LET IT REIGN:

The New Water Paradigm for Global Food Security

A report commissioned by the Swedish International Development Cooperation Agency (Sida) as input into the Commission on Sustainable Development (CSD) and its 2004–2005 focus on water and related issues.

SIWI

INTERNATIONAL FOOD POLICY RESEARCH INSTITUTE
sustainable solutions for ending hunger and poverty
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Note to Reader

For the 13th meeting of the Commission on Sustainable Development (CSD-13), the Swedish International Development Cooperation Agency (Sida) commissioned the Stockholm International Water Institute (SIWI) to produce "Let it Reign: The New Water Paradigm for Global Food Security". The report presents recommendations for policy and decision makers with regard to sustainable food production, sustainable food consumption and ecological sustainability. The topic addressed in this report is an issue identified as being of very high priority for Sida. The views put forward in this report, on the other hand, are expressed solely on behalf of the authors.

Collaborating partners for the report have been the International Food Policy Research Institute (IFPRI), IUCN – The World Conservation Union and the International Water Management Institute (IWMI).

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The views expressed in this publication do not necessarily reflect those of IUCN – The World Conservation Union.

1. Time to Act – Policy Implications

Water in the soil is the key to an agricultural revolution, the imperative for ending undernutrition and achieving global food security for our children. The new water paradigm incorporates this "green" water resource and couldn't be timelier, for farmers, consumers and policy makers. This is because the food security issue is so alarming: food needs are increasing, and food consumption is moving towards more water-intensive items. Irrigation possibilities are limited and agricultural land is shrinking.

In pursuit of the human livelihood improvements identified in the UN Millennium Goals (MDGs), the co-ordination of efforts in many areas; notably water, food and environment, can generate substantial synergies.

Globally, food consumption patterns are changing rapidly. These changing patterns are increasingly becoming drivers for food production. Since different food items require differing amounts of water to produce, changes in the consumer's food basket affect the availability of water and the ecosystems for other societal uses.

In some developing regions of the world, undernourishment is increasing. In others, it is slowly being overcome. Paradoxically coexisting with undernourishment is obesity, which is increasing in both developed and developing countries. These public health threats impede the ability of people to fight hunger, overcome poverty, resist disease and achieve other MDG-related livelihood improvements. Such improvements have at least one thing in common: water. They either depend upon it, or affect it.

Despite living in an increasingly urbanised world, we will never live in a post-agricultural society. Food production is, and always will be, highly water intensive. Huge volumes of water are transformed into vapour during plant growth, as consumptive use (transpiration and evaporation from fields, canals, reservoirs and high water tables). With prevailing land and water management practices, a balanced human diet based on a kcal consumption of 3000 kcal/day represents water depletion of 3500 litres per person per day (l/p/d), 70 times greater than the 50 l/p required for basic household water needs.

To eliminate hunger and undernourishment for the world's population by 2025, the additional water requirements may be equivalent to all blue water withdrawn and used today for agricultural, industrial and domestic purposes. Ways must be found to increase water use efficiency in both irrigated and rain fed agriculture, and also integration of food production systems, e.g. agriculture and inland fisheries. It is equally essential that efforts are launched to keep the demand for water intensive food items within reasonable limits. Ingenious management and sound stewardship of the entire water resource is required.

Unfortunately, overappropriation of blue water resources is commonplace in large parts of the world today. This trend is increasing because of a focus by individual sectors on their own, immediate water requirements, to the expense of the current needs of ecosystems and the future needs of other sectors. We need to find ways for valuing water from all different aspects – socially, economically and ecologically – in order to make better choices in the beneficial utilisation of green as well as blue water resources.
A set of governance, capacity building and awareness raising, and financial actions are needed in order to let the new water paradigm for global food security reign.

The food security issue is alarming: food needs are increasing, and food consumption is moving towards more water-consuming items. Irrigation possibilities are limited and agricultural land is shrinking.

Food item	Water requirement m^3/kg (average*)
Beef (grain fed)	15 or more
Fresh lamb	10
Fresh poultry	3.5–6
Cereals	0.6–2
Soybeans	1–2
Palm oil	2
Pulses, roots and tubers	1

** Figure ranges are due to variations in climate, water and agricultural management and methods of calculation*

Ways must be found to increase water use efficiency in agriculture, make better use of rain.

Photo: FAO/19848

Photo: SIWI

Policy Recommendations

Governance

Establish national strategies for food and nutritional security, for all countries.

1 Establish national strategies for food and nutritional security, for all countries. Strategies should be linked to the Integrated Water Resources Management (IWRM) – Water Efficiency Plan (WEP) and Poverty Reduction Strategy (PRS) planning and implementation processes and should also consider the opportunities and consequences for trade in food (i.e. trade in virtual water). (Report to CSD 2008–2009) They should include, i.a.:

a) Implementation of relevant policies on land and water rights, incentives for efficient use of water, e.g. through pricing, with due consideration to social and environmental objectives.
b) Strategies for strengthening the integration between the existing land-use and ecosystems planning and management and the IWRM-WEP planning and implementation process, preferably at the river basin level (i.e. to include both green and blue water resources)
c) Assessments of national virtual water balances (export/import)
d) Strategies for upgrading the existing water infrastructure to improve the water use efficiency and productivity of irrigated and rain fed agriculture while maintaining and restoring the integrity and productivity of ecosystems
e) Strategies for the strengthening of the water resources management institutional framework
f) Strategies for and investments in infrastructure to facilitate local, national and regional trade of food

2 Develop national policies and river basin targets for environmental flows, by 2010, as part of the IWRM-WEP planning process, to ensure sustainable ecosystem goods and services including fisheries, contribute to the Johannesburg Plan of Implementation (JPOI) biodiversity target and improve the livelihoods for people depending on such ecosystem goods and services.

3 Investigate how current and proposed trade regimes affect the trade in agricultural products (and thereby virtual water), and its subsequent effects on water resources and ecosystems. (The UN system, WTO and UNCTAD in collaboration with other relevant actors) (Report to CSD 2008–09)

Capacity Building and Awareness Raising

Strengthen capacities on all levels for rain fed agriculture and its contribution to improved livelihoods.

Start awareness-raising campaigns designed to increase knowledge of the consumptive water use of different food products.

1 Start awareness-raising campaigns designed to increase knowledge of the consumptive water use of different food products, and the related effects on water resources (FAO, in collaboration with other relevant organisations, especially consumer organisations, civil society and the private sector), including:

a) Develop proposals for labelling of food products based on their nutritional value per drop of water
b) Develop and market food products of high nutritional value per drop of water (the food-processing and retail industries)

2 Strengthen capacities on all levels (farmers, water user groups, governmental agencies and advisors), particularly for rain fed agriculture and its contribution to improved livelihoods, to:

a) Enable an integrative approach on food production, water, social, environmental and economic aspects (including legal, economic and regulatory mechanisms)

b) Foster a better understanding of the different roles and values of water (including to sustain terrestrial and aquatic ecosystems and biodiversity)

c) Share knowledge of innovative management approaches and tools (social, economic, ecological)

d) Strengthen research, management practices, extension services and technical know-how

3 Strengthen research for water productivity increase in both rain fed and irrigated agriculture including drought-, salt-, acid-tolerant and (as appropriate) bio-fortified crop varieties, and on more efficient cropping systems, including tillage, mixed cropping and agro-forestry.

Financing

1 Assess how improved opportunities for international trade (better conditions for developing countries to trade, liberalisation of trade in agricultural products) could potentially improve national income generation (in particular for the nearly 40 developing countries where agriculture accounts for over half of the export earnings.) (The UN system, WTO and UNCTAD in collaboration with other relevant actors) (Report to CSD 2008–09.)

2 Investigate how current subsidies within the agricultural sector affect water use efficiency, cause negative effects on the environment and could be phased out and re-oriented to more purposeful support and incentives. (The UN system, WTO and UNCTAD in collaboration with other relevant actors)

3 Increase investments in infrastructure and support services, including institutional arrangements, to enable local food producers to access markets and to develop the local, national and regional trade of food.

Further Policy Recommendations

- Basin-wide pollution treatment and prevention plans for all sources of pollution should be established by 2010, as part of the IWRM-WEP planning and implementation process. (Follow-up at CSD 2010–2011) They should cover, i.a.:
  - Effects on coastal areas (co-operation with UNEP's Global Programme of Action)
  - Both technology-based control measures (cleaner production strategies) and soft measures based on incentives for voluntary reductions
  - Necessary rules and regulations
  - Market-based incentives
- As long as human health is protected, and water quality standards followed, nutrients from municipal and industrial wastewater should, where possible, be recycled in agriculture.
- International processes on the water-food-environment nexus (www.waterforfood.org) on basin and sub-basin levels for better allocation, pollution prevention and sharing of benefits of water use should be supported, where knowledge is transferred into policies as well as concrete action on the ground. (Report to CSD 2008–2009)
- Governments, within their IWRM-WEP planning process, should set appropriate and time-bound national targets which would guarantee the equity and efficiency with which water resources are used within and between different sectors, as important stepping stones to achieve the MDGs. As a tool for balancing between competing demands, appropriate mechanisms for assessing the value of water from economic, social and environmental perspectives should be elaborated within IWRM-WEP planning.
- The UN system, in collaboration with other relevant actors, should further develop the concept and application of benefit sharing of water use, including the socio-economic and environmental effects, especially for international basins.
- Governments should explore the possibilities of establishing mechanisms for sharing the benefits of water use (between sectors and users, within a national and/or international river basin context).
- The UN system, other humanitarian agencies and donors should pursue programmes and effective methods that provide short-term relief and reduce long-term vulnerability of communities and food systems to climate-induced extreme weather events.
- Awareness-raising campaigns should be implemented which illustrate the need for safe drinking water as a requirement for nutritional security and health.
- The capacity in developing countries to meet emerging food quality and safety standards needs to be strengthened.

We need improved opportunities for food trade and research.

