4.8 More food with less water: The role of efficiency gains, lifestyles, and trade

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SUMMARY: *Global food demand will strongly rise over the next decades, due to population growth, average income increases, and trends towards higher consumption of animal products. Agricultural and food production already account for 70 percent of total freshwater withdrawals in the world. In addition, future water demand from private households, industry and for environmental purposes will also rise. Over the next 25 years global agricultural production has to be increased by about 40 percent, while reducing agricultural water use by 15–20 percent to avoid water scarcity. This can only be achieved through a smart combination of efficiency gains in agricultural production and irrigation, institutional and policy reforms, changes in dietary habits, and virtual water trade between nation states. However, due to conflicting interests many of these options face serious barriers and water crises with global implications may still occur in many vulnerable regions.*

The world's population will, according to various estimates, reach 9–10 billion by he middle of the 21st century and stabilise at this level (LUTZ et al. 2001). Due to further economic development and growth, in many regions people will on average have higher disposable incomes than today. This will lead to higher consumption of goods and services. With rising income, changing living conditions and lifestyles, e.g. through increased urbanisation, dietary habits will also change. Total food consumption, measured in energy units, will increase. In 1997 the average availability of food energy in the world was at 2,782 kcal per person per day. The overall range was between 1,566 kcal in Somalia and 3,699 kcal in the USA (FAO 2001). Moreover, the relative share of animal products in total food consumption will rise. It can be expected that food and dietary trends, which have been observed in rich countries over the last decades, will be taken up by most developing societies in the future (*Table 4.8-1*).

Food consumption and water demand

Quantity and composition of human food consumption have a direct influence on resource use through the production and processing chains of food. On the global level, agriculture has a significant share in land and water use. About 40% of the land surface is used for agricultural purposes. About 70% of total human freshwater withdrawals is used in agriculture, mainly for irrigation in regions with insufficient precipitation. Irrigation agriculture contributes about two thirds of the world production of rice and wheat (RIJSBERMAN 2001, ROSEGRANT et al. 2002). Human consumption of meat and milk increases the demand for land and water required for the production of animal feed. The average amount of food consumed on a daily basis in the USA requires about 5,400 litres of water, mainly in the form of evaporation and transpiration in agricultural production. A comparable vegetarian diet reduces this demand by about half. Various agricultural crops reveal different water requirements. While potatoes and vegetables use about 200 litres of water per kg harvested material, for wheat and rice this rises to more than 1,000 litres per kg. However, these values differ widely, depending on regional conditions and specific varieties (HOEKSTRA&HUNG 2002).

Agriculture has to compete with other sectors for the available renewable water resources. In the course of economic development the water demand for private households and industry will also rise. While it was possible to reduce some types of industrial water use considerably in rich countries, industrial water use in developing countries is expected to rise strongly in the future. The same holds for private households. While in the USA a slow decoupling of household income and water use has been observed, water use in fast growing mega-cities in the South will further increase. This will lead to increased competition for water. Agriculture over the next 25 years faces the challenge to increase global food production by about 40%, while at the same time reducing the specific water use by 10–20% (RIJSBERMAN 2001).

In addition, water requirements for environmental purposes, e.g. maintaining the functionalities of wetlands and rivers, will be articulated more strongly in the future and will have to be taken into account in water allocation plans, not least in order to protect and maintain biodiversity. This will exacerbate the water conditions in many regions.

Table 4.8-1: Share (%) of various raw products in total food consumption, measured in energy units (1994) (BENDER & SMITH 1997).

Product group	*Industrialised countries*	*Developing countries*
Cereals	31	56
Meat and milk	28	12
Vegetable oil / Sweeteners	23	17
Roots / Tubers	4	5
Others	14	10

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ROSEGRANT et al. (2002) have simulated in three scenarios, how the competition for water until 2025 may affect food prices on world markets and the relationship between water use and renewable water availability (»criticality ratio«) (*Table 4.8-2*).

