Crops and Drops

making the best use of water for agriculture

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FOOD AND AGRICULTURE ORGANIZATION OF THE UNITED NATIONS
Rome

Foreword

Water and food security are intimately connected. Many of the over 800 million people in the world who still go hungry live in water-scarce regions. When FAO launched its Special Programme for Food Security in 1994, it was well aware that limited access to water was often a major constraint to increasing food production.

A key question for the future is whether water shortage will act as a serious brake on food production during the coming decades. Many people profess to know the answer: they argue that the world's renewable water supply is fixed and cannot be increased; consequently, per capita water resources dwindle in direct relation to population growth and rising aspirations; furthermore, they charge, much of the world's water is recklessly squandered on wasteful irrigation schemes, many of which rely on unsustainably high rates of withdrawal from underground water resources.

Publications that are optimistic about the future of the world's water resources are thus about as rare as thunderstorms in the desert. This publication, while perhaps not the equivalent of a desert thunderstorm, could be compared to a gentle rain (often preferable, in agricultural terms). Its key message is this: over the next 30 years we can increase the effective irrigated area in developing countries by 34 percent and we will need only 14 percent more water to do so.

How is this possible?

There are two explanations. One is that the changing food habits of people in some developing countries are helping to increase the water efficiency with which crops are grown. Rice, for example, is a very water-intensive crop, using about twice as much water per hectare as wheat. When people eat less rice and more wheat, less irrigation water is needed. The effect of this trend will be small but noticeable by the year 2030.

More importantly, we believe that the efficiency with which irrigation water is used can be increased over the coming 30 years — from an average 38 percent to about 42 percent. An FAO analysis of 93 selected developing countries shows their water abstraction for agriculture in 1998 was about 2 128 km^3 a year. If irrigation efficiency can be increased to 42 percent — and we believe that with concerted efforts, using the technology currently available, this can be achieved — we calculate that only 2 420 km^3 of water will need to be abstracted in 2030 to irrigate a net harvested area more than one-third larger than it is today.

While this conclusion is globally optimistic, we should not forget that water is already in very short supply in several countries, and that many other countries also suffer locally from severe shortages. These countries and these regions will need special attention in the years to come, and they will need to increase their irrigation efficiencies by much more than just 4 percent.

Increasing irrigation efficiency — getting more crop per drop — must thus become one of our top priorities. FAO intends to do all it can to help countries along this path, a path that leads to both increased water security and improved food security.

Contents

World water resources

It is estimated that the world contains about 1 400 million km^3 of water. Of this water, 35 million km^3 (2.5 percent) are freshwater.

World water distribution

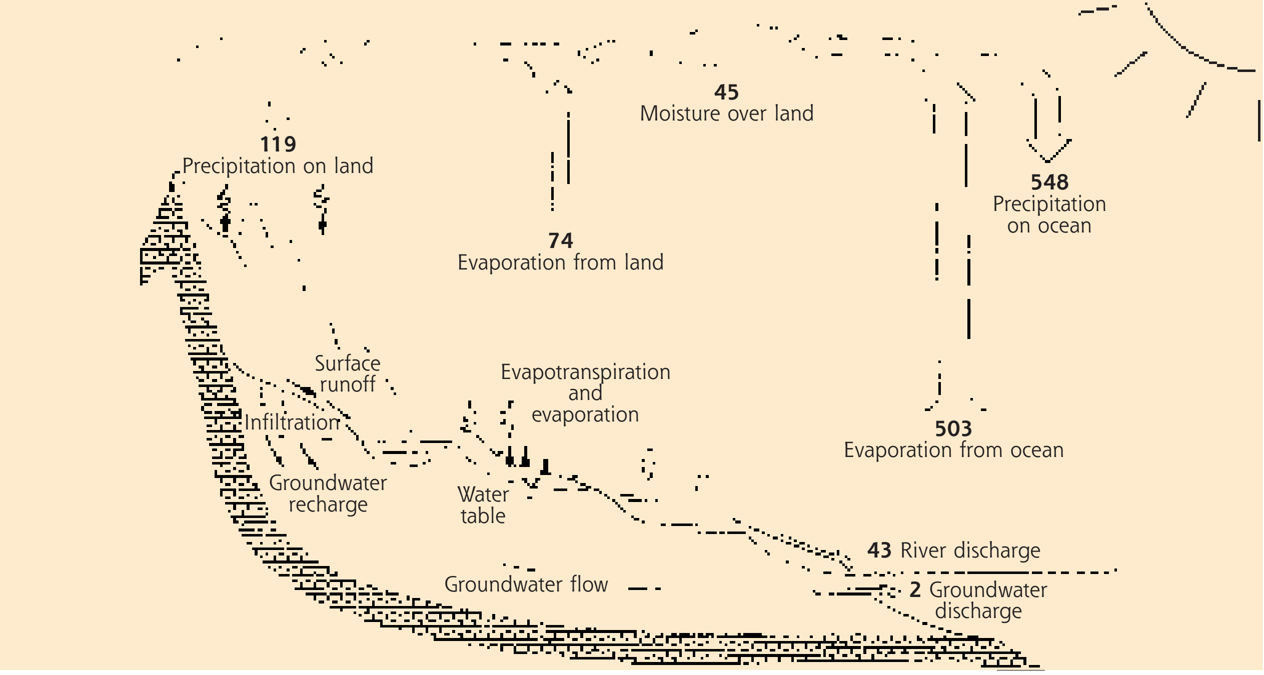
	Water volume (million km^3)	Percent of freshwater	Percent of total water
Total water	**1 386**		**100.00**
Freshwater	**35**	**100.0**	**2.53**
Glaciers and ice caps	24.4	69.7	1.76
Groundwater	10.5	30.0	0.76
Lakes, rivers, atmosphere	0.1	0.3	0.01
Saline water	**1 351**		**97.47**

The large amount of freshwater contained in ice caps, glaciers and deep in the ground is not accessible for use. Freshwater that can be used stems essentially from rainfall over land, generated through the hydrological cycle (see figure). Water is continuously recycled as a result of evaporation driven by solar energy. In this way, the hydrological cycle consumes more energy per day than that used by humankind over its entire history.

The average annual rainfall over land amounts to 119 000 km^3, of which some 74 000 km^3 evaporate back into the atmosphere. The remaining 45 000 km^3 flow into lakes, reservoirs and streams or infiltrate into the ground to replenish the aquifers. This represents what is conventionally called "water resources". Not all of these 45 000 km^3 are accessible for use because part of the water flows into remote rivers and during seasonal floods. An estimated 9 000 – 14 000 km^3 are all that are economically available for human use, a teaspoon in a full bathtub compared to the total amount of water on earth.

Annual withdrawals of water for human use amount to about 3 600 km^3. Part of the available surface water must be left to follow its natural course to ensure effluent dilution and safeguard conservation of the aquatic ecosystem. Exactly how much water needs to be left in a river will vary with the time of the year and many factors specific to each river basin. While a better understanding of the rivers' complex ecological services is still pending, instream flow needs are estimated at 2 350 km^3 per year. Adding this amount to the amount withdrawn for human use results in 5 950 km^3 of easily accessible freshwater resources that have been already subscribed. Taking into account demographic and water demand projections, the global water figures show a tightening water situation. Because both water and population are unevenly distributed, the situation is already critical in various countries and regions. Increasing areas of the world are suffering from freshwater shortages and competition among users is rising.

The hydrological cycle with annual volumes of flow given in thousand km^3



Agriculture’s use of water

Currently, about 3 600 km^3 of freshwater are withdrawn for human use — the equivalent of 580 m^3 per capita per year. The bar chart on the right shows that, in all regions except Europe and North America, agriculture is by far the biggest user of water, accounting worldwide for about 69 percent of all withdrawals, with domestic (municipal) use amounting to about 10 percent and industry using some 21 percent.

Estimated global water withdrawal (km^3 per year, m^3 per capita and as a percentage of total withdrawal)

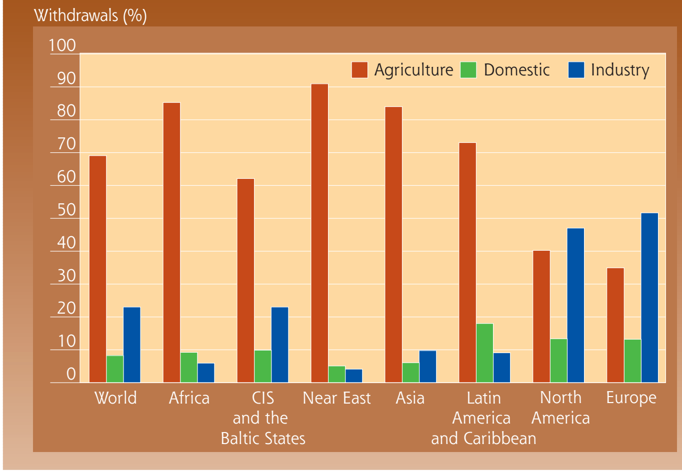
	1950	1995
Agriculture		
withdrawal	1 100	2 500
per capita	437	436
percentage of total	79	69
Industries		
withdrawal	200	750
per capita	79	131
percentage of total	14	21
Municipalities		
withdrawal	100	350
per capita	40	61
percentage of total	7	10
Total		
withdrawal	1 400	3 600
per capita	556	628
percentage of total	100	100

Note: All numbers are rounded.

It is important to distinguish between water that is withdrawn and water that is actually consumed. Of the 3 600 km^3 of water withdrawn annually, roughly half of it is consumed as a result of evaporation and transpiration from plants. Water that is abstracted but not consumed, by contrast, flows back over the surface to rivers or infiltrates the ground and is stored in aquifers. However this water is generally of a lower quality than the water that was withdrawn. Irrigation consumes much of the water it withdraws (often half or more) as a result of evaporation, incorporation into crops and transpiration from crops. The other half recharges groundwater or surface flows or is lost in unproductive evaporation.

Up to 90 percent of the water withdrawn for domestic use is returned to rivers and aquifers as wastewater. Industries typically consume only about 5 percent of the water they withdraw.

