

ON THE SUSTAINABILITY OF WATER USE

by

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Since the 1992 International Conference on Water and the Environment (ICWE) in Dublin at the latest, there has been a great deal of intensive and serious thought on very different levels about the limited availability and the possibilities of exploiting and managing the earth's fresh water resources. In June 1992 the United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro, building on the results of the Dublin Conference, brought out the need for worldwide reforms within the water sector. In Chapter 18 of Agenda 21 of the Conference it says:

Sustainability of food production increasingly depends on sound and efficient water use and conservation practices consisting primarily of irrigation development and management with respect to rainfed areas, livestock water supply, inland fisheries and agroforestry. Achieving food security is a high priority in many countries, and agriculture must not only provide food for rising populations, but also save water for other uses. The challenge is to develop and apply watersaving technology and management methods and, through capacity building, enable communities to adopt new approaches, for both rainfed and irrigated agriculture.

This was followed by a series of initiatives. The World Bank, for instance, published a long Policy Paper in 1993 defining new goals for the water sector. The FAO set up an International Action Programme on Water and Sustainable Agricultural Development (IAP-WASAD). Other UN agencies such as UNDP, WHO, UNICEF, WMO, UNESCO and UNEP started programmes or coordinated, or took part in, programmes dealing with the problem of fresh water resources.

The donor organizations, including NGOs, have recently increased their relevant activities. The German Federal Ministry of Economic Cooperation and Development (BMZ) brought out a sectoral study in September 1995 entitled "Water as a matter of survival - a resource becomes scarce". This study is the basis for sector concepts on the subject of water which are currently being revised, and it shows the problem areas, the general conditions and the most important areas of action (BMZ, 1995).

The message of all these activities is that water is an increasingly scarce and extremely valuable resource, without which sustainable development is impossible. They therefore call for everything humanly possible to be done to guarantee sustainable use of fresh water. The present paper examines whether sustainable use of water resources is possible and what the consequences of the increasing water shortage are for water management.

The supply of water

Quantitative aspects

The amount of water present on earth is estimated at about 1.41 bn km^3 , of which only about 2.5 % is fresh water. The overwhelming part, the other 97.5 %, is sea or brackish water unsuitable for human use. The greatest part of the fresh water, 87 %, is contained in ice caps or glaciers, in the atmosphere, in the ground or deep inside the earth. If the total amount of the earth's water were 100 litres, then the amount of usable fresh water would be only 0.003 litre or half a teaspoon. About 30 % of the fresh water is stored as groundwater.

Water undergoes a permanent cycle. Every year about 566 000 km^3 evaporates from the earth's surface, 80 % of it over the sea. The same amount falls back onto the earth as precipitation, but only 110 000 km^3 over the land masses, of which 71 000 km^3 evaporates directly again. Thus the average amount of water running off the land masses each year as a renewable resource is about 39 000 km^3 .

Of the 39 000 km^3 runoff described above as a renewable resource 64 %, or 25 000 km^3 flows off very quickly. This part is known as the unstable runoff. The remaining third, in other words about 14 000 km^3 , seeps into the ground and becomes groundwater, which later forms the "stable" runoff. The latter is also known as fairweather or groundwater runoff. Table 1 shows the renewable water supply continent by continent. Looking at the relationship to area, it becomes clear that South America, with an average of 583 mm, has the largest amounts of fresh water available, while Africa only has an average of 139 mm.

Table 1- *Renewable water supply of the earth*

Region	km^3 / a	mm	$m^3 / (E * a)$
<i>Europe</i>	3110	319	4410
Asia	13190	293	4130
Africa	4225	139	6581
North America	5960	287	13 925
South America	10 380	583	34 949
Australia	1965	225	75 577
Total	38 830	294	7337

According to these data on the global water supply there seems to be no lack of fresh water worldwide. But it must be taken into account that in individual regions, because of the spatial and temporal variations in precipitation, the potential usable water supply is very small.

The most frequently used criterion for assessing the availability of the renewable water supply is the per capita supply, a supply of less than $500 m^3$ per capita per annum being regarded as the critical lower limit, $1000 m^3$ per capita as very low, $2000 m^3$ as critical. According to a study carried out by the World Resource Institute it is especially the countries which are in or near semi-arid and arid regions that are in a critical situation. Based on a supply of less than $500 m^3$ per capita per annum, the most endangered regions are North Africa with 3 and the Middle East with 8 countries at threat. According to Serageldin (1995) 22 of the world's countries currently have renewable water supplies of less than $1000 m^3$ per capita per year. The World Bank estimates that by the year 2025 one person in three, in other words 3.25 billion people, in 52 countries will live in conditions of water shortage (Serageldin, 1995).

