, O&M, and guidance in water resources development.
- The Ministry of Forestry is responsible for catchment area development.
- The Ministry of Environment is responsible for environmental quality development and management.
- The Environmental Impact Management Agency is responsible for environmental impact control.

TRENDS IN WATER MANAGEMENT

The Ministry of Public Works through its Directorate General of Water Resources Development (DGWRD) has identified four main missions in water resources sector programming as part of Repelita VI (1994-999). They are:

- Maintenance of self-sufficiency in rice production to achieve long-term food security. Although Indonesia achieved self-sufficiency in rice production in 1984, demographic growth, land use changes, variations in rainfall, climatic changes, drought, flooding, drainage problems in low-lying areas and urbanization have resulted in rice shortages requiring the importing of rice and the building up of costly rice buffer stocks. The DGWRD directs its programming towards activities which support the continued increase in rice production to maintain self-sufficiency.

- Provision of water to meet increasing water supply demands. Rapid industrialization, increasing urbanization and the need to supply the nation's population with safe drinking water have necessitated the development and maintenance of adequate water sources and supplies of proper quality water in many regions of the country. Often, the water needs are at locations far away from good quality water sources, so requiring large capital investments for conveyance infrastructures. The water sources are continuously subjected to water quality degradation due to urban, industrial and upper watershed pollution. The DGWRD directs its programming to develop sources of good quality water and supply to demand centres to meet the needs for water supply.
- Flood alleviation and river management. Many of Indonesia's agricultural and urban areas are located in the lowlands. The majority of rivers flood frequently due to the high intensity rainfall in the watersheds and influx of sediment, particularly in lowland areas. In addition, the river morphology and carrying capacities are continuously changing due to sediment problems, large variations in flow, and human encroachment. To protect investment and economic activity as well as to ensure the availability of surface water resources close to demand centres, the DGWRD direct its programming to continuously improve flood protection and drainage, through both structural and non-structural measures, and to manage water bodies such as ponds, lakes and reservoirs.
- Water resources development, conservation and management. The archipelago nature of the country, variations in rainfall, large fluctuations in river flows and lack of proper storage sites have hindered the nation's ability to meet the increasing water demands. The gradual degradation of upper watersheds, poor groundwater resources, increasing water quality problems in the lower reaches of the rivers, and the inefficient use of water require a greater focus on water resources, conservation and prevention. Thus, to ensure the continued availability of water resources, the DGWRD direct its programming towards steps to improve water resources availability through appropriate conservation and management measures.

The four missions directed by the DGWRD are being implemented through a number of major and support programmes. The water resources sector now has two major subsectors:

- water resources development, with three major programmes:
  water resources development and conservation,
  supply and management of water,
  management of rivers, lakes and other water resources;
- irrigation with, two major programmes:
  development and management of irrigation networks,
  development and management of swamp areas.

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Japan

GEOGRAPHY AND POPULATION

Japan is an archipelago that stretches 2 600 km in an arc running northeast to southwest through the North Pacific. The Sea of Japan and the East China Sea separate Japan from the Asian landmass. The archipelago lies mostly between 25° and 45°N with a total land area of 376 520 km². The five main islands, Honshu, Hokkaido, Kyushu, Shikoku and Okinawa, account for about 96 percent of the total land area though there are more than 3 300 other islands. About 70-80 percent of the country is mountainous. The mountains in the central part of Honshu are more than 3 000 m high. The Fuji mountain is the highest point at 3 776 m above sea level.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	37 780 000	ha
Cultivable area	1996	4 994 000	ha
Cultivated area	1996	4 776 000	ha
- annual crops	1996	4 384 000	ha
- permanent crops	1996	392 000	ha
Population:			
Total population	1996	125 351 000	inhabitants
Population density	1996	332	inhab/km²
Rural population	1996	22	%
Economically active population engaged in agriculture	1996	5	%
Water supply coverage:			
Total population	1994	95.5	%

In 1996, the cultivated land area was 4 776 000 ha, which is 96 percent of the total cultivable area. The cultivated land area is declining gradually as it is needed for housing or industrial uses. About 4 384 000 ha, or 92 percent of the cultivated area, consist of annual crops, of which paddy fields occupy 2 560 000 ha. Cropping intensity of this land just exceeds 100 percent. The area under permanent crops is estimated at 392 000 ha.

In 1996, the population of Japan was estimated at 125 351 000 inhabitants (22 percent rural). The average population density is 332 inhabitants/km², which makes Japan one of the most densely populated countries in the world. About 70 percent of the population is concentrated in the coastal zone extending from the capital, Tokyo, to the northern part of Kyushu island. Despite a low birth rate, it is projected that Japan's population will still be increasing at an annual rate of 0.2 percent up to 2 000, mostly as a result of increased life expectancy. However, it is expected that after 2005 the annual growth rate will be 0 percent.

In 1995, there were 2 651 000 farm households with a population of 15 084 000 inhabitants. Five out of every six households are part-time farmers who also earn income from other jobs. There are another 792 000 households owned by part-time farmers who cultivate small plots for own consumption and do not produce any surplus crops for sale. Japan's agriculture contributed approximately 2.1 percent of GDP in 1995, and provided employment for just over 5 percent of all employed persons in 1996.

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		1 728 mm/year
		652.8 km^3/year
Internal renewable water resources		430 km^3/year
Total renewable water resources	1993	430 km^3/year
Dependency ratio		0 %
Total renewable water resources per inhabitant	1996	3 430 m^3/year
Total dam capacity	1993	28 980 10^6 m^3
Water withdrawal:		
- agricultural	1992	58 600 10^6 m^3/year
- domestic	1992	17 000 10^6 m^3/year
- industrial	1992	15 800 10^6 m^3/year
Total water withdrawal		91 400 10^6 m^3/year
per inhabitant	1996	729 m^3/year
as % of total renewable water resources		21 %
Other water withdrawal		- 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater	1992	32 800 10^6 m^3/year
- treated wastewater	1993	11 370 10^6 m^3/year
- re-used treated wastewater	1993	81 10^6 m^3/year
Desalinated water	1996	40 10^6 m^3/year

CLIMATE AND WATER RESOURCES

Climate

Most parts of Japan are within the north temperate zone with four seasons a year. However, the length of the archipelago and the ocean currents along the coasts lend a wide variety of climates to Japan. Due to their proximity to the Asian landmass, the major islands of Japan are subjected to seasonal winds. These winds and the mountainous backbone divide the major landmasses into two typical climatic zones: the Pacific coast climatic zone and the Sea of Japan climatic zone, which have different seasonal distributions of precipitation. The difference in climate between the two zones is caused by the summer monsoon, which blows from the Pacific Ocean bringing warmer temperatures and rain, and the winter monsoon from the Asian landmass, which brings freezing temperatures and heavy snowfalls to areas on the Sea of Japan side. Thus, the weather on the Pacific Ocean side of Japan is warm and humid in summer (June-August), while it is dry and windy in winter (December-February). The regions facing the Sea of Japan receive a lot of precipitation in the form of snow from December to February.

The mountainous topography of the interior also forms special weather pockets in the Inland Sea and the central highlands. The former is characterized by the lowest amount of precipitation, and the latter by extremely variable weather throughout the year. Japan is often struck by typhoons during the year, some of which bring a huge amount of rainfall in August and September. The rainy season lasts from June to mid-July. The mean annual precipitation is 1 728 mm, ranging from 800 mm in the north of Hokkaido island to 3 600 mm in the south of the country. Though Japan would appear to have plentiful water resources, it is so densely populated that the annual amount of rainwater per caput is only 3 430 m^3. Moreover, this amount varies significantly with area and time.

River basin and water resources

In Japan, there are more than 2 700 river basins. Among them, 109 rivers are designated as being managed by the central government in principle because of their major importance to the economy and to the protection of the environment. The catchment area of these Class A rivers covers about 239 900 km^2. Class B rivers consist of the other rivers which are managed at lower level.

Only ten rivers exceed 200 km in length. The longest, the Shinano River, winds through the Nagano and Niigata prefectures of Honshu island and empties into the Sea of Japan. It is 367 km long and has a specific runoff of 1.389 $m^3/s/km^2$. Average surface water resources are estimated at 420 km^3/year.

There are 247 freshwater aquifers underlying a total area of 69 130 km^2. The renewable potential of groundwater resources is estimated at about 27 km^3/year, though because of the steep slopes, a significant part (estimated at 17 km^3/year) probably returns to the river system. Where land subsidence, saline intrusion and excessive lowering of the water table have occurred, groundwater use has been restricted to a safe yield by applying legal regulations and ordinances to critical areas. The total annual renewable water resources are estimated at 430 km^3/year.

Lakes and dams

More than 600 lakes are scattered among the seaside districts and the volcanic zones. The major lakes in the country are:

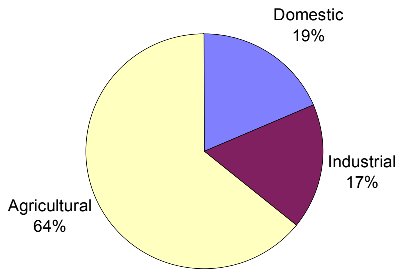
- Biwa-ko, which lies in the inland basin near Kyoto in central-west Honshu with an area of 674 km^2 and a water volume of 27.5 km^3;
- Kasumi-ga-ura, which is close to the mouth of the Tone-gawain with an area of 220 km^2 and a water volume of 0.848 km^3;
- Inawashiro-ko, which is a lake created after a volcanic eruption in northwest Honshu with an area of 104.8 km^2 and a water volume of 3.86 km^3.

The history of dams and reservoirs in Japan dates back many centuries, and a number of ancient earthen dams are still used for paddy irrigation. Since the 1920s, technological advances have led to the construction of dams and weirs with modern designs, and these have contributed mainly to irrigation development and hydropower generation. The construction of large-scale multipurpose dams including flood control began in the 1950s to meet increasing water demand for municipal and industrial use as well as irrigation. In 1993, there were 2 556 dams over 15 m high in service for water supply, hydropower generation and flood control, for a total effective storage capacity of 16.5 km^3. In addition, 587 dams under construction at that time were planned to provide 7.7 km^3. The total storage capacity of all these dams is about 29 km^3. A 1990 survey showed that another 4.8 km^3 were provided by small dams. In 1996, the installed capacity of all power plants in operation was 226 994 MW, of which 21 171 MW or 19 percent was hydropower.

Water withdrawal

In 1992, the total water withdrawal for agricultural, domestic and industrial uses was 91.4 km^3. The amount of water withdrawn for agricultural purposes in 1992 was estimated at 58.6 km^3, which represents 64 percent of the total water withdrawal (Figure 1). With the exception of 3.9 km^3 from groundwater, almost all water comes from rivers and small reservoirs in the fields. Out of 58.6 km^3, 55.9 km^3 (95.4 percent) is used for the irrigation of paddy fields, 2.2 km^3 (3.8 percent) for the irrigation of non-rice fields, and the rest for livestock farming. The amount of water withdrawn for

FIGURE 1
Water withdrawal
Total: 91.4 km^3 in 1992



industry is estimated at 15.8 km³, and that for domestic purposes at 17 km³. About 9 km³ of groundwater is annually withdrawn for industrial and public use. This amount has gradually been reduced through efforts to recycle the water used in the industrial sector.

Other sources of water include recycled sewage and industrial wastewater as well as the desalination of seawater. The amount of water involved remains small compared with river water, but it is growing gradually. The volume of treated water re-used in 1993 was 11 370 million m³. In 1995, the desalination capacity of plants was 69 500 m³/d. In addition, another project to establish a desalination plant has recently started in Okinawa prefecture with a capacity of 40 000 m³/d. A first stage of 10 000 m³/d was completed in February 1996.

Large amounts of water are also required for freshwater fish cultivation. About 8.2 km³ of water was reportedly allocated for this purpose in 1991, of which 29.5 percent was withdrawn from aquifers.

IRRIGATION AND DRAINAGE DEVELOPMENT

Rice cultivation dates back about 2 000 years, and irrigation did not lag behind. Since then, land reclamation for rice cultivation has spread as the population has grown. In the early decades of this century, several irrigation schemes were undertaken as national projects. However, it is since the 1940s that a number of irrigation projects have been extensively carried out nationwide not only by the central government but also by local governments and Land Improvement Districts (LIDs) through subsidies.

In the 1940s, irrigation projects either modernized old systems or provided new ones often associated with land reclamation for paddy. They included the construction of dams for increased water supply and of weirs to unify intakes. Later integrated with farmland consolidation projects, many projects have had the objective of reorganizing irrigation networks to facilitate water distribution and meet increased water requirements as a result of improved drainage.

With the need to adjust to a changing residential environment, the development of irrigation has tended to move to the construction of pipeline systems instead of open channels, a fact which has also led to more effective water use. Due to the overproduction of rice in the early 1970s, resulting from an increase in yields and a decrease in consumption, efforts have been made to plant non-rice crops on paddy fields such as wheat, corn, beans and vegetables. The expansion of irrigation systems to dryland crops is being carried out in various parts of the country (Figure 2).

FIGURE 2
Evolution of irrigated rice 1982-1995

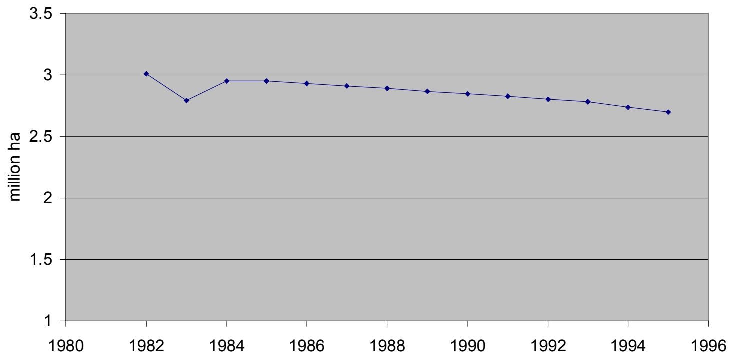


TABLE 3
Irrigation and drainage

Irrigation potential		- ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1993	3 128 079 ha
- surface irrigation	1993	2 830 079 ha
- sprinkler irrigation	1993	243 000 ha
- micro-irrigation	1993	55 000 ha
% of area irrigated from groundwater (*)	1993	16 %
% of area irrigated from surface water	1993	100 %
% of equipped area actually irrigated	1993	100 %
2. Spate irrigation	1993	0 ha
Total irrigation (1+2)	**1993**	**3 128 079 ha**
- as % of cultivated area		65 %
- power irrigated area as % of irrigated area		- %
3. Other water management area	1993	0 ha
Total water managed area (1+2+3)	**1993**	**3 128 079 ha**
- as % of cultivated area		65 %
- increase over last 10 years		- %
- power water managed area as % of water managed area		- %
Full or partial control irrigation schemes:		
Large-scale schemes (> 3 000 ha)		- ha
Medium-scale schemes (200-3 000 ha)		- ha
Small-scale schemes (< 200 ha)		- ha
Total number of households in irrigation		-
Irrigated crops:		
Total irrigated grain production	1994	18 885 490 t
as % of total grain production	1994	98 %
Harvested crops under irrigation		**- ha**
- permanent crops: total		- ha
- annual crops: total		- ha
. rice	1994	2 200 000 ha
. wheat	1994	62 700 ha
. barley	1994	52 900 ha
. pulses	1994	44 300 ha
. buckwheat	1994	10 100 ha
Drainage - environment:		
Drained area		- ha
- drained area in full or partial control irrigated areas		- ha
- drained area in equipped wetland and i.v.b.		- ha
- other drained area		- ha
- area with subsurface drains		- ha
- area with surface drains		- ha
Drained area as % of cultivated area		- %
Power drained area as % of total drained area		- %
Flood protected areas		- ha
Area salinized by irrigation		- ha
Population affected by water-borne diseases		- inhabitants

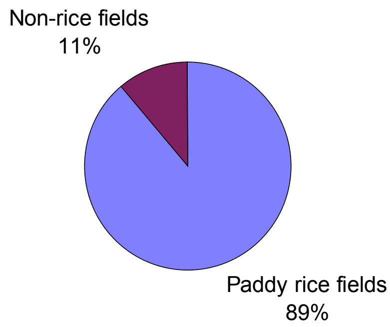
(*): Supplementary irrigation on land supplied by surface water.

In Japan, irrigation is used predominantly for rice cultivation through basin irrigation. Cultivation techniques and mechanized farming require several drainages during one cropping season. This leads to water loss in the fields. Furthermore, the percolation rate in paddy fields through vertical drainage is relatively high, so leading to poor on-farm irrigation efficiency. However, water that returns to a river is re-used by other irrigation systems downstream. Thus, densely developed and stratified irrigation systems contribute to good water use efficiency at river basin level.

In 1993, the total area of land equipped for full or partial control irrigation was estimated at 3 128 079 ha. Almost all paddy fields are irrigated, and little rainfed land remains. In addition, irrigation for non-rice fields reached 346 668 ha in 1993 (Figure 3).

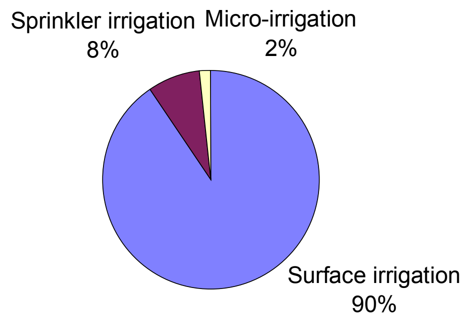
Groundwater is used mainly to satisfy supplementary irrigation water requirements during the low water season from April to September, and especially in August. The total area of land benefiting from supplementary irrigation from groundwater is estimated at 500 000 ha. More than 90 percent of it is paddy fields, the remainder being upland fields, orchards and grasslands. Irrigation facilities using groundwater are generally designed on a smaller scale than those based on surface water from streams and reservoirs.

FIGURE 3
Irrigated crops
Total: 3 128 079 ha in 1993



Most irrigation systems for paddy fields are of the gravity type though some have pumping stations to lift water from rivers or other sources. For upland fields, sprinkler irrigation is usually applied. Drip irrigation is used mainly in greenhouses (Figure 4).

FIGURE 4
Irrigation techniques
Total: 3 128 079 ha in 1993



The central government finances one-third of the cost of construction through loans to local government and beneficiaries. Projects operated by local governments and LIDs receive subsidies from the central government of 50 and 45 percent of their cost respectively. The remaining costs are usually shared by both. Users or LIDs operate and maintain the systems at their own expense including those projects completed by the central government, though there are some exceptions.

Drainage projects have been carried out successfully in flood-prone areas to protect land from excessive inundation. Farmland consolidation projects, implemented widely in the country, include the improvement of on-farm irrigation systems and of surface or subsurface drainage. The improved drainage systems also contribute to the conversion of paddy land to land suitable for non-rice cropping.

INSTITUTIONAL ENVIRONMENT

Water resources development and management in Japan are conducted by various institutions. The National Land Agency is responsible for the overall planning and coordination concerning land and water. The agency formulates water resources development plans in cooperation with other relevant governmental organizations.

The Ministry of Construction administers affairs concerning river conservation as stipulated by the River Law. It implements flood control, erosion control and river retention for Class A rivers. It is also in charge of the construction and management of multipurpose dams.

Public water services are supervised by the Ministry of Health and Welfare. Industrial water and hydropower generation are supervised by the Ministry of International Trade and Industry.

The Environment Agency is responsible for setting standards for water quality and for carrying out water pollution control.

The Ministry of Agriculture, Forestry and Fisheries is responsible for irrigation and drainage. In accordance with Japan's Basic Agricultural Law, the Ministry prepares long-term prospects for agricultural demand and production to direct its policies in each area of agriculture. The Ministry formulates a fundamental policy or long-term plan for land improvement based on the Land Improvement Law, setting specific goals every ten years and the amount of investment for farmland improvement. Individual projects stated in the plan are carried out in accordance with an agricultural and rural development programme which covers a wide range of developments such as irrigation and drainage, farmland consolidation, disaster prevention, reclamation of agricultural land, improvement of rural water supply and sewage in rural communities. Its activities include the planning and execution of national projects as stated by the rules and regulations of the Land Improvement Law, and supervising subsidized projects.

The main body responsible for the implementation of an irrigation project (which may be the central government, a prefectural government or an LID) is determined by the scale of the project defined according to the area involved. In a typical case, the central government takes responsibility where the beneficiary area is more than 3 000 ha of paddy field; the local government where more than 200 ha are involved; and LIDs for schemes of more than 20 ha. Construction projects operated by central and local government are limited to the canal sections that command at least 500 and 100 ha respectively. To complete an entire irrigation system in a project area, these three entities work together in an integrated manner in accordance with their responsibilities.

TRENDS IN WATER RESOURCES MANAGEMENT

In the current long-term plan for land improvement which began in 1993, it was decided to allocate funds of ¥41 000 000 million (US$369 000 million at the 1993 exchange rate), of which 15 percent is accounted for by irrigation and drainage, and 54 percent by farmland consolidation targeting 900 000 ha for paddy fields and 500 000 ha for dryland. The initial budget for the 1995 fiscal year was ¥2 024 000 million. To conform with the Uruguay Round Agreement in 1995, the Government has accelerated implementation of its agricultural and rural development programme to develop a strong agricultural structure and promote a production environment through efficient and stable agricultural management.

Figure 2 shows that the area of paddy fields continues to decrease due to urbanization. In addition, production control of rice will probably remain in effect for some time, a fact which might lead to a decrease in water consumption for rice cultivation. Nevertheless, the total water withdrawal cannot be expected to fall in proportion to a decrease in irrigated paddy land because much of the land converted from rice cultivation for housing or for other crops can be found relatively isolated in the middle of, or adjacent to, paddy fields, so contributing to a decrease in river basin water use efficiency. In addition, water requirements for rice tend to increase because of a prolonged irrigation period due to the increased use of planting equipment, which is able to handle only younger seedlings, and because of the introduction of improved cultivation techniques. Upland irrigation is also expected to increase steadily. It is estimated that the overall water demand by agriculture, including livestock farming, should reach 62.6 km^3 by 2000.

Public water use is increasing at a rate of around 2 percent a year as a result of improved living standards, growing domestic use and service industries. It is projected that the total amount of water withdrawal for public water will reach 20.8 km³ by 2000. In the industrial sector, especially in steel, chemical, paper and pulp plants, efforts have been made to recycle and re-use water, and a recovery rate of 76 percent was achieved in 1994. In recent years industrial water use has remained almost static. However, it is predicted that continuing economic growth will soon cause industrial water use to rise again as water recycling is approaching its limits. The estimated water withdrawal by industry will reach 22.2 km³ by 2000.

In addition to these increases, 2.3 km³ of water will need to be switched from groundwater to surface water sources, and 3.2 km³ of additional stable water supply should be provided, a volume which is not available in low water flow periods. In total, river water demand should reach 111.1 km³ by 2000. To meet the increased water demand, water resources development is planned to increase water supply by 23.4 km³ between 1983 and 2000.

In order to keep pace with increased water demand, it is necessary to accelerate the construction of dams and reservoirs which are major water resources. However, such developments are becoming increasingly difficult due to the shortage of suitable sites, environmental conservation and the problems of human resettlement. The result is prolonged construction and attendant rising costs. In addition to dam construction, the Government is promoting river basin transfers for more effective water use. Demand management also encourages rationalization of water use and the utilization of reclaimed water from sewage and industrial waste.

Apart from dam construction, the following water resources development projects can be observed:

- lake development, which is being implemented in lakes such as Biwa and Kasumigaura for the purpose of exploiting more water resources through intensive water control;
- salinization prevention barrages at estuaries, which are built in the downstream reaches of rivers to control seawater intrusion and stabilize the intake of fresh water;
- inter-basin transfers, which allow the simultaneous adjustment of excess or insufficient discharge occurring in adjacent water courses;
- subsurface dams, which catch groundwater flow for beneficial use.

Rapid urbanization and the development of industry in the 1960s resulted in severe pollution of watercourses. This reached its peak in 1971. After the introduction of appropriate measures, the quality of water has been improving in recent years. However, water does not yet meet environmental water quality standards for day-to-day living. There are still lakes and reservoirs which experience eutrophication and result in a taste and odour problem in water supply. It can be observed that not only industrial waste but also discharges from some rural communities and agricultural activities such as livestock farming contribute to the pollution.

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Democratic People's Republic of Korea

GEOGRAPHY AND POPULATION

Located on the northern part of the Korean peninsula in the far east of Asia, the Democratic People's Republic of Korea (DPR Korea) has a total area of 120 540 km². It is bounded in the north by China, in the northeast by the Russian Federation, in the east by the Sea of Japan, in the south by the Republic of Korea and in the west by the Yellow Sea and the Korea Bay. There are nine provinces and three cities under central authority, including the capital city Pyongyang.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	12 054 000	ha
Cultivable area	1994	2 410 800	ha
Cultivated area	1994	2 000 000	ha
- annual crops	1994	1 700 000	ha
- permanent crops	1994	300 000	ha
Population:			
Total population	1996	22 466 000	inhabitants
Population density	1996	186	inhab/km^2
Rural population	1996	39	%
Economically active population engaged in agriculture	1996	33	%
Water supply coverage:			
Urban population	1990	100	%
Rural population	1990	100	%

Some 80 percent of the total area of the country consists of mountains and uplands. The average height of the highlands in the northeast is 1 000 m above sea level. Based on topographic features and land use, the country can be divided into four zones:

- the northeast, where high mountain area represents 21 percent of the territory, is essentially a forest area with practically no agriculture;
- the hilly areas surrounding the high mountains in the north and the central chain of mountains (40 percent of the territory) with large areas under forest are suitable for the cultivation of scattered plots of potato, wheat, barley and vegetables. They also have some pasture land;
- the east coast (22 percent of the territory). Most of the area is sub-mountainous or hilly, but it also includes some lowlands where rice is cultivated. In addition to forest and pasture, there are slopes suitable for maize and vegetable cultivation;
- the western plains, mainly devoted to rice cultivation, represent 17 percent of the territory.

Only 20 percent of the country is cultivable, which represents 2 410 800 ha. In 1994, cultivated land amounted to 2 000 000 ha, of which about one-third was for rice and one-third for maize. In the 1980s it was estimated that DPR Korea had about 38 000 cooperative farms (kolkhoz) and 180 state farms (sovkhoz), the former cultivating more than 90 percent of the total cultivated land. However, since the mid-1990s, there has been a tendency by the Government to advocate the gradual transfer of the cooperative farms to state farms.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		1054	mm/year
		127	km^3/year
Internal renewable water resources		67	km^3/year
Total renewable water resources	1995	77.135	km^3/year
Dependency ratio		13.1	%
Total renewable water resources per inhabitant	1996	3 433	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1987	10 336.8	10^6 m^3/year
- domestic	1987	1 557.6	10^6 m^3/year
- industrial	1987	2 265.6	10^6 m^3/year
Total water withdrawal		14 160.0	10^6 m^3/year
per inhabitant	1996	630	m^3/year
as % of total renewable water resources		18.4	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

In 1996, the population was estimated at 22 466 000 inhabitants (about 39 percent rural), with a growth rate of about 1.9 percent. The average population density is 186 inhabitants/km², ranging from 44 inhabitants/km² in Ryanggang province to 1 177 inhabitants/km² in Pyongyang. The contribution of agriculture (including fishing and forestry) to GNP was estimated at 27 percent in 1990, which was lower than in the 1980s as a result of the industrialization of the country. About 33 percent of the economically active population was engaged in agriculture in 1996.

CLIMATE AND WATER RESOURCES

Climate

The country has a continental climate with four distinct seasons. Long winters bring cold clear weather interspersed with snow storms as a result of north and northwest winds from Siberia with temperatures ranging from –20 to –40°C. The average snowfall is 37 days during the winter. The weather is harsh in the northern mountainous regions. Spring and autumn are marked by mild temperatures and variable winds. Summer tends to be short, hot, humid and rainy because of the south and southeast monsoon winds that bring moist air from the Pacific Ocean. The average summer temperature is 25°C.

The average annual precipitation is 1 054 mm, ranging from 810 to 1 520 mm. About 60 percent of all precipitation occurs between June and September.

Water resources

Most of the rivers run west to the Yellow Sea (Korea Bay). They rise in the mountain ranges of the north and east of the country. There are five river basin groups:

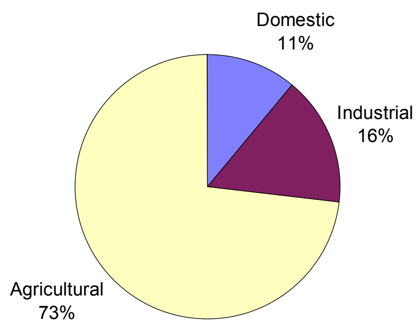
- the Yalu River basin, which flows southwest from the Changbai mountain range to the Korea Bay. The Yalu River forms the border with China;
- the Tumen River basin, which flows east from the Changbai mountain range to the Sea of Japan. The Tumen River forms the border with China and further downstream with the Russian Federation;

- the Taedong River basin is internal and is the largest one within the country. The Taedong River flows west to the Korea Bay near Pyongyang;
- the west coast river basin, which comprises many small streams rising in the northern and eastern mountain ranges,
- the east coast river basin.

The internal renewable surface water resources are estimated at 66 km³/year. By analogy with the Republic of Korea (approximately the same area and precipitation), groundwater resources are estimated at 13 km³/year, most of which (12 km³/year) constitute the base flow of the rivers. The internal renewable water resources are therefore estimated at 67 km³/year.

As the Yalu and Tumen rivers form the border with China, half of the average discharge of these rivers (10.135 km³/year) is, by convention, considered as external resources of DPR Korea. The total renewable water resources of DPR Korea are therefore estimated at 77.1 km³/year.

FIGURE 1
Water withdrawal
Total: 14.16 km³ in 1987



Lakes and dams

The West Sea Barrage involving an 8-km dam across the Taedong River was completed in June 1986. It consists of a main dam, 3 locks and 36 sluices, and is believed to be the longest dam in the world. Another major dam has been built on the Yalu River.

About 60 percent of electricity generation is provided by hydropower, with an installed hydropower capacity in operation estimated at 5 000 MW.

Water withdrawal

The total water withdrawal was estimated at about 14.16 km³/year in 1987, of which 73 percent for agriculture (Figure 1).

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation development in DPR Korea has always been a major objective in the agriculture sector. In 1976, as a way of increasing the arable land area, the authorities launched a 'nature re-making programme' with the following objectives:

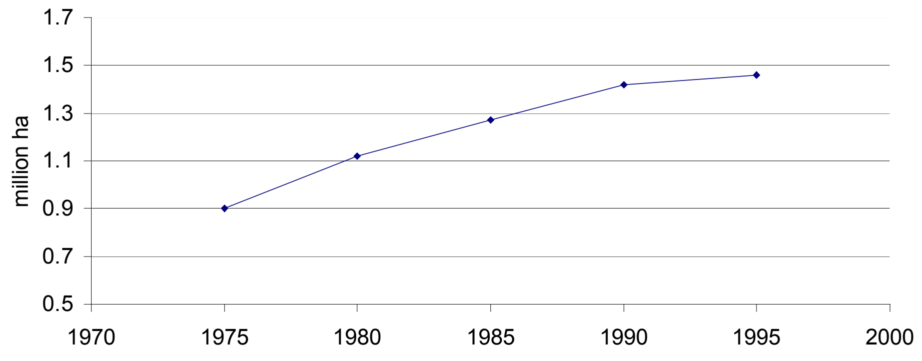
- to complete the irrigation of non-paddy lands;
- to reclaim 100 000 ha of new land;
- to build 150 000-200 000 ha of terraced fields;
- to reclaim tidal land;
- to conduct work on forestation and water conservation projects.