Water withdrawals by region and by sector

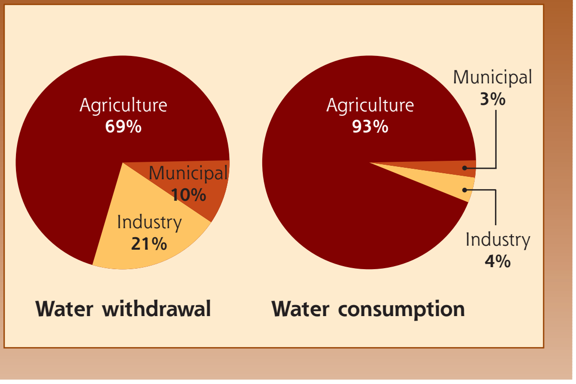


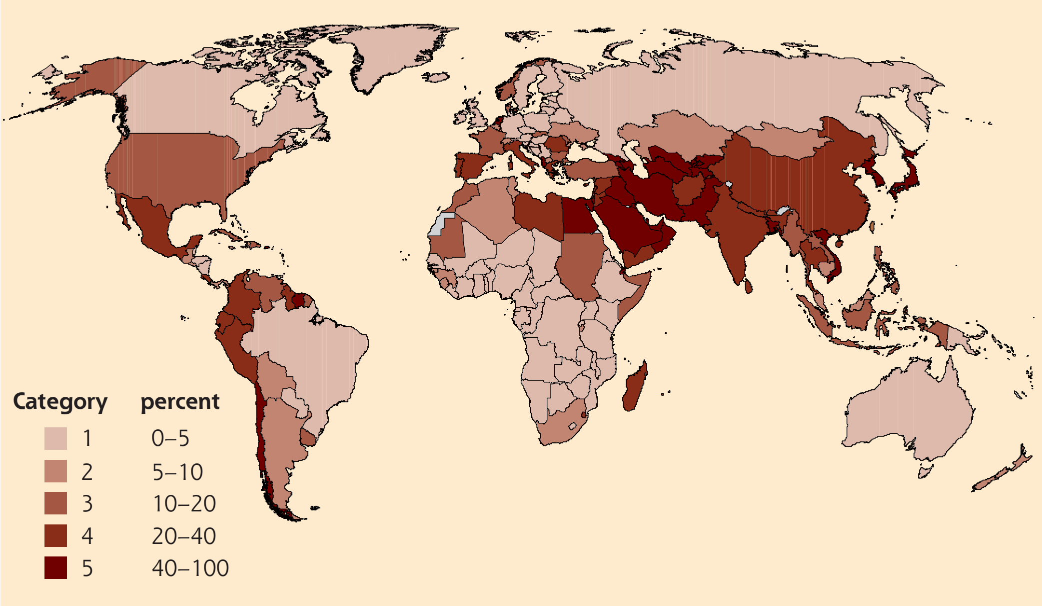
Wastewater from domestic sewage systems and industries should be treated before it is released into rivers and possibly re-used but it is often heavily polluted.

Figures for water withdrawal in agriculture do not include the direct use that is made of rainwater in rainfed agriculture. In fact, more food is produced from the direct use of rainwater than from the use of irrigation water — and even irrigated agriculture uses considerable rainwater.

These figures highlight the importance of agriculture in the challenge of making the Earth’s available water serve the needs of its growing number of users. The water needed for crops amounts to 1 000–3 000 m^3 per tonne of cereal harvested. Put another way, it takes 1–3 tonnes of water to grow 1 kg of rice. Good land management can significantly reduce the amount of water needed to produce a tonne of cereal, both in rainfed and irrigated agriculture.

Water withdrawal and water consumption for the three main use sectors (1995)



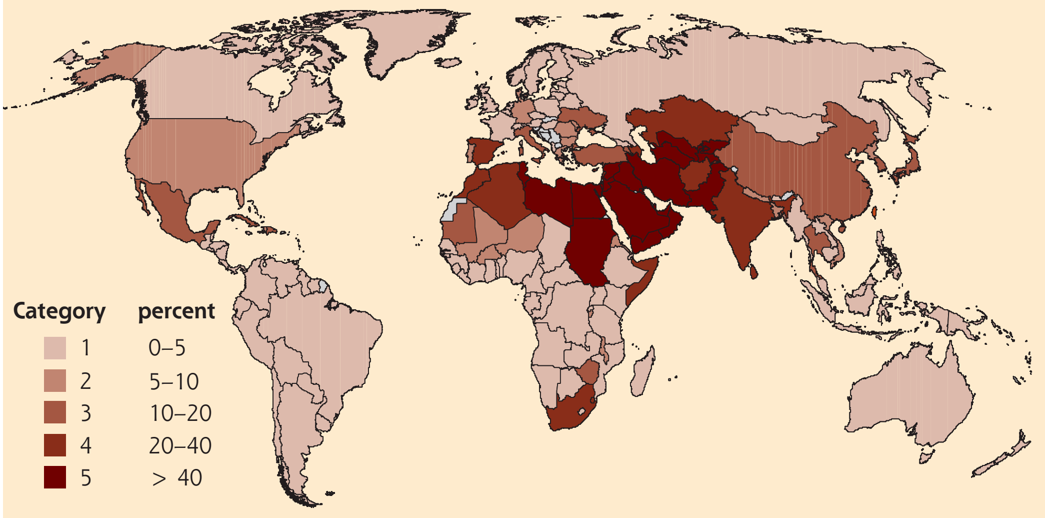


Area equipped for irrigation as a percentage of cultivated land (1998)

Map highlights countries where irrigation plays an extremely important (category 5) and a major role (category 4) in agriculture. Irrigation is little used in northern temperate zones and in sub-Saharan Africa.

While much can be done to increase the crop/drop yield in rainfed agriculture, most of the attention currently focuses on irrigated agriculture which relies mainly on water that runs into rivers or is stored in aquifers. As the map above shows, many developing countries rely heavily on irrigation. In an FAO analysis of 93 developing countries, it was found that 18 of them use irrigated agriculture on more than 40 percent of their cultivated land; an additional 18 countries irrigate between 20 and 40 percent of their cultivated area (FAO, *World Agriculture: Towards 2015/2030*).

Inevitably, such an intensive use of water for agriculture can strain resources. The map below shows that, 20 countries are in a critical condition in that more than 40 percent of their renewable water resources are used for withdrawals for agriculture. Countries could be defined as water stressed if they abstract more than 20 percent of their renewable water resources. By this definition, 36 of 159 countries (23 percent) were already water stressed in 1998.



Agricultural water withdrawals as a percentage of total renewable water resources, 1998

Map showing where withdrawals for agriculture are critically high (category 5) and indicative of water stress (category 4).

Production and food security

Nearly 1 000 million people currently live in what is defined as absolute poverty, with incomes of less than US$1 a day.

Most of these suffer from chronic hunger. In the developing countries, more than one child in four is underweight — and in the poorest of these countries, every other child is underweight. Such children are at great risk to disease, and many of them never become adults: the underlying cause of more than half of all child deaths in developing countries is malnutrition. Those that do survive to adulthood face a future that is likely to be scarred by hunger, homelessness, illiteracy and unemployment.

Hunger is not a natural condition: it is produced by human action (or lack of it) and, in a world that can produce more than enough food for everyone, its root cause is poverty. Remarkably, in the early 1990s nearly 80 percent of all malnourished children lived in developing countries that produced food surpluses.

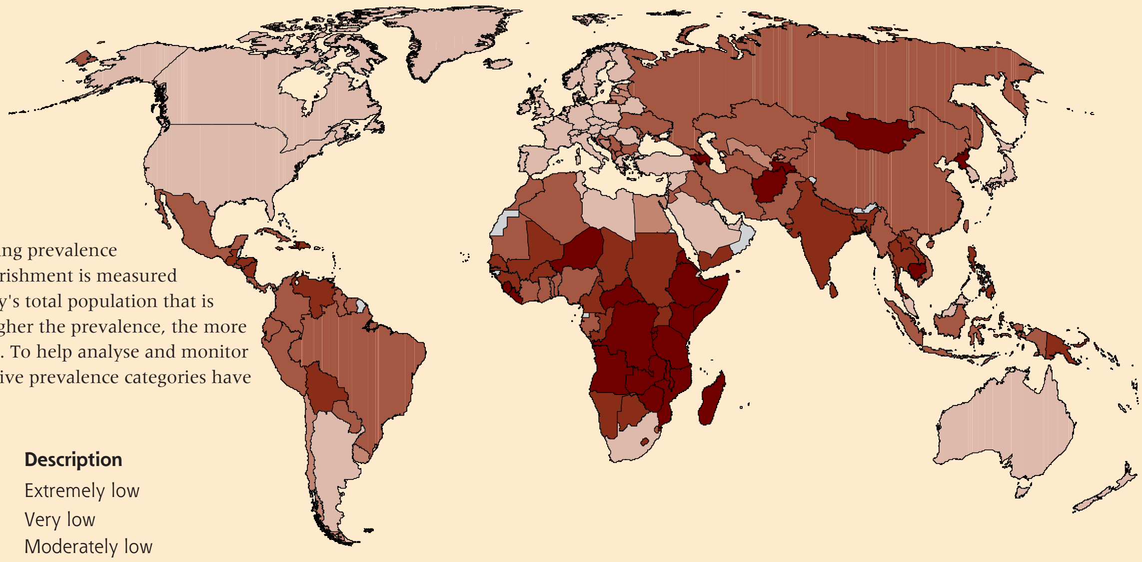
Although the number of people going hungry has declined by about 5 percent since the early 1990s, it is estimated that almost 800 million still go hungry in the developing countries and some 30 million in other countries. As populations increase and more people move from rural to urban areas, the task of reducing hunger will become even more difficult than it is today.

The key issue is to increase food security by ensuring that all households have real access to adequate food for all their members and do not risk losing such access. This means not only that the food must be available but also that people can afford to buy it. There are several ways of increasing food security: increasing local food production and productivity, increasing food imports on a regular and assured basis, providing more jobs and increased incomes for those who are too poor to buy the food they need, and improving food distribution systems.