Qualitative aspects

The supply of water for human use entails not only the problem of quantity described above but also one of quality, since practically all human activities impair the natural quality of the water. Beyond a certain degree of pollution water becomes unusable. The result is a reduction in the supply of usable water and problems with the disposal of the polluted water. The most important causes of pollution (BMZ, 1995) are:

- the discharge of untreated or insufficiently treated industrial and domestic waste water (bacterial, organic and heavy metal etc. pollution);
- storage of domestic and industrial waste on insufficiently safe dumps (pollution by seepage water);

- irrigation (discharge of salt etc. into groundwater reservoirs and surface waters through unsuitable irrigation and drainage methods);
- excessive use of fertilizers and inefficient use, unsuitable storage and disposal of pesticides (discharge of nitrate, pesticides, herbicides etc.); deforestation and ploughing-up of grassland (pollution of outlets with nutrients and suspended matter);
- overuse of the groundwater (salt water contamination of groundwater bodies in coastal areas, subsidence and consequent changes in the behaviour of surface runoff, rising salt content and ultimately the drying up of lakes).

To these direct kinds of pollution of the groundwater with harmful substances must be added the indirect harm done by atmospheric pollution, since the substances released into the atmosphere (such as nitrogen monoxide) enter the water via precipitation.

While a sufficient overview of the pollution of the water stocks with harmful substances in the Western industrial countries has been obtained in the past few decades through monitoring programmes and publication of the results, similar comprehensive information on the quality of water in the developing countries is hardly available. What information does exist leads to the conclusion that water in developing countries, especially in metropolitan areas, is already heavily polluted.

Water use and the development of demand

Water use

World-wide water use has increased more than tenfold since the turn of the century. Water exploitation has risen particularly sharply in the second half of the 20th century. Disproportionate increases in water exploitation have taken place during this period in Asia and Europe (Table 2).

Table 2 - *Development of water use by continent, 1950 in km³ per annum*

	1950	1960	1970	1980	1990	2000
Africa	56	86	116	168	232	317
North America	286	411	556	663	724	317
Latin America	59	63	85	111	150	216
Europe	94	185	294	435	554	673
Asia	865	1237	1543	1939	2478	3187
Total	1360	1982	2594	3316	4138	5189

Source: Clarke, 1993

Of the renewable water resources of the world of some 38 830 km³ per annum, more than 4500 km³ per annum are used at present. It is estimated that almost two thirds of the water is used for consumption and thus in the short term is not available for further use, while over a third is discharged back directly into the cycle, but mostly as contaminated water.

If the renewable water supply is compared with current water exploitation, then water seems to be abundantly available for use. Unfortunately, however, the water is unevenly distributed over the world and it is certainly not abundant where the mass of people live. There are also large seasonal differences. For example large parts of Bangladesh suffer flooding during the monsoon period, which is then always followed by a period of extreme water shortage. Water shortage is thus not a general problem but is a regionally, locally and seasonally specific problem.

Germany for example, with a long-term average precipitation of 837 mm in the western part and 662 mm in the eastern part (the former GDR), is a country rich in water, all the more so if the inflows from the Rhine and the Elbe, for example, are counted on the supply side. For the public drinking water supply just 2-3 % of the naturally available water from precipitation and feeder rivers are used. In Germany as a whole, even in future, there should not really be any problems of shortage in the water supply. And yet even in Germany, as a result of dense population and a high degree of industrialization, the supply in some places does not always balance the demand. Water storage and long-distance transport from water-rich areas will certainly make it possible to sustain a seasonal and a regional balance, but this does require putting an end to the degradation of the water resources. Such action to achieve a balance also entails high costs.

With a share of almost 70 % of the water exploited, agriculture is currently the largest water-using sector worldwide. Within this sector by far the largest share is used by irrigated agriculture, which in some regions at least has contributed to the rapid rise in the amount of water used in the last 40 years. The gross irrigated area has increased world-wide from 94 million hectares in 1950 to about 270 million hectares today. More than 70 % of the irrigated area is located in the developing countries. It was only the increase in irrigated area, though, that made it possible in densely populated countries for food production to keep up with population growth in the past few decades. Over 30 % of the world's food production takes place on irrigated areas, which account for 17 % of the arable areas. In Asia irrigated agriculture accounts for 60 % of food production and in some countries, such as Pakistan, the figure is 80 %.

Industrial water use is estimated at 24 % over the whole world. The share of the developing countries varies widely depending on the level of economic development, the particular economic structure and the technologies used.

It lies between 10 and 30 %, compared to 60-80 % in the industrial countries. The share of households etc. in the total worldwide use of water is about 8 %, though 4 % of the world's population uses a disproportionate amount of 300-400 litres per day, while on the other hand water consumption of two thirds of the world's population is less than 50 litres per day.