Investments in infrastructure and support services need to be prioritised.

Prevention plans for all sources of pollution are required.

Better allocation, pollution prevention and sharing of benefits of water are needed.

Photo: SIWI

2. Executive Summary

Feeding the World is a Daunting Water Challenge

Even though a post-industrial society is conceivable, "there is no such thing as a post-agricultural society"[1]. Just as there cannot be a post-agricultural society, there should not be a world where people lack a proper diet. Yet, for hundreds of millions, hunger and undernourishment is a reality. For today's undernourished, and for the 70 million added to the planet each year, the need for more food is obvious. Fairer access to the food actually produced is as important. While the number of undernourished had slowly but steadily declined for decades, the most recent analysis shows disturbingly that it has turned upward in the new Millennium. Currently, 852 million are undernourished, or about 15% of the world's population. Paradoxically, the number of overweight and obese has increased, too; an additional 15% fall in this category (Chapter 4).

The challenge to increase food production is daunting, given that water and land resources are already under severe pressure, with serious repercussions on natural aquatic and terrestrial ecosystems. The only alternative is to produce more food from each unit of water and each plot of land, without further jeopardising ecosystem functions (Chapters 3 and 5).

Food and nutrition insecurity coincide with a host of constraining circumstances: rampant poverty, use of outdated technologies and a lack of farm-to-market roads and other infrastructure. Similarly, institutional weaknesses and poor access to credit effectively block opportunities to improve land and water use practices. Mental barriers, disenfranchisement and disengagement are major obstacles. The bad news is that these circumstances tend to reinforce each other. The good news is that investments for improvements are likely to yield higher returns. The synergy that can be realised if packages and programmes are co-ordinated is substantial (Chapters 3 and 6).

Water – The Key to Food Production

Food production is inconceivable without water. Each loaf of bread, each vegetable, each fish – indeed every meal – requires substantial volumes of water to produce. A projected diet of about 3000 kcal, calculated at 20% animal and 80% vegetable, requires

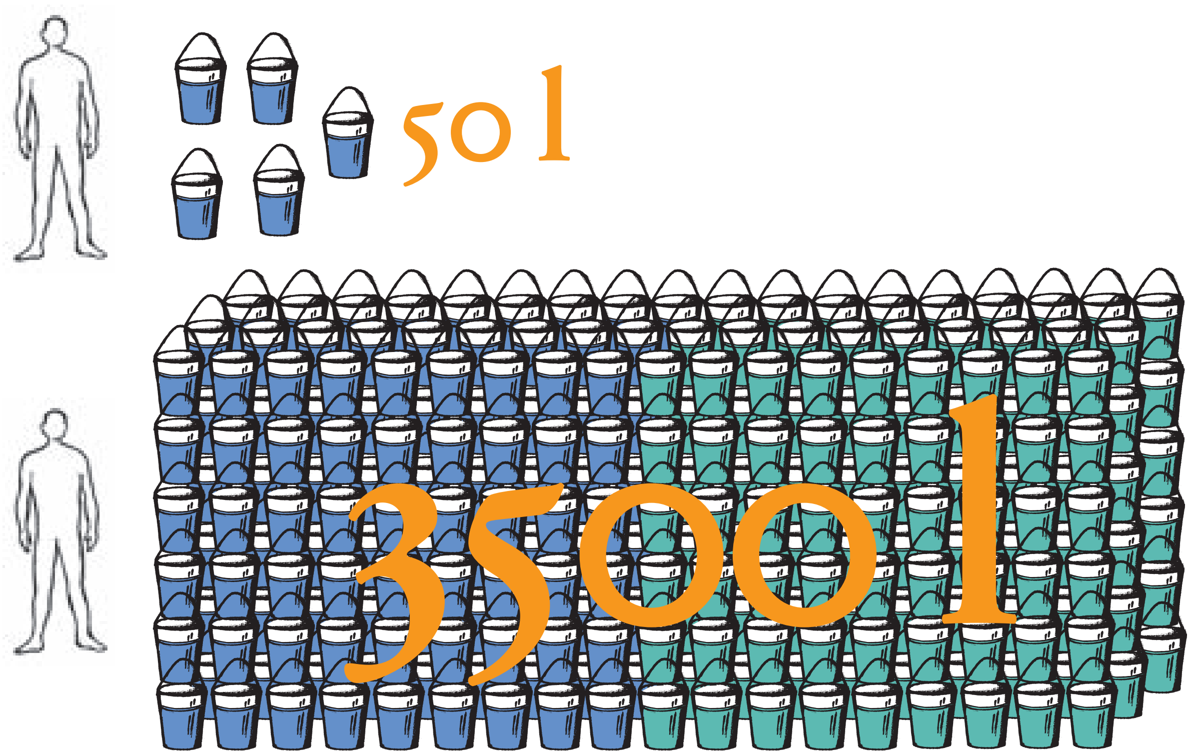


Figure 2.1: While 50 litres of water per day per person is the recommended minimum for household use, 70 times as much is needed to meet the consumptive water use for producing a projected human diet for one person based on a kcal consumption of 3000 kcal/day .

between 3–4 m^3 per day to produce. This is some 70 times more than the 50 litres used to indicate daily basic household needs of water (Chapter 3).

Ingenious management and sound stewardship of the entire water resource is required. Discussions about water inputs into an increased food production have invariably focused on the blue water resources, i.e. the water that is available in rivers, lakes and aquifers, while the significantly larger green water resource, i.e. the water invisible to the naked eye which is available as soil moisture, is overlooked. Also neglected during the discourse is that the planet's renewable water resource comes from rain. Two-thirds of the precipitation over the continents take the green water path and return to the atmosphere as vapour flow. Only one-third feeds the rivers and aquifers and generates blue water. With blue water resources already heavily overappropriated in many parts of the world, it is time to revisit, and revitalise, green water-based food production (Chapter 3).

About 1.4 billion people, mostly impoverished, live in river basins where all the blue water is already committed or overcommitted. Climate change and variability compounds the risks of such overcommitment in many parts of the world. With current levels of water productivity, the additional consumptive use of water linked to food security by 2025 and 2050 is estimated at 3800 and 5600 km^3/year, respectively. Currently, the total annual withdrawals of blue water are between 3500 to 4000 km^3. From where can the additional water needed to achieve food security be taken? Is it through additional withdrawals from blue water resources, i.e. rivers, lakes and aquifers? Is it from proper utilisation of green water, i.e. the invisible soil moisture? Or is it through enhanced water productivity and yield improvements? (Chapters 3 and 5).

Food production is inconceivable without water and is a daunting challenge.

With blue water resources already heavily overappropriated in many parts of the world, it is time to revisit, and revitalise, green water-based food production.

Recognise Links Between Food, Nutrition and Environmental Security

Many of the world's inhabitants do not have access to a diet which is required to lead a healthy and productive life. Apart from causing millions of premature deaths, unhealthy diets contribute to high levels of illness, which means that some of the food eaten does not benefit the body nutritionally. Similarly, a person made infirm through a poor diet cannot be a productive, hard working or innovative farmer or fisherman (Chapter 4).

Food security should be linked to the broader notion of nutrition security. Nutrition security presumes access to food but also a proper composition of the "food basket" and the ability of the human body to absorb the nutritional value of the food consumed. The inclusion of safe household water and sanitation in the nutrition security concept is obvious (Chapter 4).

An increasing number of people, poor as well as rich, are malnourished in terms of being overweight

Food security should be linked to the broader notion of nutrition security.

Nutrition security presumes access to food but also a proper composition of the "food basket".

Demand for meat and dairy products is increasing which implies an increased demand for water per unit of food produced.

and obese. The World Health Organization calls this a global public health epidemic. Here, urbanisation, increased purchasing power and the associated changes in consumer preferences have changed the composition of the food basket. The roles of the food processing industry and retail trade outlets are very important in this context.

Changed consumer habits and demographics have become major drivers of production and distribution patterns (Chapters 4 and 6). For example, demand for meat and dairy products in the Least Developed Countries (LDCs) is increasing, while the relative share of staples goes down. These trends bring opportunities but also imply a changed "water foot print" through an increased demand for water per unit of food produced (Chapters 3 and 4).

A conscious co-management of water for agriculture and ecosystems is a precondition for ecological sustainability.

Prevailing agricultural production patterns induce groundwater overexploitation, water logging and salinisation and heavy appropriation of stream flow (resulting in river depletion and changing ratios in pollution loads versus dilution and assimilative capacity). The damage is felt in aquatic ecosystems, fisheries, biodiversity, salinisation and a reduction in production potential. A conscious co-management of water for agriculture and ecosystems is a precondition for ecological sustainability (Chapters 3 and 5).

The productive utilisation of green water presents a window of opportunity.

Imperative of Governance, Trade, Investments and Human Beings

It is often heard that the potential to produce additional food is tremendous. Why, then, is the gap so wide between what could or should be produced and what actually is produced? What will it take to close the gap? In many cases, what is required are changes in governance, terms for trade and investments in human resources, together with measures that will recapitalise land and water resources (Chapter 3).

Political commitment is one precondition for development. Entrepreneurship and courage to venture into new packages for change and associated support services is crucial. The productive utilisation of green water presents a window of opportunity. Ultimately, it is the individual and groups of producers and consumers who will have to be the players in the orchestration for "food and nutrition security for all". Without entrepreneurship, engagement and skills, the status quo will remain or worsen the situation. Also, without the proper support from society to strengthen these human qualities, people can and will do little (Chapters 3 and 6).