Food self-sufficiency, achieved by meeting all food needs through domestic supplies, used to be a common national policy objective. It had the advantages of saving foreign exchange for the purchase of other commodities that could not be locally produced and of insulating countries from the vagaries of international trade and uncontrollable fluctuations in agricultural commodity prices. It also ensured that sufficient food was always available to feed local populations. A number of political factors – notably a sense of national insecurity (as in the Near East) – also militated against extensive dependence on food imports in some water-short countries.

In practice, there were many drawbacks. Where food self-sufficiency was difficult to achieve, climatic variations such as storms, floods and

Percentage of population undernourished (1997-1999)



Measuring and monitoring prevalence
Prevalence of undernourishment is measured by the share of a country's total population that is undernourished. The higher the prevalence, the more widespread the problem. To help analyse and monitor progress, the following five prevalence categories have been established:

Category	percent	Description
■ 1	< 2.5	Extremely low
■ 2	2.5–5	Very low
■ 3	5–20	Moderately low
■ 4	20–35	Moderately high
■ 5	> 35	Very high

droughts could quickly make nations dependent on either food aid or food imports. In arid countries, the price for food self-sufficiency was also high in that a high proportion of available water and land resources had to be devoted to irrigation, depriving the domestic and industrial sectors of the relatively small volumes of water they needed to flourish. Some countries accumulated substantial water deficits as a result of mining underground aquifers for water with which to produce their own cereals.

Today, the trend is away from food self-sufficiency to partial reliance of food imports. One of the main driving forces to this change is water scarcity, caused by rapidly growing populations which have reduced per capita water and land availability. At the same time, there have been increasing municipal demands on limited water resources. Some countries have also found that there are higher returns on labour in industries other than agriculture — in short, that it is easier and more profitable to earn foreign exchange to buy food imports than it is to grow water-hungry agricultural crops.

Importing food is equivalent to importing water in a condensed form, sometimes called ‘virtual water’. In a recent survey of irrigation and water resources in the Near East, FAO estimated that 86.5 km^3 of water would be needed to grow the food equivalent to net food imports to the region in 1994 — a figure that is comparable to the total annual flow of the Nile at Aswan.

It makes obvious sense for water-scarce countries to import basic foods such as cereals from water-surplus areas and use their own limited water resources to grow high value crops for export — such as cut flowers, strawberries and other fruit. The foreign exchange thus earned can then be used to buy cereal imports.

Countries facing food insecurity and water stress, however, need to be assured that they can have fair and secure trade with water-abundant nations. Secure basic food trade conditions for water-poor countries should become a priority for the World Trade Organization.

Some countries that are not food self-sufficient, however, cannot export enough to earn the foreign exchange needed to purchase the food imports they need. Similarly, individuals may not have the cash to purchase food for themselves and their families, even though food is available in the market. This highlights the continuing need for agriculturally-based rural development programmes in such areas as sub-Saharan Africa and South Asia. Such programmes need to be aimed simultaneously at increasing productivity, reducing poverty and improving gender equity — three of the keys to improving food security.

FAO’s Special Programme for Food Security

FAO launched its Special Programme for Food Security (SPFS) in 1994. Focusing on low-income, food-deficit countries, SPFS was endorsed during the World Food Summit in 1996. The main objective is to help countries to improve their national food security — through rapid increases in productivity and food production, and by reducing year-to-year variability in production — on an economically and environmentally sustainable basis. By working with farmers and other stakeholders to identify and resolve constraints to food production and to demonstrate ways of increasing production, the SPFS opens the way to improved productivity and access to food. The Programme is currently operational in 55 countries and under formulation in 25 others.

In drought-prone areas, limited access to water is often a major constraint to improving food production, making small-scale irrigation, water harvesting and water development technologies top priorities for the SPFS.

Food security also depends on maximizing both the food and the number of jobs produced for every drop of water used — whether in irrigated or rainfed agriculture. Irrigated agriculture has played a significant role in the increase of food production in recent decades but its absolute contribution is still lower than that of rainfed agriculture. Of the 1 500 million hectares of global cropland, only about 250 million hectares (17 percent) are irrigated. However, this 17 percent provides about 40 percent of world food production; the remaining 60 percent comes from rainfed agriculture. In water-scarce tropical regions such as sub-Saharan Africa, rainfed agriculture is used on more than 95 percent of cropland, and will remain the dominating source of food for growing populations.

Means of increasing the productivity of both rainfed and irrigated agriculture are discussed on pages 14–19.

Overuse and misuse

The ways in which freshwater resources are used, particularly for agriculture, leave much to be desired. In some places, these resources are overused in the sense that use exceeds renewable supply rates, and so cannot be indefinitely continued; elsewhere, wasteful overuse in one area deprives users in other areas, leading to falls in agricultural production and loss of jobs. Misuse occurs where clean water is abstracted and returned to the water system in an unusable state. Used irrigation water is often contaminated with salts, pesticides and herbicides. Industry and urban centres also return contaminated water to both surface and underground water resources.

Abandoned boat on the dried-up sea floor of the Aral Sea.

The Aral Sea is one of the planet's greatest environmental disasters. Prior to 1960 an average of 55 000 million m^3 of water flowed into the Aral Sea. Withdrawal for cotton irrigation and the construction of flood storage reservoirs resulted in a decline in average annual inflow to 7 000 million m^3 between 1981 and 1990. As a result, the sea level fell by 16 metres between 1962 and 1994 and the lake volume was reduced by three-quarters. Twenty of the 24 species of fish that used to be present in the sea have disappeared, and the fish catch that totalled 44 000 tonnes a year in the 1950s and supported 60 000 jobs has dropped to zero. Toxic dust-salt mixtures picked up from the dry seabed and deposited on surrounding farmland are harming and killing crops. The low river flows have concentrated salts and toxic chemicals, making water resources hazardous to drink and contributing to the high rate of many diseases in the area. Those who remain in the area have lost their main livelihood. Those who have left have become environmental refugees.

One of the most conspicuous results of overuse is that some large rivers — including the HuangHe, the Colorado and the Shebelli — now dry up before reaching the sea. The Amu Darya River which feeds the Aral Sea (see box left) has been deprived of its entire water reserves for irrigating cotton plantations. The Yellow River in China did not complete its descent to the sea for a total of seven months during 1997 (see box on page 9).

Dried-up rivers are a good example of the overuse of freshwater resources. Overuse in one place means deprivation in another. The flat fertile deltas of many rivers were once centres of high agricultural production. Where the rivers no longer flow, water for irrigation becomes unavailable, farmers go out of business and local production fails.

The causes are usually upstream development. Logging, road building and upstream agriculture often increase soil erosion, resulting in increased sedimentation. This leads to flooding in mid-stream areas and reduced water flows downstream. Sedimentation is also clogging the world's major water reservoirs, currently estimated to hold about 6 000 km^3 of water. About one percent of this — the equivalent of 60 km^3 — is now being lost annually through sedimentation.

Irrigated agriculture has a significant impact on the environment. One positive impact is that high-productivity irrigation of a small area can often replace the use of a much larger area of marginal land for growing crops. However, abstraction of irrigation water from rivers and lakes can also jeopardize aquatic ecosystems such as wetlands, leading to losses in their productivity and biodiversity. This has important implications for human populations that once depended on the major inland fisheries that such areas previously supported and on the natural filtering action of wetlands which have historically been responsible for cleaning up much of the world's wastewater. Where wetlands have been eliminated in the name of irrigation, the results have usually been regretted.

The agricultural chemicals used in irrigated farming often contaminate surface runoff and groundwater. Potassium and nitrogen from fertilizer applications on both rainfed and irrigated land may be washed into groundwater or surface water where they can lead to algal blooms and eutrophication.

Poplars being irrigated with raw sewage water in India.

Irrigation can also concentrate naturally-occurring salts in the water, which then accompany return flows to groundwater or to surface streams and rivers. Irrigation in arid regions can also leach naturally-occurring toxic elements such as selenium from soils and into surface water and groundwater. Overirrigation can lead to waterlogging which reduces yields substantially.

All these problems are amplified as water use intensifies. Furthermore, unconventional water sources have to be tapped as conventional supplies dry up: brackish water and sewage effluents may have to be used for irrigation, and risks to human health may result if not managed properly.

Many countries are already using more water than their renewable supply, and are in a water-deficit situation. Water deficits are created mainly by exploiting groundwater faster than it is replenished. This is in effect the mining of a natural resource, and some arid countries rely substantially on such mined resources, particularly for irrigation (see table). This is a non-sustainable use of resources which cannot be continued far into the future.

The overuse of groundwater as a resource for food production has serious implications. Aquifers have been overexploited in many countries. Estimates of annual depletion in the major water-deficit countries add up to about 160 km^3. This suggests that about 180 million tonnes of grain, or some 10 percent of the global harvest, are being produced by depleting water resources. Ironically, an equal or greater amount of food production is under threat from rising groundwater tables in places where irrigation is used but drainage is inadequate.

Overuse of limited water resources is exacerbated by waste, which occurs at almost every point at which humans interfere with the natural water cycle. Irrigation is notoriously wasteful: water is wasted at almost every point in the cycle, from the leaking canals that are used to supply irrigation water to the huge volumes of water that fall uselessly on soil where there are no crops or which are in excess of the uptake required by the crop. Improving irrigation efficiency — currently less than 40 percent — is a key goal for the future.

Groundwater mining in selected countries

Country	**mining as % of total water withdrawal**
Kuwait	46.5
Bahrein	40.2
Malta	32.2
United Arab Emirates	70.9
Qatar	14.9
Libyan Arab Jamahirija	90.0
Jordan	17.5
Saudi Arabia	79.7

Source: *Water Resources of the Near East Region: a review* (FAO, Rome, 1997)

Floods and droughts

Too much water and too little water have always been the natural curse of agriculture. Today, despite greatly improved knowledge of weather systems, the use of meteorological satellites and advanced computer simulation of the climate, farmers are more exposed to climate extremes than ever before. While such extremes may be becoming more common as a result of climate change, vulnerability has increased for other reasons as well: population densities have increased; marginal land is increasingly used to grow inappropriate crops, leading to potential soil erosion and flash floods; deforestation has denuded steep land of its protective vegetative cover; powerful machinery has made it possible to strip land of its vegetation in a fraction of the time that used to be required; and economic pressures on farmers to increase productivity through high input farming have led to unstable and unsustainable farming practices. It will prove impossible to maximize agricultural production from limited water resources unless the factors that so accentuate the effects of natural disasters can be corrected.