The »business-as-usual« scenario (BAU) assumes a moderate improvement in water management and slightly higher investments in water-saving technologies. In addition, a crisis scenario (CRI) and a sustainable scenario (SUS) with regard to world-wide efforts for more efficient water use are investigated. In the crisis scenario, world market prices for wheat and maize may double, and the prices for rice may rise by 40%. The criticality ratio could rise up to 0.90 in North Africa.

Water availability and climate change

Water availability for agricultural production is mainly determined by local precipitation. Not only the total amount of rainfall per year or within the growing period is important, but also to a large extent the temporal distribution and variability within the growing period and at critical stages of crop development. Even though groundwater, reservoirs and fossil water resources are increasingly exploited as sources for irrigation water, agricultural production in many regions depends strongly on natural precipitation and soil moisture.

Table 4.8-2: Criticality ratio and world market prices for food (Model calculations for 1995 and 2025) (ROSEGRANT et al. 2002).

	Reference 1995	*Projection 2025*		
Criticality ratio [1]				
Region		***BAU***	***CRI***	***SUS***
China	0.26	0.33	0.38	0.25
India	0.30	0.36	0.39	0.26
South-east Asia	0.04	0.05	0.06	0.04
Latin America	0.02	0.03	0.03	0.02
Sub-Sahara Africa	0.02	0.04	0.05	0.03
West Asia/North Africa	0.69	0.90	0.88	0.61
Industrialized countries	0.09	0.10	0.10	0.08
Developing countries	0.08	0.10	0.11	0.08
World total	0.08	0.10	0.11	0.08
Average world market prices (US$/ton)				
Product		***BAU***	***CRI***	***SUS***
Rice	285	221	397	215
Wheat	133	119	241	111
Maize	103	104	224	98
Soybeans	247	257	422	253
Potatoes	209	180	317	166
Sweet potatoes	134	90	233	77

[1] Criticality ratio: Ratio of water withdrawal over total renewable water
BAU: Business-as-usual scenario
CRI: Crisis scenario
SUS: Sustainable water use scenario

Climate change will lead to changing precipitation patterns, the extent of which is still uncertain for some parts of the world. Climate simulations with different models sometimes yield ambiguous results (MENZEL et al. 2003). In Europe, on average, more precipitation can be expected in winter months. More droughts in the summer months are to be expected in Southern Europe, but slightly wetter conditions in Northern Europe. Some important agricultural production areas, like North America, may become considerably dryer by the end of the 21st century (IPCC DATA DISTRIBUTION CENTRE 2004). This could have severe impacts on world agricultural markets.

Apart from these direct impacts on water availability, rising temperatures and CO_2 concentrations have an influence on important metabolic processes in plants, which are relevant for the water balance. With increasing CO_2 concentrations the specific water use per unit carbohydrates produced by plants is reduced. But climate change also causes changes in soil fertility, soil erosion, increased pressure from pests and diseases, and more frequent extreme events, like tropical storms, floods and droughts. Possible negative impacts on product quality, e.g. content of nutrients, and direct impacts of higher temperatures on livestock production are further important aspects. Especially the complex interactions between these different impacts on food production are still not well understood. Poor countries in tropical zones with few possibilities for adaptation are likely to be strongly affected by climate change (IPCC 2001, LOTZE-CAMPEN & SCHELLNHUBER 2004).

Options to avoid a water crisis

Efficiency gains

Over the last four decades, agricultural yields for many crops have been steadily increased by 1–2% per year, mainly due to technological advances in plant breeding and mechanisation. Global agricultural production was, on average, able to keep pace with population growth. However, the goals of plant breeding research were mainly focussed on increased yields per area, but less so on increased water use efficiency. For the future, the big question remains, to what extent productivity growth rates of the past can be maintained in the future, and at what level resource constraints become binding. With a strong focus on the optimisation of water use in crop production, it is likely that substantial progress can be achieved. For example, yield potentials of new rice varieties are up to four times higher than traditional varieties, but with the same level of water use through evapotranspiration (SMIL 2000). It must be kept in mind, however, that all technological improvements require continuous investments in research and development. At least in the area of interna-

tional agricultural research institutes this seems to be uncertain, as financial resources have not increased substantially in recent years (CGIAR 2002).