The 1987-93 plan target was to reclaim some 300 000 ha of tidal land. In 1989, a project was initiated to build a 400-km-long canal by diverting the flow of the Taedong River along the west coast. As part of the irrigation system, the canal would provide water to rural areas and newly reclaimed tidal land in South Hwanghae and South Pyongan provinces.

TABLE 3
Irrigation and drainage

Irrigation potential		- ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1995	1 460 000 ha
- surface irrigation		- ha
- sprinkler irrigation		- ha
- micro-irrigation		- ha
% of area irrigated from groundwater	1990	14 %
% of area irrigated from surface water	1990	86 %
% of equipped area actually irrigated		- %
2. Spate irrigation		- ha
Total irrigation (1+2)	**1995**	**1 460 000 ha**
- as % of cultivated area		73 %
- power irrigated area as % of irrigated area		- %
3. Other water management area		- ha
Total water managed area (1+2+3)	**1995**	**1 460 000 ha**
- as % of cultivated area		73 %
- increase over last 10 years	1995	15 %
- power water managed area as % of water managed area		- %
Full or partial control irrigation schemes:		
Large-scale schemes		- ha
Medium-scale schemes		- ha
Small-scale schemes		- ha
Total number of households in irrigation		
Irrigated crops:		
Total irrigated grain production		- t
as % of total grain production		- %
Harvested crops under irrigation		**- ha**
- permanent crops: total		- ha
- annual crops: total		- ha
Drainage - environment:		
Drained area		- ha
- drained area in full or partial control irrigated areas		- ha
- drained area in equipped wetland and i.v.b.		- ha
- other drained area		- ha
- area with subsurface drains		- ha
- area with surface drains		- ha
Drained area as % of cultivated area		- %
Power drained area as % of total drained area		- %
Flood protected areas		- ha
Area salinized by irrigation		- ha
Population affected by water-borne diseases		- inhabitants

FIGURE 2
Growth of irrigation areas since 1975

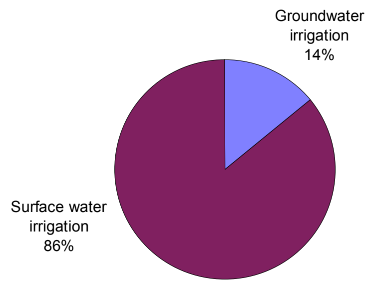


By late 1990, a total of 800 km of large and small irrigation waterways had been completed. In December 1995, the Kangryong Waterway (40 km) was the latest to be constructed. In early 1994, there were about 40 000 km of irrigation waterways together with 1 770 reservoirs and 26 000 pumping stations for irrigation purposes (Figure 2).

In 1990, about 200 000 ha were irrigated from groundwater resources (Figure 3). In 1995, the total land area under irrigation was estimated at 73 percent of the cultivated area (about 1.46 million ha). The irrigated land includes plains, terraced fields and tidal land. About 46 percent of this area consists of paddy fields.

Although no figures are available, the main irrigation technique is surface irrigation, while sprinkler and micro-irrigation were introduced on non-paddy fields in the late 1980s.

FIGURE 3
Irrigated area by source of water
Total: 1.42 million ha in 1990



INSTITUTIONAL ENVIRONMENT

At national level, the agriculture sector is directed by the Agriculture Commission. The Agriculture Commission is in charge of the planning, management and technical direction of production.

The Department of Irrigation and Drainage, within the Agricultural Commission, has the tasks of providing technical assistance to farmers and of developing irrigation techniques. At provincial level, the Agricultural Commission is represented by the Provincial Rural Economy Committee (PREC). The PREC is directly responsible for the production and management of the state farms and supervises agricultural production through District/County Cooperative Farm Management Committees (CCFMCs). The country has over 200 districts and counties where the CCFMCs are entrusted with the planning, production and management of cooperative farms. The CCFMCs also directly supervise state enterprises concerned with agricultural production (i.e. farm machinery and implement factories, tractor stations and irrigation offices).

TRENDS IN WATER RESOURCES MANAGEMENT

The Government has adopted two strategies to meet its future cereal requirements:

- to increase production by using HYVs, and through more efficient, environmentally sound soil and crop management practices;
- to increase the area of cultivated land by reclaiming tidal lands.

In view of the shortage of arable land and the loss of land through natural disasters such as those caused by the 1995 floods, DPR Korea has undertaken rehabilitation work, as the following data provided by the Agricultural Commission indicate:

Rehabilitation works undertaken after 1995 floods

Facilities	Damaged	Recovered	In need of recovery
Reservoirs	102	54	48
Pumping stations	2 804	2 711	93
Embankments	6 528 km	2 569 km	3 959 km
Irrigation canals (inside plots)	1 974 km	1 974 km	-
Irrigation structures (dikes, flood gates, etc.)	3 760	2 653	1 107

According to an FAO report, the agriculture sector faces the following challenges and constraints:

- shortage of arable land and increasing cost of land reclamation;
- massive rise and fall of river/lake levels caused by heavy rainfalls and drought at critical points in the crop cycle.

Strategic options aiming at achieving sustainable food security by improving agricultural production systems could be based on:

- reconstructing flood-stricken areas;
- developing hilly mountainous land and reclaiming tidal land;
- modernizing irrigation systems through increased more investment;
- improving anti-flood forestation.

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Republic of Korea

GEOGRAPHY AND POPULATION

The Republic of Korea is located in the semi-tropical area along the east coast of the Asian landmass. It is bounded by DPR Korea in the north, the Sea of Japan in the east, the Yellow Sea in the west, and is separated from Japan by the Korea Strait to the south and southeast. For administrative purposes, the country is divided into one metropolitan city (the capital Seoul), five extensive cities and nine provinces.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1996	9 926 000	ha
Cultivable area		-	ha
Cultivated area	1996	1 945 480	ha
- annual crops	1996	1 747 037	ha
- permanent crops	1996	198 443	ha
Population:			
Total population	1996	45 314 920	inhabitants
Population density	1996	457	inhab/km^2
Rural population	1996	17	%
Economically active population engaged in agriculture	1996	11	%
Water supply coverage:			
Urban population	1996	95	%
Rural population	1996	37	%

The country has a total land area of 98 730 km², which represents about 45 percent of the Korean peninsula. Some 65 percent of the land is mountainous, especially along the east coast with the highest point (Halla-san) at 1 950 m above sea level. The main mountains are the Taebaek range, which cross the country from north to south with their highest point at Mount Sorak (1 708 m), and the Sobaek range running from the southwest to the northeast, whose highest point is Chiri mountain (1 915 m). The plains are located mainly along the west and south coasts.

The cultivable area is relatively small and is largely spread along the southwest coast. Most of the cultivable area in the country has been reclaimed and is intensively cultivated. In 1996, about 1 176 000 ha, or 60 percent of the cultivated area, were cultivated, mainly with rice. About 10 percent of the cultivated area, or 198 443 ha, was occupied by permanent crops.

In 1996, the total population was estimated at 45 314 000 inhabitants. Due to the rapid industrialization of the country, the agricultural population decreased from 68 percent of the total in 1965 to 17 percent in 1996. The average population density is 457 inhabitants/km². The highest population density is 17 289 inhabitants/km² in Seoul and the lowest density is 284 inhabitants/km² in Cheju province. The annual population growth rate was 1 percent in 1996.

The agriculture, forestry and fisheries sectors produced 17 583 000 million won or about 6.5 percent of GNP in 1996 at the 1990 constant price (the average currency exchange rate of the Korean won to one US dollar in 1990 was 707.8), a much reduced contribution from the almost 40 percent of 1965. An average farm family earned an annual income 23 298 000 won in 1996, of which non-agricultural earnings constituted 32.1 percent. In 1996, 11 percent of the employed population was engaged in agriculture.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		1 274	mm/year
		127	km^3/year
Internal renewable water resources		64.85	km^3/year
Total renewable water resources	1994	69.7	km^3/year
Dependency ratio		7.0	%
Total renewable water resources per inhabitant	1996	1 538	m^3/year
Total dam capacity	1994	16 200	10^6 m^3
Water withdrawal:			
- agricultural	1994	14 877	10^6 m^3/year
- domestic	1994	6 209	10^6 m^3/year
- industrial	1994	2 582	10^6 m^3/year
Total water withdrawal		23 668	10^6 m^3/year
per inhabitant	1996	522	m^3/year
as % of total renewable water resources		34	%
Other water withdrawal	1994	6 476	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater	1996	7 947	10^6 m^3/year
- treated wastewater	1996	4 180	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

CLIMATE AND WATER RESOURCES

Climate

The country's climate is determined by its latitude and geography, and presents four distinct seasons. Wind and precipitation are largely affected by the surrounding Pacific Ocean in the south and the Eurasian landmass in the north.

The mean annual rainfall is 1 274 mm, of which about 70 percent is concentrated during the summer months from June to September. The rainfall is evenly distributed over the country. The average annual precipitation is 1 300 mm in Seoul in the north, 1 100 mm in Taegu in the centre, and 1 400 mm in Pusan in the south. Typhoons accompanied by heavy rainfalls during summer or early autumn often cause severe crop damage, as do the droughts before the beginning of the summer monsoon.

The mean monthly temperature varies from below freezing in winter to over 25°C in summer. Frost-free days extend from around the end of April until mid-October, varying from 175 days a year in the north to 220 days in the south. Double cropping is practised in the south.

River basins and water resources

Most of the rivers flow west and south through the plains. There are five main drainage systems, which altogether cover two-thirds of the territory:

- the Han River basin in the northwest, with an average runoff estimated at 19.4 km^3/year and a drainage area of 26 018 km^2;
- the Kuem River basin in the west, with an average runoff estimated at 6.2 km^3/year and a drainage area of 9 810 km^2;
- the Nag Dong River basin in the south, with an average runoff estimated at 13.9 km^3/year and a drainage area of 23 817 km^2;
- the Seom Jin River basin in the south, with an average runoff estimated at 3.8 km^3/year and a drainage area of 4 897 km^2;

- the Young San River basin in the south, with an average runoff estimated at 2.6 km³/year and a drainage area of 3 371 km².

The total annual volume of surface runoff produced internally is estimated at 62.25 km³, while internal groundwater resources amount to approximately 13.3 km³. About 10.7 km³ of groundwater resources constitute the base flow of the rivers. Some transboundary rivers cross the border with DPR Korea. By analogy with the annual discharge of the Han River in DPR Korea (19.4 km³/year with a catchment basin four times that of the basin flow into the Republic of Korea), the inflow to the Republic of Korea from DPR Korea is estimated at 4.85 km³/year. The total average surface water discharge in the Republic of Korea is therefore estimated at 67.1 km³/year. Due to the intensive nature of the rainfall and the steeper natural channel slopes, about 37 percent of the annual water resources are flood runoffs, concentrated in summer. Out of the 64.5 km³ of river runoff, 47 km³ run off in flooding time. The total renewable water resources are estimated at 69.7 km³/year

Lakes and dams

During the last 50 years, a considerable effort has been made to regulate the course of rivers. Multipurpose river basin schemes have been developed for flood control, irrigation, community water supply and hydropower production. In 1997, there were 765 dams of over 15 m in height. There are more than 18 000 small irrigation reservoirs. Man-made lakes account for 93 percent of all lakes in the Republic of Korea. The water storage for dams and reservoirs totals 16.2 km³.

In 1997, the total hydropower electricity generation amounted to 5 404 GWh, representing 2.4 percent of the country's total electricity generation.

Non-conventional water sources

In 1996, total produced wastewater was estimated at 7 947 million m³. Only 4 180 million m³ were treated. A desalination plant has recently been installed at a steel-milling factory in the southeast. However, this has not been included in the water balance as its capacity is insignificant.

Water withdrawal

In 1994, the total water withdrawal for agricultural, industrial and domestic uses was estimated at 23.7 km³/year (23.4 km³/year in 1975) (Figure 1). In addition, about 6 476 million m³ were withdrawn for river maintenance uses.

Rapid industrialization and economic growth have changed the pattern of water demand. Domestic and industrial water consumption increased steadily from 10 percent and almost 0 percent in 1975 to 26 and 11 percent respectively in 1994, while agricultural water consumption decreased from 90 to 63 percent in the same period.

FIGURE 1
Water withdrawal
TOTAL: 23.67 km³ in 1994

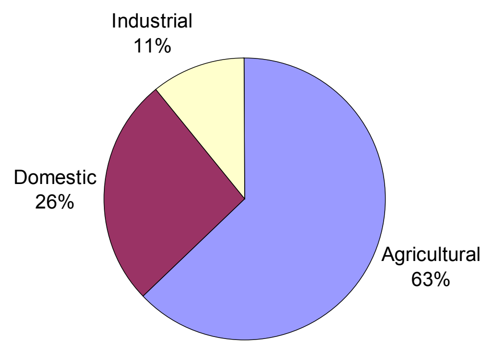


TABLE 3
Irrigation and drainage

Irrigation potential	1996	1 945 480	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1996	888 795	ha
- surface irrigation	1996	888 795	ha
- sprinkler irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater	1996	5	%
% of area irrigated from surface water	1996	95	%
% of equipped area actually irrigated		-	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1996**	**888 795**	**ha**
- as % of cultivated area		46	%
- power irrigated area as % of irrigated area	1996	18	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1996**	**888 795**	**ha**
- as % of cultivated area		46	%
- increase over last 10 years	1996	-9	%
- power water managed area as % of water managed area	1996	18	%
Full or partial control irrigation schemes:			
Large-scale schemes (> 3 000 ha)	1996	156 946	ha
Medium-scale schemes	1996	369 626	ha
Small-scale schemes (< 50 ha)	1996	362 223	ha
Total number of households in irrigation	1996	678 469	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation	**1996**	**888 795**	**ha**
- permanent crops: total	1996	0	ha
- annual crops: total	1996	888 795	ha
. rice	1996	888 795	ha
. wheat		-	ha
. barley		-	ha
. vegetables		-	ha
. other		-	ha
Drainage - environment:			
Drained area	1996	1 039 137	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains	1996	1 500	ha
- area with surface drains	1996	1 037 637	ha
Drained area as % of cultivated area		53	%
Power drained area as % of total drained area	1995	5.3	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

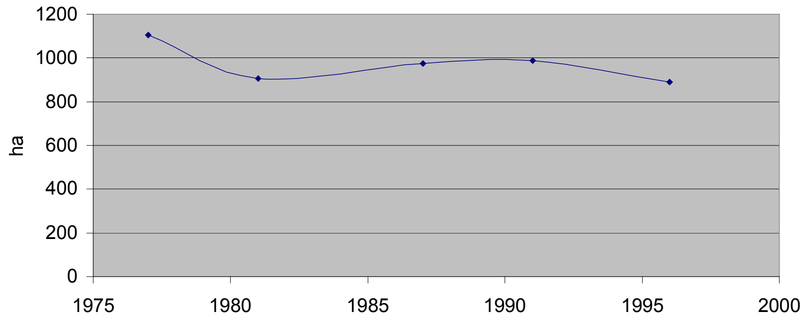
IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation development in Korea has a long history. Weirs (headworks) were built in the first century, and the first reservoirs were constructed in 390 AD. Historical records show that there were about 26 000 diversion weirs, ponds and dikes for irrigation water supply in 1910.

Irrigation development in Korea (Figure 2) can be divided into three stages:

- stage I, before 1945, when numerous small-scale systems were constructed by mobilizing local technology;
- stage II, 1946-1961, when existing systems damaged by war were repaired;
- stage III, since 1961, when large-scale comprehensive agricultural development projects have been implemented. During this stage, the Government has invested large amounts from international loans for the development and rehabilitation of irrigation systems and for the improvement of technical, institutional and social aspects of irrigation.

FIGURE 2
Evolution of irrigation areas since 1977



In 1982, the estimation of water requirements for irrigation was adjusted to cover the ten-year drought frequency, and an inventory of existing irrigation systems throughout the country was prepared to identify rehabilitation requirements. As a result, many systems with insufficient capacities were categorized for rehabilitation.

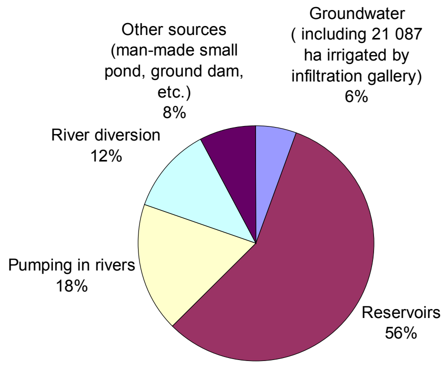
In 1996, approximately 76 percent of all paddy was under irrigation. The main irrigated crop is paddy rice. The potential irrigable area has been taken same as the same as the total cultivated area, or 1 945 480 ha.

Installed irrigation systems cover approximately half of the cultivated area. However, most of the cultivated areas are irrigated by virtually any means during the critical crop periods when threatened by drought. Typically, in high valleys where irrigation systems are not economically viable, farmers irrigate by pumping water from rivers, streams and reservoirs using small portable pumps or power tillers.

As fertile paddies can be more easily and economically developed in flat plains than hilly areas, more farmland and consequently the accompanying irrigation systems have been developed by reclaiming river plains and tidelands. This also partly explains why surface drainage predominates. It is difficult to find a large and shallow river-swamp left idle in Korea. Irrigation development along the west coast is often implemented as part of tideland reclamation.

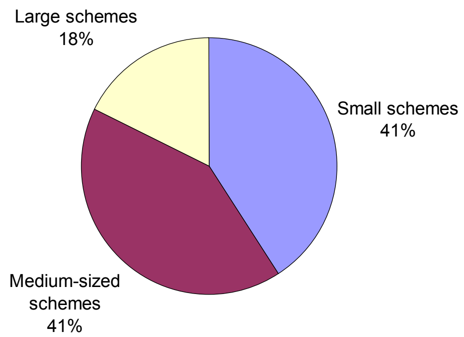
The main type of intake system is the reservoir. Reservoirs are used to store concentrated runoff during summer. Out of the total area of irrigated paddy of 888 795 ha, the area served by surface water is 770 917 ha, which consists of about 504 987 ha fed by 18 000 reservoirs, 159 987 ha by 6 000 pumping stations, and 105 943 ha by 18 000 headworks. The area irrigated by groundwater is 49 639 ha, using 15 156 tube-wells and 3 921 infiltration galleries (Figure 3).

FIGURE 3
Irrigation by source of water
TOTAL: 888 795 ha in 1996



Irrigation systems are classed as small (<50 ha), medium (51-3 000 ha) or large (>3 000 ha) (Figure 4). Using local government budgets, small systems are constructed by the cities or counties, and handed over to farmers' organizations for O&M. Medium-scale systems are funded from the central government's budget, constructed by the provinces, and handed over for O&M to Farmland Improvement Associations (FLIAs). Large systems are financed by the central government, executed by the Rural Development Corporation (RDC), and also handed over to FLIAs for O&M. There are some privately developed and owned irrigation systems, but no data on their area are available.

FIGURE 4
Irrigation schemes
TOTAL: 888 795 ha in 1996



In any system, the full cost of construction is paid for by the Government. The farmers still provide labour for the final land levelling of paddies to avoid possible dissatisfaction or disputes over quality control. The cost of land acquisition is always paid for by the Government, and the farmers pay more than 6 000 won (US$7.72) per 0.1 ha of paddy as an annual fee.

The cost of irrigation development has increased sharply in recent years. This has largely been due to rising labour costs and land prices. The cost of developing conveyance systems down to secondary canals was approximately US$5 000/ha of irrigated area in 1989.

The major irrigated crops are paddy rice, vegetables and fruits. Winter barley is mostly sown on paddies after the rice harvest in autumn, and grown without irrigation during the winter with residual soil moisture until spring. Wheat and maize are seldom cultivated on irrigated paddy for economic reasons. The average yield of irrigated rice was 6.8 t/ha for single cultivation in 1996. The yields of other crops (partly irrigated) were 3.9 t/ha for wheat, 4.3 t/ha for winter barley and 4.0 t/ha for maize.

INSTITUTIONAL ENVIRONMENT

The main institutions involved in irrigation and drainage include the Ministry of Agriculture, Forestry and Fisheries (MAFF), the RDC, the Federation of Farmland Improvement Association (FFIA), the FLIAs and the WUAs.

The MAFF, through the Rural Development Bureau (RDB), is responsible for policy, planning and financing of all rural infrastructure projects, and for the supervision of local government institutions, the RDC, the FFIA, the FLIAs and the WUAs.

The RDC is a semi-autonomous agency which carries out the planning, study, design, and supervision of the rural infrastructure projects in the country and overseas; the execution of large-scale agricultural development projects; the O&M of the important facilities of large-scale agricultural development projects; and the provision of O&M training courses for FLIA staff as well as engineering and administrative training courses for its own staff.

The FFIA is a public corporation which mainly carries out the planning, design, and supervision of the farmland improvement projects for farmland consolidation as well as providing guidance on the operational improvement of FLIAs.

There are 105 FLIAs in the country which are responsible for the O&M of public irrigation systems.

WUAs are organized by the farmers for the O&M of small irrigation systems which are not included in FLIA systems. The small systems are constructed and/or rehabilitated by the Government through the cities or the counties before being transferred to WUAs.

TRENDS IN WATER RESOURCES MANAGEMENT

Agricultural consumption of water is generally decreasing, while domestic and industrial consumption are increasing. However, peak irrigation water requirements are tending to increase because the extensive use of rice-transplanting machines has led to a reduced duration of the transplanting period in spring. Due to urbanization and industrialization, water consumption in and near cities and industrial sites is growing more rapidly. Water quality is deteriorating rapidly in the natural channels and reservoirs.

As the remaining development options become increasingly expensive, emphasis is being placed on the efficient use of water resources and on the rehabilitation and upgrading of existing systems. The need to save water resources and contain rising labour costs the installation of automatic control systems more feasible.

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Lao People's Democratic Republic

GEOGRAPHY AND POPULATION

The Lao People's Democratic Republic (Lao PDR) is a landlocked country in the Indochina peninsula with a total area of 236 800 km^2. The country stretches more than 1 700 km along a north-south axis. Some 80 percent of the country's area consists of hills and mountains. The highest point is the Phu Bia at 2 820 m above sea level. Administratively, Lao PDR is divided into 17 provinces plus the municipality of the capital, Vientiane.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	23 680 000	ha
Cultivable area	1995	2 000 000	ha
Cultivated area	1994	719 410	ha
- annual crops	1994	674 410	ha
- permanent crops	1994	45000	ha
Population:			
Total population	1996	5 035 000	inhabitants
Population density	1996	21	inhab/km^2
Rural population	1996	78	%
Economically active population engaged in agriculture	1996	77	%
Water supply coverage:			
Urban population	1995	60	%
Rural population	1995	49.4	%

The cultivable area is estimated at 2 million ha, consisting of narrow valleys and the flood-prone plain of the Mekong River and its tributaries. The cultivated land area fluctuates between 650 000 and 750 000 ha (720 000 ha in 1994, of which 600 000 ha of rice cultivated during the wet season). In 1984, about 23 percent of the cultivated area was managed by cooperatives. However, following the New Economic Mechanism implemented in 1986, the cooperatives were dissolved, and all the cultivated area is now privately managed.

The total population was estimated at 5.04 million inhabitants in 1996 (78 percent rural), with an annual growth rate of 2.6 percent. The average population density is 21 inhabitants/km^2, which is one of the lowest rates in southeast Asia. It ranges from 8 inhabitants/km^2 in the southern provinces of Attapeu and Sekong near the Vietnamese border up to 30 inhabitants/km^2 in Savannakhet or Champasack provinces, and 150 inhabitants/km^2 in Vientiane municipality.

The agriculture sector accounted for 56 percent of GDP in 1994, and employed nearly 85 percent of the work force. Agriculture's contribution to export earnings is officially recorded at 40 percent (mainly timber and wood products, and coffee) but rises to 55 percent if unofficial exports of livestock and logs are included. Hydroelectricity sold to Thailand represented 60 percent of total export earnings in 1990.

CLIMATE AND WATER RESOURCES

Climate

Climate is typically tropical with a rainy season from mid-April to mid-October dominated by the humid southwest monsoon. The average rainfall is 1 600 mm but ranges from 1 300 mm in the

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		1 600 mm/year
		379 km^3/year
Internal renewable water resources		190.42 km^3/year
Total renewable water resources	1995	333.55 km^3/year
Dependency ratio		42.9 %
Total renewable water resources per inhabitant	1996	66 181 m^3/year
Total dam capacity	1995	7 300 10^6 m^3
Water withdrawal:		
- agricultural	1987	812 10^6 m^3/year
- domestic	1987	79 10^6 m^3/year
- industrial	1987	99 10^6 m^3/year
Total water withdrawal		990 10^6 m^3/year
per inhabitant	1996	196 m^3/year
as % of total renewable water resources		0.30 %
Other water withdrawal		- 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater	1995	0 10^6 m^3/year
- treated wastewater	1995	0 10^6 m^3/year
- re-used treated wastewater	1995	0 10^6 m^3/year

northern valleys to over 3 700 mm at high elevations in the south. About 75 percent of the rainfall occurs during the rainy season. The water level in the Mekong River may fluctuate by up to 20 m between wet and dry seasons.

River basins and international rivers

The Mekong River is the main river in Lao PDR. Forming the border with Thailand, in Lao PDR it flows for about 1 860 km, of which almost every part is navigable. The Mekong River basin covers 90 percent of the total area of the country. About 25 percent of the Mekong River basin is located in Lao PDR, which contributes 35 percent of the Mekong's total flow. The main tributaries of the Mekong River in Lao PDR are, from north to south, the Nam Où (11 percent of the area of the country), Nam Ngun (6 percent), Nam Theun (7 percent), Xe Banghieng (9 percent) and Xe Kong (10 percent). The Lao part of the Mekong River basin is divided into 32 sub-basins for planning purposes.

Lao PDR has been a member of the Mekong River Commission since its inception in 1957. A new agreement was signed in April 1995 between the four riparian countries of the lower Mekong, regarding all aspects of Mekong River basin development (navigation, irrigation, hydropower, flood control, fisheries, timber floating, recreation and tourism).

In addition to the Mekong, six small river basins drain from Lao PDR towards Viet Nam: the Tale, Nam Ma, Nam Mat and Nam Xa rivers, and two others, the Nam Luang and Nam Mô, meet in Viet Nam before reaching the sea.

Water resources

A significant part of the water resources of Lao PDR come from neighbouring countries, namely 73.63 km^3/year from China and 17.6 km^3/year from Myanmar while the outflow from Lao PDR to other countries consists mainly of the Mekong River to Cambodia (324.45 km^3/year at Paksé) and small rivers, the Ca and Ma rivers (9.1 km^3/year), to Viet Nam.

The internal surface water resources have been estimated as the difference between the outflow and the inflow to the country, i.e. 190.42 km^3/year, while groundwater resources are roughly estimated at 38 km^3/year, most forming the base flow of the rivers. The total renewable water resources are therefore estimated at 333.5 km^3/year.

Dams and hydropower

Lao PDR has great potential for hydropower development. Considering only the tributaries of the Mekong River, 18 000 MW could be generated according to recent estimations. The largest hydropower plant, Nam Ngun located north of Vientiane, has a total capacity of 150 MW and a storage capacity of 7.01 km^3. Two other dams in the south (Xeset and Selabam) have a total storage capacity of 0.3 km^3 and can generate 50 MW. Hydropower accounts for 95 percent of electricity generation in Lao PDR.

Two dams are under construction, mainly for power production. In 1998, the two projects (Nam Theun Hinboun in central Lao PDR and Houay Ho in the south) will have an installed capacity of 210 and 143 MW and a storage capacity of 0.02 and 0.52 km^3 respectively. The Government has also launched feasibility studies for 21 other hydropower projects throughout the country. All these projects are located on tributaries of the Mekong River. Projects on the main stream have been planned for many years (more than 40 years in the case of the Pa Mong dam) but have not yet been implemented. The installed capacity will greatly exceed local demand and is mainly destined for export to neighbouring countries.

Water withdrawal

The total water withdrawal was estimated at 0.99 km^3 in 1987, of which 82 percent for agricultural purposes (Figure 1). There is no wastewater treatment in Lao PDR.

FIGURE 1
Water withdrawal
TOTAL: 990 million m3 in 1987

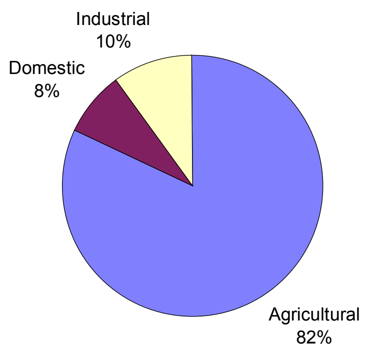
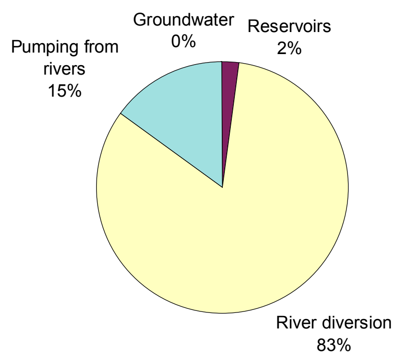


FIGURE 2
Origin of irrigation water
TOTAL: 155 394 ha in 1995



IRRIGATION AND DRAINAGE DEVELOPMENT

A rough estimate of the irrigation potential for Lao PDR is 600 000 ha.

The total area equipped for irrigation was estimated at 155 394 ha in 1995. This area covers 123 917 ha designed for supplementary irrigation during the wet season and 31 477 ha designed for dry season irrigation and also used for supplementary irrigation during the wet season. While wet season irrigation is common throughout the country, dry season irrigation is mainly concentrated near the major cities: Vientiane (59 percent of total dry season irrigated areas), Savannakhet (11 percent) and Luang Prabang (6 percent). Although irrigation by groundwater is considered as a possible form of irrigation development, it does not exceed 100 ha at present. River diversion is the main source of water for irrigated schemes, particularly the smaller ones (Figure 2). All areas are irrigated by surface irrigation; sprinkler and micro-irrigation are not used in Lao PDR.