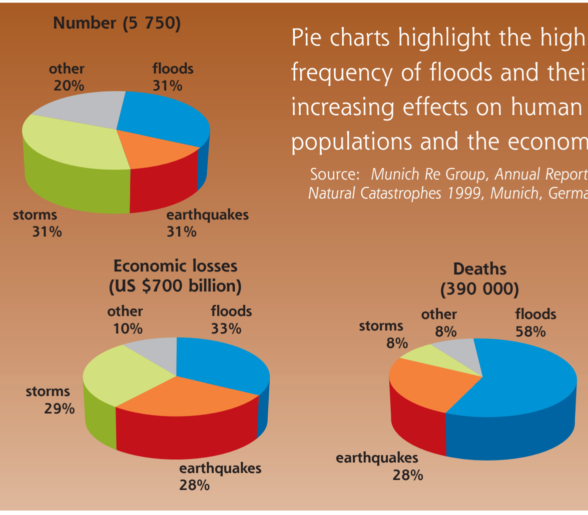
According to studies made by the Munich Re Group, there were 3.2 times more major natural catastrophes — notably floods, storms and earthquakes — in the 1990s than in the 1960s, and their economic damage increased 8.6 times.

Major flood disasters

Date	Location	Approx. no. of Deaths
1421	The Netherlands	100 000
1530	The Netherlands	400 000
1642	China	300 000
1887	Yellow River, China	900 000
1900	Texas, United States	5 000
1911	Yangtze River, China	100 000
1931	Yangtze River, China	145 000
1935	Yangtze River, China	142 000
1938	Yellow River, China	870 000
1949	Yangtze River, China	5 700
1953	The Netherlands	2 000
1954	Yangtze River, China	30 000
1960	Bangladesh	10 000
1963	Vaiont, Italy	1 800
1979	Morvi, India	15 000
1991	Bangladesh	139 000
1991	The Philippines	6 000
1991	Huai River, China	2 900

Source: *World Commission on Water for the 21st Century, World Water Vision: Making Water Everybody's Business, Draft Report of the Commission, Version of 14 November 1999*

Floods and other natural catastrophes worldwide, 1988–97



Pie charts highlight the high frequency of floods and their increasing effects on human populations and the economy.

Source: *Munich Re Group, Annual Report on Natural Catastrophes 1999, Munich, Germany.*

The increase in the frequency and seriousness of floods, and the mudslides often associated with them, has been the most striking. During 1988–97, floods accounted for about one-third of all natural catastrophes, caused more than half of all deaths from catastrophes and were responsible for one-third of overall economic losses from catastrophes.

An increasing number of people are being severely affected by floods – more than 130 million between 1993 and 1997. Environmental degradation has made a substantial contribution to the devastation caused by flooding. So have poverty and marginalization, which often require the poor to live in unsuitable and exposed conditions.

Land degradation is a major cause of the increasing impact of floods and droughts on human populations and the environment. About 70 percent of drylands and one-sixth of the world population are currently affected by land degradation. It occurs in most regions of the world but is most pronounced in the semi-arid and drought-prone regions of Africa, Asia and South America. Drought and desertification have led to major migrations in both Brazil and the Sahel. During the past three decades, many people have lost livelihoods once based on agriculture, and there has been widespread famine, malnutrition and migration.

FAO's *Water for Life*, published on the occasion of World Food Day in 1994, reported that:

> *'In many parts of the world, rainfed cropland is in poor shape. Increasing human and livestock*

populations have led to land degradation through soil erosion, overgrazing, bush fires, deforestation and the expansion of arable farming onto unsuitable marginal land. In arid and semi-arid areas, which cover a third of the Earth's land surface, these forms of degradation lead to desertification …

'The cost in terms of human suffering is high. The African droughts of 1984–85 affected 30–35 million people; land degradation and desertification caused some 10 million of them, later known as environmental refugees, to be permanently displaced.'

In 1998, weather patterns associated with *El Niño* dried out crops in some regions, flooded them elsewhere and battered Central America with Hurricane Mitch which caused the deaths of more than 9 000 people and left nearly 3 million homeless. Honduras and Nicaragua were the hardest hit, with Honduras losing more than half its maize crop. Losses in coffee and other export crops were estimated at US$480 million.

Human-made factors greatly increased the impact of Hurricane Mitch. Mudslides poured down slopes denuded by deforestation and the cultivation of marginal land. Flooding was aggravated by poor watershed management. The most affected countries are attempting to address the structural problems that contributed to the disaster by examining land tenure practices, supporting reforestation projects and providing training in watershed management.

Severe flooding in several Asian countries and the worst drought for decades in the Near East have worsened prospects for food security. Drought was expected to lead to a 16 percent fall in cereal production for the Near East region in 1999. Losses will be far greater in the Islamic Republic of Iran, Iraq, Jordan and the Syrian Arab Republic. Unhappily, there is no evidence to suggest that these setbacks are only transitory in either Asia or the Near East.

Downstream dessication is also becoming increasingly problematic in many areas. The tragic history of the Aral Sea (see page 6) is well known; what is less well known is that a similar fate is facing farmers on the deltas of many rivers from which so much water has been used on the upper and middle reaches that little is left for those who farm and live lower down.

Floods and droughts on China's Yellow River

Draining a basin of 745 000 square kilometres which nourishes 120 million people, the Yellow River is the second longest river in China

The Yellow River in China has become a classic example of how upstream use can led to mid-stream floods and downstream dessication.

The Yellow River dries up before it reaches the sea on an increasing number of days each year, some 200 in 1997. Annual flow at the delta during 1986–94 was half what it was in the previous decade. Research has shown that upstream development and diversions, and the success of programmes of water and soil retention in the middle reaches, are responsible, and that climate change is not a significant factor.

The Yellow River has the highest sediment concentration and total load of any river in the world. It transports some 1 600 million tonnes of sediment a year, most of which results from erosion on the Loess Plateau. Much of the sediment is deposited on the channel bottom when the river flows onto the great North China Plain, where the bed of the river is now up to 10 metres higher than the surrounding land, retained there by flood banks. These banks are frequently breached after heavy rains, leading to catastrophic floods which are regularly responsible for heavy loss of life and economic damage in the area.

However, water shortages on the North China Plain now amount to some 5 000 million m^3 for municipal and industrial uses, and 35 000 million m^3 for agricultural purposes. This is some 70 percent of the total long-term average flow of the Yellow River. It is the high level of abstraction in this area and downstream that causes the river to dry up so often before it reaches the sea, depriving agriculture in the delta area of the irrigation water needed to maximize production on the fertile downstream plains.

The future

Global population will continue to expand at a rate of 1.1 percent until 2015 and more slowly thereafter. Today's population of 6 000 million will reach 8 100 million by 2030, an increase of about 33 percent. As a result, demand for food will increase over this period but at a slowing rate.

The nature of the demand will also change as incomes rise and urbanization continues. The urban population is expected to increase from 43 percent of the world population in 1990 to 61 percent by 2030. As incomes rise, there will be a shift first from maize and coarse grains to rice, and then from rice to wheat. At the same time, there will be a shift in preference from cereals to meat and fish, with increasing demand for maize and other coarse grains as animal feed.

The growing population and changes in food preferences will result in a strong demand for additional food production, though the types of cereals demanded for food and feed, and the mix of cereals and animal products in the diet, will change. Predictions suggest that over the next 30 years overall crop production will thus increase considerably more than that required simply by population growth. Although net food imports into the developing countries are expected to increase, most of the increasing demand in those countries will be met by increased local production.

Increases in demand can be met in three ways:

- increasing agricultural yield;
- increasing the area of arable land; and
- increasing cropping intensity (number of crops per year).

Over the past 30 years or so, most of the increase — more than three-quarters — came from increases in yield, mainly as a result of the Green Revolution. This is also expected to be the case in developing countries over the next 30 years, with 69 percent of the production increase being covered by yield increase, 12 percent by increases in cropping intensity and the rest from increase in the area of cultivated land.

Much of the increase in crop production will come from irrigated land, three-quarters of which is in developing countries. Currently, some 20 percent of agricultural land in the developing countries is irrigated and it provides about 40 percent of crop production in these countries. Over the past 30 years, the irrigated area expanded at about 2 percent a year, giving a total increase of some 100 million hectares during 1962–98. The irrigated area in developing countries in 1998 was nearly double what it was in 1962.

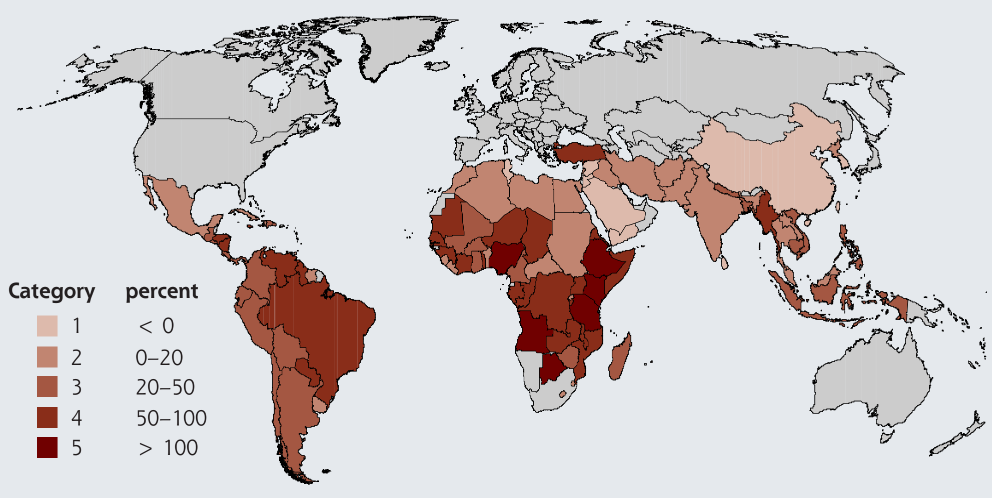
There are many reasons why such rapid expansion will not continue, and most analysts expect the irrigation area to grow much more slowly in the future. FAO expects that irrigated areas in 93 developing countries could grow by 0.6 percent a year between 1998 and 2030. Such a rate of growth would lead to only a 23 percent increase in irrigated area over the period. However, when coupled with increased cropping intensity, the effective harvested irrigated area is expected to increase by much more: from 241 to 323 million hectares, a 34 percent increase.