Another important sector of water use is nature and environment protection. In terms of quantity, water use in this sector is not documented and is certainly difficult to record. Water is particularly important in this area for preserving wetlands as a habitat for plants and animals. Tropical wetlands for example, which currently cover an area of 2.64 million km² world-wide, are being increasingly threatened by drainage or the discharge of contaminated water.

Development of demand

According to Clark (1993) worldwide water use will probably increase to 5189 km³ a year by the year 2000. Regional increases are estimated at 3187 km³ for Asia, giving Asia the largest volume of water extracted; 317 km³ for Africa; 796 km³ for North America; 216 km³ for Latin America and 673 km³ for Europe. A further increase in the use of water is to be expected beyond the year 2000, corresponding to population growth.

In relation to other sectors, the percentage rise in water use in agriculture until the year 2000 is likely to be modest. The World Resource Institute (1990) forecasts a global increase in demand in agriculture by the year 2000 of 17 %, based on the situation in the 1980s. This is explained by the expected increase in irrigated area of less than 1 % per year. The use of water for irrigation, according to these estimates, will decrease proportionately from 68 % at present to 52-62 % in the year 2000.

Because of the impending population increase, especially in developing countries, a further significant increase in demand for drinking water is expected until well into the next century. The cause given for this is the likely rise in population by 3.06 billion in the developing countries. In addition to this, the increasing urbanization is giving rise to a concentration of demand, which can only be covered by the expensive transfer of water from more and more distant areas or by the overuse of local water resources. The rise in living standard, which is clearly illustrated historically by the example of today's industrial countries, is accompanied by a rise in expectations regarding the supply of water and a change in consumer behaviour. Consumption data from developing countries show that the per capita consumption in households connected to the public water supply is comparable to corresponding specific consumption figures from industrial countries.

Improvements in the standard of supply thus lead to a considerable rise in specific consumption and therefore also in the volume of waste water. A disproportionately sharp increase in demand is additionally encouraged by free use or by water rates which do not cover costs (GITEC, 1993).

In the industrial sector too there will be a clear increase in water exploitation up to the year 2000 and beyond. In 1990 the World Resources Institute estimated the worldwide increase in industrial water use until the year 2000 at 52-72 % of the levels of use during the 1980s, with increases of 171-438 % in the developing countries. The expected increase, especially in Africa and Latin America, is explained by the continued use of mostly water-intensive industrial plants which are not equipped for recovery. The possibilities of no longer linking production increases with water demand, which has been put into practice in countries like Germany in the past few decades, have not been used in the developing countries so far.

A clear increase in water demand is to be expected in future in the field of nature and environment conservation. People in general, but especially those in developing countries, are becoming increasingly conscious of the value of both intact running and still waters, unspoilt landscapes and wet biotopes. These resources are irreplaceable as habitats for flora and fauna, for the aesthetic enjoyment and leisure time activity especially of the urban population, and the scarcer they become, the more the demand for their preservation or restoration grows. The restoration or even creation of wet biotopes, as practised for example for some time by conservationist groups in the west of the United States, will lead to changes in the use of water - changes which in many cases will be at the expense of irrigated agriculture.

Challenges

The guaranteed sustainable supply of water, the quality of which is also good enough to meet requirements of people, is an enormous challenge to the governments of many countries, especially in the developing world, because that is where in many cases the existing water shortage is increased or even caused by a number of problems. These problems include among other things the rising costs of tapping new water reserves, the wasteful use of those already made available, soil degradation in irrigated areas, the overuse or exhaustion of groundwater resources, the release of harmful substances into the water with negative effects on the health of water users and massive subsidies for providing water, which militates against the sustainable use of water resources.

Rising costs of exploiting water resources

Water resources which are usable and can be exploiting at reasonable cost are limited in practically every country. In many cases the water reserves which can be opened up easily, in other words at little cost, have actually been opened up, so the development of so far unused water reserves will become more and more expensive in the future. Even for the recent past enormous cost increases for the supply of water have been reported (Rosegrant, 1995). In Sri Lanka, for example, the costs of building new irrigation systems rose from US\$ 1474 in 1966-69 to US\$ 5776 in 1986-88 (basis of price 1986). A study in 1993 of local administration water supply projects financed by the World Bank came to the conclusion that water costs in the next generation of projects will be two or three times more than today's cost per cubic metre (Biswas, 1993). Examples of such inevitable cost increases are Amman, Jordan; Shenyang, China; Lima, Peru; Mexico City, Mexico, etc.