TABLE 3
Irrigation and drainage

Irrigation potential	1995	600 000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1995	155 394	ha
- surface irrigation	1995	155 394	ha
- sprinkler irrigation	1995	0	ha
- micro-irrigation	1995	0	ha
% of area irrigated from groundwater	1995	0	%
% of area irrigated from surface water	1995	100	%
% of equipped area actually irrigated	1995	96	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1995**	**155 394**	**ha**
- as % of cultivated area		21.6	%
- power irrigated area as % of irrigated area	1995	15.1	%
3. Other water management area	1995	231 500	ha
Total water managed area (1+2+3)	**1995**	**386 894**	**ha**
- as % of cultivated area		53.8	%
- increase over last 10 years		-	%
- power water managed area as % of water managed area	1995	6.1	%
Full or partial control irrigation schemes:			
Large-scale schemes		-	ha
Medium-scale schemes		-	ha
Small-scale schemes		-	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation	**1994**	**162 692**	**ha**
- permanent crops: total	1994	0	ha
- annual crops: total	1994	162 692	ha
. rice	1994	160 272	ha
. vegetables	1994	2 420	ha
Drainage - environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

In the dry season, the actual irrigated area is far below its maximum as only 43 percent of the equipped area of 31 477 ha is actually irrigated. Pumping costs and market access difficulties for other cash crops, particularly in the north, do not make paddy cultivation attractive in the dry season. Nevertheless, it has been noted that after poor yields during rainy seasons, the irrigated area in the dry season was higher than the average in order to compensate for the low production of the previous season. During the wet season, the areas actually irrigated are 149 272 ha, or 96 percent of the total equipped area.

A typology of irrigation schemes is presented in the following table.

The large-scale and several medium-scale schemes are generally underexploited and face O&M difficulties. Government policy is to transfer management responsibilities to users, but farmers lack management skills as they have never been involved in scheme and water management.

Size	Type of water control	Description	Location	Population involved
Small schemes < 100 ha	Weir schemes	Traditional wet season supplementary irrigation systems. Most of them are < 50 ha.	Mountainous provinces	1-2 villages, up to 50 households
	Pump schemes	Designed for dry and wet season irrigation.	Along the Mekong and its tributaries	
Medium schemes 100-500 ha	Weir schemes	Wet season supplementary irrigation. Most built with external assistance.	In the floodplains	Up to 8 villages, up to 500 households
	Pump schemes	Designed for dry and wet season irrigation.	Near Vientiane and Pakse	
	Reservoir schemes	Gravity irrigation in dry and wet season. Built by provincial irrigation services on behalf of communities.	Near Savannakhet	
Large schemes > 500 ha	Reservoir schemes	Gravity irrigation in dry and wet season.	Two reservoirs: Nam Houm and Nam Souang near Vientiane	
	Pump schemes	Dry and wet season irrigation.	Near Vientiane, using water from the Mekong and Nam Ngun rivers	

Another classification of irrigated schemes is by type of management. Some schemes are wholly managed by the farmers themselves, while others receive the assistance of irrigation department services. Pump schemes belong to the latter. More than 80 percent of the gravity irrigated schemes are managed by the farmers themselves

In the north, beaver dams are in use, but they are generally flushed away two or three times a year. These highly maintenance intensive structures are being gradually replaced (generally with international assistance) by more permanent weirs of mortared rock or reinforced concrete.

Drainage and flood protection structures have generally been taken into consideration in the irrigated schemes design plan but have often not been developed because of budget restrictions.

The main irrigated crop is rice. About 11 000 ha were cultivated with paddy during the 1994 dry season, and 149 272 ha actually irrigated in the 1994 wet season. Other irrigated crops are vegetables in the dry season near urban markets (Vientiane, Savannakhet, Saravane and Champassak). Although no precise data are available, the total figure has been estimated at 2 420 ha.

Non-irrigated paddy was estimated at 450 000 ha in 1994, of which 49 percent was upland rice (shifting cultivation), and 51 percent was lowland flooded rice in the alluvial plains.

The average cost of small-scale weir scheme development is about US$200-400/ha. Large schemes implemented by the Government, sometimes with external aid, cost between US$3 500 and 7 000/ha.

INSTITUTIONAL ENVIRONMENT

The Water Supply Company is responsible for the preparation of programmes and the implementation of all works connected to drinking water production and distribution. The Ministry of Health is in charge of water supply to rural populations, while urban water supply is under the responsibility of the Urban Planning Division within the Ministry of Communications, Transports, Posts and Constructions.

The Ministry of Agriculture and Forestry and the provincial authorities are jointly responsible for investigation and implementation of maintenance, repair and construction works for agricultural hydraulics, land development, dikes and flood protection structures. Two departments are involved:

- the Department of Hydrology and Meteorology, which is responsible for collecting and analysing climatic and hydrological data, and for flood forecasting;

- the Department of Irrigation, which provides central planning and coordination of irrigation development throughout the country. It also offers advice to provincial administrations on matters concerning irrigation services. It consists of the following divisions: technical management; operation and maintenance; and planning and cooperation. The Study Survey and Design Centre, under this department, has the capacity to survey and design 10 000 ha/year, and supervise its realization in cooperation with provincial administrations. The function of the Irrigation Section of each province is to provide services in the survey, design and supervision of construction, while a construction enterprise undertakes the implementation of projects.

An initiative called the 'Strengthening and restructuring irrigation development project' (SRIDP) is being implemented. It aims to develop and provide assistance in implementing strategies in the irrigation subsector. Another project called 'Farmer irrigated agriculture training' (FIAT) aims to train technicians and farmers in irrigation scheme design and management.

The Ministry of Communications, Transports, Posts and Constructions is in charge of improving inland waterways and facilitating navigation on the Mekong River and its tributaries. There is no legislation governing the use of water for inland navigation.

Together with the Société d'électricité du Laos, the Office of Hydropower within the Ministry of Industry and Handicrafts is responsible for the maintenance of hydropower dams and power generation.

In 1991, a constitution was adopted which enshrined the principle that land belongs to the State, but that individuals are guaranteed rights to use it. Land titles have not yet been distributed, but the principle has been accepted and a land market has been developing rapidly since 1992. A land registry survey is planned for the irrigated areas. A water law was drafted in 1995.

TRENDS IN WATER RESOURCES MANAGEMENT

In terms of water supply, the Government's long-term objective is to provide 80 percent coverage to the population by 2015. Although each province has benefited from an urban water supply programme financed by international aid (from Japan, Germany, the Asian Development Bank, the World Bank and the European Union), rural water supply programmes have not been numerous. The national water supply and environmental health programme, supported by the Swedish International Development Agency (SIDA) through the UNDP-World Bank Water and Sanitation Programme, aims to improve rural water supply and sanitation. Water supply activities still remain concentrated in and around major towns along the Mekong River.

A master plan for comprehensive water resources development is in preparation for two Mekong tributaries: the Nam Ngun and Nam Theun rivers.

Seven programmes have received top priority from the Government for the coming years. One deals with infrastructure development: rural roads and the electricity network will be developed, medium and large-scale hydropower dams will be constructed, and small-scale irrigation systems will be designed and constructed to increase dry season agricultural production.

Considerable investments have already been made in the last 20 years in irrigation development. Despite these efforts, only 13 500 ha are irrigated in the dry season. Although the returns on public investment in irrigation were low to negative in 1993, the irrigation sector still receives attention from donors. About 38 percent of all planned donor support in agriculture for the period 1994-2000 is for new irrigation projects.

The Government has recognized the problems facing the country and the strategy in the irrigation sector has been redefined. The new water law is based on:

- improving the planning of new irrigation projects so that they are based on the needs of the farmers and are driven and managed by them. WUGs are being set up, and the new water law should provide a legal framework for these associations. The objectives of the Irrigation Department are now: (i) to develop irrigation for all lowland paddy fields in the wet season as long as farmers are interested and group themselves in WUGs; and (ii) to develop dry season irrigation.

- making the existing schemes economically viable and self-sustaining, by: (i) helping farmers to establish WUGs; (ii) training farmers in irrigation management; (iii) encouraging farmers to introduce O&M cost recovery systems; and (iv) developing marketing infrastructures.

Under the New Economic Mechanism, policy on irrigated agriculture emphasizes the role of markets and prices as allocation mechanisms and a shift to cost recovery for services and facilities provided by government to farmers. Electricity and operating costs have been paid directly by farmers since 1992. secondary and tertiary canals are the responsibility of farmers for all maintenance matters.

Until 1994, the Irrigation Department was responsible for the O&M of weirs, dams, pumps and primary canals. It is planned that these responsibilities will be handed over to WUGs or WUAs. However, in many cases, O&M are still carried out by the Irrigation Department or its provincial services.

A pragmatic approach has been adopted for a transitional period while the establishment of WUGs is encouraged and farmers are trained in irrigation management, irrigation scheduling, and O&M. It is expected that, eventually, each WUG will be able to define the water charge needed to sustain the irrigation scheme.

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Malaysia

GEOGRAPHY AND POPULATION

Malaysia is situated in southeast Asia. It consists of two regions: peninsular Malaysia in the west lying between Thailand and Singapore, and the states of Sabah and Sarawak located in the east on the island of Borneo. The two regions are separated by the South China Sea. The total land area of the country is 328 550 km². Malaysia is a federal country, divided into 13 states plus the federal territories of Kuala Lumpur and Labuan Island.

TABLE 1
Basic statistics and population

Physical areas:		
Area of the country	1996	32 975 000 ha
Cultivable area	1996	14 174 688 ha
Cultivated area	1996	5 095 818 ha
- annual crops	1996	445 700 ha
- permanent crops	1996	4 650 118 ha
Population:		
Total population	1996	20 581 000 inhabitants
Population density	1996	63 inhab/km²
Rural population	1996	45.5 %
Economically active population engaged in agriculture	1996	22 %
Water supply coverage:		
Urban population	1995	99 %
Rural population	1995	77 %

In peninsular Malaysia, a mountainous spine known as Banjaran Titiwangsa separates the east of the peninsula from the west. About 61 percent of the peninsula is below 100 m above sea level and the land is generally suitable for cultivation. The interior of Sabah is criss-crossed by a series of mountain ranges and hills, the most prominent of which is the Crocker range with the highest point at Gunung Kinabalu (4 101 m). Sarawak is generally mountainous with the highest range forming the border with Indonesia.

In 1996, the total cultivable area was 14.17 million ha, or 43 percent of the total land area. About 5 095 818 ha, or 36 percent of the cultivable area, were cultivated. Permanent crops represented 91 percent of this cultivated area, while the remaining 9 percent (445 700 ha) was under annual crops, mainly paddy. The agriculture sector is divided into large-scale plantations concentrating on three crops (rubber, oil palm and cocoa), and smallholders who constitute the majority of the farming population.

In 1996, the population of Malaysia was estimated at 20.58 million inhabitants (45.5 percent rural). The population is concentrated along the west coast of peninsular Malaysia and in the capital city, Kuala Lumpur. The average population density in Malaysia is 63 inhabitants/km². The Malaysian population grew at an average annual rate of 2.8 percent in the 1980s, but the rate has since slowed to the current 2.3 percent.

The total active population is estimated at 8 321 000 inhabitants, of whom 22 percent are engaged in agriculture. The contribution of agriculture to GDP declined from 18.7 percent in 1990 to 13.6 percent in 1995. In the same year, the agriculture sector contributed 19.1 percent of export earnings. Palm oil, rubber and saw logs account for more than 58 percent of total agricultural exports.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		3 000	mm/year
		990	km^3/year
Internal renewable water resources		580	km^3/year
Total renewable water resources	1996	580	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	28 183	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1995	9 750	10^6 m^3/year
- domestic	1995	1 342	10^6 m^3/year
- industrial	1995	1 641	10^6 m^3/year
Total water withdrawal		12 733	10^6 m^3/year
per inhabitant	1996	619	m^3/year
as % of total renewable water resources		2	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater	1995	2 690	10^6 m^3/year
- treated wastewater	1995	398	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

CLIMATE AND WATER RESOURCES

Climate

Malaysia lies entirely in the equatorial zone. The climate is governed by the regime of the northeast and southwest monsoons. The northeast monsoon blows from October to March, and is responsible for the heavy rains which hit the east coast of the peninsula and frequently cause widespread floods. It also causes the wettest season in Sabah and Sarawak. The southwest monsoon period occurs between May and September, and is a drier period for the whole country. The period between these two monsoons is marked by heavy rainfall.

The average temperature throughout the year is very stable (26°C), and the mean annual rainfall is 3 000 mm. Regional variations in temperature and rainfall are mainly due to relief, e.g. the Cameron Highlands have a mean temperature of 18°C and an annual rainfall of over 2 500 mm, compared to Kuala Lumpur’s 27°C and 2 400 mm. In general, Sabah and Sarawak experience more rainfall (3 000-4 000 mm) than the peninsula. The humidity is high (80 percent) due to the high evaporation rate.

River basins and water resources

Peninsular Malaysia is drained by a dense network of rivers and streams (there are about 150 major river basins), the longest being the Pahang River which follows a course of 434 km before reaching the South China Sea. It drains a catchment area of 29 000 km^2. Other major rivers that also drain into the South China Sea are the Kelantan, Terengganu, Dungun, Endau and Sedili rivers. Major river basins in the east of Malaysia tend to be larger than those in peninsula Malaysia. Malaysia’s longest river is the Rajang River (563 km) in Sarawak.

Out of an annual rainfall volume of 990 km^3, 360 km^3 (36 percent) are lost to evapotranspiration. The total surface runoff is 566 km^3, and about 64 km^3 (7 percent of the total annual rainfall) contribute to groundwater recharge. However, about 80 percent of the groundwater flow returns to the rivers and is therefore not considered an additional resource. The total internal water resources of Malaysia are estimated at 580 km^3/year.

Major floods occurred in 1967, 1971, 1973 and 1983. Some 29 000 km² are considered as flood-prone areas, affecting about 2.7 million people. The average annual economic damage caused by floods was estimated at US$40 million in 1980.

Lakes and dams

On the west coast of peninsular Malaysia, the low gradient has resulted in large extensions of tidal flats and swamps. One of the swamp lakes is Lake Tasek Bera in Pahang State, with an area of 61.5 km².

Malaysia has a total of 56 dams, of which 32 are more than 15 m high. The gross theoretical hydropower potential of peninsular Malaysia is 123 000 GWh/year, and that of Sabah and Sarawak together is 107 000 GWh/year. In 1995, the total hydropower generation was about 5 800 GWh, or 30 percent of all power production in Malaysia.

Water withdrawal

The annual internal renewable water resources are estimated at 630 km³. As surface water is readily available throughout the year, it is abstracted mainly for irrigation and domestic uses. The groundwater potential is limited to some pockets of the coastal region and is generally exploited by rural people to supplement their piped water supply. Surface water represents 97 percent of the total water use, while groundwater represents 3 percent (Figure 1). About 60-65 percent of groundwater utilization is for domestic and/or municipal purposes, 5 percent for irrigation and 30-35 percent for industry (Figure 2).

In 1995, the total production of drinking water from treatment plants was 3.95 km³, while the quantity supplied to domestic and industrial sectors was only 2.98 km³ (Figure 3). About 32 percent of the water produced is lost in the distribution system due to several factors such as pipe leakage, under-metering, and other unaccounted water losses.

FIGURE 1
Water use by source

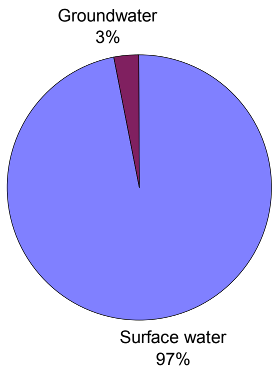


FIGURE 2
Groundwater utilization by sector

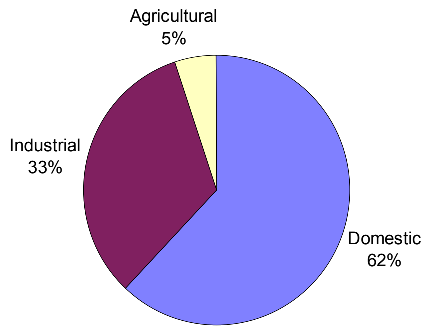
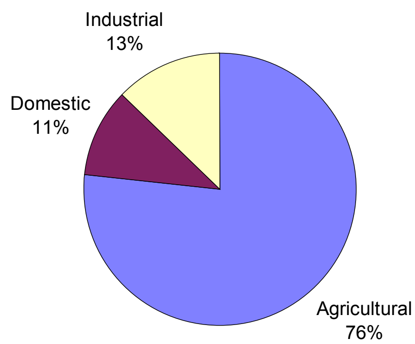


FIGURE 3
Water withdrawal
TOTAL: 12.73 km³ in 1995



Water supply is undertaken by government agencies and privatized water companies. The coverage for water supply is 99 percent for urban areas and 77 percent in the rural areas.

TABLE 3
Irrigation and drainage

Irrigation potential	1987	413 700	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1994	362 600	ha
- surface irrigation	1994	362 600	ha
- sprinkler irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater	1994	8	%
% of area irrigated from surface water	1994	92	%
% of equipped area actually irrigated	1994	100	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1994**	**362 600**	**ha**
- as % of cultivated area		7	%
- power irrigated area as % of irrigated area		-	%
3. Other water management area	1994	0	ha
Total water managed area (1+2+3)	**1994**	**362 600**	**ha**
- as % of cultivated area		7	%
- increase over last 10 years		-	%
- power water managed area as % of water managed area		-	%
Full or partial control irrigation schemes:			
Granary schemes (8 large schemes)	1994	210 500	ha
Mini-granary schemes (74 schemes)	1994	29 500	ha
Non-granary schemes (850 schemes)	1994	100 633	ha
Controlled flooding	1994	21 967	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production	1994	1 664 843	t
as % of total grain production	1994	70	%
Harvested crops under irrigation	**1996**	**477 606**	**ha**
- permanent crops: total	1996	0	ha
- annual crops: total	1996	477 606	ha
. rice	1994	433 553	ha
. vegetables	1996	32 017	ha
. tobacco	1996	11 195	ha
. flowers	1992	841	ha
Drainage - environment:			
Drained area	1994	960 600	ha
- drained area in full or partial control irrigated areas	1994	960 600	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area	1994	600 000	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		18	%
Power drained area as % of total drained area		-	%
Flood protected areas	1994	840 000	ha
Area salinized by irrigation	1994	0	ha
Population affected by water-borne diseases	1992	7 000	inhabitants

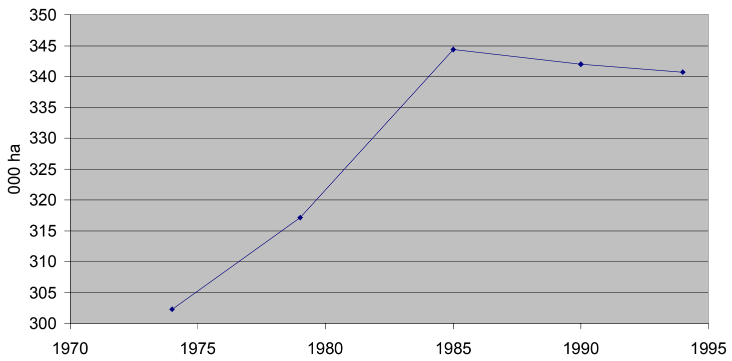
The total water demand increased from 8.7 km³ in 1980 to 12.7 km³ in 1995, and is projected to increase to 15.2 km³ by 2000. Irrigation currently accounts for about 9.7 km³ or about 76 percent of the total water consumption. However, irrigation demand is expected to taper off as no further expansion in irrigated paddy cultivation is envisaged.

IRRIGATION AND DRAINAGE DEVELOPMENT

In Malaysia, the potential irrigable area accounts for about 413 700 ha. Irrigation development dates back to the end of the eighteenth century. The Kerian irrigation schemes were the first large schemes to be constructed, in 1892. Since the formation of the Department of Irrigation and Drainage in 1932, irrigated areas for paddy cultivation have progressively increased. By 1960, about 200 000 ha had been developed, the emphasis then being on supplementing rainfall for single crop cultivation.

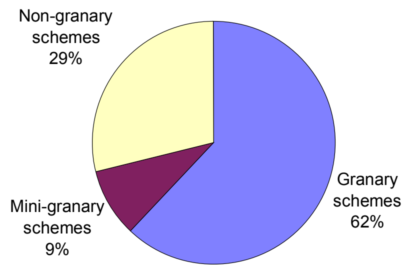
During the 1960s and early 1970s, the introduction of double cropping of rice cultivation required the development of adequate water resources for the second cropping season. During the 1980s, the priority for irrigation took on a new dimension with the need to rationalize rice cultivation and increase its productivity (Figure 4). The Government developed a policy to concentrate efforts in irrigation development in eight large irrigated areas, designated as granary areas of the country and totalling 210 500 ha. They are the irrigated areas of Kada, Seberang Muda Perai, Trans Perak, Northwest Selangor, Kerian-Sungai Manik, Besut and Kemasin-Semarak.

FIGURE 4
Evolution of irrigated area



Malaysia has over 932 irrigation schemes covering an area of 340 633 ha, comprising 8 granary schemes (210 500 ha), 74 mini-granary schemes (29 500 ha) and 850 non-granary schemes (100 633 ha) (Figure 5). The non-granary schemes are scattered all over the country and their size varies between 50 and 200 ha. In addition, there are 21 967 ha which are inundation and control drainage schemes (1994 estimates). The total irrigation areas was estimated at 362 600 ha in 1994.

FIGURE 5
Irrigation schemes
TOTAL: 340 663 ha in 1994



Irrigation is predominately for paddy cultivation and to a minor extent for vegetables and cash crops. Paddy cultivation is mostly carried out by individual farmers working on small plots of about 1-1.5 ha. Irrigation facilities for double cropping are mainly focused on the eight main granary schemes and the 74 mini-granary schemes, with an average cropping intensity of 150 percent. The current irrigation efficiency is around 35-45 percent with a water productivity index for rice of about 0.2 kg/m³. The average yield for irrigated rice was 4 t/ha in 1995.

In the major irrigation schemes, flooding irrigation is practised on paddy fields, and the water depth is controlled individually by the farmers. Major irrigation schemes are designed with proper farm roads to cater for farm mechanization especially for ploughing and harvesting. Most of the irrigation schemes are provided with separate drainage facilities. The issues of salinity, waterlogging and water-borne diseases are not reported as being significant.

Farmers pay nominal irrigation charges which vary from US$3 to 15/ha/year. It is estimated that fees collected from farmers cover only 10-12 percent of the actual operational cost. The Government does not seek full cost recovery because the farming community is considered a low income group. A total of US$917 million have been spent on irrigation development by the Government since 1970.

The long-term objectives of irrigation development are:

- to provide infrastructure for 74 secondary granary areas in order to raise the cropping intensity from 120 to 170 percent by 2010;
- to provide infrastructure for the main granary areas in order to raise the cropping intensity from 160 to 180 percent by 2010;
- to convert 120 small paddy schemes to other crops by 2010;
- to develop 20 small reservoirs, 100 groundwater tube-wells and 4 dams by 2010 in order to provide reliable irrigation by introducing new technologies and modern management to increase crop production.

In 1994, the total drained areas was 940 633 ha. About 600 000 ha were drained for oil palm cultivation, using public funding for smallholders.

INSTITUTIONAL ENVIRONMENT

The responsibility for water resources planning and development is shared by various government agencies. Malaysia has no single water resources authority for an overall coordinated planning and integrated river management approach.

The Department of Irrigation and Drainage (DID), under the Ministry of Agriculture, is responsible for the planning, implementing and operation of irrigation, drainage and flood control projects throughout the country.

The Department of Agriculture (DOA) is responsible for providing advice and extension services to the farmers.

In the water supply sector, the Public Works Department (PWD), under the Ministry of Public Works, is responsible for the planning, implementation and operation of urban water supply projects. However, in line with the Government's privatization policy, many water supply projects have already been taken over by water supply companies or privatized.

The Ministry of Health (MOH) provides untreated but drinkable water to rural communities not served by the local water authorities. The MOH also monitors water quality at water treatment plant intakes as well as the quality of water within the distribution system for compliance with national drinking water standards.

The control of water pollution is the responsibility of the Department of Environment (DOE), which is empowered to enforce compliance with effluent standards for point sources of pollution. The Ministry of Housing and Local Government is responsible for compliance with regulations and standards on sewerage works which have been privatized to a national sewerage company.

Although either directly or indirectly much legislation touches on water resources, most of the existing laws are considered outdated. The Water Act of 1920 is inadequate for dealing with the current complex issues related to water abstraction, pollution and river basin management.

TRENDS IN WATER RESOURCES MANAGEMENT

Agriculture will remain the main user of water in the future. However, its importance will decline from the present 76 percent to about 70 percent of total water consumption by 2000. In the irrigation sector, future efforts will focus on demand management through improved water management rather than on supply management.

Future trends in paddy cultivation will focus on group farming as practised in the Trans Perak Area Integrated Agriculture Development Scheme. In the long term, sustainable paddy cultivation will depend on the setting up of effective farmers' organizations. A more business-oriented paddy farming is seen as a way to reduce government subsidies to small farmers. Owing to the high cost of paddy production, the National Agriculture Policy (1992-2010) aims to reduce gradually the country's self-sufficiency in rice from the current 80 to 65 percent.

In the water resources sector, there is a need to review the planning and development of dams. Most of the existing dams were generally designed for one single purpose by various government agencies and privatized utility companies. Future dams will be designed with consideration for multipurpose usage through improved coordination and the optimization of resources. There is also an urgent need to address the issue of water pollution, which could have a serious economic impact if left unchecked. The Government is studying the feasibility of setting up a national body to manage the rivers as well as the creation of a national water council to improve federal-state government cooperation in water resources management.

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Maldives

GEOGRAPHY AND POPULATION

Maldives consists of 1 190 low-lying islands, lying along a north-south axis over a distance of some 1 000 km, about 600 km southwest of Sri Lanka in the Indian Ocean.

The total land area of Maldives is 300 km^2. The islands form 26 natural atolls, which for administration purposes are grouped into 19 units. Most of islands are small, few with a land area in excess of 1 km², and with elevations of not more than 2 m above sea level. The atoll lagoons are shallow, but there are deep passages between the atolls. All the main islands lie on the edge of the atolls around their rim. Some sandbars and cays are found within the atolls.

In 1974, the cultivable area was estimated at some 2 800 ha, 9 percent of the total land area. However, in 1995 the total cultivated area was estimated to be 3 000 ha. Of the cultivated area, 2 000 ha were under permanent crops such as coconut and arecanut. Annual crops such as maize, sorghum, cassava, onion and chilies were grown on an area of 1 000 ha.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1996	30 000	ha
Cultivable area		-	ha
Cultivated area	1996	3 000	ha
- annual crops	1996	1 000	ha
- permanent crops	1996	2 000	ha
Population:			
Total population	1996	263 000	inhabitants
Population density	1996	877	inhab/km^2
Rural population	1996	73	%
Economically active population engaged in agriculture	1996	29	%
Water supply coverage:			
Urban population	1990	98	%
Rural population	1990	57	%

In 1996, the total population was estimated at 263 000 inhabitants with an annual average growth rate of 2.8 percent. The population is concentrated on Male island, which had about 63 000 inhabitants in 1995 . Many of the other islands remain sparsely populated and the average population density is 877 inhabitants/km².

In 1995, the country's GDP was US$270.9 million, of which the agriculture sector contributed approximately 7.7 percent. In 1996, the agriculture sector provided employment for 29 percent of the population.

CLIMATE AND WATER RESOURCES

Climate

The islands have a tropical climate with two monsoons, which are:

- the southwest monsoon from May to September;
- the northeast monsoon from November to March.

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		1 883 mm/year
		564.9 km^3/year
Internal renewable water resources		0.03 km^3/year
Total renewable water resources	1998	0.03 km^3/year
Dependency ratio		0 %
Total renewable water resources per inhabitant	1996	114 m^3/year
Total dam capacity	1990	0 10^6 m^3
Water withdrawal:		
- agricultural	1987	0 10^6 m^3/year
- domestic	1987	3.32 10^6 m^3/year
- industrial	1987	0.054 10^6 m^3/year
Total water withdrawal		3.37 10^6 m^3/year
per inhabitant	1996	12.81 m^3/year
as % of total (actual) renewable water resources		11.2 %
Other water withdrawal		- 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater		- 10^6 m^3/year
- treated wastewater		- 10^6 m^3/year
- re-used treated wastewater		- 10^6 m^3/year
Desalinated water	1991	0.37 10^6 m^3/year

During the months of April and October, the islands experience many thunderstorms. The precipitation is uniformly distributed throughout the year, except for a dry period of about 90 days from January to March. The mean annual rainfall for the period 1991-95 was 1 883 mm.

The daily temperature varies little throughout the year. The annual mean temperature is 28°C, ranging from 26.2° to 30.6°C.

River basins and water resources

The islands do not have any rivers, but small brackish ponds are found on some islands. Rainwater is collected through water harvesting on a small scale and used for drinking purposes.

Groundwater is found in freshwater lenses underlying the atolls and floating on top of the saline water. Heavy abstraction of this as the main source of drinking water has depleted the freshwater lenses, especially in the capital city of Male, causing salt water intrusion. Groundwater is recharged by rainfall but becomes contaminated while percolating through the soil, which is generally polluted with organic and human wastes. A rough estimate of the groundwater resources, based on an assumed 0.1 m/year recharge throughout the country (300 km^2), is 0.03 km^3/year, which would be the only renewable resource of Maldives, though hardly exploitable because of seawater intrusion and pollution.

Maldives finds it extremely difficult to obtain suitable drinkable water. In 1991, there were three desalination plants in operation with a total production of 1 000 m^3/d.

According to 1990 statistics, 98 percent of the urban population in the city of Male and 57 percent of the rural population on the atolls had access to safe drinking water.

Water withdrawal

In 1987, water demand for domestic (including municipal) and industrial (including commercial) uses were 3.32 and 0.054 million m^3 respectively (Figure 1).

TABLE 3
Irrigation and drainage

Irrigation potential		-	ha
Irrigation:			
1. Full or partial control irrigation: equipped area		-	ha
- surface irrigation		-	ha
- sprinkler irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater		-	%
% of area irrigated from surface water		-	%
% of equipped area actually irrigated		-	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1998**	**0**	**ha**
- as % of cultivated area		0	%
- power irrigated area as % of irrigated area		0	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1998**	**0**	**ha**
- as % of cultivated area		0	%
- increase over last 10 years	1998	0	%
- power water managed area as % of water managed area	1998	0	%
Full or partial control irrigation schemes:			
Large-scale schemes		-	ha
Medium-scale schemes		-	ha
Small-scale schemes		-	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
Drainage - environment:			
Drained area	1998	0	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

FIGURE 1
Water withdrawal
TOTAL: 3.37 million m³ in 1987

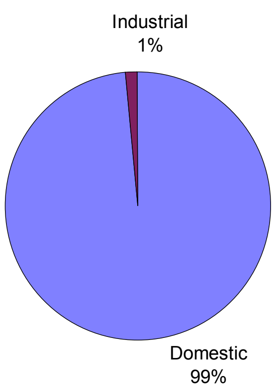
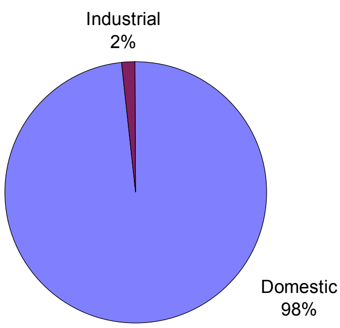


FIGURE 2
Groundwater withdrawal
TOTAL: 3.20 million m³ in 1987



Groundwater sources met the majority of this demand with quantities of 3.15 and 0.053 million m^3 (Figure 2). There is no irrigation and crops are rainfed.