Will there be enough freshwater to satisfy the growing needs of agriculture and other water uses? Agriculture already accounts for about 70 percent of the freshwater withdrawals in the world and is seen as the main factor behind increasing global freshwater scarcity.

An FAO analysis of 93 developing countries reaches comparatively encouraging conclusions on this question. During the period 1998–2030, irrigation water withdrawal in these countries is expected to grow by a total of only about 14 percent, from the current 2 128 km^3/year to 2 420 km^3/year in 2030. This increase is low compared to the increase projected in the harvested irrigated area. Most of this difference is explained by an expected improvement in irrigation efficiency, leading to a reduction in the withdrawals needed for irrigation water per irrigated hectare. Another part of this reduction will be due to a change in cropping pattern for some countries, such as China, where a substantial shift from rice to wheat production is expected: irrigation water requirements for rice are usually twice those of wheat.

Irrigation water withdrawal was estimated to account in 1998 for only 8 percent of total water resources for the 93 countries (see table on page 11). There are, however, wide variations between regions, with the Near East/North Africa region using 53 percent of its water resources in irrigation while Latin America barely uses 1 percent of its resources. At the country level, variations are even higher (see map on page 3). Of the 93 countries, 10 already used more than 40 percent of their water resources in 1998 for irrigation, a situation which can be considered critical. An additional eight countries used more than 20 percent of their

Increases in withdrawals for agriculture 1998–2030, percent



Increases in water withdrawal for agriculture over the period 1998–2030 will be high (more than 100 percent) in 6 countries, and fairly high (50–100 percent) in 27 others. Increases will be less than 20 percent in 41 countries.

water resources, a threshold which can be considered to indicate impending water scarcity. The situation should not change drastically over the period of the study, with only two additional countries crossing the 20 percent threshold. Since additional water withdrawals will be needed for the non-agricultural sectors, the global picture in 2030 would not be very different from that in 1998, when agriculture used 85 percent of water withdrawals in developing countries. The key, of course, is how to increase irrigation efficiency (see pages 16–19).

For several countries. however, relatively low national figures may give a biased impression of the level of water stress: China, for instance, is facing severe water shortage in the north but the south still benefits from abundant resources. Even in 1998, two countries, the Libyan Arab Jamahiriya and Saudi Arabia, withdrew more water for irrigation than their annual renewable resources; groundwater mining also occurs in many other countries. Irrigation consumed a relatively small fraction of renewable water resources for the 93 developing countries in 1998. With a relatively small increase in irrigation water withdrawal expected by 2030, no major water crisis should affect irrigated food production at global level. This finding, however, should not lead to complacency since severe water shortages are already being experienced at local levels, particularly in the countries of the Near East and North Africa.

Irrigation efficiency and withdrawals for irrigation as a percentage of renewable water resources, 1998 and 2030

	sub-Saharan Africa	*Latin America*	*Near East/ North Africa*	*South Asia*	*East Asia*	*93 developing countries*
Irrigation efficiency (%)						
1998	33	25	40	44	33	38
2030	37	25	53	49	34	42
Irrigation water withdrawals as a percentage of renewable water resources						
1998	2	1	53	36	8	8
2030	3	2	58	41	8	9

People and water

There are two key ingredients to maximizing agricultural production from a given and limited volume of water: people and technology. Of these, people are the more important. The best and most innovative technology in the world is of no use if people themselves cannot use it, see no advantage in it or do not understand it.

Getting people involved in water management for agriculture at local levels is not a new idea. Indeed, it is already practised successfully in many parts of the world — for example, in the irrigation systems of Bali. However, the difficulty of introducing real participation and transparent decision making in societies accustomed to centralized and bureaucratic methods should not be underestimated. Big changes are required, both from the institutions that previously held total power and from the individuals and their user groups, who perhaps previously played only a token role. Some of these changes are listed in the box below.

This is not to say that there are not still special roles for specialists: enthusiasm and participation at local levels can always be well complemented by technical expertise on sustainable management, irrigation technology, water distribution systems, watershed management and other subjects. Training and facilitation are also required in many areas — for example, to establish measures to protect freshwater ecosystems and to enable communities to resolve conflicts among competing resource users.

Water engineer in Tanzania …

'We engineers used to design water projects in our office and keep the plans there. We thought the villagers couldn't understand such things. Now we go to the village to do the design work and even the old ladies can draw a plan of the water project using a stick in the dust. It is a big change and a better way of working.'

Barnabas Pulinga
Government water engineer
United Republic of Tanzania

Gender equity is crucial. Women and men have an equal right to access water even though they may have different roles in relation to the maintenance and use of water resources. However, a gender approach to water resource management can be controversial because it requires changes from men and women in the way they manage water and agricultural issues, and hence in how they relate to one another. Both traditional and innovative mechanisms are needed to resolve these issues.

Class equality is also crucial. There is no room in an efficient water management scheme for elitist roles for the wealthy or socially distinguished;

Involving people to improve water management

Legal reforms to improve access to water are needed in many countries. They should cover:

- allocation of water resources between different users, particularly those in rural and urban areas;
- minimizing conflict between those who use the resource for water supply and those who use it for waste disposal;
- promotion of efficient water use;
- regulation of use of wastewater as a safe source of supply;
- reduction of the role of government in rural water projects, increasing the importance of local user groups, and removal of impediments to charging for water and recovering costs;
- evolution of systems of land tenure towards written and individual or group titles;
- ensuring legal access to land and water for women heads of household and women generally; and
- creation or improvement of an effective water rights administration to manage the water sector in general and the rural water sector in particular.

often, the people who most need a new say in how water is managed, and who know most about how it should be managed, are poor women smallholders.

In fact, there is ample evidence that inclusion of the poor can have disproportionate effects on agricultural growth. Studies that have assessed the influence of holding size on land productivity for a range of holdings that applied modern varieties, fertilizer and irrigation show that smaller holdings are more productive than larger ones. Data from Green Revolution areas in India, Bangladesh, Pakistan, the Philippines and Sri Lanka show that irrigated small holdings, compared with irrigated large holdings, tend to have higher net sown proportions of their irrigated land, have higher cropping intensities, apply more fertilizer per unit of cultivated land, cultivate more diversified, higher-value and more labour-intensive crops and obtain higher yields per crop per unit of land. Recent research in Côte d'Ivoire and Latin America has also done much to debunk the myth that large farmers are more efficient than smaller ones. Given their share of cultivable land, smallholders contribute disproportionately to the production of major crops, particularly traditional ones. In a study of 55 developing countries, smallholder production in 39 countries was found to be considerably higher than its share in arable land would suggest.

In the end, what is needed is a new water contract. The Green Revolution was staged by scientists. The Blue Revolution should be staged by making water use and management everyone's business: its goal would be to maximize the production of food and the creation of jobs per water unit consumed. Enabling individuals and communities to understand their options for change, to choose from these options, to assume the responsibilities that these choices imply, and then to realize their choices could radically alter the way the world uses its limited water resources.

Gender in water issues

Woman watering seedlings in a tree nursery in Palcalancha, Bolivia, watched by her children.

Abundant evidence is available showing that where women and men take part in consultation, decision making and training, facilities are better used and management is improved. In contrast, absence of consultation of female water users and managers in projects in Guatemala, Indonesia and Togo, and many other places, led to these women not using new facilities — not because they had not been educated to do so but because the new facilities had been wrongly designed or sited, or ignored conventions on gender usage.

In one project in Sri Lanka, the design of irrigation schemes was adjusted to make safe water available to women for domestic use. Similarly, in St Lucia laundry facilities were added to an irrigation system to avoid women standing in the water too long and hence contracting schistosomiasis.

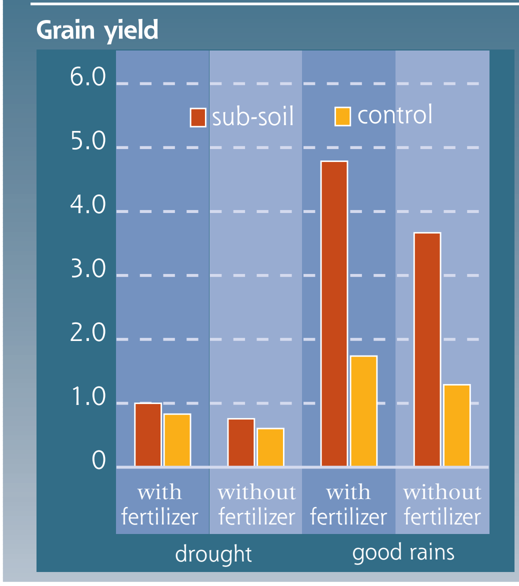
On a household rainwater harvesting project in Gujarat, India, water committees were formed in five villages. The committees comprised approximately equal numbers of women and men. Despite hostility in the community towards women's participation in project activities traditionally seen as men's work, they were active in many aspects: committee decision making, construction work, seeking a loan from a local bank for the project and, in one village, resolving a conflict between two social groups that was jeopardizing the success of the project. In assessing the effects of the project, women felt particularly relieved by the availability of water at home at the end of each day's agricultural work.

Source: Vision 21: A shared vision for hygiene, sanitation and water supply.

Improving rainfed production

Increasing the productivity of rainfed agriculture, which still supplies some 60 percent of the world's food, would make a significant impact on global food production. However, the potential to improve yields depends strongly on rainfall patterns. In dry areas, rainwater harvesting can both reduce risk and increase yields. As the diagram below shows, there are various forms of rainwater harvesting: using microstructures in the field to direct water at specific plants or plant rows (*in situ* water conservation); capturing and directing external water from the catchment area to the field in which crops are grown (flood irrigation); and collecting external water from the catchment area and storing it in reservoirs, ponds and other structures for use during dry periods (storage for supplementary irrigation).