Photo: Mats Lannerstad

Photo: SIWI

3. Enhance Food Production for a Growing Humanity

Main Message

In both rain fed and irrigated food production systems, the potential to improve water productivity, i.e. to produce more food per unit of water, is substantial. Measures required include:

- Improved management of water in irrigated and rain fed agriculture, based on secure water use rights and land tenure
- Improvement of biological, chemical and physical properties of the soil through i.a. appropriate tillage practices
- Dryspell mitigation though rainwater harvesting and supplementary irrigation
- Effective arrangements and support services for marketing, affordable credit, technological improvements and extension services, with particular focus on rain fed agriculture
- Investment in new irrigation and storage infrastructure and improved management of existing irrigation

Proper Water and Land Management – Precondition for Enhanced Food Production

Food production in many developing countries, particularly in Sub-Saharan Africa (SSA), is far too low to meet current and future food requirements in the region and to ensure a decent income for millions of food producers. Many subsistence farmers there suffer from hunger. In fact, the highest incidence of undernourishment is among subsistence farmer families (Chapter 4), with on-farm yields of 1–2 tonnes per hectare (t/ha), and often dropping to less than 1 t/ha in SSA and South Asia, the world's major food insecurity hotspot regions. Low crop yields reflect low productivity of both land and water, and insufficient income to satisfy basic needs.

Water is now the number one food production limiting factor in many parts of both Asia and Sub-Saharan Africa. For millions of people, the desperation for water is real.

However, land and water per se are not the key on-farm constraints; rather, it is the combination of fertile land and water in the root zone, i.e. soil moisture.

Water Moving Up the Food Policy Agenda

Feeding a world of nearly 9 billion in 2050 is a long-term challenge which implies enormous increased pressure on the world's finite freshwater resources. Water scarcity, poverty, under- and malnourishment and environmental stress coincide in many parts of the world. Much of Asia's intensive blue water development (Box 3.1) for irrigation means that many basins have become closed to the point where all water is committed and additional withdrawals are impossible. Sinking groundwater tables are a serious problem in developed as well as developing countries. A real challenge is inter-sector competition, including growth in urban and environmental demand, which moves water from irrigation into higher value urban and industrial uses, and growing water pollution (Chapter 5). On the other hand, agriculture in Sub-Saharan Africa is mainly rain fed, and few water storage and irrigation sites have been developed.

Water is now the number one food production limiting factor in many parts of both Asia and Sub-Saharan Africa.

Green and Blue Water

Traditionally, and particularly since the Green Revolution in the 1960s, the role of water in food production has been associated with irrigation. i.e. with blue water. In discussing food security, experts often forget that the green water is more important (Box 3.1).

Feeding a world of nearly 9 billion in 2050 is a long-term challenge which implies enormous increased pressure on the world's finite fresh-water resources.

Consumptive Water Use and Water Productivity

Escalating water scarcity has been a concern for some time. However, scarcity is more about wise use of resources than a lack of resources [2]. Water productivity – the produce or value derived or potentially derived from each unit of water that is put to beneficial use [3, 4] must be improved.

Based on today's water productivity and a projected diet of 3000 kcal/day [5], an additional 5600 km^3/year of water needs to be appropriated by 2050 to eradicate undernutrition and feed an additional 3 billion world inhabitants [6]. This is almost three times as much as the present global consumptive water use in irrigation [7]. Eliminating poverty and food insecurity, and protecting the natural environment requires a paradigm shift in policy orientation, research and development programmes.

The role of water in food production has been associated with irrigation. i.e. with blue water. Experts often forget that the green water is more important.

Water scarcity, poverty, under- and malnourishment and environmental stress coincide in many parts of the world.

Simply put, climate determines the water requirement in food production. Hot landscapes are thirstier; water returns to the atmosphere as evaporation and transpiration substantially quicker. While this is a "non-negotiable law of Nature", the quantity of these two flows can be altered positively. Proper crop and land management can improve agricultural production by converting non-beneficial evaporation to beneficial transpiration through the crops. In addition, the portion of rain which infiltrates the surface and forms vital soil moisture can be increased through proper tillage and water management (see below). The development of more drought and salt-tolerant plant varieties can also increase crop water productivity.

Water productivity concerns also apply to irrigation. A portion of the irrigation water (which often exceeds actual crop water requirements) percolates and replenishes aquifers, while another portion drains from the field. Figures on water requirements in irrigated agriculture are often deceptive since the portion that does not return to the atmosphere can be reused, *in situ*, through lifting the groundwater, or by users downriver in the catchment.

The consumptive water use is the *de facto* depletion of the resource available in the landscape. By comparing figures on consumptive water use with the amount of food produced, the actual and potential water and land productivity is calculated. Consumptive water use could also be related to nutritional contents of food (Chapter 4), investments, labour, etc. (Box 3.4)

Proper crop and land management can improve agricultural production by converting non-beneficial evaporation to beneficial transpiration through the crops.

Box 3.1

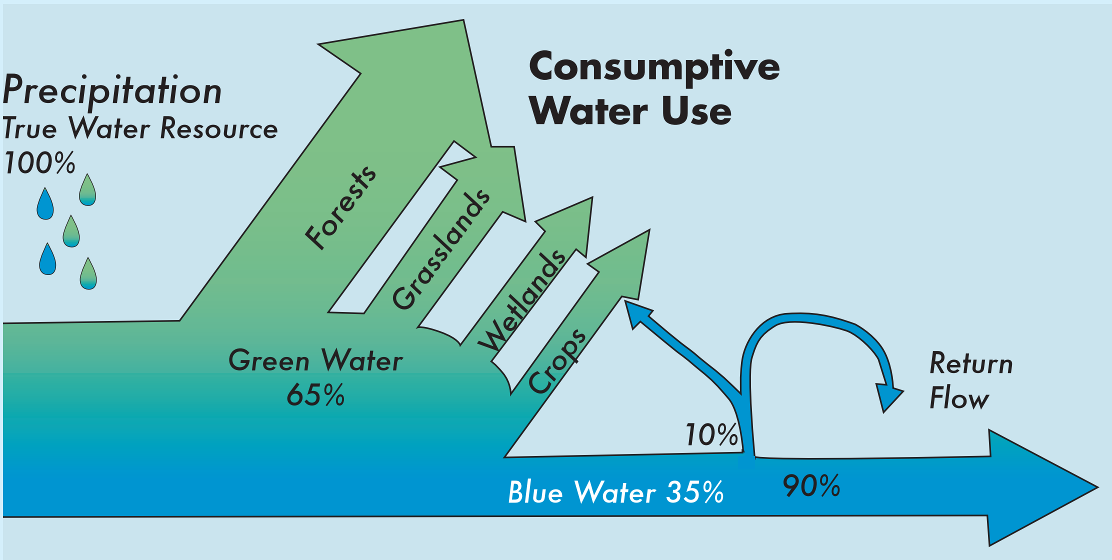
Blue and Green Water

An average of 110,000 km^3 of rain falls over the continents annually. Around one-third reaches the aquifers, rivers and lakes (blue water) out of which only about 12,000 km^3 is considered readily available for human use. Current water withdrawals for municipal, industrial and agricultrual use amounts to some 10 percent of the blue water resource. The remaining two-thirds form soil moisture or returns to the atmosphere as consumptive water use (evaporation from wet soil and transpiration through plants). Green water is a significant water resource, much larger volume-wise than the water replenishing streams, lakes and aquifers.

Demographic trends and changes in consumer food preferences (Chapter 4) necessitate that food production benefit from both green and blue water resources. Many blue water resources such as rivers and lakes are already depleted beyond what is acceptable for downstream fisheries and coastal life. A more intensive withdrawal from blue water resources will further threaten inland and coastal fisheries.

Adding flow to rivers that are desiccated through inter-basin transfers of water, or to parched regions, is technically possible but meets with a number of constraints and protest.

Failing to increase water, land and crop productivity will likely lead to more land being converted from natural vegetation, tropical forests, etc., into farming areas. This may harm biodiversity and ecological sustainability.



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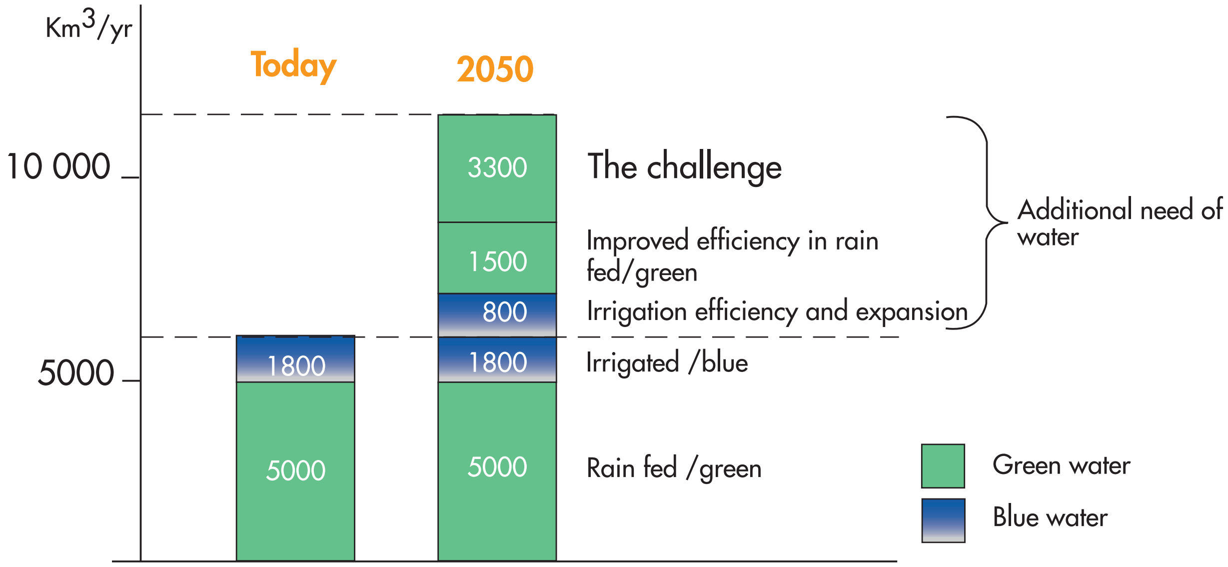

Figure: 3.1: Today's food production involves a consumptive water use of altogether 6800 km3/yr (out of which 1800 are supplied from blue water resources). To feed humanity by 2050 on 3000 kcal per person per day will require an additional 5600 km3/yr, out of which a maximum of 800 will come from blue water resources. The 2050 column shows that the remaining 4800 have to be contributed from new green water resources (e.g. horizontal expansion) or from turning evaporation into transpiration (vapour shift). Data from [7].