Wasteful use of water

One of the most important challenges of the immediate future is to introduce economies in agricultural, municipal and industrial water use. The efficiency level of water use in irrigation in the developing countries is often only 25 to 40 %. Water losses in the cities of developing countries are usually about 50 % and above. These high losses could be turned into a great savings potential in water use and thus a clear improvement in sustainability. But the savings potential is far less dramatic in practice. The water lost in one part of the system is very often used somewhere else. For the system as a whole or for the catchment area this results in a quite acceptable efficiency level. Nevertheless there are still considerable possibilities of saving, which should be put into practice during periods of water shortage.

Soil degradation in irrigated areas

Soil degradation by paludification, salinization and alkalinization is an age-old problem of irrigated agriculture. In the past few years the problem has worsened dramatically with the expansion of irrigated areas. Figures available on the size of the areas which become unsuitable for production each year due to waterlogging, salinization and alkalinization vary between 160 000 and 1.5 million hectares. The figure for total area worldwide under saline influence also varies considerably between 20 and 46 million hectares. The differences in area figures can be explained among other things by the fact that ideas differ widely about when soil starts becoming degraded and damaged.

Notwithstanding such problems of definition these soils are usually extremely fertile soils whose yield potential, because of the degradation, cannot be used to the full or breaks down altogether. The reduction in fertility of these soils not only reduces their area productivity, however, but also the productivity of water use, since the use of water in irrigating salt-influenced soils is usually much greater than in irrigating soils not influenced by salt, because of the eluviation requirement. Lower area productivity and higher water use must inevitably lead to lower production for the amount of water used.

The degradation of irrigated soils, regardless of area figures given, is a serious and growing problem of sustainability. Even worse, there is not only a onside but also an offside problem involved, because the salts accumulated in or on the soil are occasionally leached out and enter the receiving body via the drainage water. This leads to a deterioration in water quality and to contamination of the underlying bedrock. According to Glazovsky (1989; cited in Golubev, 1993) two billion tonnes of salt enter the running waters of the world each year via the drainage water from the irrigated areas. This salt is the major part of what the running waters in the arid regions carry.

Soil degradation as a result of salinization can also be seen under conditions of rainfed agriculture. One example of this is the Murray-Darling Basin in Australia. Here, in the wake of the conversion of tree/grass savannah into arable land there was a significant increase in groundwater levels, in the capillary rise and thus in the soil salinization. To this is added the influx of highly saline groundwater into the surface waters, which has meant an impairment of the quality of the water to the detriment of the surface waters and their bedrock.

Overuse and exhaustion of groundwater resources

Overuse of groundwater occurs when the exploitation of water exceeds supply in the medium and long term. Overuse leads to lower groundwater levels and increasing costs of supply, and, under certain circumstances also to subsidence and landfalls. The latter usually results in irreversible damage to the water-bearing bed. In nearshore areas it is not unusual for the sinking of the water level to allow saline seawater into the water-bearing bed, thus leading to its degradation.

Overuse of groundwater is today a widespread phenomenon, from the High Plains in the United States to the North China Plain, and can be seen in practically all dry regions. There is also a sharp increase in the use or exploitation of fossil water resources, especially in eastern North Africa (Libya and Egypt) and on the Arabian Peninsula. Three quarters of the water used in Saudi Arabia comes from fossil non-renewable groundwater resources.

Groundwater exploitation there exceeds the rate of renewal by a factor of five, and the underlying trend is rising.

In all the regions where there is continual overuse of water and there is no economically viable alternative way to provide water, medium or long-term sustainable development can be ruled out.

Contamination of water with harmful substances

Contamination of water with harmful and pathogenic substances, as mentioned above, is not only a problem of the industrialized countries. In developing countries too contamination can be observed with an underlying sharp upward trend. The contributing factors include untreated or inadequately treated waste water from settlements, industrial waste, diffuse contamination from agriculture and the usually isolated contamination by mining. A large part is also played by the deposit of settlement waste on the slopes of water-courses and its disposal via waterways.

In India, for example, only eight out of 3119 cities are equipped with waste water treatment plants. The Yamuna River, which flows through the Indian capital New Delhi, is contaminated with 0.2 million m^3 of untreated waste water every day. This leads to a 3200-fold increase in the coliform organism content in the river's water within New Delhi. It is no rare occurrence to have 24 million coliform organisms per ml there.

The unsatisfactory amount of drinking water available in combination with inadequate sanitary conditions at the domestic and municipal levels is one of the main causes for the high incidence of disease, especially among children, in the developing countries. On a worldwide scale about one billion people have to manage without access to water of satisfactory quality; 1.7 have inadequate sanitary facilities. In the developing countries each year there are an estimated one billion cases of diarrhoea. The World Bank has found that in the developing countries, given a significant improvement in the quality of drinking water and water used for other needs there would be about 2 million fewer deaths from diarrhoea among children. These figures illustrate clearly the importance of the sustainability of water supplies of sufficient quality for development in the countries of the Third World.