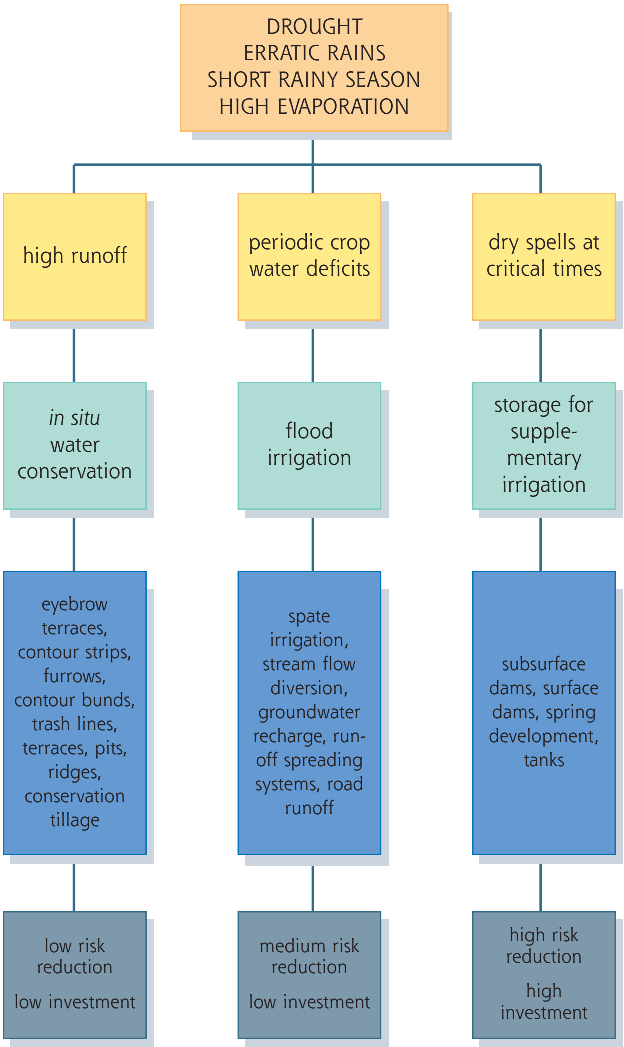
Effects of subsoiling in trials in Tanzania



Maize yields were increased from less than 1 to more than 4.8 tonnes per hectare by subsoiling with good rains and fertilizer.

Work in Burkina Faso, Kenya, the Niger, the Sudan and the United Republic of Tanzania has shown that rainwater harvesting can increase yields two to three times as compared with conventional dryland farming. Furthermore, rainwater harvesting often has double or triple benefits: not only does it provide more water for the crop but it also adds to the recharging of groundwater and helps reduce soil erosion.

Ways of dealing with arid conditions



Risk management is crucial in rainfed agriculture. The higher the risk of crop reductions from droughts and dry spells, the lower the likelihood that farmers will invest in inputs such as fertilizers, improved varieties and pest management. *In situ* soil and water conservation contributes relatively little to reducing risks in rainfed agriculture. To make substantial risk reductions, flood irrigation, with the option of supplementary irrigation, has to be introduced. Unfortunately, technologies that reduce risk are usually more expensive and require more know-how to construct.

IN SITU WATER CONSERVATION

In dry areas, poor land management can greatly reduce crop yields, even to below 1 tonne per hectare. One reason is that land degradation often affects the soil surface, leading to crust formation and other phenomena that prevent infiltration by rainwater. Most rainfall then simply runs off the land surface, collects in silt-laden torrents and produces severe gully erosion. Crops benefit little.

A major cause is turning the soil, by hand, with animal traction or with a tractor, too often. This leaves the soil exposed and prone to both wind and water erosion. While ploughing techniques developed in temperate regions, with their gentle rains and light winds, are harmless enough, they are often poorly suited to tropical climates and soils.

Alternative forms of tillage — such as turning the soil only along plant lines, deep ploughing to break up soil crusts, building raised ridges that follow the contour, growing crops in pits, and building eyebrow terraces round trees and shrubs — can improve crop yields and reduce erosion. They lead to a much more efficient use of limited rainfall. Trials in the United Republic of Tanzania have shown, for example, that breaking up the plough-pan increased maize yields from 1.8 to 4.8 tonnes per hectare in a year with good rains and if manure was applied as fertilizer. In Damergou in the Niger, 310 hectares were equipped with microcatchments and contour furrows in less than one month using special ploughs. Costs were only US$90/hectare. Average yields were 2 tonnes/hectare of sorghum with an annual rainfall of only 360 mm.

Flood irrigation

More needs to be done to cope with the effects of the dry spells that occur every year in arid and semi-arid areas. Although these periods of drought often last less than three weeks, if they occur during sensitive growth stages — such as during flowering or grain filling — there is a high risk of serious yield reductions.

The best way of tackling the problem is to divert rainfall from the surrounding catchment area to the soil in which the crops are being grown. Providing the right infiltration conditions have been established, water can be stored in the soil around the crop roots for considerable periods — certainly for long enough to be of considerable use during a three-week drought. Methods of diverting water within the catchment area towards the crops themselves include diverting streams, using spate flow from wadis, directing runoff with low walls (a system used to great effect by the ancient inhabitants of the Negev desert) and even diverting flow towards crops from roads and paths.

Storage for supplementary irrigation

Finally, there are ways of storing the runoff from rainy periods for use during the dry spells: these include the tanks, ponds, cisterns and earth dams used for supplementary irrigation in China, India, sub-Saharan Africa and many other areas. Although they are more costly and require considerable know-how on the part of the farmers who have to build them, they have the advantage of greatly reducing the risk of small or non-existent harvests as a result of drought.

Small-scale farming can be productive in marginal rainfed areas if supplementary irrigation is available to overcome short-term droughts which are critical to the crop and reduce yield considerably. If there are cost-effective ways to store water before critical crop stages and apply it when the rain fails in these critical stages, crop production can be considerably increased.

Keita Valley, Niger

Halting land degradation by dune fixation in the Keita Valley, the Niger

In five years the people of the Keita Valley in the Niger, with the help of an Italian-funded FAO integrated development project, transformed nearly 5 000 square kilometres of barren and non-productive landscape into a flourishing garden for crops, livestock and trees. Public participation was the key to the project's success which has benefited from more than 4 million man- and woman-hours of work on planting trees, digging wells, constructing weirs and damming streams, building terraces and bunds, deep ploughing land and erecting dune fences.

The project provided training and helped villagers construct new schools, roads, community centres, clinics and mills. New skills have been introduced into the community, including growing cash crops, producing handicrafts and farm processing. Thousands of people have participated in work teams and hundreds have been trained to manage them.

Improving irrigated production...

Sprinkler irrigation of cotton crops in Israel's Hula Valley.

Irrigated agriculture has been an extremely important source of food production over recent decades. As the graph below shows, the highest yields that can be obtained from irrigation are more than double the highest yields that can be obtained from rainfed agriculture. Even low-input irrigation is more productive than high-input rainfed agriculture. Such are the advantages of being able to control, quite precisely, water uptake by plant roots.

Even so, irrigated agriculture contributes less food than rainfed agriculture. Globally, rainfed agriculture is practised on 83 percent of cultivated land, and supplies more than 60 percent of the world's food. In water-scarce tropical regions such as the Sahelian countries, rainfed agriculture is practised on more than 95 percent of cropland. One reason is that, in these areas, conventional irrigation development of food crops may be extremely costly and hardly justified in economic terms.

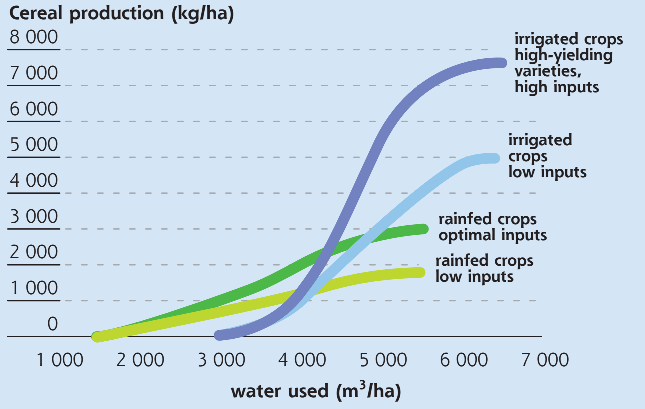
There are other reasons why conventional irrigation cannot continue to grow as fast it has over the past few decades. For one thing, the real cost of irrigated food production is far from clear since, to quote one author, irrigation is 'one of the most subsidized activities in the world'. The environmental costs of conventional irrigation schemes are also high (and are not reflected in food prices) — high-intensity irrigation leads often to waterlogging and/or salinization. About 30 percent of irrigated land is now severely or moderately affected. The salinization of irrigated areas is reducing the existing area under irrigation by 1–2 percent a year.

In spite of these reservations, of course, not only will irrigation continue to be used but the area under irrigation will also expand. What is also badly needed is improved efficiency in the use of irrigation water (see box on opposite page).

There are basically five types of irrigation:

- surface irrigation, in which the entire or most crop area is flooded;
- sprinkler irrigation, which imitates rainfall;
- drip irrigation, in which water is dripped onto the soil above the root zone only;
- underground irrigation of the root zone by means of porous pots or pipes placed in the soil; and

Yields and water requirements of irrigated and rainfed agriculture



Irrigation has the potential to provide higher yields than rainfed agriculture but water requirements are also much higher.

- sub-irrigation, in which the groundwater level is raised sufficiently to dampen the root zone.