Enough Rain for Doubling Yields

Develop Explicit Policy on Rainwater Management

Rain fed agriculture in tropical zones is at risk from floods, droughts and dryspells and the associated threat to livelihood conditions. For rain fed farming systems in semi-arid Sub-Saharan Africa, dryspells exceeding 15 days are typical and reduce crop growth almost annually [8]. Climate variability and climate change will likely exacerbate the frequency and shocks of floods and droughts (see Box 3.2).

Since the total rainfall over the course of a season is often enough, the high risk of water deficiencies in rain fed agriculture usually refers to short, albeit critical, periods.

Low crop yield not only results in low food production and income, and thus poor livelihoods for farmers, but also implies a large loss of water that could be beneficially utilised. Water productivities of 5000 m^3 water/tonne grain, are common in rain fed systems in semi-arid regions such as SSA and parts of Asia. Supplemental irrigation of about 100 mm of water per year, i.e. around 15% of rainfall, potentially can double yields from, say, 1 to 2 t/ha. Such improvements mean that water productivity increases to 2000 m^3 water/tonne (Figure 3.3). Such a doubling could reduce the need to withdraw an additional 1500 km^3/year blue water for food production on a global basis by 2050, corresponding to about 80% of current global consumptive water use in irrigation[7].

Harvesting of rainwater for supplemental irrigation is common practice in India and China and an ancient survival strategy in the Middle East and North Africa, but less practiced in Sub-Saharan Africa [9, 10, 11]. Supplemental irrigation entails important synergy since dryspell mitigation may motivate farmers to invest in fertilisers, improved seeds and pest management [12].

Low crop yield not only results in low food production and income but also implies a large loss of water that could be beneficially utilised.

Maximise Infiltration of Rain

The key to maximising rainfall infiltration into the soil is *in situ* soil and water management. Terracing, contouring and micro-basins are important measures. Many farmers in Sub-Saharan Africa have increased yields and reduced animal traction needs by adopting different types of conservation tillage practices such as ripping and subsoiling. In some Latin American countries, no-tillage systems have resulted in higher yields and improved income. In South Asia, conservation tillage practices in rice farming reduced capital investment and improved productivity [13]. Full yield response can, however, only be achieved if physical measures are combined with soil fertility management (see Chapter 5).

Supplemental irrigation of about 100 mm of water per year, i.e. around 15% of rainfall, potentially can double yields.

The key to maximising rainfall infiltration into the soil is in situ soil and water management.

Invest in Green/Blue Water Management Innovations

Green/blue water management innovations will be necessary to jointly enhance rural food and water

Box 3.2

Projected Impacts of Climate Change

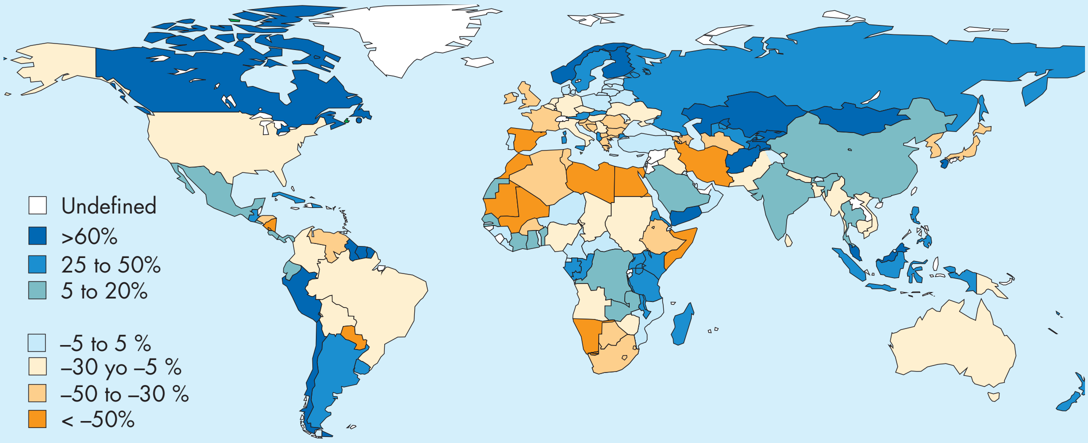

Figure 3.2. Country-level climate change impacts on rain fed cereal production potential on currently cultivated land. Source: [14]

The 40 poorest countries, with a total population of some 1–3 billion, may lose on average up to a fifth of their cereal production potential in the 2080s.

As many as 40% of the Sub-Saharan countries could lose a substantial part of their agricultural production.

The potential threat to global water and food security is severe if mean temperatures rise 1.5–2° C, with particularly disastrous consequences for the Mediterranean region and Southern Africa. While climate change may by gradual, extreme events appear more immediate as the number of droughts and floods have increased recently. A farmer can survive one less productive year, but two or more are hard to survive.

The uncertainties of future climate variability modelling make it difficult to simulate the vulnerability of food production on a country-by-country basis. For some countries, climate change may lead to an increase in food production, as in North America and Europe, where high gains are projected. The 40 poorest countries, with a total population of some 1–3 billion, may lose on average up to a fifth of their cereal production potential in the 2080s.

This demonstrates two important factors. First, the net balance of changes in food production potential for poor regions such as Sub-Saharan Africa will very likely be negative, with up to 12% of the region's current production potential lost. Second, there will be large variations from country to country. As many as 40% of the Sub-Saharan countries could lose a substantial part of their agricultural production.

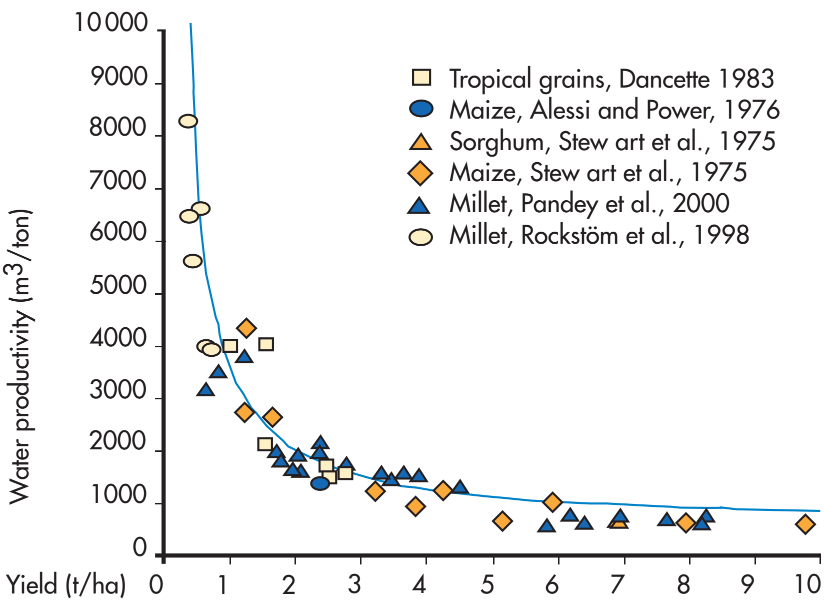

Figure 3.3. Water productivity (consumptive water use per ton grain produced) as a function of grain yield for tropical C4 grains. Source: [15]

Photo: Mats Lannerstad

security. Innovations include the conservation of rain water and improvement in the efficiency of water use in existing systems through water management and policy reform. Increases in crop productivity per unit of water and land will require agricultural research and policy efforts, including crop breeding and water management for rain fed agriculture.

There is a continuum of water management systems, from the completely rain fed which receive no additional blue water, to irrigation systems which, lying literally in the desert, rely almost entirely on river and groundwater diversions. Similarly, markets, other infrastructure and policies which impact food production and demand systems also diverge widely. These varying conditions have to be considered when investment decisions are made.

Risk reduction, together with a perception of quick and tangible benefits and market opportunities, is a key element for communities to adopt innovative practices to reverse natural resource degradation while maintaining or enhancing food security.

Affordable, small-scale technologies and approaches for farmers hold tremendous promise for improving rural livelihoods. Low-cost drip irrigation, low-cost pumps (including manually operated treadle pumps), alternation of wet and dry irrigation in rice intensification, small-scale water harvesting structures, and other water storage mechanisms are but a few examples. Poor rural populations have the capacity to assimilate these technologies. Added benefits are that the technologies do not need large sources of water and that the payoff can be quick. Experience has shown that small plot irrigation technology can motivate the farmer to move to diversified, high-value marketable crops, and thereby add significantly to annual incomes [16]. Supporting innovations in these areas is likely well worth the investment.

Investment in water for agriculture is a must for Sub-Saharan Africa and other poverty-stricken areas. Investment:

- Enhances farmer income in significant ways by relieving yield losses due to water scarcity
- Provides incentives for farmers to adopt yield-boosting complementary agronomic inputs
- Contributes to natural resource conservation by creating disincentives for farmers to expand into ecologically fragile environments

Enhancement of food production and yields is, however, often a complex process. Generally, it requires a package of support services and investments (Box 3.3. Cf. Figure 6.1).

Close the Water Productivity Gap in Irrigation Systems

Water productivity levels in today's large irrigation systems are well below the potential in many areas. A comparatively liberal supply of heavily subsidised water encourages inefficiency and lack of reliability. With growing urban centres, the context is changing. Farmers in many irrigation systems are seeing "their" water being reallocated to cities or, increasingly, released back to rivers and streams to improve environmental flows [17, 18, 19].