IRRIGATION AND DRAINAGE DEVELOPMENT

Available information indicates that irrigation activities are insignificant.

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Mongolia

GEOGRAPHY AND POPULATION

Mongolia is located in the north of the central Asian plateau and has a total area of 1 566 500 km². It is bordered in the north by Siberian Russia, and in the east, south and west by China. There are 18 provinces (aimags), each with a provincial capital and a local government headed by an aimag governor. In addition, there are three self-governing cities: Ulaanbaatar (the national capital), Darkhan and Erdenet.

The country consists principally of inter-mountain plateaux. About 80 percent of the territory lies above 1 000 m. The main mountain ranges are the Mongolian Altai in the west and the Hangai and Hentii mountains in the north and centre, with the large depression of the Great Lakes located between the two ranges. A large part of south Mongolia is covered by the Gobi Desert steppe, while the eastern part consists of elevated plains.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	156 650 000	ha
Cultivable area	1994	1 800 000	ha
Cultivated area	1992	664 700	ha
- annual crops	1992	664 000	ha
- permanent crops	1992	700	ha
Population:			
Total population	1996	2 515 000	inhabitants
Population density	1996	1.6	inhab/km²
Rural population	1996	38	%
Economically active population engaged in agriculture	1996	28	%
Water supply coverage:			
Urban population	1990	100	%
Rural population	1990	58	%

The total cultivable area is estimated at 1.8 million ha, which is about 1 percent of the total area. Some 80 percent of the total land area can be used for pastoral activities. The main crop growing areas are in the central-northern part of the country and include portions of Selenge, Tuv and Bulgan aimags, which account for about 67 percent of all cultivated land. These areas comprise a broad basin draining to the north. Only valley bottom land and the lower slopes of hills with sufficiently deep soils are cultivated. In 1992, the total cultivated area was 664 700 ha. Cereals, occupying nearly 600 000 ha or over 90 percent of the total cropped area in 1992, are the most important crops, but have declined recently due to the reduced availability and increased cost of production inputs and shortage of working capital. About 53 000 ha, or 8 percent of the total arable area, were devoted to fodder crops in 1992. Potatoes and vegetables together accounted for 11 000 ha, or 1.5 percent of the area planted, while fruit trees covered an area of about 700 ha.

In 1996, the population of Mongolia was estimated at 2.5 million inhabitants (600 000 in Ulaanbaatar). The annual population growth rate in the 1980s was 2.7 percent. Mongolia is sparsely populated with an average density of 1.6 inhabitants/km², and about 38 percent of the population is rural. In 1995, the agriculture sector (including livestock) accounted for over 25 percent of GDP, and employed 28 percent of the economically active population.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		251	mm/year
		393.46	km^3/year
Internal renewable water resources		34.8	km^3/year
Total renewable water resources	1995	34.8	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	13 837	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1993	227.04	10^6 m^3/year
- domestic	1993	85.36	10^6 m^3/year
- industrial	1993	115.72	10^6 m^3/year
Total water withdrawal		428.12	10^6 m^3/year
per inhabitant	1996	170	m^3/year
as % of total renewable water resources		1.2	%
Other water withdrawal	1993	11.88	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

CLIMATE AND WATER RESOURCES

Climate

The country has severe climatic conditions with long cold winters. The average annual precipitation is 251 mm, ranging from 400 mm in the north to less than 100 mm in the southern Gobi region. The mean monthly temperature is below 0°C over the entire country between November and March. Late spring and early autumn (even late summer) frosts reduce the vegetation period to 80-100 days in the north and 120-140 days in the south. Summer precipitation occurs between June and August, representing 80-90 percent of the total annual rainfall. Other climatic factors affecting agricultural production include low soil moisture and air humidity in spring and early summer, and strong winds in spring, resulting in high evaporation and soil erosion.

River basins and water resources

Mongolia's water resources include 32.70 km^3 of surface water and 6.10 km^3 of groundwater. Part of the groundwater flow (estimated at 4 km^3/year) returns to the river system as base flow, the rest evaporating in endoreic basins. The river network is more developed in the north than in the south. Several of Asia's major rivers rise in Mongolia including the Yenisei, Irtysh and Selenge rivers. Rainfall is the principal source of water for the rivers of the region, while water from melting snow makes up 15-20 percent of the annual runoff. From November to May, the rivers in the north are frozen. Further south, the shallow water courses of the Gobi are fed almost exclusively by groundwater.

Mongolia can be divided into five major river basins:

- the Amur basin in the east, comprising the Kerulen River, which flows into Lake Hu-Lun in China, and the Onan River, a tributary of the Amur River; the outflow to China from this group of rivers is estimated at 1.4 km^3/year;
- the Lake Baikal basin in the north-central part of the country, with the Orhon and Selenge rivers rising in the north and central mountains;

- the Shishhid basin in the northwest is an extension of the Yenisei basin; the total outflow of the Mongolian rivers to the Russian Federation is estimated at 25 km³/year (Russian information);
- the Bulgan basin is an extension of the Irtysh basin in the southwest of the country;
- the Gobi Desert basin covers the south and west of the country and consists of small rivers which drain internally into lakes or are lost in the ground.

About two-thirds of the surface runoff leaves Mongolia. Mongolia has a formal understanding with the Russian Federation on water quantity and quality.

Lakes and dams

The largest lakes are in the northwest. Among these are the Uvs Nur, a large saline lake without an outlet with an area of 3 350 km^2; and the Huvsgul, the largest (2 620 km^2) and the deepest (238 m) freshwater lake in Mongolia, which is fed by 46 rivers and other large lakes.

About 27 earth dams currently store water for sprinkler irrigation systems. A small part (55 km^2) of the catchment drained by the Boroo River is intercepted by the Shariin Am dam and storage reservoir facility. The Shariin River is a narrow and shallow river with a small dam about 4 m high capable of impounding a small storage reservoir with a regulating capacity of about 250 000 m^3.

Mongolia is estimated to have a theoretical hydropower potential of 5 500-6 000 MW. There is a 528 kW mini-hydroplant in operation (the Kharakhoum scheme) on an irrigation canal which diverts water from the Orkhon River.

FIGURE 1
Water withdrawal
TOTAL: 0.43 km³ in 1993

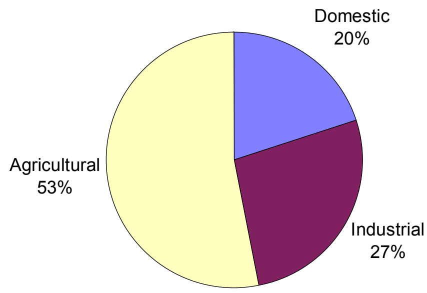
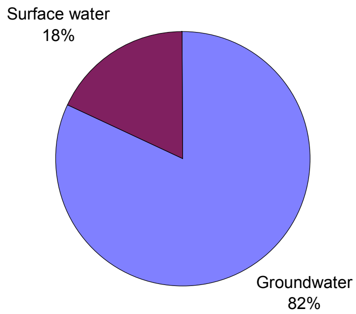


FIGURE 2
Water use by source



Water withdrawal

The total water withdrawal was estimated at about 0.43 km³/year in 1993, of which 52 percent was for agriculture (Figure 1). Groundwater is currently the main source of supply for household and drinking use, watering points for pastures, and industrial consumption. About 82 percent of the total water supply is contributed by groundwater resources (Figure 2).

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation in Mongolia was probably developed under the Huns in the first century AD. Irrigation development appears to have peaked at about 140 000 ha during the seventeenth and eighteenth centuries.

TABLE 3
Irrigation and drainage

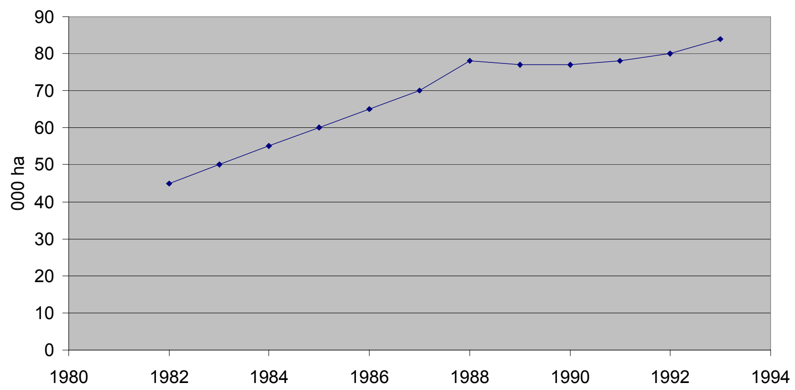
Irrigation potential	1993	518 000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1993	57 300	ha
- surface irrigation	1993	13 900	ha
- sprinkler irrigation	1993	43 400	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater		-	%
% of area irrigated from surface water		-	%
% of equipped area actually irrigated	1993	61	%
2. Spate irrigation	1992	27 000	ha
Total irrigation (1+2)	**1993**	**84 300**	**ha**
- as % of cultivated area		13	%
- power irrigated area as % of irrigated area		-	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1993**	**84 300**	**ha**
- as % of cultivated area		13	%
- increase over last 10 years	1993	8.7	%
- power water managed area as % of water managed area		-	%
Full or partial control irrigation schemes:			
Large-scale schemes		-	ha
Medium-scale schemes		-	ha
Small-scale schemes		-	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
Drainage – environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

Traditional irrigation methods had been largely abandoned by the end of the nineteenth century. Chinese ‘migrants’ developed comparatively small-scale schemes on the larger rivers. Modern irrigation development started in the 1950s, and the first modern irrigation scheme was designed in 1955.

About 518 000 ha of irrigation potential area were identified at reconnaissance level in the early 1970s, of which 117 000 ha have been studied in more detail for potential development. Starting in 1971, some small irrigation schemes were built in the western aimags. A government campaign began in 1975 to produce irrigated fodder in the western and Gobi regions. The construction of further irrigation schemes, large and small, continued until 1988.

In the 1980s, irrigation schemes were characterized by sprinkler systems, generally serving 400-500 ha or more, primarily for fodder and cereal production and, to a lesser extent, for vegetables and potato production (Figure 3).

FIGURE 3
Evolution of irrigation, 1982-1993



In 1993, the total irrigated area was estimated at 84 300 ha. The total area equipped for irrigation amounted to 57 300 ha, of which 43 400 ha under sprinkler systems (registered schemes) and about 13 900 ha of systems using surface irrigation methods (unregistered schemes) (Figure 4). In addition, an estimated 27 000 ha of pasture benefited from traditional floodwater diversion (Figure 5).

There is an inventory of 156 registered schemes, covering a total of 43 400 ha, varying in size between 5 and 3 300 ha, two-thirds of them being smaller than 50 ha. Most schemes have been developed in the north (48 percent) and west (47 percent). Unregistered schemes, an estimated 80 percent of them concentrated in the west of the country, are smaller in size (1-100 ha) and are the result of spontaneous efforts by local people, or are state schemes taken over by companies and private individuals after being abandoned.

Of the sprinkler irrigated area, side-roll systems account for 43 percent; tractor mounted water guns or sprinkler booms, 28 percent; centre pivots, 25 percent; and movable laterals, 4 percent. About 46 percent of the total irrigated area is served by gravity canals and the remaining 54 percent by buried steel pipes.

FIGURE 4
Irrigation techniques (full and partial control areas)
TOTAL: 57 300 ha in 1993

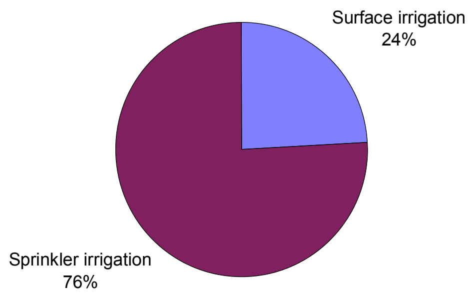
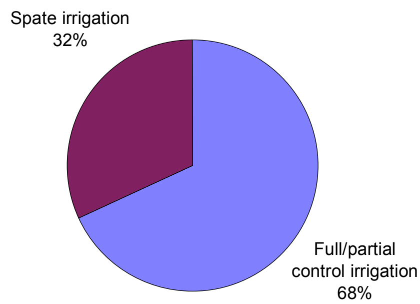


FIGURE 5
Distribution of areas under irrigation
TOTAL: 84 300 ha in 1993



The total sprinkler irrigated area has been in steady decline with the privatization of the state farms operating the systems and the subsequent lack of finance. In 1992, only 52 percent of the total area under sprinkler systems, or 22 000 ha, was operational. Of the remaining area, 11 000 ha are classified as abandoned for irrigation purposes, while the other 10 000 ha are defined as non-functional due to failed or missing equipment. Individual irrigators have established plots on schemes as the farming companies have withdrawn from irrigation.

According to updated cost estimates provided by the Ministry of Food and Agriculture, registered irrigation investment averaged about US$1 300/ha at 1993 prices, with infrastructure representing 87 percent of this amount. In 1995, an FAO mission estimated new irrigation establishment costs at approximately US$2 000/ha and rehabilitation costs at approximately US$700-1 000/ha.

During the 1980s, fodder crops accounted for approximately 50 percent of the area irrigated under sprinkler systems; annual cereal crops (mainly wheat), 20-40 percent; potatoes, 5-10 percent; vegetables (mainly cabbage, onions, carrots and turnips), 5-10 percent; and fruit (seabuckthorn, blackcurrant and Siberian apples), less than 2 percent. Unregistered irrigation schemes have focused primarily on potatoes, vegetables and fruit production, with significant areas of fodder production in the west and south. Fodder, cereals and potatoes have suffered from the reduction in irrigation extension. Vegetables, some fruits and early potatoes are the main crops currently grown on irrigation schemes.

INSTITUTIONAL ENVIRONMENT

The main institutions dealing with agriculture and water resources development are the Ministry of Food and Agriculture (MOFA) and the Ministry for Nature and the Environment (MNE).

The MOFA has overall responsibility for formulating irrigation development policy through the Crop, Machinery and Irrigation Department. A three-member Irrigated Crop Unit is located within the Ulaanbaatar head office of the department, with responsibilities extending into rural water supplies and groundwater, as well as irrigated crop production. However, the ministry does not have a design function in the planning of irrigation schemes.

The MNE is responsible for implementing state policy related to land, weather, water, wildlife and forests. It determines whether water use by irrigation schemes has impacts on the environment. Institutes relevant to irrigation within the MNE are the Water Policy Institute, the Land Policy Institute, and the Hydrometeorological Research Institute.

The MOFA and MNE are represented at aimag level through the Chief of Agricultural and Environmental Section (CAES). The CAES is assisted by a team of technicians and is answerable to both the aimag government chairman and the MOFA. There are a number of crop and irrigation technicians posted at soum level (soum is an administrative subdivision of the aimags) in charge of assisting large crop production farms.

A water law has been in force since June 1995.

TRENDS IN WATER RESOURCES MANAGEMENT

Mongolia's goal is to develop a market-oriented agriculture sector with minimal state intervention. According to the 'Mongolia irrigation rehabilitation project' the objectives are:

- to restore to full productive capacity around 1 550 ha of irrigation schemes in the north-central region;

- to strengthen the capacity of government and private institutions involved in irrigation development;
- to form WUAs and train farmers in the O&M of irrigation systems and irrigated crop production;
- to develop irrigated crop production technologies adapted to the new production systems, especially to smallholders, and to identify and promote new irrigated crops adapted to Mongolian conditions.

In addition, a 12-15-MW hydropower project has been planned for the west of the country, on the Haraigth River in Hovd province. It has been designed by Erdenet University of Mongolia with the Hydroprojekt Institute of the Russian Federation. A 2-MW hydroplant is soon to be completed in the province of Zafkhan.

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Myanmar

GEOGRAPHY AND POPULATION

Myanmar has a total area of 676 580 km². It is situated at the juncture of the Indian subcontinent and southeast Asia. The country is divided into seven states, mainly covering the hill regions, and seven divisions covering the plains.

Topographically, the country can be divided into five regions. They are the northern and western mountains, the eastern plateau (Shan plateau), the central basin and the coastal strip. The country is mountainous, rising to more than 5 800 m above sea level in the far north, reaching an elevation of well over 2 000 m over much of Shan state in the northeast, and in Rakhine and Chin states in the west.

TABLE 1
Basic statistics and population

Physical areas:		
Area of the country	1995	67 658 000 ha
Cultivable area	1995	18 270 000 ha
Cultivated area	1995	10 141 000 ha
- annual crops	1995	9 571 000 ha
- permanent crops	1995	570 000 ha
Population:		
Total population	1996	45 922 000 inhabitants
Population density	1996	68 inhab/km^2
Rural population	1996	74 %
Economically active population engaged in agriculture	1996	72 %
Water supply coverage:		
Urban population	1995	41 %
Rural population	1995	50 %

The cultivable area is estimated at 18.27 million ha, while the cultivated area amounts to 10.14 million ha, or 55 percent of the cultivable area. The cultivated area can be divided into fallow area (14 percent), net sown area (66 percent) and multiple cropping area (20 percent). The cultivated areas are concentrated in the Ayeyarwady River basin, while potential for further expansion lies mainly in upper Myanmar, namely in the Chin, Kachin and Shan states.

In 1996, the total population was estimated by the UN at 45.922 million inhabitants (74 percent rural). With a population density of 68 inhabitants/km², Myanmar is well below the level of other countries in south and southeast Asia. The population growth rate is estimated at 1.87 percent. About 72 percent of the total labour force is engaged in agriculture, and 70 percent in the primary sector, including livestock, fisheries and forestry. The agriculture sector contributes 50 percent of GDP, and generated 33 percent of total export earnings in 1994.

CLIMATE AND WATER RESOURCES

Climate

Myanmar's climate is tropical monsoonal in type. Rainfall is highly seasonal, being concentrated in the hot humid months of the southwest monsoon (May to October). By contrast, the northwest monsoon (December to March) is relatively cool and almost entirely dry.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		2341	mm/year
		1584	km^3/year
Internal renewable water resources		880.6	km^3/year
Total renewable water resources	1990	1045.6	km^3/year
Dependency ratio		15.8	%
Total renewable water resources per inhabitant	1996	22 769	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1987	3 564	10^6 m^3/year
- domestic	1987	277.2	10^6 m^3/year
- industrial	1987	118.8	10^6 m^3/year
Total water withdrawal		3 960	10^6 m^3/year
per inhabitant	1996	86	m^3/year
as % of total renewable water resources		0.35	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater	1997	0	10^6 m^3/year
- re-used treated wastewater	1997	0	10^6 m^3/year

The mean annual rainfall is estimated at 2 341 mm. The most significant regional variations are those associated with the intensity of the southwest monsoon rains. Annual rainfall ranges from as high as 4 000-6 000 mm along the coastal reaches and in the mountains of Rakhine and Tanintharyi to as low as 500-1 000 mm in the central dry zone. Intermediate levels of rainfall characterize the Ayeyarwady Delta areas (2 000-3 000 mm/year), the Shan plateau (1 000-2 000 mm/year) and the transitional areas. As with the rainfall, 90 percent of the discharge flows between May and October.

River basins and water resources

The north-south direction of Myanmar's mountain ranges is reflected in the flow of its major rivers, of which two are international rivers. There are six river basins:

- the Ayeyarwady and Chindwin river basin, which is almost entirely located in Myanmar and drains 58 percent of the territory;
- the Sittoung River basin, which is also entirely located in Myanmar to the east of the Ayeyarwady, drains 5.4 percent of the territory;
- the Thanlwin (Salween) River basin, which drains 18.4 percent of the territory, mainly the Shan plateau in the east of the country. The river comes from China and after entering the country forms the border with Thailand for about 110 km;
- the Mekong River basin, which drains 4.2 percent of the territory in the far east and forms the border with Lao PDR. The Mekong River has 2 percent of its catchment area in Myanmar. Myanmar is not a member of the Mekong River Commission;
- the Rakhine (Arakan) coastal basin in the west draining into the Bay of Bengal;
- the Tanintharyi (Tenasserim) coastal basin in the south draining into the Andaman Sea.

The inflow from other countries is estimated at 128.2 km^3/year from Chinese and Thai information and includes: 20 km^3/year from India, 68.7 km^3/year (Yuan Yiang) and 31.3 km^3/year (Lancang) from China, and 8.2 km^3/year from Thailand. The total surface water produced internally (total runoff minus inflow from other countries) is estimated at 874.6 km^3/year. Groundwater resources have been estimated at 156 km^3/year but a large part of this water (estimated at 150 km³/year) constitutes the base flow of the rivers and is also accounted for as surface runoff.

The Mekong River forms the border with Lao PDR over 170 km, from which 36.815 km³/year can theoretically be considered as an additional external resource. The total natural renewable water resources (including flow from incoming or border rivers) are estimated at 1 045.6 km³/year.

Average annual river runoff in Myanmar

River basin	Catchment area for each stretch (000 km²)	Average annual flow for each stretch (km³/year)
Ayeyarwady River		
Chindwin (Monywa)	115.3	146.3
Upper Ayeyarwady (Sagaing)	193.3	244.8
Lower Ayeyarwady (Pyay)	95.6	85.8
Other rivers		
Bago, Sittoung, Bilin	48.1	81.1
Streams of Rakhine State	58.3	139.2
Streams of Taninthayi	40.6	130.9
Thanlwin	158.0	157.1
Mekong at Myanmar border	28.6	17.6
Total	737.8	1 002.8

Source: Government of Myanmar (1995).

Lakes and dams

There are few lakes in Myanmar. The largest is Lake Inle which covers an area of 155 km². In 1994, there were 70 dams over 15 m high.

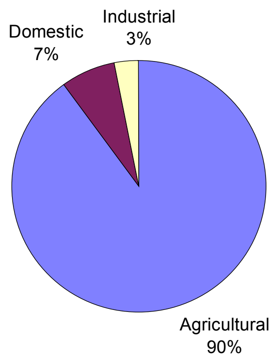
The theoretical hydropower potential has been estimated at more than 100 000 MW, of which 9 000 MW with detailed feasibility studies. In 1995, 288 MW had been developed, which represented at that time 34 percent of the total installed power capacity of the country.

Water withdrawal

Water withdrawal was estimated at 4 km³/year in 1987, of which 90 percent for irrigation purposes (Figure 1).

About 46 percent of the population have access to adequate protected water supplies. Extreme conditions persist in the coastal and delta regions where overall coverage rates are 10-13 percent. There is no wastewater treatment in Myanmar.

FIGURE 1
Water withdrawal
TOTAL: 3 960 million m³ in 1987



IRRIGATION AND DRAINAGE DEVELOPMENT

Because of the rainfall and hydrological pattern of the country, the need for irrigation is highest in the central dry zone, while the delta is more concerned with drainage and flood protection problems.

It is thus logical that the first irrigation works should have been undertaken near Bagan (Pagan) in the central region in the eleventh and twelfth centuries. They typically comprised diversion systems based on tributaries of the middle Ayeyarwady, and were designed essentially to

TABLE 3
Irrigation and drainage

Irrigation potential	1992	10 500 000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1995	1 555 416	ha
- surface irrigation	1995	1 555 416	ha
- sprinkler irrigation		-	ha
- micro-irrigation		-	ha
% of area irrigated from groundwater	1995	3.5	%
% of area irrigated from surface water	1995	96.5	%
% of equipped area actually irrigated	1995	100	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1995**	**1 555 416**	**ha**
- as % of cultivated area		15	%
- power irrigated area as % of irrigated area	1995	3	%
3. Other water management area		-	ha
Total water managed area (1+2+3)	**1995**	**1 555 416**	**ha**
- as % of cultivated area		15	%
- increase over last 10 years	1995	47	%
- power water managed area as % of water managed area	1995	3	%
Full or partial control irrigation schemes:			
Large-scale schemes		-	ha
Medium-scale schemes		-	ha
Small-scale schemes		-	ha
Total number of households in irrigation	1993	611 595	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation	**1995**	**1 911 161**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
. rice	1995	1 591 687	ha
. sesame	1995	71 213	ha
. pulses	1995	41 298	ha
. jute	1995	29 890	ha
. others	1995	177 073	ha
Drainage - environment:			
Drained area	1994	193 363	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains	1994	193 363	ha
Drained area as % of cultivated area		2	%
Power drained area as % of total drained area		-	%
Flood protected areas	1995	1 235 941	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

provide security to the main season paddy crop. Storage reservoirs were also constructed for the same purpose. The ancient systems were subsequently modernized, extended and operated in the traditional manner, with a greater emphasis on the upgrading and development of the existing flood protection and drainage facilities in the Ayeyarwady Delta. This enabled the development of paddy cultivation and made Myanmar a major rice-exporting country before World War II. Dam construction and irrigation network implementation were significantly accelerated in the 1960s, 1970s and after 1990 (Figure 2). The irrigation potential is estimated at 10.5 million ha, considering both water and soil resources.

The irrigated areas are estimated at 1 555 416 ha. Irrigation expansion has been significant (up 50 percent) in the last five years.

FIGURE 2
Evolution of irrigation since 1962

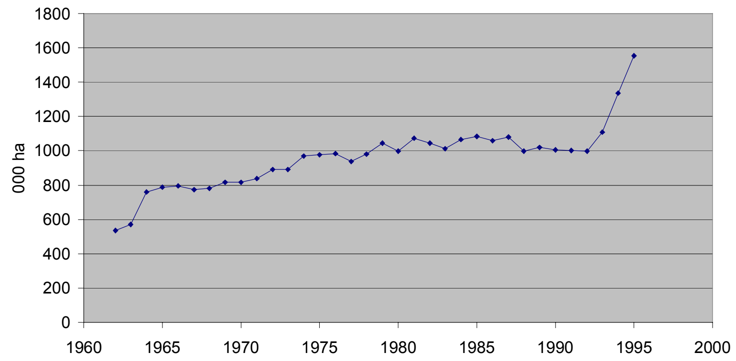
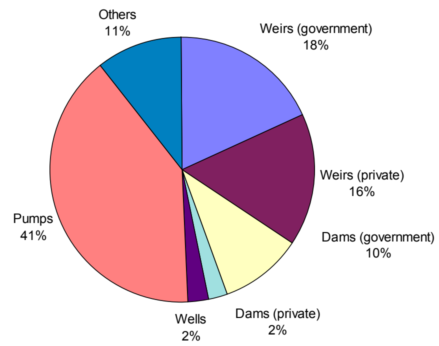


FIGURE 3
Type of irrigation by source of water
TOTAL: 1 555 416 ha in 1995



Irrigated areas were traditionally supplied through weirs for river diversion or dams and tanks, but wells and pumping in rivers have developed quite substantially in recent years (Figure 3). Pump irrigation was promoted in the 1980s by programmes implemented by the Agricultural Mechanization Department. Other types of irrigation water supply include windmills, watermills, watering with buckets, ponds, etc.

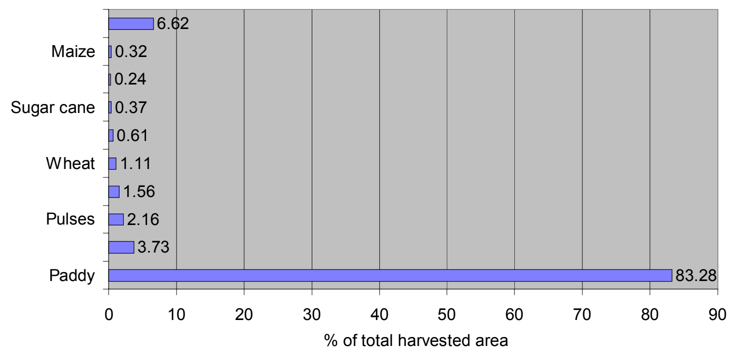
All irrigation in Myanmar is surface irrigation. Sprinkler and localized irrigation have been developed only on pilot farms, and altogether do not exceed 50 ha.

Two types of irrigation management coexist in Myanmar: public and private schemes. Government schemes account for 53 percent of weir schemes and 81 percent of the dams and tanks (all dams of and above 6.1 m). Wells and pump irrigation, although possibly originally implemented by the services of the Ministry of Agriculture, are mainly private.

Although farmers are responsible for implementation, management and O&M in the private schemes, both the Irrigation Department and the Water Resources Utilization Department provide technical and financial assistance. The main irrigated crops are paddy, oil crops and fibre crops (Figure 4).

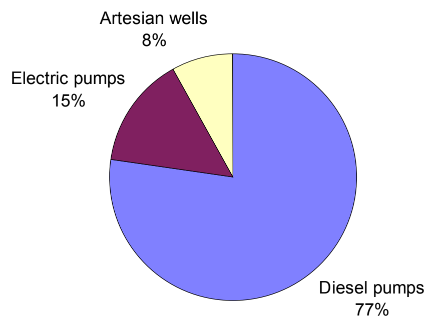
There are important groundwater aquifers in Myanmar. However, their exploitation has been limited to domestic water supply and to the intensive irrigation of vegetables and other high value crops from hand-dug wells. In the central dry zone, where most of the potential for economical run-of-the-river diversion schemes has been utilized, dams, irrigation projects and groundwater irrigation projects were started in the 1980s. Irrigation from groundwater was practised on 55 175 ha in 1995, mainly for cotton, wheat, beans and pulses. Groundwater is mobilized mainly by diesel pumps (Figure 5). Generally, one tube-well allows supplementary irrigation on 4 ha. Since the development of tube-well irrigation in 1992, 3 000 tube-wells have been drilled every year by the Department of Water Resources Utilization. Following this example, the private sector drills around 9 000 tube-wells each year.

FIGURE 4
Main irrigated crops (full and partial control)
TOTAL: 1 911 161 ha in 1995



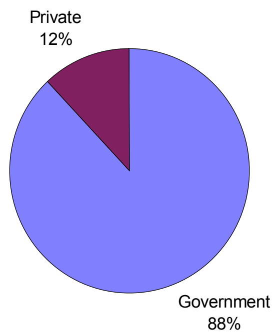
Inland valley bottoms equipped for irrigation are generally known as maye land in the Myanmar classification of cultivated areas. In order to generate increased paddy production, a combination of paddy and fish farming on plots of 1-2 ha protected by embankments has been introduced in maye land areas, where rice yields were uncertain. Another type of water management is what is called kaing land in the Myanmar classification (flood recession cropping). These lands are generally cultivated with vegetables, mainly in the Ayeyarwady Delta.