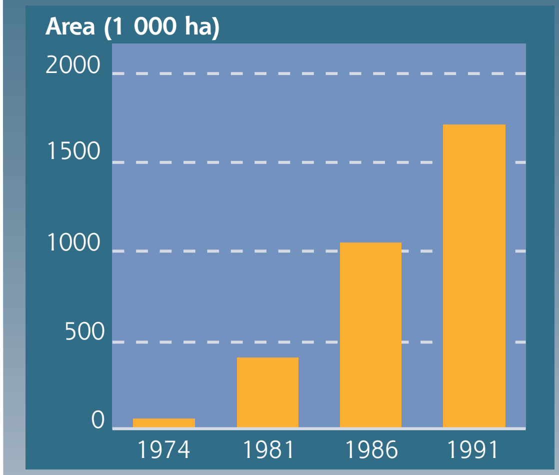
The first two of these, surface and sprinkler irrigation, are together known as conventional irrigation. Surface irrigation is currently by far the most common technique, and is used particularly by small farmers since it does not involve operation and maintenance of sophisticated hydraulic equipment. For the same reason, surface irrigation is still likely to be dominant in 2030, even though it is wasteful of water and is a major cause of waterlogging and salinization.

Drip irrigation and underground irrigation are examples of localized irrigation, an increasingly popular form of irrigation in which water efficiency is maximized because water is applied only to the places where it is needed and little is wasted. However, technology is not all. Such things as small-scale irrigation and the use of urban wastewater promise to increase water productivity as much as changes in irrigation technology.

LOCALIZED IRRIGATION SYSTEMS

If incentives are in place — and increasing the price of irrigation water is likely to be a principle one — farmers will adopt water-saving irrigation technologies. The main technologies likely to be used in developing countries, where labour is normally abundant but capital scarce, are underground and drip irrigation. Both technologies depend on the frequent application of small amounts of water as directly as possible to the roots of crops. A major advantage of water-saving technologies, particularly drip irrigation, is that as well as saving water they can increase yields and reduce the rate of salinization. Furthermore, since neither system brings water into contact with foliage, they can be used with brackish water for crops that are not too sensitive to salinity. Some of the underground irrigation systems are simple techniques that do not require costly inputs in equipment but are labour intensive. Indeed, one of the oldest methods of irrigation is placing porous clay jars in the soil around fruit trees and along crop rows. The jars are filled by hand, as required. Porous or perforated pipes buried underground serve the same purpose, and can usually be used to irrigate two rows of crops, one on either side of the pipe. The rate of application cannot be controlled (although the frequency can) since it depends on the size of the perforations and soil characteristics.

Worldwide growth of localized irrigation



Localized irrigation has grown rapidly since the invention of cheap plastic pipe in the 1970s.

Drip irrigation has been applied only on a small part of the area for which it is suited. It depends on a pressurized system to force water through perforated pipes running above ground, at rates of 1–10 litres per hour per emitter. Though the technology is simple, it does require both investment and careful maintenance — emitters can easily become clogged. However, results from many countries show that farmers who switch from furrow (trench) systems or sprinkler irrigation to drip systems can cut their water use by 30 to 60 percent. Crop yields often increase at the same time because plants are effectively 'spoon-fed' the optimal amount of water (and often fertilizer) when they need it.

Six keys to improving irrigation efficiency

- reduce seepage losses in channels by lining them or using closed conduits;
- reduce evaporation by avoiding mid-day irrigation and using under-canopy rather than overhead sprinkling;
- avoid overirrigation;
- control weeds on inter-row strips and keep them dry;
- plant and harvest at optimal times; and
- irrigate frequently with just the right amount of water to avoid crop distress.

Drip systems, which cost in the range of US$1 200–2 500 per hectare, tend to be too expensive for most small-scale farmers and for use on low-value crops but research is under way to make them more affordable. One drip system has been developed that costs less than US$250 per hectare. The keys to keeping costs down are simple materials and portability: instead of each row of crops getting its own drip pipe, a single pipe moved every hour or so can be used to irrigate as many as ten rows. Bubbler irrigation is another cheap variation which eliminates the need for emitters, pressure regulators and other fittings; instead, water is allowed to bubble out of short lengths of pipe placed vertically and connected to underground lateral distributor pipes.

SMALL-SCALE IRRIGATION

There is considerable promise in a range of traditional and modern small-scale and supplementary irrigation systems to increase the productivity of rainfed areas. Technologies such as treadle pumps (see box opposite) can allow resource-poor farmers to manage their own systems to suit their needs, providing water is locally available. Pumping water with small-scale diesel or electric engines can also be more economic than large-scale schemes that rely heavily on centralized control. Furthermore, because individual farmers are in full control of their own systems, they can often maximize production to suit their own lifestyles — something impossible with large, centrally-controlled schemes.

IMPROVING DRAINAGE, REDUCING SALINITY

Drainage of irrigated land serves two purposes: to reduce waterlogging and, equally important, to control and reduce salinization that inevitably accompanies waterlogging in the semi-arid and arid regions. Proper drainage also allows crop diversification and intensification, the growth of high-yielding varieties, effective use of inputs such as fertilizers, and mechanization.

The problem is restricted to about 100–110 million hectares of irrigated land located in semi-arid and arid zones. At present, about 20–30 million hectares of irrigated land are seriously damaged by the build-up of salts and 0.25–0.5 million hectares are estimated to be lost from production every year as a result of salt build-up. The currently drained area of 25–50 million hectares is insufficient. Therefore, drainage of irrigated land is badly needed.

However, drainage has two important drawbacks. First, drainage effluent is often contaminated with salts, trace elements, sediments and traces of agricultural inputs. The drainage effluent needs to be safely disposed of. Second, improved drainage in upstream areas causes larger downstream flows, increasing the risk of floods. Therefore, new drainage projects should consider not only the benefits of sustainable agricultural production but the side effects on the environment.

Some 100–150 million hectares of rainfed land, mostly in Europe and North America, have been drained while another 250–350 million hectares are in need of drainage. Much crop production takes place on what were once wetlands. However, this type of drainage development has come to a standstill as the value of natural wetlands has become better appreciated.

Drip irrigation in Cape Verde

In the early 1990s, an FAO project funded by the Netherlands sought to develop horticulture in Cape Verde. The project was a success but its extension was limited by the availability of water — average precipitation on the islands is about 230 mm/year, providing little more than 700 m^3/person/year. Drip irrigation was then introduced, first in experimental plots and then in farmers' fields. The new system increased production and saved water, allowing for an expansion of the irrigated land and cropping intensity. Convinced by the experiment, many farmers spontaneously adopted drip irrigation on their land. In 1999, six years after the first experiment, 22 percent of the irrigated area of the country had been converted to drip irrigation, and many farmers had converted their crops from water-consuming sugar cane plantations to high-return horticultural crops such as potatoes, onions, peppers and tomatoes. Total horticultural production increased from 5 700 tonnes in 1991 to 17 000 tonnes in 1999. It is estimated that a plot of 0.2 hectares provides farmers with a monthly revenue of US$1 000.

USING WASTEWATER FOR IRRIGATION

Reducing the pollution loads of water used by farms, industries and urban areas would enable much more of it to be re-used in irrigation. There are enormous potential benefits to be had from the use of wastewater for irrigation.

As an example, a city with a population of 500 000 and a water consumption of 120 litres/day/person produces about 48 000 m^3/day of wastewater (assuming 80 percent of the water used reaches the public sewerage system). If this treated wastewater were used in carefully-controlled irrigation at a rate of 5 000 m^3/ha/year, it could irrigate some 3 500 hectares.

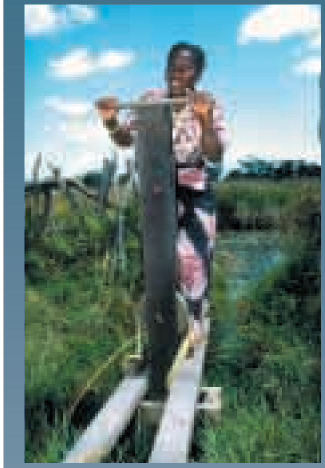
The fertilizer value of the effluent is almost as important as the water itself. Typical concentrations of nutrients in treated wastewater effluent from conventional sewage treatment are: nitrogen, 50 mg/litre; phosphorus, 10 mg/litre; and potassium, 30 mg/litre. At an application rate of 5 000 m^3/ha/year, the fertilizer contribution per year of the effluent would be: nitrogen, 250 kg/ha; phosphorus, 50 kg/ha; and potassium, 150 kg/ha. Thus all the nitrogen and much of the phosphorus and potassium normally required for agricultural crop production would be supplied by the effluent. In addition, other valuable micronutrients and organic matter contained in the effluent would provide additional benefits.

An added benefit is that because most of these nutrients are absorbed by the crop they are removed from the water cycle and hence play no further role in the eutrophication of rivers and the creation of Dead Zones in coastal areas.

THE NEED FOR MORE STORAGE

Projections indicate that even with optimistic views about productivity growth, efficiency and the expansion of irrigated area, 14 percent more water will be needed for irrigated agriculture in the developing countries by 2030. This will require some 220 km^3 of extra storage. In addition, storage that is lost due to the siltation of existing reservoirs must be replaced; this is estimated at 1 percent or 60 km^3 a year — 1 800 km^3 over 30 years. A further 160 km^3 of water that is mined from aquifers should also be replaced. The total required over the next 30 years is thus in the region of an additional 2 180 km^3 of storage, or more than 70 km^3 a year (not allowing for increasing evaporation losses as a result of the increased area). The task is thus to put in place at least the equivalent of a new Aswan High Dam every year.

Introducing the treadle pump to Zambia



Zambian farmer operating treadle pump

In Zambia, FAO's Special Programme for Food Security (SPFS) has successfully promoted the introduction of small-scale irrigation technology. In drought-prone areas of the country, farmers traditionally used laborious bucket-carrying methods to irrigate their plots. During the SPFS pilot phase, treadle pumps were introduced which could pump water from a depth of eight metres with a discharge of 1.5 litres/second. Modifications were made to adapt the pumps to local conditions, and three types of pumps are now being locally produced by nine manufacturers. Farmers from all over Zambia have so far bought 1 500 pumps. Consequently, the supply of fresh vegetables both at household level and village level in Zambia has improved considerably.

For a variety of economic, environmental and social reasons, it is not likely that this amount of additional surface storage will be constructed in the next 30 years.

Storing more water in aquifers is an attractive alternative. New techniques and institutional mechanisms are urgently needed to stimulate the recharge of groundwater aquifers.