Water supply subsidies

Despite the already existing supply bottlenecks and the many different challenges, fresh water is still not regarded as a scarce resource in most regions of the world, which indeed it is in many cases. In a large number of countries, especially the developing countries, both urban and rural water users are supplied with highly subsidized water.

Irrigation water is provided largely free of charge. In urban areas the prices charged for water fall far short of the cost of providing it. In Mexico, for example, according to Rosegrant (1995), annual subsidies for water account for 0.5 % of the GNP, which is far more than the country spends on agricultural research. In Jordan there is considerable waste of water despite a situation of acute shortage due to the water policy practised there. This waste worsens the water shortage and leads to strict rationing. It is especially in irrigation that water wastage is financed by high subsidies. The situation in a large number of countries is similar. The annual subsidy of irrigation water is estimated at US\$ 0.6 bn in Pakistan, US\$ 1.2 bn in India, and US\$ 5.0 bn in Egypt (Bhatia and Falkenmark, 1993; cited in Rosegrant, 1995)

What makes the subsidization of the cost of providing water particularly precarious is the fact that subsidies benefit the better off to a disproportionately large extent. The poorer strata of the population, whose homes are not connected to the public water supply or have no near access to public standpipes, and are therefore forced to buy the necessary water from private water sellers, usually pay many times more for their water than privileged people.

Because water in the developing countries is provided very cheaply or even free of charge by public water utilities, users have no incentive to use water as a resource economically. The result is that water is treated very wastefully by all groups of users. In irrigation this all too often leads to ineffective decisions on crop rotation and production, soil paludification and salinization, overuse of the groundwater and an increased amount of drainage water contaminated with noxious substances.

Institutional obstacles

The development of the sustainable use of water as a resource is hindered in many countries by institutional problems. Besides the usually inflexible and centralist water management structures, the cause for this situation may be seen in the negative political and legal framework conditions. Where the necessary legal provisions exist, the responsible authorities or organizations often lack the ability to enforce them. This applies especially to water conservation and to the cost-covering operation of water supply and disposal utilities. In other words the enterprises are not able to cover running costs, let alone the investment costs, out of the receipts from charges. Added to this, the organizations dealing with water management mostly lack the necessary service orientation.

Another problem is the purpose-oriented, often one-sided competence of the agencies and ministries responsible, which hinders the development of a

holistically oriented, forward-looking water management. This situation is made worse by the increasing competition of the agricultural, industrial and municipal sectors for water resources. In typical irrigation countries, in addition, the whole of the water sector is dominated by the irrigation subsector, though recently there have been signs of clear changes, and the influence of the local authorities, industry and nature conservation is steadily increasing. The governments and their subordinate agencies are also withdrawing from the area of water supply and are leaving the management of the water supply facilities to the water users (Vermillion, 1996). However, the outcome of this turnover process remains unclear.

Changes in the landscape water balance

With the forecast increase in the world's population to 8 billion in the year 2020 and 12 billion around the end of the next century, considerable harm and change to the natural and the man-made landscapes is to be expected, especially in the tropics. This will have tangible effects on the water balance of the landscapes (Wolff, 1995). The situation will be worsened if the forecast change in climate materializes.

Estimation of the expected climate change with the help of general circulation models is still burdened by the inherent uncertainties of circulation modelling, so that a certain caution is called for in using the results of these model calculations. As far as the water budget is concerned it is assumed that global warming will produce an increase in evaporation of about 5 % per 1 °C rise in temperature. At the same time, however, an increase in precipitation is expected with a change in times and intensity. If this really happens, it will certainly bring about serious changes in the landscape water budget.

Changes in the landscape water balance are brought about above all by the land use in the particular catchment area. Precisely in the tropics drastic increases in surface runoff have been observed. A runoff of 25 % and more of the precipitation, combined with considerable soil loss, are by no means rare. If these high runoff amounts are seen in relationship to the anticipated changes in evaporation loss due to the forecast climate change, then it becomes clear that in future too land use will, under certain circumstances, have a much greater influence on the landscape water balance than the expected global climate change and the increasing amounts of evaporation. Theoretically at least, the latter are easily cancelled out by the retention of atmospheric water. This does presuppose, though, sufficient storage space in the ground. Research and development expenditure for soil protection and the regulation of the landscape water balance may thus be of greater practical importance than spending on research into the anticipated climate change.

Despite all efforts the apparently hopeless situation of small farmers in the tropics - and not only there - cannot be improved in the long run by goal-directed promotion schemes. Rather, most small farmers will be forced to give up their farms, especially in the marginal regions. But what will then be done with these pieces of land, and what will be the effects on the water balance there? What effects will the intense urbanization and industrialization have? A distinction will have to be made here between (a) urban areas, (b) the periurban areas, (c) the rural areas from which the cities get their drinking and general purpose water and/or in which they dispose of their waste, (d) the leisure and recreational areas and (e) the countryside areas which remain more or less uninfluenced by the cities. In view of the fact that so far hardly any studies have been carried out on water balance from the point of view of the changing man-made landscape, no prognoses are possible in this area, and certainly not on the development of urgently needed strategies. An enormous need for research seems to be looming here.