FIGURE 5
Irrigation from groundwater
TOTAL: 55 175 ha in 1995



In the Ayeyarwady Delta, drainage, salt intrusion and flood protection are major concerns. Embankments have been developed to protect large areas from both floods and salt intrusion. These embankments may have drainage facilities. There are a total of 318 flood protection works, both government and private, protecting a total of 1.2 million ha of cultivable land (Figure 6). A small portion of this area (less than 10 percent) is also irrigated by small lift pumps.

FIGURE 6
Area protected by embankments
TOTAL: 1 239 941 ha in 1995



In 1995, 193 363 ha were reported as equipped with surface drainage networks. Drainage works are also considered a form of flood protection.

Salinization due to irrigation is mainly found in the central dry zone, near Meiktila in Mandalay Division, where groundwater is used for irrigation purposes.

After the decision of the Government to move towards a market-oriented economy, and the consequent freedom given to farmers to cultivate crops of their choice, agricultural cropping patterns have changed dramatically. Jute used to be the second most widely cultivated crop (after rice), but it has now been replaced by cash crops such as beans, pulses, sunflowers, chilies and vegetables.

Farmers have to pay a tax of 25 kyatts/ha/year for irrigated areas (which is equivalent to US$4.1/ha/year at the official rate and US$0.2/ha/year at the open market rate), and 12 kyatts/ha/year for flood protected areas. Once collected, this revenue is channelled to the Revenue Department. The amount of the tax, decided in 1982, does not take into consideration the nature of the crop, cropping intensity or irrigation technique. It is not clear whether this tax applies to both public and private schemes.

Average irrigation development costs vary from 12 300 to 49 100 kyatts/ha (US$2 000-8 000 or 100-400/ha). Drainage and embankment development cost around 7 400 kyatts/ha (US$1 200 or 60/ha).

The Irrigation Department is responsible for the O&M of the government schemes, and the annual budget for both irrigated and flood protected areas is 200 million kyatts (US$33 million or 1.65 million).

INSTITUTIONAL ENVIRONMENT

The Ministry of Agriculture is the main ministry involved in water resources through its various departments:

- the Water Resources Utilization Department, which is responsible for groundwater use (for both irrigation and rural water supply), irrigation by pumping in rivers, and the development of sprinkler and micro-irrigation;
- the Irrigation Department, which is responsible for O&M of irrigation works, construction of new projects, and investigation, design and implementation of proposed projects, as long as surface water is used;
- the Settlement and Land Records Department, which is responsible for collecting agricultural statistics and land administration;
- the Agricultural Planning Department, which is in charge of planning, monitoring and evaluation of all agricultural projects, including irrigation and drainage projects.

The Meteorology and Hydrology Department of the Ministry of Communication, Posts and Telegraphs is in charge of collecting hydrological and meteorological data, while the Irrigation Department has also its own hydrological network. Hydropower generation is supervised by the Myanmar Electric Power Enterprise, within the Ministry of Energy.

Since the promulgation of the Land Nationalization Act (1953), all land officially belongs to the State. However, farm households benefit from a customary usufruct right to the land. There is no water law in Myanmar.

TRENDS IN WATER RESOURCES MANAGEMENT

The Government has set a target of 100 percent for water supply coverage in 2000, but a more realistic objective considering the funds allocated for this programme would be near 70 percent.

Within the framework of its irrigation policy, the Ministry of Agriculture has decided to undertake:

- the construction of new reservoirs and dams;
- the rehabilitation of existing reservoirs and networks of both government and private sectors, in order to upgrade the storage capacity and allow for an efficient delivery of irrigation water;
- the development of flood protection by embankment, and irrigation expansion after flood recession;
- the development of pump irrigation;
- the development of an efficient use of groundwater for irrigation.

The official target for irrigation development is to irrigate 25 percent of cultivated areas before 2000, which is realistic regarding the ongoing and planned projects. Concerning the flood protected areas, no target has been fixed by the Government although some 400 000 ha in the delta are in need of reclamation.

All new projects related to dam construction are now multipurpose projects and include flood control, town water supply, hydroelectricity and irrigation. The priority for multipurpose projects with hydropower is an indicator of the expanding demand for energy.

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Nepal

GEOGRAPHY AND POPULATION

Nepal is located entirely in the Ganges basin and is bordered by India in the east, south and west and by China in the north. With fifteen peaks higher than 7 000 m, including the world's highest peak Mount Everest at 8 848 m, Nepal is one of the highest countries in the world. The total land area of Nepal is 143 000 km^2. Physiographically, the country can be divided into three parts: the high Himalayas in the north (23.7 percent of the country's total area); the hill and mountain slopes in the centre (56.2 percent) which include the lower hills called siwalik where elevations vary between 300 and 700 m; and the plain in the south at elevations below 300 m (20.1 percent). For administrative purposes, the country is divided into 5 development regions and 75 districts.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1996	14 718 000	ha
Cultivable area	1994	3 955 100	ha
Cultivated area	1994	2 641 742	ha
- annual crops	1994	2 598 742	ha
- permanent crops	1994	43 000	ha
Population:			
Total population	1996	22 021 000	inhabitants
Population density	1996	154	inhab/km^2
Rural population	1996	86	%
Economically active population engaged in agriculture	1996	93	%
Water supply coverage:			
Urban population	1993	67	%
Rural population	1993	39	%

The cultivable area has been estimated at some 4 million ha, of which 34 percent in the terai plain, 8 percent in the siwalik, 48 percent in the mountain and hill region and 10 percent in the high Himalayas. Some 2.6 million ha are cultivated, mainly with annual crops.

The total population was estimated in 1996 at 22 million inhabitants (86 percent rural). The latest national census (1991) showed that 7.8 percent of the total population was living in the mountain region, 45.5 percent in the hill region and 47.6 percent in the terai region. Through comparison with 1981 census data, the annual average growth rate of population has been established at 2.1 percent. The highest population density reached 1 710 inhabitants/km^2 in 1991 in the capital district Kathmandu and 1 454 inhabitants/km^2 in Bhaktapur district near the capital. The lowest density was 2.4 inhabitants/km^2 in Manang district (a Himalayan valley).

Agriculture contributed 40 percent of GDP in 1996 and employed more than 93 percent of the economically active population of the country. The main agricultural exports are pulses, jute and rice. The prevailing high population growth and low growth rates in the agricultural and industrial sectors have resulted in a continuous deterioration in real per caput GDP.

CLIMATE AND WATER RESOURCES

Climate

Extremely varied topography within a small width ranging from 145 to 241 km influences the weather and climate of Nepal. The country experiences tropical, meso-thermal, micro-thermal,

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		1 500	mm/year
		221	km^3/year
Internal renewable water resources		198.2	km^3/year
Total renewable water resources	1995	210.2	km^3/year
Dependency ratio		5.7	%
Total renewable water resources per inhabitant	1996	9 545	m^3/year
Total dam capacity	1995	85	10^6 m^3
Water withdrawal:			
- agricultural	1994	28 702	10^6 m^3/year
- domestic	1994	246	10^6 m^3/year
- industrial	1993	5	10^6 m^3/year
Total water withdrawal		28 953	10^6 m^3/year
per inhabitant	1996	1 315	m^3/year
as % of total renewable water resources		14	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional water sources:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- reused treated wastewater		-	10^6 m^3/year

taiga and tundra types of climate. The mean annual rainfall is 1 500 mm, with a maximum annual rainfall record of 5 581 mm in 1990 at Lumle in Kaski district (elevation of 1 740 m) in the mountain region; and a minimum record of 116 mm in 1988 at Jomosom in Mustang district located at 2 744 m in the Kaligandi River valley near the Annapurna Himalayan range. There are two rainy seasons in Nepal: one in the summer (June to September) when the southwest monsoon brings more than 75 percent of the total rainfall, and the other in winter (December to February) accounting for less than 25 percent of the total. With the summer monsoon, rain first falls in the southeast of the country and gradually moves west with diminishing intensity. Thus, more rain naturally occurs in the east of the country. On the other hand, during winter, rain occurs as a result of westerly disturbances. This rain first enters Nepal in the west and gradually moves east with diminishing intensity.

The temperature decreases from the lowland terai (northern part of the Ganges plain) to the high Himalayan region. The extreme temperatures recorded show that in Lomangtang (Mustang district) located at an elevation of 3 705 m the minimum temperature was -14.6°C in 1987, while in Dhangadhi (Kailali district) located at an elevation of 170 m the maximum temperature reached was 44°C in 1987. Precipitation falls as snow at elevations above 5 100 m in summer and 3 000 m in winter. Temperature is a constraint on crop production in the Himalayas and the mountain region where only a single crop per year can be grown. On the other hand, in the terai, three crops a year are common where the water supply is adequate. Single rice cropping is possible up to elevations of 2 300 m while double rice cropping is limited to areas below 800 m.

River basins and water resources

All rivers in Nepal drain into the Ganges River. The country is divided into five river basins, which are from west to east:

- the Mahakali River basin, which is shared with India, with an average flow from the Indian tributaries into the border river estimated at 15 km^3/year and some 3.4 km^3/year from the Nepalese tributaries;
- the Karnali River basin, with an average outflow estimated at 43.9 km^3/year;
- the Gandaki River basin, with an average outflow estimated at 50.7 km^3/year;

- the Kosi River basin, with an average outflow estimated at 47.2 km^3/year, but which receives a contribution of some 12 km^3/year from the upper catchment area located in China (47 290 km^2);
- the southern river basins, which produce some 65 km^3/year of water flowing into India.

The seasonal distribution of flow is extremely variable. It might be as low as 1.5-2.4 percent of the total runoff in January, February and March, and as high as 20-27 percent in July and August for snowfed rivers, while the corresponding figures for purely rainfed rivers are 0.5-3 percent from March to May and 19-30 percent in July and August.

The surface water resources produced internally are estimated at 198.2 km^3/year. The groundwater resources have not been fully assessed. Ongoing studies show that a good potential for groundwater extraction exists, especially in the southern lowland plains (terai) and inner valleys of the hilly and mountainous regions. Much of the terai physiographic region and some parts of siwalik valleys are underlain by deep or shallow aquifers, many of which are suitable for exploitation as sources of irrigation water. A rough estimate can be made by assuming a groundwater resource equivalent to ten percent of surface water, i.e. approximately 20 km^3/year, which corresponds to the base flow of the rivers. The total internal water resources would therefore amount to 198.2 km^3/year. Chinese statistics mention an average outflow to Nepal of 12 km^3/year, which brings the total renewable water resources of Nepal to 210.2 km^3/year. This makes Nepal one of the Asian countries with the highest level of water resources per inhabitant. It is assumed that all the renewable water resources of Nepal flow out of the country to India.

No agreements have been established with China for the sharing of water resources. A joint commission for the exploitation of the Kosi River was set up with India in 1954 and 1966, and another for the exploitation of the Gandak River in 1959. Recently, a new treaty on the Mahakali River has been ratified by parliament. The treaty makes provision for equal entitlement in the utilization of water from the Mahakali River without prejudice to respective existing consumptive uses.

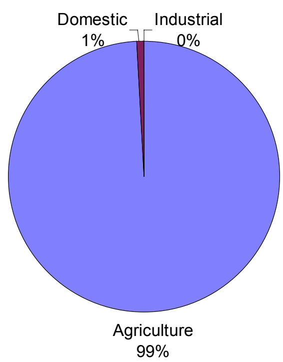
Lakes and dams

The total dam capacity is 85 million m^3, although the potential exists for at least 138 km^3. Hydroelectricity accounts for more than 96 percent of total electricity generation. The two main diversion barrages are the Kosi and Gandaki reservoirs.

Water withdrawal

Water withdrawal for the domestic sector is from different types of sources such as springs, wells (open and tube), rivers/streams, traditional stone taps and modern piped systems (Figure 1). Data on withdrawals exist only for public piped systems developed after 1974. However, a feasibility study conducted by a Thai study team in November 1993 on the Kodkhu Water Supply Project estimated that the industrial consumption (including commercial) for the urban valley of Kathmandu represented about 5 percent of the domestic demand in the year 1991.

FIGURE 1
Water withdrawal
Total: 29.0 km^3/year



None of the irrigation systems in Nepal measures the quantum of water supplied to irrigation. The available data are: (i) annual diversion requirements for monsoon and year-round irrigation based on physiographic regions; and (ii) irrigation command areas split into seasonal (monsoon) and year-round. Considering that water application depends on soil type, land type, cropping pattern, evapotranspiration, effective rainfall and conveyance losses, a special study needs to be conducted to determine a more accurate estimate of irrigation water withdrawal.

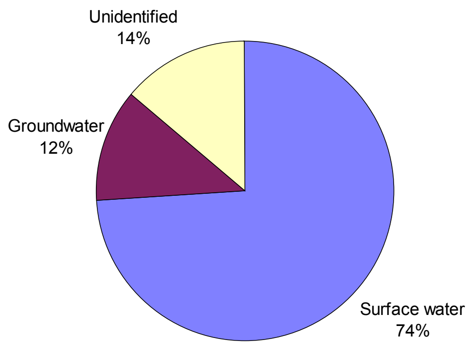
It is reported that the piped domestic water supply reached 67 and 39 percent of the population in urban and rural areas respectively in 1992. Compared with the statistical data on piped water supply for the 1994/95 fiscal year, the average consumption per caput per day in the areas with access to piped water is about 83 litres.

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation development in Nepal has a long history. Numerous small raj kulos (canals) in the government sector first appeared in and around Kathmandu valley in the seventeenth and eighteenth centuries. The first large public sector irrigation canal system (the Chandra Canal System) with a net command area of 10 000 ha was constructed in 1922 and is still in operation.

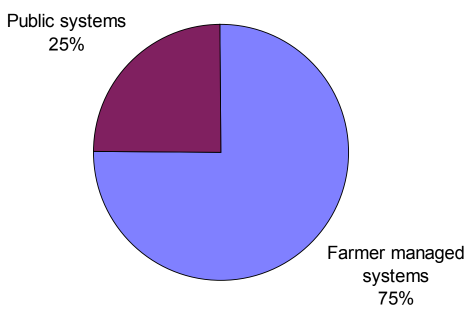
The irrigation potential of the country has been estimated at 2 177 800 ha, including some 412 000 ha which are not cultivated, mainly in the terai area. This potential is mainly for surface irrigation, but some 352 050 ha are potentially irrigable from groundwater in the terai region, consisting of 292 600 ha from shallow tube-wells (83 percent) and 59 450 ha from deep tube-wells (17 percent).

FIGURE 2
Irrigated areas
TOTAL: 1 134 334 ha in 1994



In 1994, the total irrigated area in Nepal was estimated by the Land Resources Mapping Project at 1 134 334 ha. This included 140 195 ha of groundwater irrigation, 837 913 ha of surface water irrigation and 156 226 ha of irrigation systems not fully identified (Figure 2). Except for one system (the Banganga system with 6 500 ha), all the areas under existing surface irrigation systems are dependent on transit flow availability at the sources. Therefore, the irrigated area varies from season to season and from region to region. The total year-round irrigated area has been estimated at 355 054 ha.

FIGURE 3
Typology of irrigated schemes
TOTAL: 1 134 334 ha in 1994



Irrigated areas in Nepal are often classified as public systems and farmer managed irrigation systems (FMISs) (Figure 3).

Public schemes cover an area of 283 658 ha, with 258 416 ha (91 percent) dependent on surface water and 25 242 ha (9 percent) dependent on groundwater (Figure 4). They are managed by the Department of Irrigation. These public surface irrigation schemes have expanded steadily since 1973 (Figure 5). Out of the 283 658 ha equipped for irrigation, only 187 153 ha are irrigated in summer, 86 056 ha in spring and 3 200 ha in winter (Figure 6).

TABLE 3
Irrigation and drainage

Irrigation potential	1994	2 177 800 ha
Irrigation:		
1. Full or partial control irrigation: equipped area		- ha
- surface irrigation		- ha
- sprinkler irrigation		- ha
- micro-irrigation		- ha
% of area irrigated from groundwater (*)		12.4 %
% of area irrigated from surface water (*)		73.9 %
% of equipped area actually irrigated		- %
2. Spate irrigation area		- ha
Total irrigation (1+2)	**1994**	**1 134 334 ha**
- as % of cultivated area		43 %
3. Other water management area		- ha
Total water managed area (1+2+3)		**- ha**
- as % of cultivated area		- %
- increase over last 10 years		- %
- power irrigated area as % of water managed area		- %
Full or partial control irrigation schemes:		
Large-scale schemes		- ha
Medium-scale schemes		- ha
Small-scale schemes		- ha
Total number of households in irrigation		-
Irrigated crops:		
Total irrigated grain production		- tons
as % of total grain production		- %
Harvested crops under irrigation (full or partial control)		**- ha**
- permanent crops: total		- ha
- annual crops: total		- ha
Drainage - environment:		
Drained area		- ha
- drained areas in full or partial control irrigated areas		- ha
- drained areas in equipped wetland and i.v.b		- ha
- other drained areas		- ha
- total drained area with subsurface drains		- ha
- total drained area with surface drains		- ha
as % of cultivated area		- %
Flood protected area		- ha
Area salinized by irrigation		- ha
Population affected by water-borne diseases		- inhabitants

(*) The source of water is not known for 156 226 ha (13.7% of irrigated area)

FMISs in Nepal have operated successfully for centuries. Most FMIS diversion structures are constructed from brushwood and boulders, and are therefore temporary and often washed away during monsoon season. The FMIS canals are generally unlined and prone to damage. There is, typically, a large expenditure of labour every year to restore the systems or to maintain them. In spite of these physical limitations, FMISs have demonstrated managerial skills (at community level) that have kept them functioning and contributing significantly to Nepal's food supply. The total area of the FMISs was estimated at 850 676 ha in 1994. FMISs can be either entirely managed by farmers or assisted by specialized agencies.

FIGURE 4
Public schemes: origin of water
TOTAL: 283 668 ha in 1994

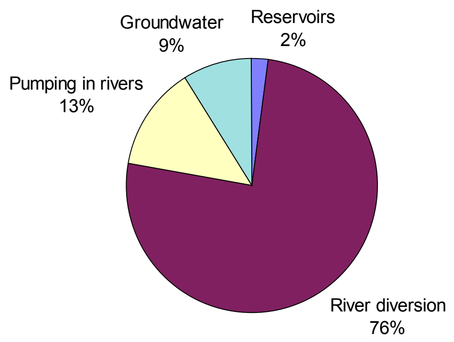


FIGURE 5
Evolution of public schemes irrigated area, 1973-1994

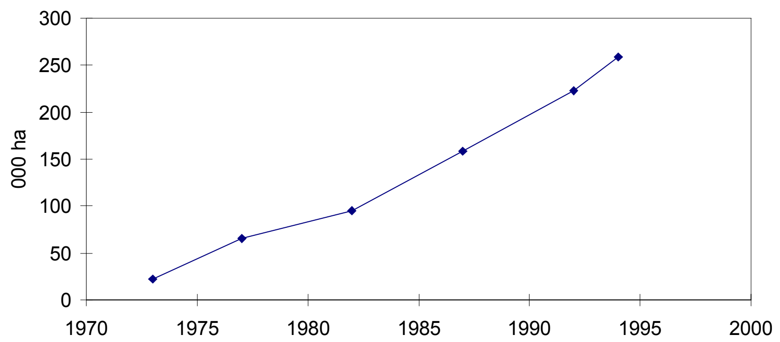
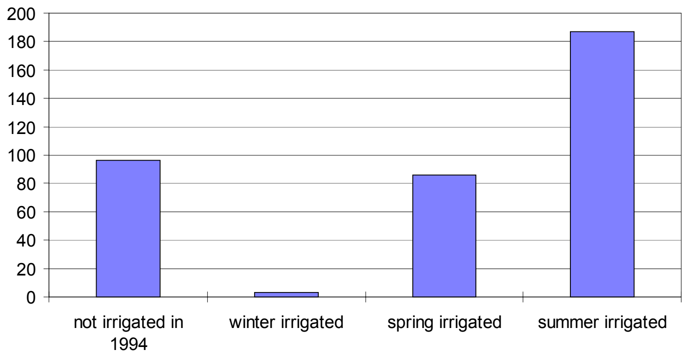


FIGURE 6
Public schemes
TOTAL: 283 658 ha equipped



The great majority of irrigation systems use surface irrigation (basin, furrow). Recently some areas in the hills and mountains have begun to use sprinkler irrigation, but no figures are available.

The modernization of irrigation systems and improved water management practices could lead to a reduction in irrigation water withdrawal. On the other hand, a higher cropping intensity on the irrigated areas (only 16 percent of the irrigable areas are irrigated year-round), which would be desirable because of the increasing need for food supply, would result in increased agricultural water withdrawal.

Nepal is mainly a rural society, and there is a traditional belief that water is a god-given free commodity. Only the water supplied to urban areas for domestic use is charged on a volumetric basis. Irrigation water is levied as a service charge. This charge is levied only for the public irrigation systems. It varies from US$1.3 to 8.0/ha depending upon the type and source of supply.

The average cost for irrigation development varies from US$2 900 to 3 700/ha for the large schemes, and from US$850 to 4 300/ha for small hill schemes. The average cost for irrigation rehabilitation varies from US$1 000 to 1 800/ha. The average cost of O&M is about US$42/ha in the smaller schemes, and US$8-14/ha in the larger schemes.

The main irrigated crop is paddy, followed by wheat in winter.

Non-formal associations have existed for a long time in almost all FMISs. WUAs received legal status after the promulgation of the 1992 Water Resources Act. The WUA has now become a prerequisite for the transfer of public schemes to users.

INSTITUTIONAL DEVELOPMENT

The major government institutions currently involved in the water resources and irrigation sectors are:

- the Ministry of Water Resources (MOWR);
- the Department of Hydrology and Meteorology, in charge of water resources assessment and monitoring;
- the Department of Irrigation (DOI). The DOI's main functions consist of the planning, design and implementation of major and minor irrigation systems and the sustained O&M of some of the completed systems. Its mandate covers all aspects of irrigation, irrigated agriculture and policy implementation.

Other institutions that have direct linkages with the irrigation sector are:

- the National Planning Commission Secretariat (NPC), which prepares plans for all sectors including irrigation;
- the Water and Energy Commission Secretariat (WECS), which is a consultative body of the Government;
- the Department of Agriculture (DOA), whose function is to increase agricultural productivity, notably through irrigation;
- the Agriculture Development Bank of Nepal (ADB/N), which provides concessional loans and channels government subsidies for rural projects.

In addition, FMISs can also be classed as institutions in that they are voluntary associations of farmers who organize themselves to build irrigation infrastructures, and to manage them in accordance with formal or informal rules and procedures.

TRENDS IN WATER RESOURCES DEVELOPMENT

The 8th Five Year Plan (1992-97) recognized that farmer participation is crucial for the improved management of the available supply of irrigation water. Accordingly, the following policy elements have been emphasized by the Government:

- The irrigation projects managed at government level should be gradually transferred to WUAs. Such a transfer would affect the schemes of 2 000 ha in the terai and 500 ha in the hills and mountains.
- No water service charge should be levied on schemes transferred to WUAs.
- Before transferring the schemes to WUAs, the schemes should be rehabilitated and strengthened in accordance with the demands of WUAs. For this, a cost-sharing mechanism should be introduced with a view to providing WUAs with a sense of ownership. About 5-15 percent of the rehabilitation cost should be financed directly from WUAs and farmers.

In addition, the Government has also given individual farmers the possibility of receiving subsidies. Farmers wishing to manage small irrigation systems (up to 25 ha in the terai and 10 ha in the hills and mountains) would be required to bear the investment cost (in kind or cash) up to a maximum of 60 percent as follows:

- for shallow tube-wells - 60 percent;
- for sprinkler or drip irrigation - 40 percent;
- for lift irrigation - 25-60 percent;
- for surface (gravity) irrigation - 40 percent.

The remainder could be financed by the Government, NGOs or social organizations.

Water management should be adjusted to enable the conjunctive use of surface water and groundwater.

MAIN SOURCES OF INFORMATION

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Papua New Guinea

GEOGRAPHY AND POPULATION

Papua New Guinea lies to the north of Australia just south of the equator. Apart from the mainland, Papua New Guinea consists of a collection of islands, atolls and coral reefs scattered around the coastline. The total land area of Papua New Guinea is 452 860 km² and the country encompasses a large marine jurisdictional zone covering 2.3 million km². For administrative purposes, the country is divided into 20 provinces. The capital city is Port Moresby.

The principal topographical features of the mainland, the Bismarck Archipelago and the north Solomon Islands are the highly dissected mountain ranges which reach 4 509 m on the mainland. In the western half of the mainland are the extensive lowland plains and swamps of the Sepik-Ramu and Fly rivers, lying respectively north and south of the main mountain ranges.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	46 284 000	ha
Cultivable area	1997	12 500 000	ha
Cultivated area	1996	540 000	ha
- annual crops	1996	60 000	ha
- permanent crops	1996	480 000	ha
Population:			
Total population	1996	4 400 000	inhabitants
Population density	1996	9	inhab/km^2
Rural population	1996	84	%
Economically active population engaged in agriculture	1996	77	%
Water supply coverage:			
Urban population	1990	94	%
Rural population	1990	20	%

In 1997, the cultivable area of the country was estimated at 12 500 000 ha, or about 27 percent of the total area. Some 540 000 ha were reported to be cultivated in 1996, mainly with starch food crops such as taro, sweet potato, yam, cassava, banana and sago. Export crops planted in extensive plantations and by subsistence farmers include coffee, cocoa, oil palm, coconut and minor export crops such as tea, cardamon, vanilla and rubber.

In 1996, the total population was estimated to be at 4.4 million inhabitants with a growth rate of 2.23 percent. The rural population represented 84 percent of the total. The population density was approximately 9 inhabitants/km². According to the 1990 census, population densities were higher in pockets such as Simbu, Western Highlands province and Eastern Highlands province with 31, 48 and 29 inhabitants/km² respectively.

In 1996, GDP per caput was US$420. The agriculture sector contributed 40 percent of GDP. In 1996, about 77 percent of the total economically active population was engaged in agriculture.

CLIMATE AND WATER RESOURCES

Climate

The climate is humid and rainy. Temperatures are not extreme for tropical climates and most areas, apart from the high altitudes, have a daily mean temperature of 27ºC with little variation. Humidity in the lowland areas varies around 80 percent. Varied topography and location

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		3 500 mm/year
		1 585 km^3/year
Internal renewable water resources		801 km^3/year
Total renewable water resources	1992	801 km^3/year
Dependency ratio		0 %
Total renewable water resources per inhabitant	1996	182 045 m^3/year
Total dam capacity		- 10^6 m^3
Water withdrawal:		
- agricultural	1987	49 10^6 m^3/year
- domestic	1987	29 10^6 m^3/year
- industrial	1987	22 10^6 m^3/year
Total water withdrawal		100 10^6 m^3/year
per inhabitant	1996	23 m^3/year
as % of total (actual) renewable water resources		0.012 %
Other water withdrawal		- 10^6 m^3/year
Wastewater - non-conventional sources of water:		
Wastewater:		-
- produced wastewater		- 10^6 m^3/year
- treated wastewater		- 10^6 m^3/year
- re-used treated wastewater		- 10^6 m^3/year

determine localized climates in the country. There are two principal wind directions, which strongly influence the rainfall patterns of the country. They are:

- southeast, from May to October;
- northwest, from December to March.

April and November are transition months.

However, high mountain barriers across the path of these winds induce heavy orographic convective rainfall on the northern and southern slopes in the highlands themselves. Thermal convective rainfall is characteristic of the Fly and Sepik lowlands.

The average rainfall varies from one location to another. On the mainland, the mean annual rainfall ranges from less than 2 000 mm along the coast to more than 8 000 mm in some mountain areas. The island groups to the north and the northeast receive an average rainfall between 3 000 and 7 000 mm/year. Areas lying southwest of Fly River, west of Lae in the Markham valley, receive less than 2 000 mm of rain per year. The Port Moresby coastal area receives least rain with less than 1 000 mm/year.

River basins and water resources

Geologically, Papua New Guinea is a young country. The presence of high mountain ranges and abundant rainfall leads to high runoff over most of the country.

There are nine hydrological drainage divisions (basins) in the country. The largest river basins of the country are the Sepik, Fly, Purari and Markham. Even though the Sepik has the lowest annual discharge, it has the largest catchment area, 78 000 km², followed by the Fly River with 61 000 km², Purari with 33 670 km², and Markham with 12 000 km². The other catchments are less than 5 000 km² in area and are very steep.

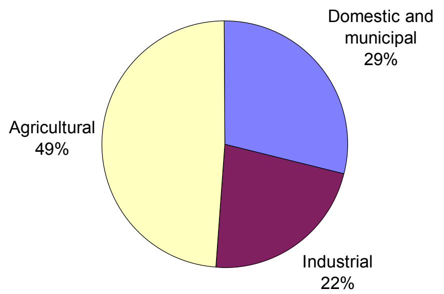
The internal renewable water resources are estimated at 801.0 km^3/year. As the country has an abundance of surface water resources and as there are few large-scale consumers, groundwater resources have not been developed much. However, there is evidence that groundwater is being used increasingly as a source of reliable high quality water. In 1974, 34 percent of the villages surveyed relied on groundwater from boreholes, dug-wells or springs. In the 1970s and 1980s, groundwater was developed for urban water supply schemes in seven major towns. The bacteriological and chemical quality of most of the groundwater in Papua New Guinea is good. Groundwater resources have not been assessed but it is assumed that most groundwater returns to the river systems and is therefore included in the surface water resources.

Lakes and dams

There are around 5 383 freshwater lakes in the country. The lakes are mostly small, and only 22 have a surface area exceeding 1 000 ha. Lake Murray is the largest with a surface area of 64 700 ha.

In 1986, there were three dams in the country over 15 m high. The gross theoretical hydropower potential for Papua New Guinea is 175 000 GWh/year. In 1990, the total installed capacity was 163 MW and the annual generation was 438 GWh/year.

FIGURE 1
Water withdrawal
TOTAL: 0.1 km³ in 1987



Water withdrawal

In 1987, the total water withdrawal was 0.1 km^3. The main consumer was the agriculture sector with 49 percent, followed by the domestic (29 percent) and industrial sectors (22 percent) (Figure 1). In 1990, 94 percent of the urban population and 20 percent of the rural population had access to water supply.

IRRIGATION AND DRAINAGE DEVELOPMENT

In Papua New Guinea, subsistence agriculture is the largest single economic activity. Most of the crops are rainfed and there is very little irrigation.

There is evidence that simple flood irrigation techniques began in the highlands at least 450 years ago. In Papua New Guinea, the traditional methods of water application include:

- simple flooding, where water is led to the upper edge of the garden and then circulates down, usually with simple wood or stone barriers to slow down the flow. This acts to control erosion and trap sediments. In some cases, rough terraces are constructed directly in small stream beds. This is a highland practice found in Enga, Madang, Western Highlands, Eastern Highlands and Morobe provinces. Irrigated garden areas are generally small;
- the pondfield system, where the planted area is an artificial pond through which water is kept constantly flowing. The system is reported in Papua New Guinea's Mussau islands;
- corrugated or furrow irrigation, where water is applied to the ground in small, shallow furrows so that it soaks laterally through the soil, wetting the area between the corrugations. This system is used in west New Britain and Bougainville.