About 60% of global agricultural production occurs without additional irrigation. In water-scarce regions, such as Sub-Saharan Africa, the limited rainfall could be used more efficiently with relatively simple, low-cost measures. On the small scale, »rainwater harvesting«, improved land management, and mixed agro-forestry systems could improve food security (ROCKSTRÖM et al. 2003).

Agricultural irrigation systems in most countries have large potentials for efficiency gains. In most irrigation systems only about 25–30% of primary water withdrawals actually reach the crops in the fields. The remainder is either lost through evaporation or disappears at various critical points in the system. Low efficiency rates could be improved with better technology, e.g. »drip irrigation«, to 75–90%. However, it is important to note that the overall water use efficiency of a whole river basin might not improve substantially through specific gains at some parts of the irrigation system. Water which is lost somewhere upstream, is very likely to be used elsewhere further downstream in the system. In any case, a substantial increase in water use efficiency of irrigation systems requires investments in new technologies. In addition, technologically advanced irrigation systems usually imply higher energy use (SMIL 2000, RELLER et al. 2002).

Many poor developing countries face two serious constraints for the introduction of new technologies. They usually lack the financial resources for substantial investments. Moreover, if new production methods are not well adapted to regional conditions, they may cause negative economic and environmental effects, e.g. through over-exploitation of resources, salinisation, soil erosion or badly managed large-scale projects. These effects have been analysed in research on syndromes of global change (WBGU 1997, LUEDEKE et al. 2004).

Infrastructure improvements

In the past there have been many attempts to alleviate local water scarcity with improved water supply. Large-scale dams and canals were built to regulate and stabilise water supply. There are many examples, where these measures have indeed increased and stabilised agricultural production. The long-term sustainability of these effects, however, is subject to a controversial debate. Many of the roughly 45,000 large dams in the world reveal technical problems, e.g. through sedimentation. Cost-benefit ratios ex post are often much worse than originally planned and expected. Environmental damages, economic risks, and social disruption caused by re-settlements have changed the perspective of international donor organisations over the last decades (POSTEL 1999, WCD 2000). Still, large infrastructure projects for long-distance water transport are being planned and implemented, e.g. in Spain and China.

Institutional reforms

Institutional and political measures are further important building blocks for improved water management. In many regions, water is seriously under-valued, especially in the agricultural sector. This is one major reason for over-use and wastage. There is often a lack of well-defined property rights or, if they exist on paper, they are not implemented or strongly enforced. Largely free or heavily subsidised water use is in many countries an important component of government support for farmers and, hence, is strongly defended by the beneficiaries. The issue of water pricing cannot be isolated from the general political and economic circumstances (ROTHENBERGER &TRUFFER 2002).

Tradable user rights for irrigation water provide a possible way towards a more appropriate valuation of scarce water resources. In the Australian Murray-Darling Basin this instrument has been used since the beginning of the early 1990s. First successes are to be observed: trading with user rights indeed takes place, prices for water licenses have risen strongly, and overall water use in the river basin has become more efficient. At the same time, total expenses for water use tend to fall, in some cases strongly, as farmers have invested in water-saving technologies. It remains to be seen, whether this system will be sufficient in the long term, when additional challenges from climate change and salinisation will have to be met (JONES&PITTOCK 2002, WITTWER&STRINGER 2002). In the case of poorest countries, it is questionable, whether cost-covering price increases for water are appropriate and politically feasible.

Beyond water pricing alone, co-operation between various levels of administration and the integration of water users into the planning and decision-making process play key roles for an improved water management. The adoption of approaches such as integrated river-basin management could improve and institutionalise this co-operation (WELP 2002). In this respect it is crucial, not only to achieve horizontal integration between various sectors, but also vertical integration between different administrative levels. It is too often the case that different administrative units pursue different, sometimes even contradicting goals. Integrated water management will become especially important under changing climate conditions. While many adaptation options can be identified by integrated management, some regions may reach their limits to adaptation.