Undeniably, irrigation is very important for overall food production by enabling 40% of the production on only 17% of the cropland. Irrigation reduces poverty through higher yields and incomes for farmers, and it is also crucial for society in general through increased employment directly in the sector and indirectly in related sectors, and through its impact on lowering food prices. By creating higher crop production levels, irrigation development has also saved millions of hectares of forest land from conversion to agriculture. Irrigated agriculture also plays a significant macroeconomic role in many countries since, among other things, it generates significant foreign exchange. By virtue of their character, irrigation schemes have substantial multiplier effects through backward and forward linkage effects. Huge capital and political

Green/blue water management innovations will be necessary to jointly enhance rural food and water security.

Affordable, small-scale technologies and approaches for farmers hold tremendous promise for improving rural livelihoods.

Investment in water for agriculture is a must for Sub-Saharan Africa.

Box 3.3

Policy Interventions to Enhance Food Security

The necessary improvements in water and land management will not be possible on a grand scale without a number of supporting measures.

Market access

Investments must be made in rural roads, telephones, electricity connections and supply. Lack of such infrastructure is a serious obstacle for millions of farmers.

Investment in complementary services

On the supply side, access to education and health services is important since these complementary services allow farmers to produce food more efficiently and effectively. On the demand site, people become more aware of which foods to consume.

Organisation of food producers

All forms of collaboration or organisation for or by farmers – associations, co-operatives, micro-credit groups, etc. – can help reduce costs for agricultural inputs, process agricultural outputs and create economies of scale for marketing (Chapter 4).

Trade

Opportunities and services that support trade are highly desirable. Poorly developed national trading systems increase transaction costs and hinder farmers from selling their produce. Removal of trade distortions in the agriculture sector can significantly increase efficiency in agricultural production.

Labour and technology

Particularly for LDCs, a high percentage of the population is in rural areas and offers a huge pool of labour. Many of the means to enhance production are labour intensive, for instance, water harvesting, composting and other nutrient replenishing practises. At the same time, there is disguised unemployment. Long, hard hours for little pay are likely to discourage people, especially the young. High rates of illness, including HIV/AIDS as well as water- and sanitation-related sicknesses, reduce the ability to work. Given the challenges related to labour, it is also crucial to promote labour-saving technical substitutes. Affordable technology for supplementary irrigation has proven its worth. Examples include treadle pumps and other water-lifting devices that the farmer or group of farmers can handle.

Research and extension

Throughout the 1990s, African governments reduced investments in extension service and research. Today, public spending on agricultural research and extension is paltry. Moreover, most research investments are for commercial farming, and for temperate climates, or blue water irrigated systems. Research on drought and salinity tolerant crops is insufficient but important, as is research on closing the productivity gap for smallholders.

Credit

Agricultural (and rural, non-farm) development presumes timely and efficient credit. Thus, microfinance services targeted at low-income and poor households need to be expanded. Cultivation loans and credit to producers are essential. Currently, farmers often pay devastatingly high rates of interest for credit. In some African countries it is in excess of 40% [20].

Today, public spending on agricultural research and extension is paltry.

Research on drought and salinity tolerant crops is insufficient but important, as is research on closing the productivity gap for smallholders.

investments have been made in irrigation structures; a failure to improve performance is tantamount to capital degradation and is politically spurious.

Increasing water productivity in irrigation systems can be done through:

Agronomic and on-farm water management practices: different innovative on-farm water management practices such as alternate wetting and drying, systems of rice intensification, precision land levelling, mulching for increased water holding capacity of the soil, improved crop varieties, and precision water application technologies such as drip and sprinkler irrigation.

Irrigation management measures: deliver more reliable water supplies to allow farmers to invest in improved on-farm management practices, deliver supplies more equitably, and make sure the poor and disadvantaged get their share of water.

Innovative water pricing systems and incentives: innovative allocation, pricing, and incentive systems can be designed for efficient water use, cost recovery, and at the same time protect and increase farm income

Policy Implications for Existing Large-scale Irrigation

Investments which improve the performance of large-scale irrigation can significantly improve water productivity and enhance benefits derived. Farm-scale innovative technologies and management approaches for improving water productivity are desired, particularly if they increase basin-level efficiencies. Institutional reforms in underperforming or outdated management systems must be actively pursued. Naturally, "non-water" factors influence productivity, including markets, transportation, rural service industries, trade restrictions, subsidies and food aid (Box 3.3.; [21, 22].

Agronomic advances have been one of the most important factors in yield increases and improved farmer incomes. A large part of the research has focused on irrigated agriculture and high potential areas. Today, new dimensions and options are being explored. Research and trials related to crop breeding, including agro-biotechnologies have rapidly become hot issues (Box 3.4).

Connect River Fisheries to Agriculture

According to published data, more than 8 million tonnes of fish are harvested each year from inland fisheries in Asia, Africa and Latin America. Approximately 50% of this is estimated to come from rivers, with the Mekong alone accounting for 2 million tonnes. These figures, however, are widely considered conservative [23]. In large parts of Asia, Africa and Latin America, freshwater fisheries are a crucially important resource for poor rural families. Rich in protein and minerals, fish are a high-value food. Many are also rich in healthy unsaturated fatty acids that play an important role in the development of bones, nervous system and brain in children. The pressure on capture fisheries is very high, and it is primarily through aquaculture production that figures for total world fish production is not declining [24].

For livelihood improvement, and as a pro-poor strategy, the integration of aquaculture into farming systems is an important management option. Rice-fish culture, cage culture, and development of capture fisheries in small water bodies and reservoirs used to store water for irrigation are among the most promising [25]. Hence, water productivity can be increased by integrating fish and other living aquatic resources into water use systems.

Crucially, fisheries need a water regime where the water is of high quality. The rationale for an integration of this need – and balancing it with irrigation requirements – in the overall water management rests not just on fisheries

Box 3.4

Agro-biotechnologies

Breakthroughs in molecular precision technologies during the late 1970s and early 1980s made it possible to intervene in microbiological processes and to alter the genetic set up of plants and organisms. The resulting products were characterised by new genetic traits and properties that could not be created with earlier technologies. It now became possible to cross species barriers and incorporate genetic traits from species that earlier could not be made to mate. The new products became known as genetically modified organisms, or GMOs. In agriculture, GMO-crops were introduced in the mid 1990s (with insect/herbicide, resistant/tolerant soybeans and maize, later cotton). By late 2003 the global area for GM crops was estimated at 67.7 million hectares, with 30% being in developing countries. The increase in area is expected to continue.

The rapidly expanding use of GM seed has created an intense public debate about biosafety and seed monopolies. Questions arose over who controls the seeds, and on issues related to the use of patented genetic material in GM crops with regard to farmer's and breeder's freedom to operate. The impact on human health and on ecological effects, such as unintended outcrossing of GM traits to non GM crops and wild relatives with impacts on agro-biodiversity, are also concerns which have been raised and remain unresolved.

On the other hand, GM crops offer new opportunities to match global challenges such as climate change and rapid population growth. Agro-biotechnology offers the possibility of developing, for example, salt-tolerant rice, drought-tolerant maize and wheat, and new disease-resistant varieties of major staple crops. It further promises the possibility to improve plants' capacity to fix nitrogen. Continued research under thorough testing and controlled circumstances is vital.

Farm-scale innovative technologies and management approaches for improving water productivity are desired.

The rapidly expanding use of GM seed has created an intense public debate about biosafety and seed monopolies.

Photo: Dr. Katrin Teubner

Photo: Mats Lannerstad

Trade in food is literally also trade in water.

At the global level, trade in virtual water can reduce consumptive water use in agriculture if exporters are able to achieve higher water productivity than importers.

Freshwater fisheries are a crucially important resource for poor rural families.

	Barotse	Caprivi-Chobe	Lower Shire	Delta
Cattle	120	422	31	0
Crops	91	219	298	121
Fish	180 (43%)	324 (28%)	56 (13%)	100 (39%)
Wild animals	6	49	1	0.4
Wild plants	24	121	48	29
Wild foods	0	11	7	4
Clay	2	0	8	0.08

Table 3.1. Value of river and floodplain resources to rural households in four stretches of the Zambezi River (US dollar per year and household). Source: [26].

being the most important wild resources harvested from river systems (Table 3.1), but also because they are especially accessible to the rural poor.

Significance of Trade for Food Security

With increasing pressure on water resources in many countries, the difficulties to domestically produce all the food required to feed the population are mounting with demographic trends. Given the mismatch between distribution of population and the resource endowments to produce the food demanded, trade is necessary. For instance, countries in the Middle East, where the average water availability is extremely limited, rely to a large extent on food imports. Trade in food is, of course, also necessary within countries as a result of increased urbanisation (Chapter 4).

Trade in food is literally also trade in water. Since food production uses large volumes of water, a certain volume of consumptive water is used when producing each food item. The total amount of water from both green and blue water resources used to produce a crop is referred to as "virtual water" [27, 28, 29]. The international food trade can consequently be equated to virtual water flows. (Figure 3.4)

Food production is particularly water intensive in hot climate regions where high temperatures imply high rates of evaporation and transpiration, as discussed above. At the global level, trade in virtual water can reduce consumptive water use in agriculture if exporters are able to achieve higher water productivity than importers. In most cases, the major exporters (USA, Canada and the European Union) have highly productive rain fed agriculture, while most importers would have relied on irrigation or low output rain fed systems. Presently, cereal trade reduces annual global crop water depletion by 6% and irrigation depletion by 11%. Estimates that take into account trends in virtual water trade forecast 19% less irrigation use in 2025 than those that do not include trade [30].

Trade in food is very much conditioned on agricultural subsidies. In Organisation for Economic Co-operation and Development (OECD) countries, farmers receive more than one-third of their income from government subsidies, in total over USD 300 billion every year. The value of total agricultural support in OECD countries is more than five times higher than total spending on overseas development assistance and twice the value of agricultural exports from developing countries. Reduction and liberalisation of agriculture will continue to be at the top of the negotiating agenda of future international talks. Therefore, the linkages between agricultural trade and water resources need to be identified and analysed to better understand the potential impacts that a full trade liberalisation, or lack thereof, will have on water resources.