A 1986 FAO study identified a land area of 36 000 ha as agronomically suitable for irrigated rice production. A commercial company in the Markham-Ramu valley introduced limited supplementary irrigation early in its development for the purpose of establishing seed cane

TABLE 3
Irrigation and drainage

Irrigation potential	1986	36 000 ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1997	0 ha
- surface irrigation		- ha
- sprinkler irrigation		- ha
- micro-irrigation		- ha
% of area irrigated from groundwater		- %
% of area irrigated from surface water		- %
% of equipped area actually irrigated		- %
2. Spate irrigation		- ha
Total irrigation (1+2)	**1997**	**0 ha**
- as % of cultivated area		0 %
- power irrigated area as % of irrigated area		- %
3. Other water management area		- ha
Total water managed area (1+2+3)	**1997**	**0 ha**
- as % of cultivated area		0 %
- increase over last 10 years	1997	0 %
- power water managed area as % of water managed area		- %
Full or partial control irrigation schemes:		
Large-scale schemes		- ha
Medium-scale schemes		- ha
Small-scale schemes		- ha
Total number of households in irrigation		-
Irrigated crops:		
Total irrigated grain production	1997	0 t
as % of total grain production	1997	0 %
Harvested crops under irrigation	**1997**	**0 ha**
- permanent crops: total	1997	0 ha
- annual crops: total	1997	0 ha
Drainage - environment:		
Drained area	1997	0 ha
- drained area in full or partial control irrigated areas	1997	0 ha
- drained area in equipped wetland and i.v.b.	1997	0 ha
- other drained area	1997	0 ha
- area with subsurface drains	1997	0 ha
- area with surface drains	1997	0 ha
Drained area as % of cultivated area		0 %
Power drained area as % of total drained area		0 %
Flood protected areas	1997	0 ha
Area salinized by irrigation	1997	0 ha
Population affected by water-borne diseases		- inhabitants

nurseries and initial wetting of plant cane to promote germination. However, the project was later abandoned for economic reasons.

INSTITUTIONAL ENVIRONMENT

Papua New Guinea is rich in natural resources including water. However, due to a lack of both human resources and political interest, and also to underlying financial constraints, it has not been able to achieve sustainable development in the water sector. The water sector in Papua New Guinea is fragmented and poorly coordinated. The Water Resources Act (1982) regulates the use of water.

The major government institutions involved in the water resources and irrigation sector are:

- the Department of Environment and Conservation (DEC), which is responsible for: the management and protection of the country's water resources; pollution control; and water related laws and regulations, and their enforcement. Its hydrological survey branch is responsible for monitoring surface water and rainfall stations. The DEC's activities have been severely curtailed by lack of funds;

- the Geological Survey of the Department of Mineral Resources (GSPNG), which is responsible for providing advice on groundwater exploration, assessment, management and protection of resources;
- the Water Board, which is a statutory organization responsible for water supply and sewerage in 11 towns throughout the country, though not the capital city. The development and management of rural water supply and sanitation has been delegated to the Department of Health since 1987.

TRENDS IN WATER RESOURCES DEVELOPMENT

The fourth directive principle of Papua New Guinea's national constitution is to conserve its natural resources (including water), use them for the collective benefit and ensure that they be replenished for the benefit of future generations.

Papua New Guinea is a rural country, where up to 90 percent of the population is reported to depend mainly on subsistence or semi-subsistence agriculture. There is hardly any significant irrigation development programme or proper irrigation policy. Although the country receives abundant rainfall, droughts do occur, the most recent one being in 1997, and can have a severe impact on the agriculture sector.

This experience has led the Government to seriously consider irrigation development as announced by the Minister for Agriculture and Livestock in a 1997 World Food Day message. According to this message:

- There is a need to develop small-scale village water supply, irrigation and water management.
- The Government and policy-makers need to examine irrigation development as a component of the strategy for increased food production.
- It is important to establish an irrigation development unit within the Department of Agriculture and Livestock and to develop a national irrigation policy.

Irrigation will be introduced for the first time in a pilot area, under the FAO's Special Programme for Food Security, where subsistence farming is the norm.

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Philippines

GEOGRAPHY AND POPULATION

The Philippines is a tropical country consisting of more than 7 000 islands. It is one of the largest island groups in the world covering a total area of 300 000 km^2, 92 percent of which is accounted for by the 11 largest islands. The archipelago is bounded by the South China Sea in the west, by the Philippines Sea (Pacific Ocean) in the east, by the Sulu Sea and Celebes Sea in the south and by the Bashi Channel in the north. Its northernmost islands are approximately 240 km south of the island of Taiwan, and the southernmost islands lie 24 km off the coast of Borneo (Malaysia). Of the 7 000 islands, only 3 144 are named. There are also thousands of small islets grouped with the larger islands. The Philippines is divided into three major island groups: Luzon, with an area of 142 000 km^2; Visayas, with an area of 56 000 km^2; and Mindanao, with an area of 102 000 km^2. These three groups are further divided into regions, provinces, cities and municipalities, which are further divided into barangays. In 1996, the country had 12 regions plus 3 specific regions, namely the Metropolitan Manila (national capital region), the Cordillera Administrative Region, and the Autonomous Region of Muslim Mindanao. There are 76 provinces, 60 cities, 1 544 municipalities and 41 921 barangays.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	30 000 000	ha
Cultivable area		-	ha
Cultivated area	1991	9 505 310	ha
- annual crops	1991	5 332 770	ha
- permanent crops	1991	4 172 540	ha
Population:			
Total population	1996	69 283 000	inhabitants
Population density	1996	231	inhab/km^2
Rural population	1996	45	%
Economically active population engaged in agriculture	1996	41.5	%
Water supply coverage:			
Urban population	1991	93	%
Rural population	1991	85	%

The Philippines has a varied topography with highlands and numerous valleys. Its four major lowland plains are the central plain and the Cagayan valley in Luzon, the Agusan valley and the Cotabato valley in Mindanao. These lowlands contrast sharply with the adjacent high mountain areas of the central and east Cordilleras and the Zambales mountains. The highest peaks reach almost 3 000 m above sea level at less than 30 km from the sea.

The total cultivated area is estimated at 9.5 million ha, of which 56 percent for annual crops. The average farm size is 2.2 ha.

In 1996, the total population was estimated at 69.28 million (45 percent rural). The average population density is 231 inhabitants/km^2, ranging from 46.9 inhabitants/km^2 in Agusan del Sur (Region X - northern Mindanao) to 348 inhabitants/km^2 in Region IV - southern Tagalog, a region in Luzon south of Manila, and more than 13 000 inhabitants/km^2 in Metropolitan Manila. The average annual population growth is estimated at 2.4 percent.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		2 373	mm/year
		712	km^3/year
Internal renewable water resources		479	km^3/year
Total renewable water resources	1990	479	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	6 914	m^3/year
Total dam capacity	1995	4 753	10^6 m^3
Water withdrawal:			
- agricultural	1995	48 857	10^6 m^3/year
- domestic	1995	4 269	10^6 m^3/year
- industrial	1995	2 296	10^6 m^3/year
Total water withdrawal		55 422	10^6 m^3/year
per inhabitant	1996	780	m^3/year
as % of total renewable water resources		11.6	%
Other water withdrawal	1995	89 591	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater	1993	74	10^6 m^3/year
- treated wastewater	1993	10	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

Agriculture is the prime mover of the country's economy, being at present the least import-dependent activity. From 1988 to 1990, the agriculture sector's contribution to GNP varied around 17 percent. It provided about 30 percent of GDP and generated more than 60 percent of total export earnings. It employed about 41.5 percent of the labour force in 1996.

CLIMATE AND WATER RESOURCES

Climate

The climate of the country is tropical and monsoonal. It is characterized by uniformity of temperature (average temperature of 27°C throughout the year), high relative humidity (above 70 percent everywhere throughout the year except in southern Tagalog where it falls to 65 percent in March/April), low solar radiation, diversity of rainfall and high frequency of tropical cyclones. The main air streams that affect the Philippines are the northeast monsoon from late October to March, the southwest monsoon from May to October and the North Pacific trade winds, dominant during April and early May. Many of the larger islands of the Philippines have high mountain ranges, most of which lie along a generally north-south axis across the paths of movement of the important air streams. Thus, apart from temperature effects due to elevation, the orographic effects of mountains have important influences on regional rainfall patterns by causing increased precipitation on windward slopes and rain shadows in their lee during the monsoon periods.

The average annual rainfall is estimated at 2 373 mm/year as observed from 1961-1990, but this figure varies from 961 mm (General Santos City in southeast Mindanao) to more than 4 051 mm (Infanta in central Luzon). The extreme annual rainfall events ever recorded are 94 mm at Vigan in Ilocos Sur (northern Luzon) in 1948 and 9 006 mm in Baguio City (northern Luzon) in 1910.

The rainfall pattern and annual amount are influenced mainly by altitude and wind. The northwest of the country has a dry season from November to April and a wet season during the rest of the year, i.e. the southwest monsoon. The southeast receives rainfall all year round, but with a pronounced maximum from November to January during the northeast monsoon. In the areas not directly exposed to the winds, rainfall is evenly distributed throughout the year, or there are two seasons but not very pronounced; from November to April the weather is relatively dry while it is relatively wet the rest of the year. The lowest rainfall occurs in the provinces of Cebu, Bohol and Cotabato in the centre of the country.

The archipelago lies in the typhoon belt, and many islands are liable to extensive flooding and damage during the typhoon season from June to December. The frequency of typhoons is greater in the northern portion of the archipelago than in the south. Usually, two or three typhoons reach the country each year.

River basins and water resources

There are 421 rivers in the country, not counting small mountain streams that sometimes swell to three times their size during rainy months. The rivers are an important means of transportation and a valuable source of water for irrigation for the fields and farms through which they pass. There are also 59 natural lakes and more than 100 000 ha of freshwater swamps.

The five principal river basins (more than 5 000 km^2) are: the Cagayan River basin in north Luzon (25 469 km^2); the Mindanao River basin (23 169 km^2) in Mindanao island; the Agusan River basin (10 921 km^2) in Mindanao island; the Pampanga River basin (9 759 km^2) near Manila in Luzon island; and the Agno River basin (5 952 km^2) in Luzon island. Only 18 river basins have an area greater than 1 000 km^2: 8 of them are in Mindanao island, 7 in Luzon island, 2 in Panay island and 1 in Negros island. The smallest river basins are frequently under 50 km^2.

In order to have manageable units for comprehensive planning of water resources, the National Water Resources Council divided the country into 12 water resources regions. Major considerations taken into account in this regionalization were the hydrological boundaries defined by physiographic features and homogeneity in climate of the different parts of the country. However, in fact, these water resources regions generally correspond to the existing political regions in the country. Minor deviations dictated basically by hydrography affected only northern Luzon and northern Mindanao.

The country's annual average runoff is estimated at 444 km^3. In nine years out of ten, the annual runoff exceeds 257 km^3.

Groundwater resources

There are four major groundwater reservoirs (Cagayan, 10 000 km^2; Central Luzon, 9 000 km^2; Agusan, 8 500 km^2; Cotobato, 6 000 km^2) which, when combined with smaller reservoirs already identified, would aggregate to an area of about 50 000 km^2.

Private wells are extensively used in rural areas for domestic purposes. Municipal waterworks wells are drilled by the Local Water Utilities Administration for domestic purposes and deep wells have been drilled by the National Irrigation Administration (NIA) for irrigation purposes.

The groundwater resources are estimated at 180 km^3/year, of which 80 percent (145 km^3/year) would constitute the base flow of the river systems. The total internal water resources would therefore amount to 479 km^3/year.

Dams

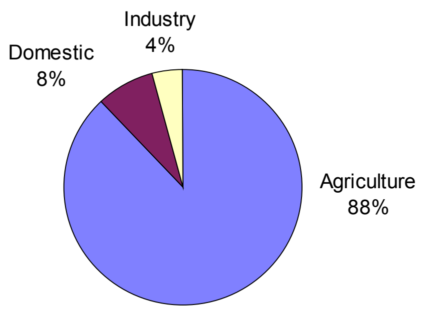
The total dam capacity in 1995 was 4 753 million m^3, consisting of about 54 small dams (for a total capacity of 80 million m^3) and 6 large dams. In the Philippines, a dam is considered large when the storage capacity exceeds 50 million m^3 and the structural height is more than 30 m. Three of the large dams are managed by the National Power Corporation (NPC) (Angat, Ambuklao and Palangui IV for a total capacity of 1 426 million m^3), the two largest dams being managed by the NIA (Magat - Magat River Integrated Irrigation System (MRIIS) and Pantabangan - Upper Pampanga River Integrated Irrigation System (UPRIIS) for a total capacity of 3 196 million m^3). One large dam (La Mesa, 51 million m^3) is managed by the Metropolitan Waterworks and Sewerage System, which is also responsible for the management of a small dam (Ipo with a capacity of 36 million m^3). The NPC is also in charge of three small dams (Agus II, IV and V for a total capacity of 27.7 million m^3) while all other small dams have been created with various objectives within the framework of the small water impounding management (SWIM) projects, which are implemented by several agencies.

A survey of surface water storage potential has identified sites for 438 major dams and 423 smaller dams.

Water withdrawal

The total water withdrawal was estimated on the basis of the water rights issued by the National Water Resources Board (NWRB) at 55 422 million m^3 in 1995, of which 88 percent for agricultural purposes (Figure 1). Other water withdrawal (non-consumptive use of water) included hydropower (89 000 million m^3), fisheries (498 million m^3) and recreation (93 million m^3).

FIGURE 1
Water withdrawal
Total: 55 422 million m^3 in 1995



Production of wastewater in the national capital region and nearby provinces is estimated at 74 million m^3, while the volume of treated wastewater reached 10 million m^3 in 1994 at the Ayala and Dagat-Dagatan pond. Disposal of wastewater is expected to increase as new sewer lines are being built every year.

IRRIGATION AND DRAINAGE DEVELOPMENT

The irrigation potential was estimated at 3.1 million ha in 1990. It corresponds to the area where irrigation facilities can easily be provided by the Department of Agriculture or the NIA. The primary definition of irrigation potential in the Philippines is land on slope less than 3 percent (this criterion might be violated by including somewhat steeper land if it is already terraced for paddy cultivation and water could be easily delivered). A World Bank survey has proposed the reassessment of irrigation potential as the figure of 3.1 million ha was obtained without considering new settlement on agricultural lands, water resources availability, water resources development cost, need of flood control and drainage facilities, etc.

Although irrigation development in the Philippines was undertaken by rural communities (Banawe terraces, cooperative irrigation societies (zinjara) and lowland schemes near Manila) in earlier centuries, the major irrigation investment periods have been the 1920s, the post-war period and the 1970s and early 1980s when public involvement in the irrigation subsector was at its maximum. In this respect, the creation of the NIA in 1964 has been decisive.

In 1992, the area of land equipped for full/partial control irrigation was estimated at 1 532 751 ha. Irrigation water is generally supplied by river diversion (Figure 2).

There are three types of irrigation systems in the Philippines (Figure 3): national irrigation systems (NIS), communal irrigation systems (CIS) and private schemes.

FIGURE 2
Types of irrigation systems
Total: 1 532 751 ha equipped in 1992

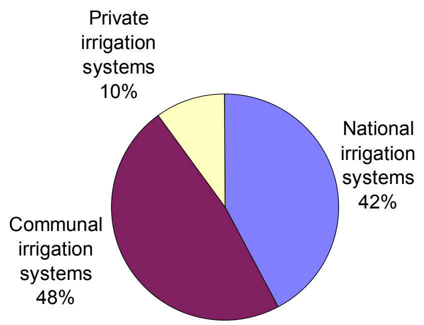
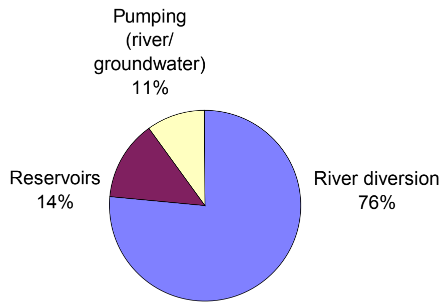


FIGURE 3
Origin of irrigation water
Total: 1 532 751 ha equipped in 1992



NIS schemes (646 519 ha in 1992) have been constructed and are operated and maintained by the NIA. The cost of the system is borne entirely by the NIA; farmers have to pay fees to cover O&M expenditure. There are about 150 NIS schemes spread throughout the country. Three main sub-types coexist, differing by water origin:

- Three large schemes (Magat, for a total area of 80 977 ha; Upper Pampanga, 94 300 ha; and Angat Maasim, 31 485 ha) are backed by multipurpose reservoirs. Although classified as single entities, they are actually conglomerates served by multiple diversion structures which also utilize supplies from uncontrolled rivers crossing the irrigated area. Parts of the service area may be too high to be commanded by the reservoir and are commanded by pump schemes. In 1989, the cropping intensity on these schemes was about 89 percent during the wet season and 78 percent during the dry season.
- Run-of-the-river diversion schemes, most of them relatively small. These diversion schemes can be fairly complicated in detail, with several intakes and re-use systems which often develop over time in response to observed drainage flows. The largest schemes are located in the alluvial plains. In 1989, the cropping intensity on these schemes was about 72 percent during the wet season and 54 percent during the dry season.
- Pump schemes. There are seven schemes irrigated only by pumps (about 10 200 ha are equipped), and five large NIS schemes served mainly by gravity flow but which use pumps for a part of their equipped area (about 12 800 ha).

CIS schemes (734 104 ha in 1992) have been created either by the farmers themselves over the centuries, or more recently by the NIA and then turned over to the irrigation associations for O&M. There are about 6 200 communal schemes, 46 percent of them in the province of Ilocos (northwest Luzon), which reflects a long history of irrigation through private initiative in this area. These schemes are predominantly diversion schemes, although a few are served by small reservoirs built within the framework of the SWIM projects. The average size of the communal schemes is about 115 ha, but ranges from 40 to 4 000 ha. The smallest schemes are found in north Luzon, while in Mindanao island these schemes are generally large, many of them being implemented by the government settlement programmes and then transferred to farmer groups. The association bears 10 percent of the direct cost of construction, and pays back the balance within 50 years at a 10 percent interest rate.

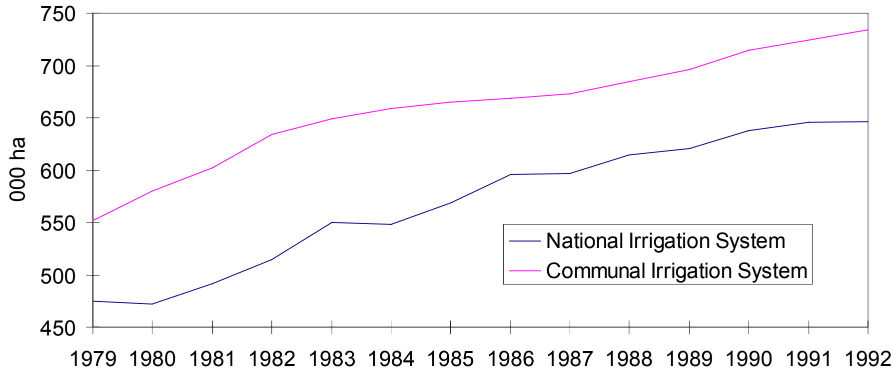
TABLE 3
Irrigation and drainage

Irrigation potential	1993	3 126 000 ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1993	1 550 000 ha
- surface irrigation	1993	1 550 000 ha
- sprinkler irrigation	1993	0 ha
- micro-irrigation	1993	0 ha
% of area irrigated from groundwater	1993	9.8 %
% of area irrigated from surface water	1993	90.2 %
% of equipped area actually irrigated	1993	95 %
2. Spate irrigation	1993	0 ha
Total irrigation (1+2)	**1993**	**1 550 000 ha**
- as % of cultivated area		16 %
- power irrigated area as % of irrigated area	1993	11 %
3. Other water management area	1993	0 ha
Total water managed area (1+2+3)	**1993**	**1 550 000 ha**
- as % of cultivated area		16 %
- increase over last 10 years	1992	18 %
- power water managed area as % of water managed area	1993	11 %
Full or partial control irrigation schemes:		
Large-scale schemes (>1 000 ha)	1991	627 473 ha
Small-scale schemes (<1 000 ha)	1991	516 857 ha
Total number of households in irrigation	1991	604 082
Irrigated crops:		
Total irrigated grain production		- t
as % of total grain production		- %
Harvested crops under irrigation		**- ha**
- permanent crops: total		- ha
- annual crops: total		- ha
. paddy	1992	1 442 678 ha
. other		- ha
Drainage - environment:		
Drained area	1993	1 470 691 ha
- drained area in full or partial control irrigated areas	1993	1 470 691 ha
- drained area in equipped wetland and i.v.b.		- ha
- other drained area		- ha
- area with subsurface drains		- ha
- area with surface drains		- ha
Drained area as % of cultivated area		- %
Power drained area as % of total drained area		- %
Flood protected areas		- ha
Area salinized by irrigation		- ha
Population affected by waterborne diseases	1989	782 193 inhabitants

Private schemes (about 152 128 ha in 1992) are generally supplied through pumping. They find their origin in publicly assisted river lift and groundwater development projects. In the past, private sugar cane plantations used sprinkler irrigation, but the figure for the total area equipped with sprinkler irrigation is not available. In 1980, public involvement in this sector ceased because of the high cost of energy needed to operate these systems. Most of the schemes have been abandoned or are now inoperable. Of the 379 public tube-wells constructed in 1971, only 22 were still in operation in 1990. Private development of shallow groundwater which started in the 1980s has proved more successful in favourable locations. These schemes are generally devoted to vegetable production during the dry season and to supplementary irrigation to paddy during the wet season. Pump schemes located along rivers have also been developed by private owners serving up to about 20 ha. Although this can be successful when supporting high value crops, many are no longer used largely due to the high cost of O&M, particularly for paddy. Figures on the total area of private schemes are generally unreliable as they are based on the last inventory of pump schemes in 1980. The figure of 152 128 ha should therefore be considered with caution. It is known that this figure includes areas which have been abandoned since 1980, but it does not include new private schemes developed along rivers or using pumped groundwater.

There are two cropping seasons in the Philippines. In principle, all schemes have been designed, both in terms of equipped area and canal capacity, to provide supplementary irrigation to the entire irrigable area during the wet season. The area actually irrigated during the season should thus be 100 percent. In practice, this level is never reached due to many reasons (optimistic design of service areas, flooding and waterlogging in the wet season, complexity of the irrigation system, pump performance, and conflicts between water supply, power and irrigation). The actual irrigated area varies significantly from one season to another, but it is always much lower than the area equipped for full/partial control irrigation.

FIGURE 4
Evolution of areas equipped for irrigation, 1979-1992



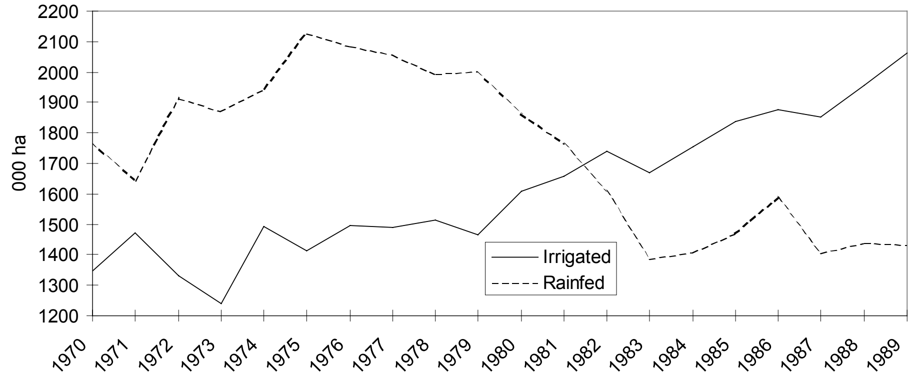
Between 1979 and 1992, the area equipped for irrigation increased substantially. It increased by 36 percent in the NIS, and by 33 percent in the CIS (Figure 4). However a survey on the cropping intensity in the NIS schemes shows that the percentage of the area actually irrigated during that period remained approximately constant (70-80 percent for the wet season, and around 60 percent in the dry season). The cropping intensity is known to be even lower in the CIS schemes. The table below shows the cropping intensity in 1992 in the different schemes.

Cropping intensity in various different schemes, 1992

	Area equipped for irrigation	Area actually irrigated in the wet season		Area actually irrigated in the dry season		Total	
Unit	ha	ha	%	ha	%	ha	%
Communal Irrigation System	734 104	368 139	50	246 830	34	614 969	84
National Irrigation System	646 519	460 129	71	395 593	61	855 722	132
Total	1 380 623	828 268	60	642 423	47	1 470 691	107

The development of irrigation has resulted in substantial increases in crop yields, as it has coincided with the introduction of HYVs, particularly for paddy. The main irrigated crop is paddy, which is cultivated throughout the country during the wet season, and in some areas during the dry season when other crops with higher added value are also grown. In 1992, almost 45 percent of the total paddy harvested area was irrigated, generating about 57 percent of output (Figure 5). The yields are much lower (30-40 percent) in the communal schemes than in the national schemes, because the water supplies are more uncertain in the small catchment areas where communal schemes are located. On average, the 1992 yield for irrigated paddy was estimated at 3.34 t/ha/season, which was 2.9 times the average yield of irrigated paddy in 1961. For rainfed paddy, the 1992 average yield was estimated at 2.07 t/ha, which is twice the 1961 average yield.

FIGURE 5
Evolution of paddy harvested area, 1970-1989



On all NIS schemes, the fees collected by the NIA should cover the costs for operation, maintenance and even the investment cost within a reasonable period of time to an extent consistent with government policy. However, in practice, capital cost recovery is confined to the communal sector and the fees collected covered only 80 percent of O&M expenditure in 1989. The average cost of O&M varies significantly: using the large schemes as an example, it was about US$31 in the Magat scheme and US$18 in the Upper Pampanga scheme in 1992.

The fees are expressed in kilograms of paddy, calculated by season and differ according to the origin of water. In diversion schemes, the fee is 100 kg/ha for the wet season and 150 kg/ha for the dry season. In reservoir systems, it rises to 125 and 175 kg respectively, and in pump schemes the fees are 190 kg and between 250 and 600 kg respectively. The fees can be paid either in paddy or in cash. For crops other than paddy, the fees are calculated on the basis of 60 percent of the rate of rice fees.

Under the NIS schemes, the average cost of irrigation development is estimated at US$3 800-7 600/ha for new schemes, while the cost for the rehabilitation of existing schemes varies from US$1 000 to 1 600/ha.

In most schemes, drainage water from one field goes into another field downstream either through the irrigation canal or directly. It is, therefore, difficult to estimate the drained areas in the Philippines. As drainage facilities have been installed only on irrigated schemes, the figure of 1 532 751 ha can be considered as a maximum for the drained area.

The main area subjected to floods is the central region of Luzon, namely the Pampanga, Zambales and Tarlac provinces. About 1 069 000 ha have been identified as flood-prone areas.

The population affected by water related diseases in 1989 was 782 193. These water related diseases include gastro-enteritis, schistosomiasis and hepatitis.

INSTITUTIONAL ENVIRONMENT

The NWRB coordinates the activities of the different agencies involved in the water sector (irrigation, hydropower, flood control, navigation, pollution, water supply, waste disposal, watershed management, etc.).

The others main agencies involved in water resources management are:

(i) in water supply and wastewater:

- the Metropolitan Waterworks and Sewerage System (MWSS) of the Department of Public Works and Highways (DPWH), which is responsible for water supply, storage, treatment, research, design, construction and maintenance of water supply and sewage systems in the national capital region and outlying service areas in nearby provinces;
- the Local Water Utilities Administration (LWUA) of the Department of Public Works and Highways (DPWH), which is responsible for the development and improvement of water and sewerage systems in areas not covered by the MWSS.

(ii) in water resources monitoring and development:

- the Philippine Atmospheric, Geophysical and Astronomical Services Administration (PAGASA), which conducts monitoring, data gathering and maintenance of information on rainfall and evaporation;
- the Bureau of Research and Standards (BRS) of the DPWH, which is engaged in monitoring and studies of water resources as well as water research and quality standards. The DPWH is also responsible for flood control;
- the NPC, which conducts water resources monitoring, research and hydropower generation.

(iii) in irrigation:

- the NIA of the Department of Agriculture, which was created in 1974 with the mandate to initiate an 'irrigation age'. Its tasks include the development, operation and maintenance of irrigation systems throughout the country. In particular, it has been responsible for the construction of NIS schemes, and is now responsible for the recovery of irrigation fees.
- the Bureau of Soils and Water Management (BSWM) of the Department of Agriculture, which handles, through its Project Management Office (PMO), the construction and maintenance of SWIM projects.

The SWIM projects have been implemented by the Government to mitigate damage brought about by insufficient water supply during the dry season and the frequent floods during the rainy season. The objectives might differ from one project to another, and the following agencies are involved: the DPWH, for water supply, inland fishing and mini-hydropower; the NIA, for irrigation; the Forest Management Bureau (FMB), for watershed management with an incidental purpose of flood control; and the National Electrification Administration (NEA), for mini-hydropower generation.

The 1976 Water Code of the Philippines revised and consolidated the laws governing the ownership, appropriation, utilization, exploitation, development, conservation and protection of water resources which are subject to government control and regulation through the NWRB.

TRENDS IN WATER RESOURCES MANAGEMENT

The majority of the population depends on agriculture for its livelihood and irrigation is considered a crucial element in agricultural production. With the potential irrigable area of 3.1 million ha, irrigation development is only at the halfway stage. Self-sufficiency in food has been set as a target by the Government. Agricultural development through irrigation, therefore, still remains a priority on the Government's agenda.

The Irrigation Crisis Act (Republic Act No. 6978) signed into law in January 1991, mandated the NIA to develop the remaining 1.5 million ha of irrigable lands within ten years through the construction of irrigation projects including other related project components. Irrigation, soil and water management have been set as a priority on the agenda of the Department of Agriculture. The Medium Term Philippine Development Plan (1994-98) also envisages a fast pace in irrigation development.

However, there are numerous economic and environmental problems.

There is growing water competition among the users: water supply, hydropower, environment, fishing and watershed management are competing with irrigation for water. The NWRB was established in order to coordinate the use of water for the different purposes, but its action is hampered, in part, by a lack of reliable data on present water resources and water use.

Erosion and siltation of the canals have resulted in high costs for the O&M of irrigation schemes, and many are thus in need of frequent rehabilitation. The conversion of agricultural lands to industrial or residential use has significantly reduced the area equipped for irrigation which can actually be used for irrigated agriculture.

The high cost of energy hampers the development of pump irrigation systems. The present pump systems are no longer economically viable if devoted solely to paddy.