Lifestyle changes

Another possible way to reduce society's water use is via a reduced consumption of animal-based food products, above all meat. A diet with a small share of meat and meat

products can be realised without big concessions regarding nutrition value. An international comparison shows that the share of animal-based calories in total food consumption varies considerably, even between countries on a similar level of income and human development. Meat consumption is not only determined by income, but also by cultural aspects, traditions and more general lifestyle choices. For example, the increasing trend of urbanisation leads even in many poor countries to a fast increase in consumption of sweeteners and animal fats (POPKIN 1999, GLEICK 2000, LOTZE-CAMPEN et al. 2003).

A change in dietary habits would not only be sensible from a resource use perspective. For health reasons the consumption of meat and other animal products should also be reduced. Rising incidences of obesity have already led to increased health care costs in industrialised countries. In Germany, for example, current meat consumption is at about 60 kg per person and year. The German Society for Nutrition, on the other hand, considers less than 30 kg as sufficient and appropriate for an overall balanced diet (DGE 2004). In any case, an active change in lifestyles and habits is difficult to achieve, and it would probably have to be introduced on a continuous and broad basis already in programmes for pre-school education.

Virtual water trade

International trade with goods, especially agricultural and food products which contain a significant amount of »virtual water«, could play an important role for increasing the global efficiency of water use. Water-scarce regions could increase their imports of water-intensive products, like cereals, so that more water would be available for non-agricultural purposes. International trade flows are mainly driven by economic forces. If appropriate regional water prices would serve as realistic indicators for water scarcity, this would be reflected in the economic calculations of producers and traders. A well functioning trading system also serves as a kind of insurance scheme against production risks, because it is rather unlikely that huge harvest losses due to floods or droughts would occur simultaneously on a global scale in several important production regions. This function could become even more important under future conditions of severe climatic change.

However, the total effects of trade on regional water use efficiency should not be over-estimated. A large share of global trade activities currently occurs between rich countries, which either have no water shortages or sufficient potential means for adaptation. Moreover, international agricultural trade is heavily dominated by political preferences and influences, which are rarely concerned with resource use efficiency and which change only slowly over time. Poor, water-scarce countries also face the problem that increased imports of water-intensive goods or »virtual water« would have to be financed with foreign exchange. This would require the development of competitive export sectors, which many developing countries, especially in Africa, failed to achieve in the past (HOEKSTRA&HUNG 2002, YANG&ZEHNDER 2002).

A possible vision for countries in North Africa could be an energy alliance with Europe, where solar-based electricity or hydrogen would be produced in the South, in order to buy food products from the North. This could, under currently predicted climate and precipitation conditions, lead to a powerful regional economic specialisation and, hence, more efficient water use. A realisation of this vision would require that solar energy production becomes more competitive and that the industrialised countries bear most of the investment costs.

Conclusion

Water is essential for food production. In many regions of the world water is already today a scarce resource. Due to insufficient price signals this is not yet recognised in all its consequences by most social actors. Many developing countries, which are heavily dependent on the agricultural sector and located in dry areas, are especially affected by water shortage. These countries will also be strongly affected by climate change in the form of altered precipitation patterns, which could further exacerbate their situation in the future. Water shortage could lead to higher food prices and negatively affect regional food security. Future trends in water consumption outside agriculture, water availability and climate change, as described above, could evolve into a global crisis, in which water scarcity could negatively affect food production, food security, health and environmental quality. A range of possible solutions are available and have been discussed in the literature. But an integrated and more efficient water management will only be achieved through a combination of measures, which are well adapted to regional conditions. Most importantly, all these measures require time, durable political will and considerable financial resources. It is time for a bold warning signal, most of all towards national and regional decision-makers ♦