Strategies for the future

There are in essence two strategies which are used to help meet the challenges indicated above: supply management and demand management. Supply management seeks to take action to identify, exploit and utilize hitherto unexplored water resources. Supply management, besides optimization of operations and of the maintenance of water supply plants, is taken to include the reallocation of water resources among the various consumer and user sectors.

In contrast to supply management, demand management tries by using special incentives and water-saving mechanisms to encourage economical and efficient use of water as a resource. Demarcation between the two strategies is not always absolutely clear. Action and legislation which influence the quantity and quality of the water outside an allocation system are today usually counted as supply management. By contrast, action which influences the use and wastage of water within the allocation system comes under demand management. A reallocation of water brought about by market economy measures, for example from agriculture to the municipal water supply, would thus be seen as a demand management measure.

There is worldwide discussion and controversy over the practical application of these strategies, especially the application of the demand of the Dublin Conference "to regard water as an economic asset".

Taking a sober look at the situation, one would normally come to the conclusion that, depending on the regional and/or local situation, it will be necessary in future to pursue both strategies. With economic growth,

increasing competition for water resources and the increase in the value of water, demand management is certainly becoming more important than supply management.

Water supply management

Making available hitherto untapped water resources has declined significantly worldwide since the late seventies. The essential reasons for this may be seen in the sharp increases in the costs of building dams and the attendant infrastructure, misgivings and resistance by part of the public to massive intervention in the natural and water balance and the unsatisfactory solution for the resettlement of people from the flooded areas of dam projects. Then there has been the fall in prices on the international grain market, which has had a negative effect on, among other things, the economic viability of new irrigation projects. The standby credits for water prospecting from the most important development banks and donor countries and the provision by developing countries of funds of their own have shown a downward turn since the 1980s which has sometimes been dramatic.

The decline in spending on exploring water resources can already be seen in the worldwide reduction of irrigated areas, which has been particularly sharp in the developed countries, because that is where the investment came to a standstill much earlier. The developing countries are now following with a corresponding delay. In the world as a whole there has been another increase in irrigated area, albeit a very small increase. The rate of increase fell from 2.18 % in the period 1970-82 to 1.36 % in 1982-93. Rosegrant (1995) is right in asking in this connection: "Is the era of building new irrigation and water supply capacity over?" In answer to this question he makes the following statement:

Although we will not see a construction boom of the 1970s, some of the new demand for water must be met from carefully selected, economically efficient development of new water both through impoundment of surface water and sustainable exploitation of groundwater resources, and through expansion in the development of non-traditional sources of water.

Taking account of all the pros and cons, this statement deserves full agreement. What gives rise to some concern is that the political decision-makers, influenced by the critical public, are pursuing policies which tend rather to go the opposite way. If we take into account the long times for planning and implementation of water exploitation, the question arises whether the current hesitation will not unnecessarily worsen the crisis in regions of scarce water.

Exploitation of new water resources is normally concentrated primarily on the surface waters by building dams. When the possibilities of their utilization are largely exhausted or become too expensive, then the exploitation of other water resources, especially groundwater, is considered. It is not until the possibilities of using renewable water resources as a whole are largely exhausted that recourse is taken to exploiting non-conventional water resources, for example by reprocessing human and industrial waste water, water transfer, the desalinisation of sea and brackish water etc. The utilization of non-conventional water resources is, however, considerably more expensive than that of conventional resources. As far as agricultural use is concerned, using nonconventional water resources can seldom be justified economically. One exception is perhaps human waste water, especially when the ecological advantages of land treatment are taken into account.

Maintaining the balance between supply and demand by means of supply management does not always depend on exploiting new water resources. It can be done in many cases by improved management of the water resources made available. Since situations of shortage are not only a consequence of a general water shortage but are all too often the consequence of inadequate operation and maintenance planning, it is possible to overcome shortage situations by proper planning and application of planning.

Reallocation of water made available from one user sector to another is today seen as one of the most effective ways of combating critical shortages. The idea is first and foremost reallocation between irrigation and other sectors of water use. Irrigated agriculture, as mentioned, is the largest water use sector worldwide, at 70 % of use. By transferring a relatively small part of the water used in agriculture, the water supply for the other sectors could theoretically be significantly improved. In Morocco, for example, by transferring 5 % of the currently used irrigation water the usable water supply for communal drinking and general purpose water could be almost doubled. Whether such reallocation measures would be socially, politically, economically and technically feasible would have to be examined in detail in each individual case. In humid regions, where water use by irrigated agriculture is significantly lower than that for municipal, business and industrial purposes, corresponding reallocation measures are usually ineffective regarding the zement deserves full water supply situation and are at best only of local significance.