In addressing these challenges, the NIA, together with the Department of Environment and Natural Resources, is expected to:

- fully enforce existing laws on environmental protection and conservation, in order to reduce erosion;
- establish institutional arrangements with the NPC, the NEA and the electric cooperatives to reduce power rates for pumps as a government subsidy to small farmers;
- work with the Department of Agrarian Reform, under the Comprehensive Agrarian Reform Law, to approve or disapprove the transfer of agricultural lands to non-agricultural uses.

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Sri Lanka

GEOGRAPHY AND POPULATION

Sri Lanka is a tropical island lying close to the southeast tip of the Indian subcontinent. Its land area is 64 630 km². Three-quarters of the land consist of a broad first peneplain of an average elevation of 75 m above sea level. A second peneplain rises to 500 m, and towards the south, a third peneplain rises steeply to form a mountain massif that reaches an elevation of 2 500 m. For administrative purposes, the country is divided into nine provinces.

In 1995, the total cultivated land was estimated at 1 887 000 ha. Of the cultivated area, 1 000 000 ha were under permanent crops such as tea, rubber and coconut. Annual crops such as paddy, sugar cane, kurrakkan, maize, manioc, green gram, green chilies and cowpea covered a total area of 887 000 ha.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	6 561 000	ha
Cultivable area		-	ha
Cultivated area	1995	1 887 000	ha
- annual crops	1995	887 000	ha
- permanent crops	1995	1 000 000	ha
Population:			
Total population	1996	18 100 000	inhabitants
Population density	1996	276	inhab/km²
Rural population	1996	77	%
Economically active population engaged in agriculture	1996	46	%
Water supply coverage:			
Urban population	1992	87	%
Rural population	1992	49	%

In 1996, the total population was estimated at 18.1 million inhabitants (77 percent rural). The average population density was 276 inhabitants/km². However, this figure varied from 3 100 inhabitants/km² in Colombo district to 35 inhabitants/km² in districts such as Mannar, Vavuniya, Mullativu and Anuradhapura. The population is concentrated largely in the wet zone (southwest coastal regions and central regions). Much of the dry zone remains sparsely populated. In 1995, the population growth rate was estimated to be 1.15 percent.

In 1995, per caput GDP in Sri Lanka was US$730. In 1996, the agriculture sector contribution approximately 18 percent of GDP, and about 46 percent of the economically active population was engaged in agriculture.

CLIMATE AND WATER RESOURCES

Climate

The island receives rain mainly through two monsoons. The rainfall intensity varies markedly across the island. Based on rainfall, several agroclimatic regions (wet zone, intermediate zone, dry zone and arid zone) can be recognized. Depending on the rainfall pattern, climatologists divide Sri Lanka's climatic year into five seasons:

- The convectional-convergence period (March to mid-April) is when the island comes under the influence of the inter-tropical convergence zone.

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		2 000	mm/year
		131.23	km^3/year
Internal renewable water resources		50	km^3/year
Total renewable water resources	1985	50	km^3/year
Dependency ratio		0	%
Total renewable water resources per inhabitant	1996	2 762	m^3/year
Total dam capacity	1996	5 942	10^6 m^3
Water withdrawal:			
- agricultural	1990	9 380	10^6 m^3/year
- domestic	1990	195	10^6 m^3/year
- industrial	1990	195	10^6 m^3/year
Total water withdrawal		9 770	10^6 m^3/year
per inhabitant	1996	540	m^3/year
as % of total (actual) renewable water resources		19.5	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

- The pre-monsoon period (mid-April to late May) presents transitional weather patterns, with convectional weather gradually being suppressed by surges of the southwest monsoon.
- The southwest monsoon (late May to late September) brings the largest amount of rainfall to the southwest lowlands and windward slopes of the central hills. After the rains, dry desiccating monsoon winds blow across the north, north-central and southeast regions.
- The convectional cyclonic period (late September to late November) begins with the weakening of the southwest monsoon. This period can include cyclones and may result in heavy rainfalls.
- The northeast monsoon (November to February), though weak compared to southwest monsoon, brings agriculturally important rainfall to northern and eastern parts of the island.

There is considerable variation around the mean annual rainfall of 2 000 mm. The highest rainfalls are in the central highlands. The maximum values are on the western slopes with several stations recording values exceeding 5 000 mm (Maliboda, 5 330 mm; Weweltalawa estate, 5 258 mm; and Kenilworth estate, 5 085 mm). The mean annual rainfall values on the eastern slopes are less than 3 500 mm and the lowest are in the northwest and southwest lowlands with a minimum value of 935 mm recorded at the Ambalantota gauging station.

The mean annual temperature is about 27ºC in the lowlands and 15ºC in the central highlands. The temperature decreases with increasing altitude, approximately 2ºC per 300 m of elevation.

River basins and water resources

Sri Lanka's radial network of rivers begins in the central highlands. There are about 103 distinct river basins covering 90 percent of the island. The southwest quarter of the island has seven major basins with catchment areas ranging from 620 to 2 700 km². They are: Kelani ganga (2 292 km²), Kalu ganga (2 719 km²), Maha oya (1 528 km²), Attanagalla oya (736 km²), Gin ganga (932 km²), Nilwala ganga (971 km²) and Bentota ganga (629 km²). An exception to the above radial pattern is the largest basin, that of the 335-km-long Mahaweli River which has a catchment area of 10 448 km². After leaving the central highlands, it runs almost north for 90 km from Minipe to Manampitiya and a then further 70 km through several distributaries as far as Verugal and Mutur on the east coast. Most Sri Lankan river basins are small. Only 17 of the 103 basins exceed 1 000 km². In addition to the Mahaweli basin, four others exceed 2 500 km². Three of these (Deduru oya, Kala oya and Malwatu oya) have their entire catchment are in the dry zone, and only Kalu ganga is in the wet zone. The total runoff in Sri Lanka is estimated at 49.2 km^3/year.

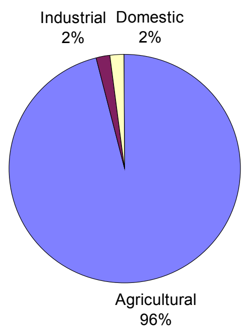
Groundwater resources have been extensively used since ancient times for domestic purposes using shallow open wells in almost all parts of the country. Sri Lanka's largest aquifer extends over 200 km in the northwestern and northern coastal areas. There are about 15 000 tube-wells in the country. The quality of the groundwater is generally fairly good and relatively constant throughout the year. However, in some parts of the country (northern and northwestern coastal areas) excessive concentrations of iron and nitrates (due to agrochemicals and fertilizers) have been reported. Furthermore, due to uncontrolled abstraction of groundwater for domestic and agricultural uses, brackish water intrusion has occurred in the coastal areas. In 1985, the internal renewable groundwater resources were estimated at 7.8 km^3, most (estimated at 7 km^3/year) returning to the river systems and being included in the surface water resources estimate. In 1991, the total internal renewable water resources of the country were estimated at 50 km³/year.

Economic development, population pressure and growing demands for food production, electric power and adequate water and sanitation services are placing increasing pressure on water resources. It is predicted that by 2000 the demand for water will outstrip supply particularly in the country's dry zone where most irrigation schemes are located.

Dams

In 1996, the total dam capacity was 5.942 km^3. Dams in Sri Lanka are classed according to the materials they use. They are mainly earthen, rockfill or concrete dams. Earthen dams are the most common type in Sri Lanka, the longest being the Parakrama Samudraya dam which is 13.5 km long and has a storage capacity of 0.12 km^3. The highest in this category is the Senanayake Samudraya dam at 44 m and with a storage capacity of 0.95 km^3. The Victoria dam, built under the Mahaweli multipurpose project, is the highest concrete (double curvature) dam with a height of 106 m and a storage capacity of 0.73 km^3. The gross theoretical hydropower potential in Sri Lanka is estimated at 8 000 GWh/year. In 1997, 16 hydropower plants were in operation with an installed capacity of 1 103 MW. Hydropower accounted for 81 percent of electricity generation in Sri Lanka.

FIGURE 1
Water withdrawal
TOTAL: 9.77 km³ in 1990



Water withdrawal

The large-scale development of water resources for irrigation and hydropower has progressed rapidly in the last 50 years. In Sri Lanka, the quantities of water required for industrial and domestic uses are low compared to irrigation and hydropower. In 1990, water withdrawal for agricultural activities was estimated at 9.38 km^3. The corresponding values for domestic and industrial activities were 0.195 km^3 each (Figure 1). Groundwater is an important source of water for irrigation and domestic use. It is increasingly used as drinking water, especially in small towns and rural areas. The total water demand for 2000 is estimated to be 10.92 km^3. Of this total, 90 percent will be for agriculture, 7 percent for domestic purposes and 3 percent for industrial purposes.

TABLE 3
Irrigation and drainage

Irrigation potential	1995	570 000 ha
Irrigation:		
1. Full or partial control irrigation: equipped area	1995	570 000 ha
- surface irrigation	1995	570 000 ha
- sprinkler irrigation	1995	0 ha
- micro-irrigation	1995	0 ha
% of area irrigated from groundwater		0.2 %
% of area irrigated from surface water		99.8 %
% of equipped area actually irrigated		- %
2. Spate irrigation		- ha
Total irrigation (1+2)	**1995**	**570 000 ha**
- as % of cultivated area		30 %
- power irrigated area as % of irrigated area		- %
3. Other water management area	1995	0 ha
Total water managed area (1+2+3)	**1995**	**570 000 ha**
- as % of cultivated area		30 %
- increase over last 10 years	1995	17 %
- power water managed area as % of water managed area		- %
Full or partial control irrigation schemes:		
Major schemes (> 400 ha)	1995	309 000 ha
Medium schemes (80-400 ha)	1995	61 000 ha
Minor schemes (< 80 ha)	1995	200 000 ha
Total number of households in irrigation		-
Irrigated crops:		
Total irrigated grain production		- t
as % of total grain production		- %
Harvested crops under irrigation		**- ha**
- permanent crops: total		- ha
- annual crops: total		- ha
. paddy	1994	661 700 ha
Drainage - environment:		
Drained area		- ha
- drained area in full or partial control irrigated areas		- ha
- drained area in equipped wetland and i.v.b.		- ha
- other drained area		- ha
- area with subsurface drains		- ha
- area with surface drains		- ha
Drained area as % of cultivated area		- %
Power drained area as % of total drained area		- %
Flood protected areas		- ha
Area salinized by irrigation		- ha
Population affected by water-borne diseases	1994	120 000 inhabitants

The supply of drinkable water to communities is in the early stages of development. In 1992, 53 percent of the population (87 percent of the urban and 49 percent of the rural population) had access to safe drinking water. The other inhabitants were using unprotected wells, rivers and tanks. High incidences of water related illnesses (120 000 recorded hospitalizations per year for diarrhoea) indicate that a serious water quality problem exists.

The Government has placed a high priority on providing water supply to urban communities where groundwater is contaminated. The Government spends about US$45.0 million/year in providing piped water to the population.

Sri Lanka's only public sewer system is in Colombo. It serves about 20 percent of the Colombo metropolitan region and the collection is not treated. Only very few industries have treatment plants whilst others discharge straight to waterways.

IRRIGATION AND DRAINAGE DEVELOPMENT

Irrigation activities in Sri Lanka date back 2 500 years. Initially, these activities started with the small-scale village tank and simple channel system. Later these were developed (275 AD to

1186 AD) so that river flows across shallow valleys could be intercepted to build large reservoirs, or water flowing down perennial rivers was diverted by weirs and conveyed through long excavated canals to be impounded in large reservoirs at appropriate locations to supply large areas of land.

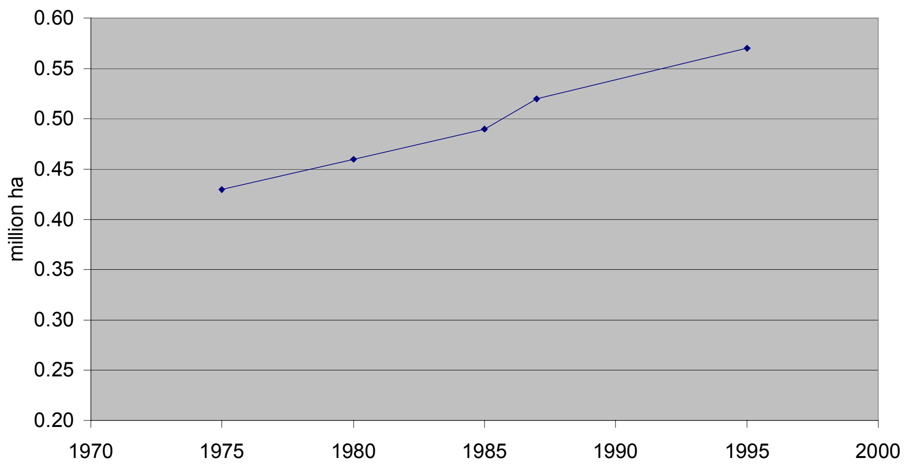
However, most of these systems fell into disuse and were abandoned after the twelfth century. In the nineteenth century, some of the tanks, such as those at Kalawewa, Tissawawe and Kantale, were restored. In 1857, irrigation ordinance was introduced in order to give legislative status to the rules governing irrigation activity. In 1952, Gal oya, a large multipurpose scheme was launched, followed in the 1960s by Mahaweli, the largest multipurpose scheme. These multipurpose projects aimed not only at irrigation development and settlement but also at hydropower generation. The Mahaweli project, which is by far the largest government project in the country, envisaged the development of more than 300 000 ha of new irrigated land and the generation of 800 MW of hydropower at the completion of the project.

The Land Reform Act of 1972 limits the private ownership of land to a per caput ceiling of 10 ha for paddy; 20 ha for tea, rubber and coconut; and 0.2 ha for residents. This act also established a land reform commission with the power to acquire and dispose of properties.

Given the state of irrigation development in the country and the present level of technology in agriculture and in construction engineering, little economic potential is left to be exploited by new irrigation construction. Hence, it is reasonable to assume that the country has reached its irrigation potential. Studies have revealed that the cost-benefit ratio of investments in irrigation construction fell sharply in the early 1980s and hit a record low in 1986.

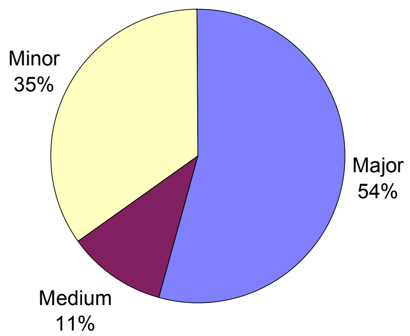
In 1995, the total irrigated land area of the country was 570 000 ha. This showed that around 30 percent of the cultivated land in the country was irrigated. From 1963 to 1993, the area irrigated by major irrigation schemes increased by about 110 percent, mainly due to major irrigation projects implemented by the Government. The total water managed area has increased by 17 percent during the past ten years (Figure 2).

FIGURE 2
Growth in irrigated area since 1975



The irrigation systems in Sri Lanka are designed solely for paddy cultivation. In 1994, the total harvested irrigated area for paddy was 661 700 ha and the average irrigated yield for paddy was 3.3 t/ha. In 1991, it was reported that 15 000 ha of chilies were grown under irrigated conditions. Other crops grown under irrigated conditions are sweet potato, banana and green gram.

FIGURE 3
Irrigation schemes
TOTAL: 570 000 ha in 1995



In Sri Lanka, irrigation schemes can b classed as minor, medium or major depending on the area they serve (Figure 3). Minor schemes provide facilities for less than 80 ha. In 1995, they served about 200 000 ha. Medium schemes provide facilities for areas of 80-400 ha. In 1995, they served 61 000 ha. Major schemes provide facilities for more than 400 ha. In 1995, they served 309 000 ha.

The major irrigation schemes can be classed as:

- storage schemes;
- diversion schemes;
- drainage, flood control and saltwater exclusion schemes;
- lift irrigation schemes.

Storage schemes have two purposes: storage and flood control. Water is impounded in these tanks by building dams across valleys, and then released when required to service areas downstream.

Diversion weirs, commonly called anicuts, are constructed in perennial streams in the wet zone to convey water to the fields below. Here, a masonry or concrete wall is built across the stream to head up and divert water. The diverted water is distributed to the fields by gravity.

In the wet zone, flood control and drainage schemes have been incorporated into the irrigation system mainly in the lower reaches of rivers. In the coastal areas, saltwater exclusion schemes have been commissioned where water salinity affects agriculture. Flood bunds and pumps are the main features in flood protection schemes, whereas gated regulators are adopted in saltwater exclusion schemes.

Lift irrigation schemes with mechanically or electrically operated pumps have been introduced recently to irrigate the highlands. It is estimated that around 1 000 ha are irrigated by groundwater wells.

Surface irrigation dominates in Sri Lanka. The main irrigation methods adopted in Sri Lanka are basin and furrow irrigation.

In 1980, an attempt was made to establish a water tax. However, this attempt failed because of the political unrest in the 1980s, a lack of policy concerning the O&M budget, and a lack of coordination between the various agencies in charge of irrigation. In 1985, the average cost of developing major surface irrigation schemes was US$1 350/ha. In 1993, the average O&M cost for a major surface irrigation scheme such as Kaudulla was US$12/ha/year.

Irrigation development, O&M and rehabilitation have been predominantly state activities. However, in the 1970s, participatory approaches were incorporated in certain irrigation rehabilitation projects. In the period 1981-83, a national programme of water management was initiated in 24 major systems covering about 80 000 ha. Positive results were achieved and a programme for the integrated management of irrigation settlement (INMAS) was launched in 1984 in 37 major systems covering 155 000 ha. This was the first official attempt at national level to mobilize farmers for participatory management in major irrigation. In 1988, the Government accepted the policy of participatory management involving beneficiary involvement at all stages of decision making and in the management of irrigation schemes.

It has been shown that large water development projects have increased the malariogenic potential of areas through increased vector propagation, aggregation of labour and resettlement from non-malarious areas of people with no immunity.

INSTITUTIONAL ENVIRONMENT

Water is managed as an input to major development sectors such as irrigation, hydropower and human and industrial water supply. However, there is little coordination between these sectors. There are about 30 government institutions dealing with water related activities which operate with little coordination. Furthermore, there are over 43 acts of parliament concerning the water sector. These laws have been enacted over time to meet specific needs, often with little consideration for existing legislation or future needs. Laws are administered by numerous agencies with a wide range of responsibilities, and there overlaps, gaps and conflicting jurisdictions.

The Department of Irrigation (DI), established in 1900, is primarily responsible for water resources planning, project formulation, construction and maintenance. It is also informally responsible for daily and seasonal allocations of water for irrigation.

The Mahaweli Authority of Sri Lanka (MASL), established in 1979, is responsible for water resources development in a large area of the country, not only in the Mahaweli project region, but also in many large basins in the country. The Water Management Secretariat of the Mahaweli Authority has the necessary technical resources to plan the distribution of water resources under the authority’s jurisdiction.

The Water Resources Board (WRB) was established in 1968. It coordinates governmental water resources functions and formulates national policies relating to the control and use of water resources.

The National Water Supply and Drainage Board (NWSDB) is the main agency for domestic and industrial water supply, sewage and surface drainage.

The Ceylon Electricity Board (CEB) is responsible for the generation, transmission and distribution of electric power, including hydropower.

The Department of Meteorology (DM) is responsible for gathering information needed for estimating available water supplies nationwide.

TRENDS IN WATER MANAGEMENT

The Sri Lankan government has launched the ‘Waga Lanka Waga Sangrama’ programme to achieve food security to face the predicted famine in 2015. This programme is to be implemented by the Agricultural and Lands Ministry after nearly two and a half years of careful planning. It includes short-term programmes for qualitative improvement in the production of main food items as well as a long-term programme, which would enable the country to reach the new targets for agriculture that should be achieved between 2000 and 2005. However, there is little scope for further gains in food crop production from new large-scale undertakings under traditional systems of irrigation. Therefore, the need is to rehabilitate or modernize existing schemes with a view to increasing their overall productivity. In addition, systems are being designed to cater to diversified cropping and higher cropping intensities and proper watershed management.

In 1994, the Institutional Assessment for Comprehensive Water Resources Management Project was completed. This was executed by the National Planning Department of Sri Lanka in association with more than thirty agencies and organizations concerned with water resources development and management. Technical assistance was provided by the Asian Development Bank and the United States Agency for International Development (USAID). The strategic framework formulated and adopted by the project's steering committee for the process of comprehensive water resources management included nine elements under three main headings:

(i) the policy and legal basis:
- national policies and goals;
- water sector policies and goals;
- laws and regulations.

(ii) the actors:
- government agencies;
- communities;
- private sector;
- mechanism for collaboration.

(iii) the information and technology basis:
- technology and research and development;
- data and information.

On the basis of this strategic framework, a time-bound action plan was drawn up which focused on:

- National water policy: develop a national water policy.
- National water legislation and regulations: prepare and enact a national water act through amendments to water related legislation.
- Institutional development: define water sector functions and create an independent agency for water resources management to strengthen the capacity of water sector agencies to carry out these functions.
- River basin planning: carry out comprehensive planning in selected watersheds.
- Information systems and public consultation: establish an improved system to provide data and information required by decision-makers and others concerned, including the public.

In July 1995, the Government approved the implementation of the strategic framework and action plan together with the establishment of the Water Resources Council to oversee the implementation of the action plan.

Other major government goals related to water use are:

- to provide safe drinking water and adequate sanitation to the entire population by 2000;
- to provide electricity to every village by 2000.

In order to achieve the latter goal, in 1998 the Government launched the US$250-million Kukule Ganga hydropower project in Kalutara district. This is to be completed by 2001 and should add another 70 MW to the national grid.

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Thailand

GEOGRAPHY AND POPULATION

Thailand covers an area of 513 120 km^2 in southeast Asia. Administratively, the country is divided into 72 changwats (provinces), 4 regions and the Bangkok Metropolitan area. The four regions correspond approximately to the physiographical regions of Thailand: the northern region is mountainous with dense forests; the northeast is dry and consists of a plateau which borders the Mekong River; the central region is an extensive plain subject to flooding; and the southern part consists of a peninsula.

About 26.79 million ha are considered as suitable for agricultural production, and in 1995 the cultivated area was estimated at 20.45 million ha, or 40 percent of the total area. Of this total, 17.09 million ha, or 84 percent of the total cultivated area, were under annual crops (mainly paddy rice) and the remaining 3.36 million ha were under permanent crops.

TABLE 1
Basic statistics and population

Physical areas:			
Area of the country	1995	51 312 000	ha
Cultivable area	1995	26 790 000	ha
Cultivated area	1995	20 445 000	ha
- annual crops	1995	17 085 000	ha
- permanent crops	1995	3 360 000	ha
Population:			
Total population	1996	58 703 000	inhabitants
Population density	1996	114	inhab/km^2
Rural population	1996	80	%
Economically active population engaged in agriculture	1996	55	%
Water supply coverage:			
Urban population	1991	67	%
Rural population	1991	85	%

The total population was estimated at 58.70 million inhabitants in 1996 (80 percent rural). The annual population growth rate was estimated at 1.5 percent in 1993. The population density is about 114 inhabitants/km^2.

The agriculture sector accounted for 11.5 percent of GDP in 1991, and agricultural exports represented 23 percent of total export earnings. In 1996, 55 percent of the total labour force was employed in the agriculture sector.

CLIMATE AND WATER RESOURCES

Climate

The climate is mainly governed by the alternation between the southwest monsoon, which brings heavy rainfalls (from May to October), and the northeast monsoon, which is comparatively dry and cool (from October to February). The transitional period is characterized by heavy thunderstorms.

The average annual rainfall is estimated at 1 485 mm. It ranges from 1 100 mm in the central plain and the northeast of the country to 4 000 mm in the southern peninsula near the Andaman Sea.

TABLE 2
Water: sources and use

Renewable water resources:		
Average precipitation		1 485 mm/year
		761.7 km³/year
Internal renewable water resources		210 km³/year
Total renewable water resources	1990	409.9 km³/year
Dependency ratio		48.8 %
Total renewable water resources per inhabitant	1996	6 983 m³/year
Total dam capacity	1995	85 000 10^6 m³
Water withdrawal:		
- agricultural	1990	30 200 10^6 m³/year
- domestic	1990	1 496 10^6 m³/year
- industrial	1990	1 436 10^6 m³/year
Total water withdrawal		33 132 10^6 m³/year
per inhabitant	1996	564 m³/year
as % of total renewable water resources		8 %
Other water withdrawal		- 10^6 m³/year
Wastewater - non-conventional sources of water:		
Wastewater:		
- produced wastewater	1992	833 10^6 m³/year
- treated wastewater	1995	35 10^6 m³/year
- re-used treated wastewater	1995	0 10^6 m³/year

Water resources

Thailand can be divided into seven river basins, but in the literature it is generally divided into 25 sub-basins. The table below shows the characteristics of the seven major river basins and indicates the total surface water resource of the country, i.e. 198.8 km³/year.

MEAN ANNUAL RUNOFF OF RIVERS IN THAILAND

River basin	Catchment area within the country		Mean annual runoff (country's contribution)	
	km²	%	km³	%
Mekong	188 623	36.8	51.9	26.1
Chao Phraya	157 923	30.8	30.1	15.1
Peninsula – east coast	63 278	12.4	65.7	33.0
East coast	32 289	6.3	20.1	10.1
Mae Klong	30 837	6.0	12.9	6.5
Peninsula – west coast	21 172	4.2	9.9	5.0
Salawin (Thanlwin in Myanmar)	17 920	3.5	8.2	4.2
Total	512 042	100.0	198.8	100.0

Aquifer recharge from rainfall is estimated at 41.9 km³/year (about 5-6 percent of the total precipitation). Approximately 30.7 km³/year are estimated to return to the river system and are included in the surface water resources. The total internal water resources of Thailand are therefore estimated at 210 km³/year.

International rivers and agreements

Thailand shares three rivers with its neighbours:

- The Mekong River forms the border with Lao PDR in the north and east. About 18 percent of the total Mekong catchment area is located in Thailand. Thailand has been a member of the Mekong River Commission since its inception in 1957, and the commission is located in Bangkok. The latest international agreement concerning the lower Mekong River was signed in

April 1995 by the four riparian countries: Thailand, Lao PDR, Cambodia and Viet Nam. This agreement concerns cooperation for the sustainable development of the lower Mekong River basin, but does not propose any sharing of water between the riparian countries.

- The Salawin River is on the northwestern border with Myanmar. No agreement has yet been signed, but a working group is assessing the irrigation and hydropower potential of the Salawin River and its tributaries.
- The Kolok River, on the southern border with Malaysia.

The Mekong and Salwin rivers constitute an additional external resource for Thailand which has been estimated as half the discharge of the rivers deducted by the contribution of the countries, i.e.: 200/2 (half the Salwin discharge) - 8.156 (contribution of Thailand to Salwin) + 324.45/2 (half the Mekong discharge) - 51.9 (contribution of Thailand to Mekong in the border reach) = 199.9 km^3/year.

Total renewable water resources

By adding the internal and external resources together, the total renewable water resource are estimated at approximately 410 km^3/year .

Lakes and dams

The total dam capacity is estimated at 85 km^3, which is about 43 percent of the annual runoff. However, a lot of dams have been overdesigned compared with the annual recharge obtainable. There are four categories of dams in Thailand:

- Large dams with a hydropower component are built by the Electricity Generating Authority of Thailand (EGAT), the Royal Irrigation Department (RID) or the Department of Energy Development and Promotion and managed by the EGAT. Their total capacity is estimated at 53.46 km^3. Hydropower generation is important in Thailand as its 21 hydropower plants account for 18 percent of installed capacity and 5 percent of energy production. However, all these dams are multipurpose dams, and the irrigation component receives priority over the other components.
- Large dams, with no hydropower component, and therefore mainly destined for irrigation, are operated by the RID. Their total capacity was estimated at 31.4 km^3 in 1995.
- Small dams, which cost about US$200 000, are developed by the Office of Accelerated Rural Development under the Ministry of Interior for irrigation, livestock and domestic purposes.
- Small dams of around 100 000 m^3 each, developed by the Land Development Department of the Ministry of Agriculture and Co-operatives. They cost about US$120 000 each and are used for agricultural and domestic purposes. Their total capacity is estimated at 0.1 km^3. Each year, about 200 such dams are constructed or rehabilitated.

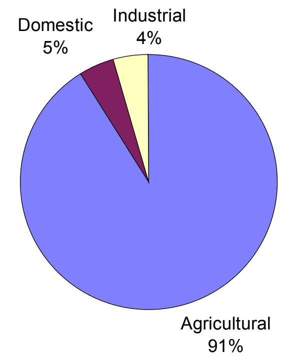
Water withdrawal

The total water withdrawal was estimated at 33.13 km^3 in 1990, of which 91 percent was for agricultural purposes (Figure 1). It is reported that domestic and industrial water withdrawals are increasing substantially every year.

Wastewater treatment is not common. Industrial wastewater is generally discharged into rivers and canals. About 833 million m^3 of wastewater were produced in 1992. In 1995, some 35 million m^3

of wastewater were treated. Numerous wastewater treatment projects are being developed in the Bangkok metropolitan area. There is no re-use of treated wastewater in Thailand.

FIGURE 1
Water withdrawal
Total: 33.132 km³ in 1990

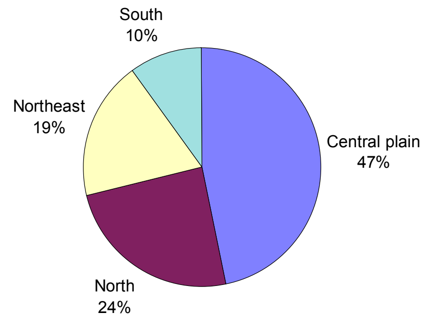


IRRIGATION AND DRAINAGE DEVELOPMENT

The irrigation potential for the wet season can be roughly estimated at 12 million ha, considering both soil and water availability but excluding basin transfers. The total area suitable for irrigation is estimated at 16 million ha.

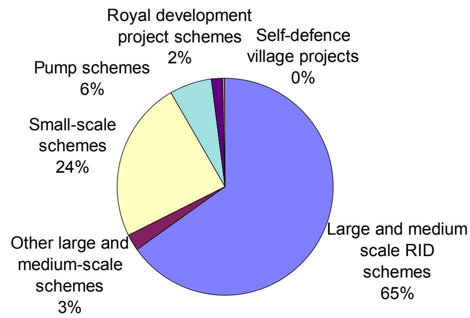
Irrigation through river diversion and from reservoirs started in the north seven centuries ago. In modern times, canal construction for irrigation started at the beginning of the century, in parallel with the creation of the RID. The aim was to maintain water in canals for irrigation and navigation, and to drain paddy fields during periods of flooding. Irrigation has traditionally been supplementary irrigation for the wet season. It is only recently that schemes have been designed for dry season irrigation.