Improving policies

Policies, institutions and laws can be devised to increase water productivity at many different levels. At the level of individual consumption, policies that encourage people to eat less water-intensive foods — wheat rather than rice, poultry rather than beef, for example — could increase water efficiency markedly. At the local level, improved irrigation management would do much to improve efficiency: the best way of doing this is to give those who actually use irrigation water the power to plan and manage their own supplies, at least at the local level. In addition, transparency and accountability must be improved, and incentives provided for saving water. At the river basin level, a major priority is to improve integration not only between land- and water-use planning but also among the many other water users involved — hydro-electric schemes, industry and urban populations, for example (see box on page 21).

IMPROVING MANAGEMENT AT LOCAL LEVEL

The role of water users

In many countries, responsibility for the management of irrigation systems is being handed over by central government to private enterprise and local user associations. Attempts are being made at many different levels of management to involve farmers and smallholders, women and men, in the planning and management of water resources. As a result of the South African Water Act of 1998, for example, Catchment Management Agencies have been formed with the participation of both poor men and women. In Turkey, the management of irrigation systems has been almost entirely handed over from government to farmer associations. In Mexico, the management of more than 85 percent of the 3.3 million hectares of publicly irrigated land has been taken over by farmers' associations, most of which are now financially independent. This has meant increasing the charges made for irrigation water but, even so, they have been kept within the 3–8 percent of total production costs that is normally considered reasonable.

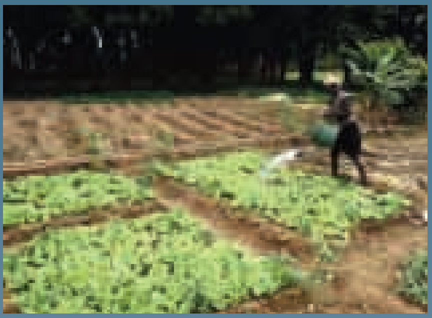
Professional organizations are often needed to manage reservoir and large canal systems but user organizations can nearly always manage the final distribution system; irrigation management organizations can often be 're-born' as service providers or service companies.

Increasing transparency and accountability

Many water institutions in many countries have a history of bureaucracy, secrecy and heavy-handed attitudes to customers and clients. There has often been a lack of transparency and accountability in the water business. As water becomes more scarce, the need for public information about how water is used, by whom and in what quantities will become increasingly acute — and so will the need for information about who pollutes and to what extent. Access to information via the Internet will make it easy for institutions to appear transparent — although real transparency involves more than the publication of a few, carefully selected data.

There is increasing legal precedence for the view that water institutions, particularly those involved with irrigation, are accountable for their actions to

The importance of urban agriculture



Urban garden outside Bissau town, Guinea Bissau.

Urban agriculture is growing fast, and not only among the poor. Latest estimates suggest that globally as many as one-third of all urban dwellers take part in urban agriculture which provides up to one-third of urban food requirements. In many urban areas, farming occupies more ground than buildings and roads: some 60 percent of the land in Greater Bangkok, for example, is farmed.

Urban agriculture often involves the constructive use of urban wastes for water and nutrients, and it can be highly efficient: intensive vegetable production may, for example, use only 5–20 percent of the water and only 8–16 percent of the land needed to grow rural, tractor-cultivated crops. In Botswana, for instance, a high technology variety of container horticulture is practised which can produce the equivalent of 20 tonnes of maize per hectare.

In some water-scarce countries, a radical vision of water use is emerging in which water is first allocated to urban areas. After use and treatment there, the wastewater is then made available to agriculture. Urban industry funds the costs of water supply and treatment, and the treated water is supplied to farmers at low cost.

their end users and to society at large. If the manufacturers of motor vehicles are to become responsible for the final disposal of their products, it is likely that water institutions can be held responsible for the timely delivery of their product in a pure state — especially since polluted water can lead to polluted food and threats to human health.

Providing incentives

One of the keenest incentives to saving water is a pricing policy that makes wasting water expensive. Removing government subsidies for irrigation water is a first step but one that should not be taken without due thought to the effects on poor farmers. Pricing policies can be pitched so that farmers neither pay the full cost of their water nor get it free. For example, charges can be based on a traditional price for a fraction, one-half for example, of the volume normally used, an increased price for the next quarter and a much higher price for the final quarter. Tiered pricing systems of this kind can produce substantial savings.

They can also be used to protect aquifers that are being overpumped. Once a study has assessed the rate at which an aquifer is naturally replenished, rights to extract this amount can be distributed among the farmers who use the aquifer. Farmers who insist on pumping more than their allowance can then either be charged very high prices or can be forced to buy pumping rights on an open market from others not using their full allowance.

Maximizing water productivity means not only maximizing agricultural production per drop of water but also maximizing the number of rural jobs that can be created with limited water resources. The value of water, in other words, is both the food it can produce and the income it can generate. Distribution of irrigation water can be a means of increasing employment if water is distributed to rural families on the basis of where they live rather than the land they own. Several schemes, notably in India and Africa, have experimented with the distribution of sufficient water to irrigate a small parcel of land to every homestead or to every man and woman in a certain area. The schemes have increased both incomes and food production. In this context, it is important that switching from rainfed agriculture, where jobs are occasional and highly seasonal, to irrigated agriculture, which often requires year-round labour in both the fields and on the distribution systems, often entails an increase in jobs.

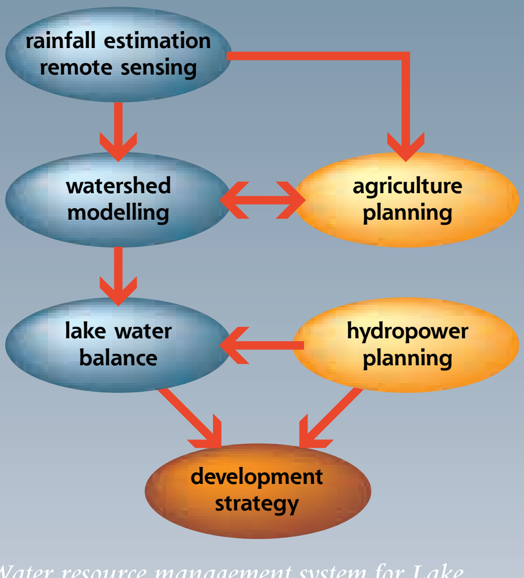
IMPROVING RIVER BASIN MANAGEMENT

The ultimate aim of water management is to optimize water use throughout a river basin in such a way that all users have access to the water they need. All users include more than the big three — urban, industrial and agricultural. Other users include electricity utilities that need water for hydro-electric schemes and for cooling water for conventional and nuclear power stations, port authorities that need water for navigation, wetland areas that are needed as natural filters and wildlife sanctuaries, and downstream fisherfolk whose livelihoods depend on river flow.

Improving management in the Nile Basin

The Nile Basin Initiative was launched in 1998 by the Council of Ministers of Water Affairs of ten states that border the Nile. FAO has been helping nations improve the management of the Nile Basin for more than ten years. It has, for example, helped:

- develop a forecasting system for the Nile River and a control and decision support system for management of the High Aswan Dam reservoir in Egypt;
- strengthen technical capacity in the Lake Victoria region to monitor water resources, develop modelling tools and establish a geo-referenced database system for the region;
- build up capacity to manage the Nile Basin water resources.



Water resource management system for Lake Victoria integrates agricultural and hydropower planning with hydrological studies.

During the next few decades, difficult priorities will have to be set. One inevitable factor will be the growing needs of urban populations. Who owns water rights is a matter of great concern since in many parts of the world urban centres have simply appropriated the water in peri-urban areas which they regard as their property, depriving farmers in the area of their livelihoods. Elsewhere intensive trading occurs between municipal authorities — which have the funds — and rural landowners, who own the water rights. Few river basins have yet rationalized all this in the logical progression which suggests that the purest water be first used for domestic supplies, that treated domestic supplies be then used for irrigation of crops such as cereals, and that the poorest quality water be used for the irrigation of forestry plantations, pasture land, parks, gardens and lawns.

Organizing water management on this scale is even more complicated for river basins that are shared by two or more countries. There are many of them: 47 percent of the Earth's land surface lies within international river basins, of which there are more than 200. Thirteen of these are shared by five or more countries. River basins that are shared by developed countries are already subject to numerous agreements governing the rational use of these water resources; those shared by developing countries are subject to far fewer agreements. FAO has been helping develop a sound basis for such agreements for many years.

Towards a better future

FAO believes in a future in which both rural and urban people have secure livelihoods and adequate nutrition. In such a future, farmers would be in control of their livelihoods and resource base, and would produce all the food needed, both by farmers and non-farmers, using their own ingenuity and the physical resources available to them. Young people would stay in their rural communities, helping care for the more elderly, and live in security. Rural areas, like urban ones, would have educational, cultural and social services, and employment opportunities. There would be access to food produced locally and elsewhere, and transportation and communication links with markets, administrative centres and the economy at large. Rural men and women would participate in a global improvement of the standard of living and its dividends reflected in quality of life, health and leisure. Agriculture and other activities would be carried out in harmony with the environment, with clean water in streams, lakes and aquifers, surrounded by and integrated with healthy natural ecosystems. Water would be managed efficiently and on a sustainable basis. Access to water and other agricultural resources would be available on an equitable basis and in a fair economic environment that provided opportunities for all.

Such a future will not come about automatically: it requires that people be given access to their human, political and economic rights. Society needs to be organized in such a way that food and water are accessible to all, even its weakest members. Each generation has an obligation to preserve the natural and agricultural heritage for its successors, so that today's production does not reduce the capacity of future generations to produce what is necessary for life. Most importantly, both men and women must have a voice in the decisions that affect them, including those that relate to water allocation and management. Decision-making authority needs to be devolved to the lowest possible level and people need to have access to the information required to make such decisions.

Hungry mouths depend on water for agriculture which provides not only the food to eat but the income with which to buy it …

water

source of food security

WORLD FOOD DAY
16 OCTOBER 2002

For further information, contact:

Land and Water Development Division
Food and Agriculture Organization of the United Nations
Viale delle Terme di Caracalla
00100 Rome, Italy

e-mail: land-and-water@fao.org
www.fao.org/landandwater

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