Only few countries have so far considered reallocation measures, and only few have actually carried them out, although those with political responsibility know that such a reallocation is inevitable in the medium or long term. The reasons for this reserve differ, but the arguments are similar. There are fears, especially in the arid and semi-arid regions, that limits on the use of water restricts or even destroys the opportunities of development in

agriculture and rural areas and that they result in depopulation of the rural areas through migration to the urban centres. Then there are many countries in the arid regions which suffer from an undersupply of food, have to rely more and more on imports and for political reasons do not want to accept the risks involved. For these and similar reasons many governments continue to call for the expansion of irrigated agriculture, although they are conscious of the precarious water supply situation.

Demand management

The effectiveness of water management, which has so far chiefly been carried out by government agencies, was judged in the past by how well the water demand was covered and in what time. With the rising demand there was and in some cases still is an attempt to maintain the balance between supply and demand by exploiting new water resources. It is still no rarity for this to be done through sometimes drastic interventions in water resources or natural ecosystems. Water shortage and drastically increased supply costs make changes in thinking more and more urgently necessary. In view of the usually inefficient water use the demand today is for a greater orientation to demand management. More efficient use of water is expected to produce not only more economic treatment of water as a resource but also less environmental impact and thus the creation of one of the important preconditions for sustainable development. In view of the highly energy-intensive water supply processes, saving water also means saving energy. In supplying drinking water in Germany, for example, it costs about $1/2$ kWh per cubic water to meet the so-called pressure of public demand.

Many different forms of demand management are possible. The corresponding direct measures range from control of water use to indirect measures which contribute to a change in behaviour on the part of water users (introduction of market mechanisms, financial incentives, programmes for raising public awareness etc.).

In view of the high water losses in all consumption sectors an increase in the efficiency of water use is seen as one of the most effective measures in demand management. This is indeed where all user sectors have a variety of technical possibilities available for improving the efficiency level of water use and thus of water saving. However, the necessary capital expenditure rises considerably with the rise in efficiency and in part rules out the use of water saving methods. One example of this is the use of drip irrigation with dense row crops. Compared with flood irrigation, drip irrigation makes savings of 50 % and more possible. The investments for drip irrigation, even on level ground, are quite often several times more than for flood irrigation.

Another possibility of demand management is seen in regulatory measures, even if they are difficult to carry out in practice. They include restrictions on the quantity of water used, prohibitions on specific uses (washing cars, watering lawns etc.), water supply on a rotation basis, water-saving crop rotations, regulation of groundwater extraction, restrictions on suspended matter in surface waters etc.

High expectations of water saving are also placed in financial incentives. Such considerations may be based on the "user pays" principle and the "polluter pays" principle. Although this makes sense generally, implementation in practice is extremely difficult and has only rarely met with success.

Water policy reforms

A crucial precondition for all the measures mentioned above in the framework of supply and demand management is a reform in water policy. Saving water especially depends on such reforms, though it will not be easy to carry out the water policy reforms needed because in the general view and as a matter of cultural and religious tradition water is regarded as a free natural asset, and ultimately also because such reforms often affect interests which profit from water policies as they stand.

The water policy reforms needed differ from country to country, and they depend on the degree of economic development, institutional capacity, and on the degree of water shortage and the intensity of agricultural production. Taking these influencing factors into account a specific and practicable water policy should be worked out. According to Rosegrant (1995) the key elements of a comprehensive water policy reform should be:

- legal and social safeguarding of water rights and if need be the introduction of trading in these rights;
- management of the irrigation systems by water users and/or user associations;
- creation of price incentives for saving water;
- introduction of suitable technologies;
- environmental safeguards;
- encouragement of international cross-border cooperation.

The Food and Agricultural Organization of the UN (1995) also sees the reform of water resource policies as one of the fundamental preconditions for sustainable use of water resources and has recently begun a number of initiatives to encourage the necessary reforms.

Consequences for agriculture

In the age of increasing scarcity of water resources the agricultural sector as the world's largest water consumer has to answer the question in many places whether its use of this resource still meets the present and future political, economic and ecological requirements. Figures are quoted which do not show exactly the careful use by agriculture of water resources. The agricultural sector, and especially irrigated agriculture, is reproached with not only being the largest water user but the fact that agricultural water use as a rule shows the least efficiency and the smallest value increase per unit of water. In many cases the large subsidies for water supplied for agricultural purposes are also criticized.