FIGURE 2
Irrigated area in wet season by region
TOTAL: 5 003 724 ha in 1995



The area equipped for wet season irrigation was estimated at 5 003 724 ha in 1995. Thailand develops 120 000 ha of irrigation each year (2 percent of the equipped area; Figure 2). These irrigated areas can be divided into five categories (Figure 3):

FIGURE 3
Type of schemes, wet season irrigated areas
TOTAL: 5 003 724 ha in 1995



- Large and medium-scale schemes (3 381 460 ha in 1995). Most of these schemes (around 650 schemes covering an irrigated area of 3 255 124 ha, or 96 percent) have been designed constructed and managed by the RID since their inception. They are mainly concentrated in the central plain within the Chao Phraya river system, which is called the rice bowl of Thailand. Some of them are pump schemes. The remaining 4 percent (or 65 projects covering 126 336 ha) have not been implemented fully by the RID, but only partially as they rely on dams constructed by the EGAT.

- Small-scale schemes. These schemes are also called private schemes. They may have been designed and built by the RID, by other departments, by NGOs or by the private sector. They

TABLE 3
Irrigation and drainage

Irrigation potential	1985	12 245 000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1995	5 003 724	ha
- surface irrigation	1995	5 003 724	ha
- sprinkler irrigation	1995	0	ha
- micro-irrigation	1995	0	ha
% of area irrigated from groundwater	1995	0.2	%
% of area irrigated from surface water	1995	99.8	%
% of equipped area actually irrigated	1988	91	%
2. Spate irrigation	1995	0	ha
Total irrigation (1+2)	**1995**	**5 003 724**	**ha**
- as % of cultivated area		24.5	%
- power irrigated area as % of irrigated area	1994	6.4	%
3. Other water management area	1995	0	ha
Total water managed area (1+2+3)	**1995**	**5 003 724**	**ha**
- as % of cultivated area		24.5	%
- increase over last 10 years	1995	44	%
- power water managed area as % of water managed area	1994	6.4	%
Full or partial control irrigation schemes:			
Large-scale schemes (see text)	1995		ha
Medium-scale schemes (see text)	1995		ha
Other schemes (see text)	1995		ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production		-	t
as % of total grain production		-	%
Harvested crops under irrigation		**-**	**ha**
- permanent crops: total		-	ha
- annual crops: total		-	ha
Drainage - environment:			
Drained area		-	ha
- drained area in full or partial control irrigated areas		-	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		-	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

should be farmer driven and managed, but farmers often require RID assistance for maintenance once the cost exceeds US$4 000. The total area of these 7 246 schemes is about 1.21 million ha.

- Pump schemes. These schemes have been implemented mainly in the northeast (50 percent of such irrigated areas) and north (35 percent) by the Department for Energy Development and Promotion, and are still managed with its assistance. The equipped area for wet season irrigation was about 318 630 ha in 1995. Only 58 240 ha (18.2 percent) were also irrigated during the dry season, of which 22 percent was for rice cultivation.

- Royal development projects. These projects have been implemented and managed by the RID after a personal decision of the king. They are supervised by the Office of the Co-ordinating Committee for Royal Development Projects. They are generally small scale and are spread throughout the country, mainly in remote areas. Some 347 projects cover a total area equipped for irrigation of 79 039 ha.

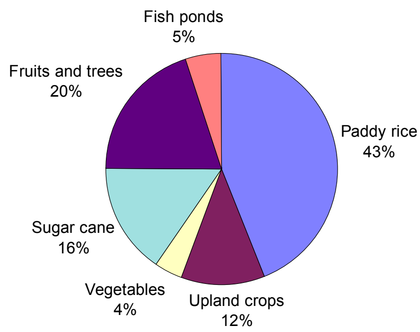
- Self-defence village projects. These are irrigated schemes implemented in military-sensitive areas, and managed by the RID. Their total equipped area for wet season irrigation is 16 377 ha in 171 projects.

In 1988, the area actually irrigated was estimated at 91 percent of the equipped area. All schemes are irrigated by surface irrigation: sprinkler and drip irrigation are at an experimental stage only on fruit trees. Generally, surface water is used, but in the Sukhotai region, some 6 758 ha (in 1990) rely on pumping groundwater for irrigation. The potential for irrigation by groundwater was estimated at 200 000 ha in 1985, though the latest estimate for groundwater irrigation is about 12 000 ha.

Early systems were designed to operate at full capacity only in the wet season. The canal capacities and control regulators are inadequate for the increasing demand for dry season irrigation. Furthermore, irrigation water demand has to compete with demand from other sectors. This becomes a sensitive issue during the dry season. A certain flow of water must be maintained for navigation, to prevent saltwater intrusion, and to supply water for domestic and industrial purposes in the Bangkok area. In the dry season, water resources can no longer meet the increasing water demand from all sectors, and particularly for the irrigation subsector which needs to withdraw more and more water because of the development of dry season irrigation. This water competition has led to poor agricultural performance in recent dry seasons.

Dry season irrigation is practised on 18 percent of the equipped area. Figure 4 shows the different crops grown on irrigated land in the 1993/94 dry season. Part of the irrigated land is used as fish ponds during the dry season.

FIGURE 4
Dry season use of irrigated land
TOTAL: 866 606 ha in 1994



Small-scale projects are those which can be completed within one year and without land compensation. Initially their cost is generally less than US$400 000. The schemes which cannot be completed within one year or which need land compensation are considered medium scale. They are classed as large scale if there is a storage capacity of more than 100 million m^3 or if they can irrigate at least 80 000 rais (12 800 ha). Generally, large-scale projects cost more than US$8 million, but this figure is not considered a criteria.

The main irrigated crop is paddy during the wet season, and its average yield for the wet season was 3.5 t/ha in 1993/94.

On average, the RID spends US$45/ha/year for O&M. Normally, the RID is responsible for the maintenance of main and secondary canals, while the tertiary and field canals are the responsibility of farmers. WUGs have not yet been set up on a wide scale, except in the north where farmers were used to forming groups in order to repair and maintain the traditional weirs.

In the northeast of the country, 10 percent of the irrigated land is affected by salt. The presence of the salt bearing nature of the soil parent material has been identified as the primary cause for this. Other activities such as irrigation could be classed as secondary causes for accelerating this locally. Many programmes have been launched in order to correctly manage cash crops and paddy on saline soils. Salinization is now reported to be affecting large areas in the coastal parts of the central plain.

The main water-borne diseases are acute diarrhoea (affecting 1.48 percent of the population) dysentery (0.14 percent) and enteric fever (0.03 percent). Malaria, as a water related disease, affects 0.12 percent of the population.

INSTITUTIONAL ENVIRONMENT

At present, 38 ministerial departments under 10 ministries, 1 independent agency and 6 national committees are involved in water resources development, with responsibilities for water policy, irrigation, domestic and/or industrial water supply, fisheries, flood alleviation, hydropower generation, navigation or water quality.

The National Water Resources Committee (NWRC), under the Office of the Prime Minister, is responsible for setting a policy to develop water resources throughout the country.

The National Economic and Social Development Board is responsible for economic planning.

The Department of Mineral Resources, under the Ministry of Industry, monitors groundwater resources, while surface water monitoring is mainly carried out by the Department of Energy Development and Promotion under the Ministry of Science, Technology and Environment, and the RID, which has its own network.

Many departments or agencies are involved in water supply for domestic or industrial purposes. The main one is the Metropolitan (or Provincial, outside Bangkok) Waterworks Authority. Wastewater treatment and water quality are mainly the responsibility of the Ministry of Science, Technology and Environment.

Large dams are operated either by the RID or by the EGAT, while small dams have been developed by the Land Development Department or the Office of Accelerated Rural Development (under the Ministry of Interior).

The Harbour Department is in charge of protecting inland waterways, and of issuing licenses for navigation.

Irrigation is managed by the RID for public schemes, or by the Department of Energy Development and Promotion for the electric pumped schemes. The RID is the supervising agency for private irrigation.

A groundwater act adopted in 1987 defines the responsibilities, rights and duties of each of the various parties involved. In May 1998, a national water resources act was awaiting cabinet approval. This act should establish the NWRC as the coordinating agency for water resources development.

Although work began some years ago on a national water resources mater plan for water resources development in the 25 river basins, this work has come to a standstill due to lack of funds.

TRENDS IN WATER RESOURCES MANAGEMENT

There are numerous water issues in Thailand.

Bangkok faces problems of both too much and too little water. Flooding occurs frequently in the wet season due to low average ground level, high tides and inadequate drainage. The Metropolitan Waterworks Authority is unable to supply water to meet all domestic and industrial demand. As a result, in the outskirts of Bangkok, private and industrial abstraction of groundwater exceeds the safe yield of the aquifer. This accelerates the rate of land subsidence (5-10 cm/year), which in turn aggravates the problem of flooding. Indeed, subsidence has caused some parts of the drainage systems to be below the normal water level and has rendered them ineffective.

The minimal discharge to maintain a water level of 1.7 m for navigation (this means 300 m^3/s released in the navigation channel from Nakhon Sawan to the Chao Phraya dam, and 80 m^3/s downstream of the dam) cannot be maintained due to large amounts of water diverted from the river for dry season irrigation in the northern and central regions. This reduced the volume of inland waterway transport fivefold between 1978 and 1990. The volumes of water released by the Bhumipol and Sirikit dams are increasingly important to prevent saltwater intrusion, even if they do not meet the navigation demand.

A lot of sites for dams have been identified in order to supply more water to the Chao Phraya River. However, nearly all the suitable sites for large-scale projects have been already exploited. The remaining undeveloped potential sites are either in heavily populated areas or in national park reserves. The resettlement of population and environmental issues are so sensitive that no decision has been taken concerning such dams, even though detailed design studies have been ready for more than 15 years in some cases. The Kaeng Sua Then and the Nam Choan projects have been a cause of conflict between developers and conservationists. It seems increasingly clear that there will be less scope for the development of such large-scale projects in the future.

There is a great need for water in the central region for both irrigation and urban water supply. Most of the water used in the central region comes from the northern region. This follows a set of rules established when the main needs were in the central region. In the last few years, there has been an increasing demand for water, especially in the irrigation sector, in the northern region. In the national master plan, the RID has identified 463 projects to be carried out in the period 1997-2006, covering an irrigated area of approximately 1.53 million ha with a storage capacity of 12 km^3 to be developed for a total estimated cost of US$3 600 million. If the observed trend continues, and if all projects are implemented, a point will be reached in the near future where water released from the northern region, after satisfying requirements there, will not be sufficient to meet the irrigation water demand in the central region.

To address this problem, the Government has launched many programmes to both reduce demand and increase the resources available. To reduce demand, the RID will encourage and increase water use efficiency both at farm and scheme levels. Furthermore, the implementation of water fees after the adoption of the new water law should encourage farmers to reduce wastage. The ongoing national economic and social development stresses the need for a more efficient use of water, and in particular the importance of collecting water fees in irrigated agriculture to avoid wastage. Agricultural water fees should cover only O&M costs, while for the other sectors (domestic and industrial) the fees should also take account of the construction and maintenance costs of water distribution systems.

To increase the available resources, inter-basins transfer projects are being studied and implemented. One such project already exists, diverting water from the Mae Klong River to the Chao Phraya central plain. Other more politically sensitive projects, such as diversion of water from the Mekong, Mae Kok and Mae Ing rivers to the Yom and Nan rivers, are still at the level of feasibility studies. Groundwater use for irrigation is also a possibility. However, the experiments carried out by the RID have not yielded satisfactory results to date, except in the Sukhotai region where the aquifer has an important yield. Desalination or re-use of treated wastewater have still not been envisaged.

In order to solve the problem of competition between sectors, some studies have been carried out in order to establish a water rights market where all parties would be able to trade water rights. This would stabilize water demand but would have important negative consequences on agriculture.

Water resources development lacks a comprehensive planning and coordination of all the actions carried out in the sector by the different agencies. As proposed in the draft water law, the promotion of the NWRC as the leading agency in terms of water policy definition would address this issue. Furthermore, a committee on water allocation by river basin should be established as a forum for all water users, and to develop seasonal water allocation plans. The master plan for water resources development will provide a framework for all activities carried out by the various agencies.

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Viet Nam

GEOGRAPHY AND POPULATION

Viet Nam is located in the eastern part of the Indochina peninsula. It is bounded by China in the north, Lao PDR and Cambodia in the west and the South China Sea in the east. The total land area is 325 490 km^2. The country is divided into seven regions based on topographic, climatic and socio-economic conditions. For administrative purposes, there are 38 provinces, including the capital city, Hanoi.

Mountains and hills cover more than three-quarters of the territory, although over 70 percent of the country lies below 500 m above sea level. Viet Nam has a dense hydrographic network. About 25 percent of the total land area is covered by plains, the most important being the Bac Bo and Nam Bo, corresponding to the courses of the Red and Mekong rivers respectively.

TABLE 1
Basic statistics and population

Physical areas:		
Area of the country	1995	33 169 000 ha
Cultivable area	1994	7 086 000 ha
Cultivated area	1995	6 757 000 ha
- annual crops	1995	5 509 000 ha
- permanent crops	1995	1 248 000 ha
Population:		
Total population	1996	75 181 000 inhabitants
Population density	1996	227 inhab/km^2
Rural population	1996	79 %
Economically active population engaged in agriculture	1996	69 %
Water supply coverage:		
Urban population	1990	47 %
Rural population	1990	33 %

The total cultivable land area is 7 086 000 ha, of which 3 300 000 ha are in delta areas. The cultivated land area is about 6 757 000 ha, or 95 percent of the total cultivable area. In 1995, about 5 509 000 ha were covered by annual crops (mainly rice), and the remaining 1 248 000 ha were under permanent crops such as coconut, tea and rubber.

The total population is estimated at 75 181 000 inhabitants (about 79 percent rural), and is growing at an annual rate of 2.2 percent. The average population density in Viet Nam is about 227 inhabitants/km^2, ranging from 115 inhabitants/km^2 in the northern mountains and midlands region to 1 085 inhabitants/km^2 in the Red River Delta region.

Agriculture, including forestry and fisheries, is the largest sector in the economy accounting for 34 percent of GDP and employing 69 percent of the labour force. The agriculture sector grew at an annual rate of 4.2 percent between 1991 and 1995.

CLIMATE AND WATER RESOURCES

Climate

The climate varies from temperate and subtropical in the north to tropical in the south. Precipitation varies from 2 000 to 2 500 mm in the mountainous areas and from 1 600 to

TABLE 2
Water: sources and use

Renewable water resources:			
Average precipitation		1960	mm/year
		650	km^3/year
Internal renewable water resources		366.50	km^3/year
Total renewable water resources	1995	891.21	km^3/year
Dependency ratio		58.9	%
Total renewable water resources per inhabitant	1996	11 854	m^3/year
Total dam capacity		-	10^6 m^3
Water withdrawal:			
- agricultural	1990	47 000	10^6 m^3/year
- domestic	1990	2 000	10^6 m^3/year
- industrial	1990	5 330	10^6 m^3/year
Total water withdrawal		54 330	10^6 m^3/year
per inhabitant	1996	723	m^3/year
as % of total renewable water resources		6	%
Other water withdrawal		-	10^6 m^3/year
Wastewater - non-conventional sources of water:			
Wastewater:			
- produced wastewater		-	10^6 m^3/year
- treated wastewater		-	10^6 m^3/year
- re-used treated wastewater		-	10^6 m^3/year

2 200 mm in the midlands and plains. The average annual rainfall is 1 960 mm, with a minimum of 650 mm in Phan Rang, and a maximum of 4 760 mm in Bac Quang. The rainy season lasts from April/May to October/November. Some 70-80 percent of the total annual precipitation occurs during the 3-6 months of the rainy season.

The driest periods are either from December to February or from January to March depending on location. The temperature varies from 15°C in winter to 25°C in summer. The annual average evaporation of the territory is 953 mm.

River basins and water resources

There are 16 river basins larger than 2 000 km^2, 9 of which are considered major rivers, each with a catchment area larger than 10 000 km^2. These nine major basins are the Bang-Ky Cung, Red River/Thai Binh, Ma, Ca, Thu Bon, Ba, Dong Nai and the Mekong Delta. Other basins are either small in area (the Tien Yen and Muc) or have several small rivers grouped together such as the Giang/Huong, Tra Khuc and Cai-Luy. The nine major basins represent 80 percent of the country's area and 70 percent of its water resources. The largest basins are the Mekong and the Red River/Thai Binh, covering half of the country's territory.

Viet Nam has abundant surface water resources in terms of total runoff, of which the Red and Mekong rivers carry 75 percent, while each of the other basins carries 1-3 percent of the water resources. The mean annual runoff totals approximately 878 km^3/year, of which about 354 km^3/year (40 percent) are generated within the country (corresponding to a runoff coefficient of 0.5).

About 60 percent of the total flow in Viet Nam originates outside the country. More than 90 percent of the Mekong basin lies outside Viet Nam. Half of the Red River basin lies outside the country. The Ma and Ca rivers both have about 40 percent of their basin area outside the country and the Dong Nai has 15 percent of the basin area outside the country. The contribution from neighbouring countries to the runoff in Viet Nam is estimated at 524.7 km^3/year, including 470.1 km^3/year (Mekong) and 1.4 km^3/year (Dong Nai) from Cambodia, 44.1 km^3/year (Red) from China, 9.1 km^3/year (Ca and Ma) from Lao PDR.

The distribution of water resources in the country during the year is highly variable due to unevenly distributed monsoon rainfalls. High variations combined with limited storage and flood control infrastructure result in devastating floods in the wet season and extreme low flows in the dry season. About 70-75 percent of the annual runoff is generated in three to four months.

The groundwater recharge in the country is estimated at 48 km^3/year. Over 50 percent of these resources are in the central part, about 40 percent in the north and 10 percent in the south. A large amount of water is stored in unconsolidated alluvial sand and gravel geological formations found in plains and valleys. A substantial part of these resources (estimated at 35 km^3/year) returns to the rivers as base flow. The exploitable reserves (the volumes of flows of satisfactory quality which can be extracted economically given the present technology) are estimated at about 6-7 km^3/year.

By adding together the internal and external water resources, the total renewable water resources are estimated at 891 km^3/year.

International agreements

Viet Nam is a downstream riparian state for most of its transboundary rivers. Six major rivers cross international boundaries. The Bang-Ky Cung and Red rivers are shared with China; the Ma and Ca cross from Lao PDR; and the Dong Nai and Mekong cross the Cambodian border. Most of the rivers flow to the Gulf of Tonkin and the South China Sea. Two exceptions are the Bang-Ky Cung, which drains to China, and the Srepok, which drains to the Mekong in Cambodia.

The 1995 agreement established by the four lower Mekong riparian countries offers new opportunities for regional collaboration in developing the basin's resources (water and related ecological resources). Some examples of promising collaboration are related to flood control in the Mekong Delta with Cambodia, and the possible importation of hydropower from upper riparians. There are no similar arrangements for other rivers.

Dams and lakes

There are two natural lakes in Viet Nam: Lake Ho-Tay with a surface area of 4.13 km^2 and a volume of 8 million m^3; and Lake Ba Be with a surface area of 4.5 km^2 and a volume of 90 million m^3.

There are 3 500 small reservoirs and 650 large and medium reservoirs. Data on the major dams and reservoirs of Viet Nam are presented in the table below.

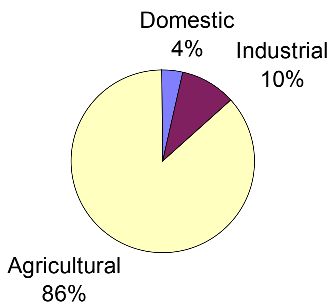
Majors dams and reservoirs in Viet Nam

Dam or reservoir	Year completed	Reservoir surface area (ha)	Reservoir storage capacity (Mm^3)
Cam Son	1967	2 600	227
Thac Ba	1971	23 400	3 600
Hoa Binh	1991	21 800	9 450
Dau Tieng	-	35 000	1 000
Tri An	1985	27 000	1 056

These reservoirs are multipurpose: hydropower, flood control, navigation, irrigation and fisheries.

Four large hydropower plants provide a total of 2 608 MW: Thac Ba (108 MW), Da Nhim (160 MW), Tri An (420 MW) and Hoa Binh (1 920 MW). Approximately 200 small hydropower plants with a total capacity of 3.7 MW are in operation, as are numerous micro-hydropower plants with a total capacity of 30 MW. Seventy percent of electricity is generated by hydropower.

FIGURE 1
Water withdrawal
TOTAL: 54.3 km³ in 1990



Water withdrawal

The total annual water withdrawal for agriculture, industries and domestic purposes was estimated at 54.3 km^3 in 1990 (Figure 1). The total domestic demand in 1990 was estimated at 2.0 km^3/year for both urban and rural consumers. This volume for domestic water use was estimated at 1.3 km^3 in 1980 and is expected to reach 2.9 km^3 by 2000. National industrial demand was 1.5 km^3 in 1980, rising to 5.3 km^3 in 1990. It is expected to reach 16.0 km^3 in 2000. In 1980, agriculture used 35.0 km^3 of water. In 1990, agricultural water withdrawal was estimated at 47.0 km^3, or 86.5 percent of the total water demand, of which some 6.5 million m^3 were for livestock. The estimated water demand for agricultural purposes for 2000 is 60.5 km^3.

It is estimated that 1.46 percent of Viet Nam's water demand is met by groundwater. The balance comes from surface water sources such as rivers, lakes and reservoirs. Groundwater is mainly used for domestic water supply in urban areas.

To date, no treatment facilities have been available in plants, factories and sewer systems before wastes are discharged into water bodies. In Hanoi, 300 000 m^3/d of wastewater are discharged into the rivers.

IRRIGATION AND DRAINAGE DEVELOPMENT

Small indigenous irrigation systems have long been employed in Viet Nam. Modern irrigation development stagnated until the reunification of the country in 1975.

Early post-1975 growth was in small and medium irrigation schemes, while in the period 1985-1990, growth was concentrated in large irrigation and multipurpose schemes. The total irrigated area expanded at a rate of 2.9 percent/year in the period 1980-87, while between 1988 and 1994 it was 4.58 percent/year.

In 1994, there were about 3 million ha of irrigated land in Viet Nam. About 73 percent of this land, or 2.1 million ha, was devoted to rice with a cropping intensity of 2.6, giving an aggregate irrigated rice area of about 5.46 million ha. In addition, 0.3 million ha of irrigated area were devoted to subsidiary vegetable and industrial crops, giving a total annual harvested irrigated area of about 5.8 million ha (Figure 2).

FIGURE 2
Irrigated crops
TOTAL: 5.8 million ha in 1994

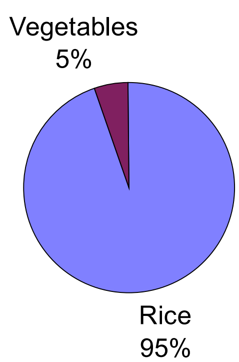


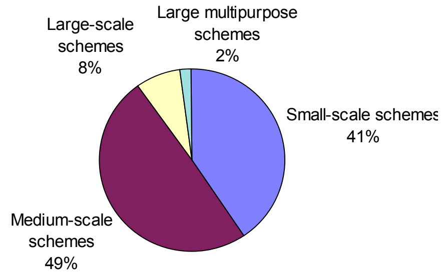
TABLE 3
Irrigation and drainage

Irrigation potential	1994	6 000 000	ha
Irrigation:			
1. Full or partial control irrigation: equipped area	1994	3 000 000	ha
- surface irrigation	1994	3 000 000	ha
- sprinkler irrigation	1994	0	ha
- micro-irrigation	1994	0	ha
% of area irrigated from groundwater		-	%
% of area irrigated from surface water		-	%
% of equipped area actually irrigated	1994	70	%
2. Spate irrigation		-	ha
Total irrigation (1+2)	**1994**	**3 000 000**	**ha**
- as % of cultivated area		49	%
- power irrigated area as % of irrigated area	1994	24	%
3. Other water management area	1994	0	ha
Total water managed area (1+2+3)	**1994**	**3 000 000**	**ha**
- as % of cultivated area		49	%
- increase over last 10 years	1994	46	%
- power water managed area as % of water managed area	1994	24	%
Full or partial control irrigation schemes:			
Small-scale schemes		-	ha
Medium-scale schemes		-	ha
Large-scale schemes		-	ha
Total number of households in irrigation		-	
Irrigated crops:			
Total irrigated grain production	1997	25 249 688	t
as % of total grain production	1997	94.5	%
Harvested crops under irrigation	**1997**	**5 800 000**	**ha**
- permanent crops: total	1997	0	ha
- annual crops: total	1997	5 800 000	ha
. rice	1997	5 460 000	ha
. vegetables	1997	376 400	ha
. others (subsidiary and industrial)	-	-	ha
Drainage - environment:			
Drained area	1994	1 000 000	ha
- drained area in full or partial control irrigated areas	1994	1 000 000	ha
- drained area in equipped wetland and i.v.b.		-	ha
- other drained area		-	ha
- area with subsurface drains		-	ha
- area with surface drains		-	ha
Drained area as % of cultivated area		14.8	%
Power drained area as % of total drained area		-	%
Flood protected areas		-	ha
Area salinized by irrigation		-	ha
Population affected by water-borne diseases		-	inhabitants

It is estimated that by rehabilitating existing infrastructures in the Red and Mekong deltas, there is the potential to expand irrigation to some 700 000 ha. The overall irrigation potential in Viet Nam is estimated at 6 000 000 ha.

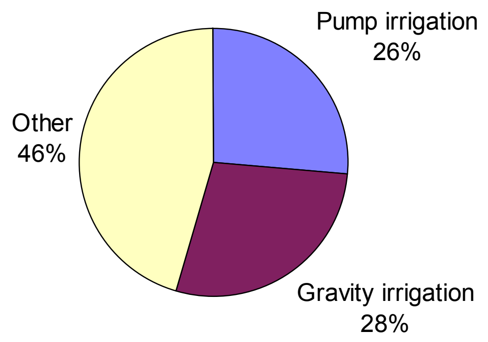
In 1994, the actual irrigation capacity was just 70 percent of the 3 million ha of equipped area. Two-thirds of this area were in the two large deltas (37 percent in the Red Delta, and 27 percent in the Mekong Delta). In 1994, about 49 percent of the cultivated area was irrigated. In 1990, there were 5 071 irrigation schemes in operation (Figure 3).

FIGURE 3
Irrigation schemes
TOTAL: 5 071 irrigation schemes in service in 1990



Of the total area irrigated in 1994, formal government schemes covered about 54.4 percent, equipped with pumped or gravity irrigation. The remainder consisted of private land irrigated by swing baskets, buckets, small private pumps, and, probably, small gravity diversions (Figure 4). This type of irrigation is concentrated in the Mekong Delta and, to a much lesser extent, in the Red Delta. Some 59 percent of the pump irrigation capacity is electrically driven, the remainder relying on oil powered engines.

FIGURE 4
Type of irrigation
TOTAL: 3.3 million ha in 1994



The drainage system covers over 1 million ha, mostly in the northern and central parts of the country, particularly the Red Delta.

The average aggregate yield for both irrigated and non-irrigated rice is 3.3 t/ha, with the spring crop providing the highest yield of around 5 t/ha, and the summer crop providing the lowest yield of around 2.8 t/ha.

Irrigation fees were first established in 1984 in some provinces, such as Vinh Long. The fee for irrigation and drainage services represents about 4-8 percent of the total crop output. After remaining constant for a number of years, water fee collections rose in the 1986-1991 period with an average collection of 31.6 kg paddy/ha, while from 1992 to 1994, collections averaged 38.8 kg paddy/ha.

INSTITUTIONAL ENVIRONMENT

The Ministry of Water Resources (MWR) is the main body charged with setting policy, and responsible for the planning, management and allocation of water resources at the central level. The MWR is responsible for constructing headworks and canals for schemes larger than 150 ha, while the provinces are responsible for developing smaller schemes.

Several divisions of the MWR are particularly important for agricultural water control. The Institute of Water Resources Planning prepares national plans, policies, objectives and strategies for water resources management and development which are used as guidelines by the provinces. It also prepares prioritized lists of investment projects for consideration by the state planning committees.

The Office of Irrigation and Drainage Management oversees the management of irrigation and drainage structures, develops policy guidance, produces operations and maintenance guidelines and collects data. It operates one national irrigation scheme in Dau Tieng, and interacts with other schemes through provincial or regional Irrigation and Drainage Management Committees and Provincial Peoples Committees.

The Vietnamese Hydraulic Investigation and Design Company is the technical design arm of the MWR.

The Construction Management Department, financially autonomous since 1994, develops procurement and construction management policies and guidelines for the water resources sector and monitors the activities of construction enterprises building MWR schemes.

There are a number of other institutions involved with irrigation planning and management, such as the Ministry of Science, Technology and Environment, which formulates environmental policies, which may include water related issues.

The General Department for Meteorology and Hydrology undertakes surveying and hydrographic data collection and monitoring.

The Ministry of Energy manages electricity generation, transmission, and distribution for uses including irrigation pumping.

TRENDS IN WATER RESOURCES MANAGEMENT

The Government has prepared plans and targets up to 2000. These plans indicate an accelerated growth rate of 4.5-5 percent for the agriculture sector. Other targets include: reducing the number of very poor people by 50 percent; reducing malnutrition among children to less than 30 percent; providing clean drinking water to all the urban population and 80 percent of the rural population. About 40 percent of the investment needed is projected to come from the Government, 15 percent from state enterprise and the rest from the private sector. The main items in the public investment programme are transport and water supply (33 percent), and irrigation and agriculture (24 percent).

The Ministry of Agriculture and Rural Development (MARD) has prepared a programme for rural development, which complements and builds on the strategy for the agriculture sector. The major objectives of this programme are to raise incomes and living standards in rural areas; diversify the rural economy through increased production of high value crops; and conserve the natural resource base, particularly land and water.

For 2010, the main targets are to: raise GDP per caput in the rural areas to US$1 000, irrigate 80 percent of all cultivated land, increase forested areas, and raise food production to 40-45 million t.

The World Bank irrigation rehabilitation project, being implemented since 1995, is funding the rehabilitation and completion of seven irrigation schemes comprising a total area of 130 000 ha. It is to be completed in five years at a total investment cost estimated at US$40 million.

The Mekong Delta water resources development project is expected to finance integrated water resources development, including irrigation, drainage, saline intrusion control, navigation, rural water supply, and agricultural diversification, in three geographical areas (South Manh Thit, Omon-Xano and Quanlo-Phunghiep) covering five delta provinces. The project is expected to start in late 1998, and the investment cost is about US$130-140 million.

The Red Delta water resources sector project provides US$75 million, financed by the Asian Development Bank, to rehabilitate or upgrade 20-30 small to medium-scale irrigation schemes in the Red Delta. The project is being implemented by the MARD and it is expected to be completed by 2000.

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The Aquastat programme aims at presenting a comprehensive picture of water resources development and irrigation, with emphasis on developing countries. This report is the fourth of a series and presents the results of surveys performed in the countries of Asia, carried out in 1997 and 1998. The survey relies as much as possible on country-based statistics and information contained in national publications. A general summary presents a regional synopsis on water resources development, irrigation and drainage in the region, and a series of country profiles describes the specific situation of each country.