Total agricultural support in OECD countries is more than five times higher than total spending on overseas development assistance.

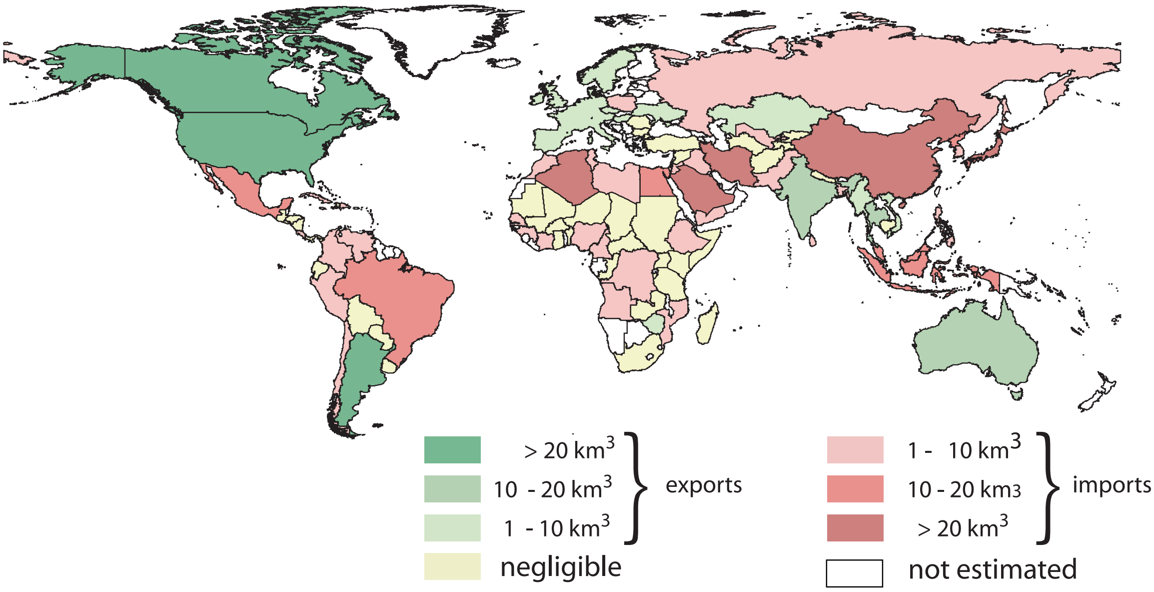

Figure 3.4. Virtual water flows, i.e. consumptive water use behind exports and imports of cereals in 1995. Source: [30]

By improving water productivity in agriculture, water can be more freely available to industry and municipalities.

Box 3.5

Pros and Cons of Virtual Water Trade in Food

Pros of Virtual Water Trade

The benefits of virtual water trade include a number of aspects:

- Water can be saved by importing water from a region with higher water productivity. Trade therefore reduces the problems of water stress in the importing country
- By improving water productivity in agriculture, water can be more freely available to industry and municipalities
- Trade might be helpful in increasing farm incomes and in increasing export possibilities
- Trade would reduce the need to claim more land for farming (with the associated ecological effects) in cases where the other national sources are insufficient
- Trade may also be a way to secure enough food during the transition period while more productive agriculture is being developed and efforts ongoing to overcome existing barriers

Cons of Virtual Water Trade

There are also negative impacts to pay attention to:

- Increasing risk for environmental impact in exporting regions
- Political opposition to and risk of moving from food self-sufficiency
- Ecological concerns for countryside in exporting regions
- Adds to urban migration by reduced agricultural employment in importing countries
- Could severely impact the access of poor people to food
- Could reduce export earnings from agriculture in importing country

Photo: Dr. Katrin Teubner

4. Food Consumption Trends: Water and Health Implications

Today, few people other than the farmer know the water requirements to produce various crops or food items.

Main Message

Globally, food consumption patterns are changing rapidly. These changing patterns are increasingly becoming drivers for food production. The composition and size of the consumer's new food basket implies a substantial increase in the pressure on water and natural ecosystems.

In some developing regions of the world, undernourishment is increasing. In others, it is slowly being overcome. Paradoxically coexisting with undernourishment is malnutrition, including obesity, which is increasing in both developed and developing countries. These public health threats impede the ability of people to fight obesity, overcome poverty, resist disease and achieve other MDG-related livelihood improvements.

It is of paramount importance to increase access to food and water so that people can lead healthy and productive lives. Furthermore, we need to change the consumption patterns. Measures required include:

- Raised awareness of, and incentives provided for consumers to chose food products with high nutritional value per drop of water
- Collaboration with the food processing and retail industries to develop and market food products with high nutritional value per drop of water
- Social safety nets to ensure that the poor get access to proper nutritional security

Historically, food was produced and consumed by literally the same person, the farmer.

Consumption Patterns Drive Food Production

The first and foremost objective of food production is to feed the population. Yet, the horrors of famine and a Malthusian concern where production is eventually outstripped by the growth in population, have been a lingering worry. After decades of decline, the number of undernourished are once again increasing. From 2000 to 2002, it grew by 18 million and is now 852 million, or about 15% of the world's population [31]. Dreadfully, at least 5 million children die from hunger annually. Moreover, overconsumption and obesity are, quantitatively, on par with undernourishment [32, 33, 34].

The potential exists to grow enough food to feed the world, but certainly not to fill any kind and any size of the consumer's food basket. If food demand and consumption deviates for too many people from a smart and sound diet, the already daunting challenge to feed the world will worsen. For instance, if demand for water-intensive food items continues to increase, then closing the water productivity gap may not bridge the more basic gap: the difference between aggregate needs and wants for food vis-a-vis the natural capacities of the earth to provide for the aggregate demand.

Moreover, if the "food problem" is tackled only from the production side, it is less likely to be dealt with effectively. In addition, the welfare of a society very much depends on food access and dietary composition. Too much food, too little food and poorly composed diets are equally problematic.

Historically, food was produced and consumed by literally the same person. Over time, more and more people bought the food they consumed. By being physically separated from where "their" food was grown, produced and/or processed, consumers lost insight into the conditions of food production. Today, few people other than the farmer know the water requirements to produce various crops or food items. Another consequence of this fundamental shift was the need for trade, the development of the food processing industry, and the challenges and opportunities they presented (Figure 4.1).

These changes in consumer/producer relations are central to this report:

- Changes in consumer preferences and purchasing power, together with the dynamics of the food processing industry and trade, will increasingly influence food production. Market access, relative prices and other factors will determine where the food comes from and what kind of food it is. Farmers, fishermen and other food producers will have to respond to, and benefit from, new patterns of consumer demand.
- Increasing purchasing power and urbanisation will change the preferences for different food items as well as for the total amount of food. The changes are felt in terms of resource pressure and environmental impacts, primarily water and land. Behind any food basket there is a "water foot print", which, generally, increases with level of consumption (Box 4.1).
- Consumers want to choose from a wide selection of food items, including imported branded items, at relatively low prices. Supermarkets meet these consumer preferences. The rapid emergence of supermarkets, together with the growth of the food processing industry, creates new and substantial challenges for a very large number of small-scale, poorly organised food producers. With more and more food produced and traded by a shrinking number of producers, many of whom receive heavy subsidies and other support, the food producing sector is under a radical change.
- While much of the world population has benefited from an increase in income, a staggering 1.1 to 1.2 billion people still live on less than USD 1/day, and another 1.6 billion have to do with between 1–2 USD/day [35]. An implication is that access to adequate food and proper nutrition for those who are currently undernourished will be relatively more constrained. The gap between undernourishment/malnutrition and overnutrition is morally unacceptable, but also ecologically unsound. In addition, public health care systems are affected. Together, these implications may block the possibility of achieving the MDGs (Box 4.2).
- At a time when consumers are increasingly distanced from production, and with the proliferation of information from commercial interests, neutral and scientifically valid information about the links between production and consumption of food and resource pressure is most important. Consumers are largely ignorant or misinformed about the resource and environmental implications of food production and, indeed, their own behaviour as a consumer. Efforts to reduce water and environmental illiteracy are a prerequisite for sustainability.

Increasing purchasing power and urbanisation will change the preferences for different food items as well as for the total amount of food.

Consumers are largely ignorant or misinformed about the resource and environmental implications of food production.

Figure 4.1: A schematical summary of three major phases in the changing relations between primary food production, food processing and trade, and consumption.

Photo: Dr. Katrin Teubner

It is telling to see how the composition of the diet changes when food consumption is increased.

The Drivers and Dynamics of Changes in Food Consumption Patterns

Urban expansion, increased purchasing power and globalisation are among the most potent drivers of change in food habits [36, 37]. Urban centres have bustling informal and formal economies [38] and urban living enables individuals to venture into new patterns of behaviour. They have a wider choice of retail products, are exposed to promotions of the food processing industry, and are nearer to stores and markets. The urban dweller's food basket after a shopping round at the local (super)market is infinitely more varied compared to that of his or her rural counterpart. At the same time, the urban poor are vulnerable to the promises and lure that they are exposed to in urban settings. Economic growth of welfare, which is associated with urban expansion, is unfortunately often a mirage for the poor [39].

Producing cereals and other staples also places comparatively modest pressure on water and land resources.

Changes in the Composition in Diets

Changes in diets are, of course, not only an urban phenomenon. In Figure 4.2 the information refers to national figures and illustrates the increase in total food consumed and how the relative share of calories from carbohydrate-based staples and pulses decreases when the total calorie intake increases, particularly in developing countries. The opposite is true for dairy products, oils and fat and meat and fish increases, which increase at a corresponding rate. The absolute and relative reduction refers to course grains, like millet and sorghum and also sweet potatoes. The demand for fine grains like rice and wheat is rapidly increasing, notably in China, which is becoming a major importer [4, 37].

A balanced diet is consequently important both from a nutritional as well as a resource utilisation point of view.