As far as subsidies are concerned, the figures can certainly be called alarming. Subsidies for irrigated agriculture have recently become the largest single item in the agricultural budget in many countries. According to the FAO (1995), for example, 80 % of public spending on agriculture in Mexico since 1940 has gone to irrigation. In China, Pakistan and Indonesia irrigation has absorbed over 50 % of public investment in agriculture. In India subsidies for the same sector even amounted to 30 % of all public investments. A considerable part of multilateral and bilateral development aid has been used in the past few decades for the development of irrigation in the Third World.

It is especially irrigated agriculture in Third World countries that was unable in many cases to meet the expectations placed in it regarding yield increase, extension of efficiently used irrigated area, economic gains and efficiency in water use. It was not only the hopes of the domestic and foreign donors that have been correspondingly disappointed. According to the FAO (1990) some 60 % of the water supplied for irrigation goes unused and leads to soil waterlogging and salinization. When such sometimes sweeping criticism is made, though, questions about the very complex causes are very seldom asked. It is easily forgotten that successive governments and also the international donor institutions have miscalculated the development of the framework conditions or have contributed little to the creation of the conditions required for the sustainable development of irrigated agriculture.

The situation described above has resulted in the currently negative image of irrigated agriculture. The consequence is a decreasing willingness on the part of governments and of international donor institutions to invest in the development of irrigation. In the view of the International Food Policy Research Institute (IFPRI) this must be seen as highly alarming, since the rapidly increasing population in the countries of the Third World is dependent upon a significant increase and safeguarding of food production. Neither is possible without a workable irrigated agriculture (Rosegrant, 1995).

In many countries irrigated agriculture has in the past taken a dominant position in the allocation of water resources. In future, with worsening water shortages, this will no longer be the case. There are already signs of this development.

The use of water-saving technologies, a demand that is repeatedly being raised, always involves higher costs for farmers in irrigated agriculture and is therefore often impracticable (Wichelins et al., 1996). If farmers are nevertheless forced to use them, it could mean giving up irrigated agriculture altogether. In many cases they will first attempt to maintain the economic viability of irrigation by adapting the crop rotation, i.e. by including other crops with a relatively high market value. But this only succeeds if there is sufficient demand on the market for such products at adequate prices.

Conclusions

Since the International Conference on Water and the Environment (ICWE) in Dublin in 1992 there has been very serious and intensive thinking on various levels of the limited availability, possibilities of exploitation and the management of the earth's fresh water resources. The United Nations Conference on Environment and Development (UNCED) in Rio de Janeiro in 1992, building on the results of the Dublin Conference showed the need for worldwide reforms within the water sector. But there has been a very slow start to meeting these demands in practice.

Over the world as a whole the supply of fresh water is far above mankind's present and future needs. Regionally and locally, however, there are considerable deficits in providing fresh water of sufficient quality. This shortage of water will spread and worsen in future with the population increase and with urbanization. Conflicts between countries and between the provinces etc. within countries and between the sectors of a country will intensify, if they do not succeed in setting up a sustainable workable water management. Such water management must take account both of quantitative and qualitative aspects.

A sustainable water supply which also satisfies people's needs for high quality is an enormous challenge to the governments of many countries, especially in the developing countries, because in many countries the existing water shortage is worsened by a large number of problems or these problems themselves cause or have caused the shortage situation in the first place. These problems include the rising costs of exploiting new water resources, the wasteful use of resources already exploited, soil degradation in irrigated areas, overuse or exhaustion of groundwater, contamination of the water with harmful substances with negative effects on the health of the water users,

massive subsidies for water supply hindering the sustainable use of water and immanent changes to the landscape water balance.

The problems to be dealt with make it necessary to develop strategies for combating the current and looming situations of shortage. This is where water supply management and demand management present themselves. In the current discussion it is demand management that is the main focus. However, it will not be possible to avoid exploiting hitherto untapped water resources. And it will not be possible to manage entirely without building more water storage facilities.

However, strategies for sustainable water management can only be carried out successfully and sustainably if the framework conditions for efficient use of water as a resource are given. Reform of water policies is thus the first and most important step in many countries towards creating conditions which make sustainable use of water possible.

Irrigated agriculture will be faced in the next few decades with a number of important challenges. On the one hand it must achieve the greatest share of world food and fibre production in order to guarantee food and clothing for the increasing world population and make its urgently needed contribution to combating poverty and economic development. On the other hand it will be faced with increasing competition for decreasing water resources. The situation is made worse by the dwindling financial resources and increasing costs for the rehabilitation of existing irrigation systems and the setting up of new ones. And all this must happen in a political and social environment which is highly critical towards irrigation.

Irrigated agriculture must face up to these challenges. It must be more sparing in its treatment of water resources, it must minimize its own influence on the environment and continually exercise self-restraint by means of eco-auditing.