Changes in the composition of the diet are important for several reasons: micro-nutrient deficiencies tend to be most common in cases where diets lack variety. Carbohydrate-based staples provide slightly more than half of the world's average daily calorie intake. They provide the necessary energy for the body to absorb proteins and other nutritional value of food and are vital for a proper nutritional standard. Producing cereals and other staples also places comparatively modest pressure on water and land resources. To produce one kilogram of meat, about 6.5 kg of grain and 36 kg of roughages are required as feed [40]. A balanced diet is consequently important both from a nutritional as well as a resource utilisation point of view. Current trends in consumer preferences for composition of the food basket imply a larger water foot print (Figure 4.3 and Box 4.1).

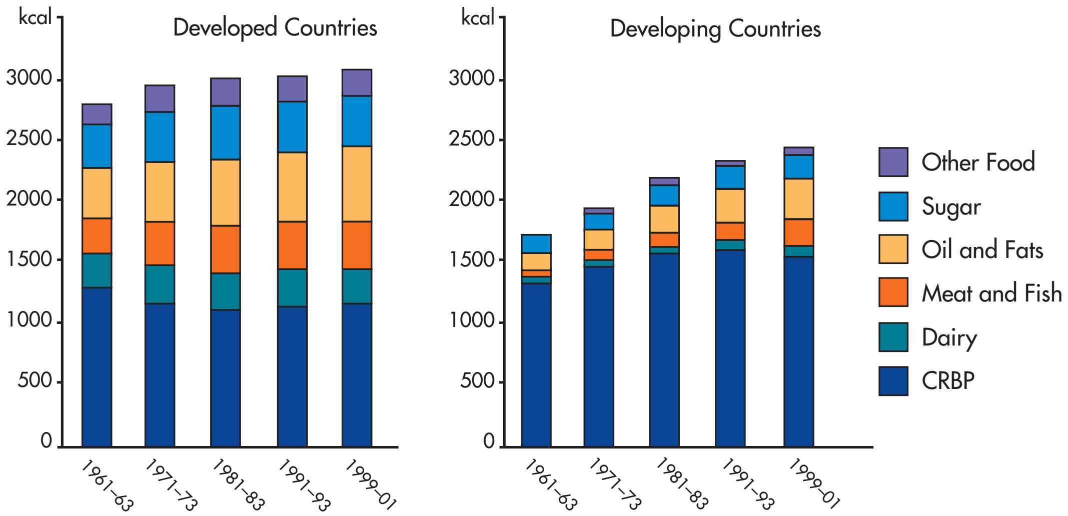

Figure 4.2. Changes in Food Consumption Patterns (average daily kcal intake) 1961–63 to 1999–01; CRBP = cereals, starchy roots, bananas and plantins. Source: [37]

Box 4.1

Water Foot Print – A Consumption-based Indicator of Water Pressure

A nation's water foot print is defined as the total volume of freshwater, both green and blue, that is used to produce the goods and services consumed by the people of the nation, i.e. both food and other goods and services [28]. The internal water foot print refers to the use of domestic water to produce the goods and services consumed by inhabitants of that country. To calculate the total national water foot print, the water used in other parts of the world to produce the imports to a particular country must be added. In most countries, the largest part of the water foot print refers to consumption of food. Evapotranspiration and transpiration from planting to harvest is the consumptive use of water. Calculations behind the map (Fig. 4.3) also include water that is percolated. For paddy, 300 mm is added. Since this water will replenish the aquifer and thus be available for reuse, the amount of water that is actually depleted from blue water sources is less than implied by the map.

Livestock products have a higher water foot print compared to crops. For each kilogram of boneless beef, it is about 6.5 kg of grain, 36 kg of roughages, and 155 litres of water (or about 15,000 litres of water on average per kilo of boneless meat). This means that 1 kg of meat involves as much water as 10 month's basic household water requirements (50l/person/day). Similar to the food sector, the average virtual water content of industrial products varies significantly. The global average is 80 litres per USD. In the USA, it is nearly 100 litres per USD; in Germany and the Netherlands about 50 litres per USD. In Japan, Australia and Canada it is only 10–15 litres per USD. It is also quite low in China and India, or about 20–25 litres per USD.

Four major factors determine the water foot print: volume of consumption; consumption pattern (e.g. high versus low meat consumption); climate (growth conditions); and agricultural practice (water use efficiency). In rich countries, people generally consume more goods and services. In many poor countries a combination of unfavourable climatic conditions (high evaporative demand) and bad agricultural practices (resulting in low water productivity) contributes to a relatively high water foot print. The map illustrates that some countries have a surprisingly high water foot print, for instance, Sudan. The reason is high crop water requirements due to the climate and very inefficient water use combined with low yields., lots of water is used per kg of output.

For further details on calculations see [40].

Livestock products have a higher water foot print compared to crops.

A nation's water foot print is defined as the total volume of freshwater, both green and blue, that is used to produce the goods and services consumed by the people of the nation, i.e. both food and other goods and services.

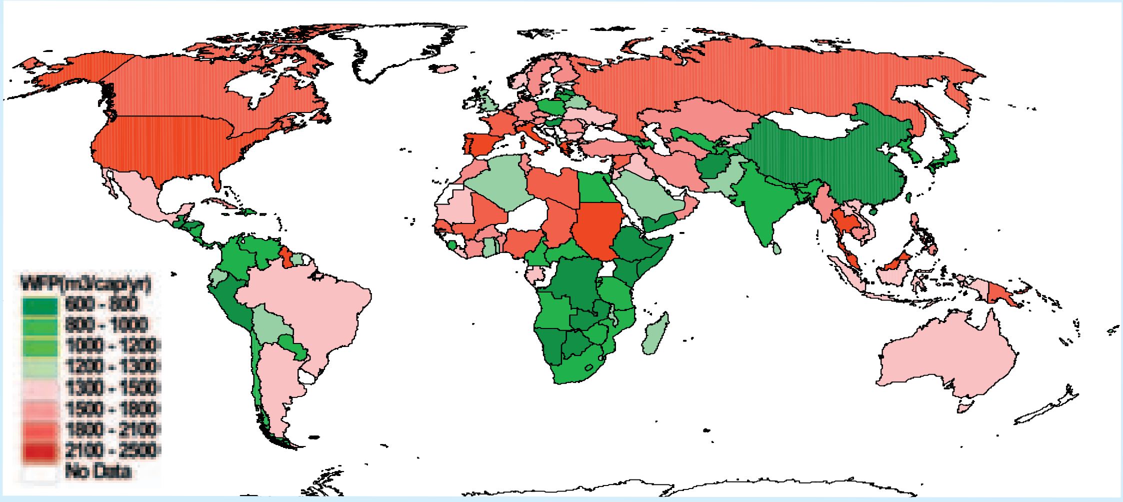

Figure 4.3. Average national total water foot print per capita (m3/capita/yr). Green means that the nation's water footprint is equal to or smaller than the global average. Countries with red have a water foot print beyond the global average. Source: [40].

The increased meat consumption is pronounced. In developed countries, it increased from 57 kg per capita/year in 1961–71 to 76 kg 20 years later. For the LDCs, average per capita meat consumption increased from 10 kg on average between 1961/71, to about 26 kg at the turn of the century [19, 5]. Per capita consumption in the LDCs is, thus, still substantially lower compared to rich countries. The difference is less stark if fish is included. A growth in the aggregate demand for meat products in LDCs from about

The higher the incidence of subsistence farming, the higher the degree of undernutrition.

200 million tonnes in the mid 1990s to about 300 million tonnes around 2020 is expected [41, 19]. A "most likely" scenario over the period 1992/94 to 2020 for meat and milk products projected an annual average increase of 2.8% and 3.3%, respectively [41].

Health and Human Welfare Implications

Undernourishment Ravages the Poor

Increased meat and dairy intake is important for those who are undernourished since protein and micro-nutrient deficiencies could be reduced [41]. However, an increase in consumption of oils, meat and dairy products in terms of fast and street food and snacks, combined with a reduction of dietary fibres, increases the risk for the diet-related non-communicable diseases such as diabetes, obesity and coronary problems [31, 32]. Around the world, the burden of such diseases has increased rapidly, particularly in LDCs. They now account for 47% of the global burden of disease [32].

An increase in consumption of oils, meat and dairy products in terms of fast and street food and snacks increases the risk for the diet-related non-communicable diseases.

On a per capita basis and also in absolute terms, food availability has improved in the world. From 1965 to 2000, the total world production of cereals increased from about 1000 million metric tonnes to about 2000 metric tons according to FAO. On a per capita basis, the situation improved during the same period from 145 to 175 kgs, with notable exceptions [36]. Enough food is produced, but low incomes due to a lack of gainful employment [35] limit purchasing power and access to food for hundreds of millions. The average intake of food in terms of kcal consumption is, however, steadily increasing as illustrated in Figure 4.6. By far, Asia has the largest number of the world's acutely undernourished, with 214 million in India, or about 20% of the entire population. In China, it is 135 million [42]. FAO estimates that about half of the world's malnourished population in 2010 will be in Asia, of which South Asia will account for two-thirds. The good news is that most Asian countries have made progress in reducing this number as well as reducing the rate of poverty. The food consumption in East and South East Asia has increased more than in any other region from 1961 to 2001 [42].

About half of the world's undernourished population in 2010 will be in Asia.

Trends are more disturbing in Africa, where 27% are undernourished on the continent [43]. In Sub-Saharan Africa, the proportion is closer to one-third. In this part of the continent, the increase in undernourishment has been about 20% from late 1960s to early 1990s. For a dozen countries, undernutrition is above 40%, notably in countries that are hit by violent conflict [43, 44]. Added to this is the high prevalence of HIV/AIDS, with truly disastrous effects. For those who are infected, and it is primarily women, the nutritional requirement of protein is about one and a half times higher than for the uninfected, and the need for additional calorie intake is significant. The affected people and their families face a double paradox: more food is required, but the ability to work and acquire the food is curtailed.

Awareness about the linkages between food production, food security and the wider concept of nutrition security is still in its infancy. In the Poverty Reduction Strategies now being prepared in many countries, these linkages have been conspicuously absent, especially in the initial formulations. Some attention is paid to water and sanitation, whereas environmental targets and strategies for nutrition security are very poorly developed [43, 45]. The lack of concern at the national level for these linkages contrasts with the targets set for the Millennium Development Goals (Box 4.2).

Undernourishment Most Severe in Areas Where Food is Produced

In Asia as well as in Africa, the highest rates of undernutrition are in the rural areas, i.e. in areas where food is produced. All hunger spots have an extremely large percentage of the labour force dependent on agriculture [39]. The higher the incidence of subsistence farming, the higher the degree of malnutrition [46]. If stunting for children under 5 is taken as a measuring stick, the prevalence of undernutrition is significantly higher in rural areas as compared to urban areas in a cross section of 18 African countries [43]. A similar situation is found in Asia [39]. Many studies agree that it is the level of poverty that is most obviously related to undernutrition; with more severe poverty, the higher the risk for being undernourished.

Overnutrition is Not Only a Sign of Affluence

Hunger is a disgraceful and terrible phenomenon. But, at least, it is subject to increasing attention (Box 4.2). Also noteworthy is the large and increasing number of people, also in poor countries, who face the opposite ailment, i.e. overnutrition. Most recent articles and reports describe this "changing face of malnutrition" [33, 32]. It is claimed that over a billion people are now overweight and obese and that a majority are found in Asia, the Pacific Islands and Latin America. Obesity affects anywhere from 25 to 50% of the population in countries as diverse as Kuwait, Colombia, the Philippines and China. For hunger stricken Africa, there are still 10 to 15% of the adults who are overweight.

This kind of malnutrition also occurs among the young segments of the population. Nearly 4% of the preschoolers in 32 African countries were overweight. Strangely enough, within the same family, some members are overweight, whereas others are underweight

[47, 33]. To what extent there is a gender bias at the household level is not known at present. Nor is it known whether juvenile obesity can be explained with reference to food habits among the parent's generation or to what extent the inexperience and credulity of children are being exploited in advertisements.

Overweight and obesity, caused by high consumption of energy-dense and often nutrient-poor foods high in fat, sugar and salt content, have many plausible causes. Improper diet in combination with a sedentary lifestyle is an important circumstance, which cuts across various social groups. As noted by WHO "the prevalence of overweight and obesity is increasing in developing countries, and even in low-income groups in richer countries"[32]. It is often women, usually the poor, who are hit by this new plague [33]. Caution is warranted in this regard since overweight and obesity may be caused by different circumstances in the various socio-economic groups.

Trade in Food is Undergoing Rapid Change

With rapid urban expansion and the increasing number of people who are far removed from sites where food is grown, the role of food processing industries and wholesale and retail trade has grown tremendously. This is so even if urban agriculture is important in many urban places. Parallel with the significant increase in consumer food purchases, which are estimated globally at USD 2.7 trillion, the development of supermarkets is radically and rapidly changing the options for the consumer.

Equally important, the new food trade alters the conditions for the primary food producers to supply the food demanded [48, 31, 49]. The small producer generally does not have the capacity to deliver the volume of food items that the large supermarket chains demand. Nor are they able to meet the quality standards and other requirements that are a common condition in the wholesale trade, especially in branded items. Moreover, some supermarket chains and food processing industries operate on a global basis. In the report "Power Hungry" that was presented in Porto Allegro in January 2005, figures are presented which illustrate the enourmous concentration of food processing, trade and markets for inputs in food production, to a few corporations. For instance, six companies control about 75% of the world trade in cereals, three companies take care of 85% of the trade in tea. As part of the new situation, local producers have to compete with food producers elsewhere. Variations in subsidies and other support, within and between countries, systematically place the small and poorly organised food producers at a disadvantage.

The rapid development of this kind of food trade serves the interest of the consumer both in terms of competitive prices, wide choice and convenience. This trade also implies a certain quality control of the products. This does not mean quality control or environmental consideration at the site of production. It is like buying a car or other goods; the consumer has considerable difficulties to find out how the good is produced. For most consumers, the important consideration is how well the purchased good fulfils the expectations for use or consumption.

The very strong connections between consumer interest and preference, the food processing industry and food trade interests create an iron triangle. A huge number of small food producers are today marginalised. Apart from social consequences, the production potential in the areas where small producers live may also be marginalised and cut off from the global food system.

Changing Food Consumption Patterns and Pressure on Water and Land Resources

Increase in the relative share of meat and dairy products in the diet implies a more intense pressure on land and water resources (Chapter 3 and Box 4.1). However, if the cattle graze on land which cannot be used for other

Connections between consumer interest and preference, the food processing industry and food trade organisations create an iron triangle.

New food trade alters the conditions for the primary food producers to supply the food demanded.

Photo: Mats Lannerstad

Water is a common denominator in the huge efforts that are required to achieve the MDGs.

Box 4.2

Sustainable Food Consumption, Water and the MDGs

A renewed commitment to improvement in human development and environmental sustainability was formulated at the UN Millennium Summit in 2000. With a coordinated set of activities, the pledge was to "..free our fellow men, women and children from the abject and dehumanising conditions of extreme poverty ...and to making development a reality for everyone". Eight goals were specified – the Millennium Development Goals (MDGs). Targets have been set for each goal with 2015 as the year when specified improvements should be accomplished. The MDGs are:

1. Eradicate extreme poverty and hunger
2. Achieve universal primary education
3. Promote gender equality and empower women
4. Reduce child mortality
5. Improve maternal health
6. Combat HIV/AIDS, malaria, and other diseases
7. Ensure environmental sustainability
8. Develop a global partnership for development

Food and nutrition security is directly related to MDGs 1, 2, 4, 5, 6 and 7. Water is a common denominator in all MDGs.

In order to half the number of undernourished by 2015, as stipulated by the target for MDG 1, the rate of decrease must be increased (Figure below). For the world as a whole, the annual reduction in the number of undernourished has been about 2 million during recent decades. The new Millennium could not have started more badly: instead of an accelerated decrease, as pledged, the number increased [31].

Increase in the relative share of meat and dairy products in the diet implies a more intense pressure on land and water resources.

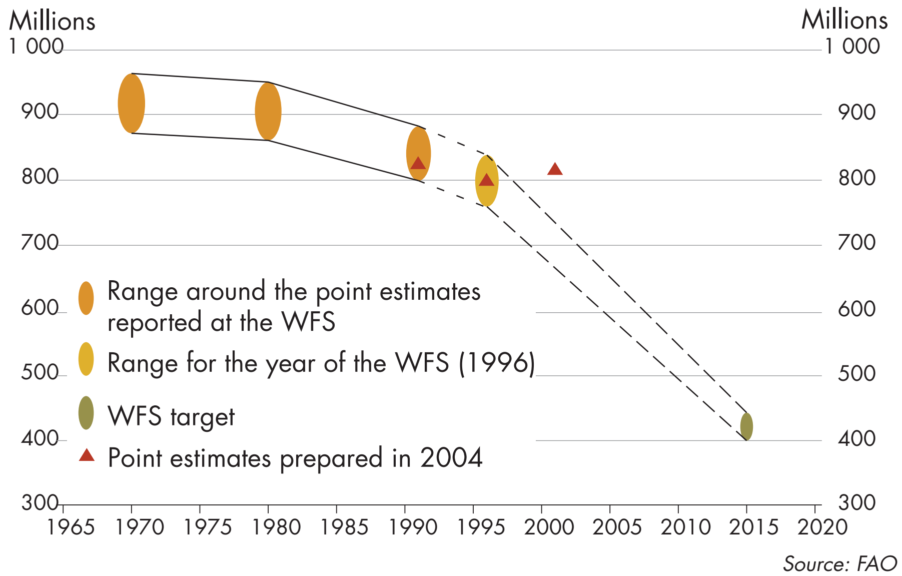

Figure 4.4. Number of undernourished in the developing world: observed and projected ranges compared with the World Food Summit target. The dotted lines illustrate that the reduction in the number of undernourished must accelerate substantially if the MDG targets for 2015 should be achieved. Instead the estimates prepared in 2004 (the triangles) show that the number of undernourished has increased. Source: [31].

The consumer has considerable difficulties to find out how the good is produced.

food production, the implications are quite different as compared to meat production in feedlots. Estimates are that 43% of the world's beef comes from feedlots and indicates that more than half of the world's pork and poultry are raised in factory farms [50]. With current trends in food trade and with application of quality standards, which are particularly important in the meat and dairy sector, the increased demand for these food items will largely have to be met through production in a context where part of the fodder is produced on crop land.

So far, global figures show that the production of cereals for food has increased more rapidly compared to cereals for feed (Fig. 4.5). But the area used to grow fodder crops increases and will compete with area used to produce for direct food crops. Similar trends are reported from many parts of the developing countries, e.g. the Asian region [39].

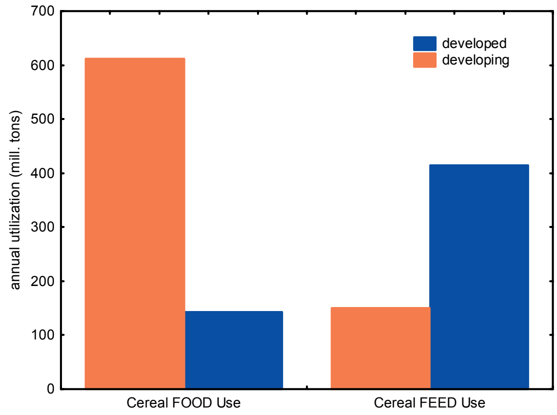

Figure 4.5. Comparison of total cereal use for feed and food consumption by region, 1981–1994. Average annual utilisation (million metric tons). Data: [19]

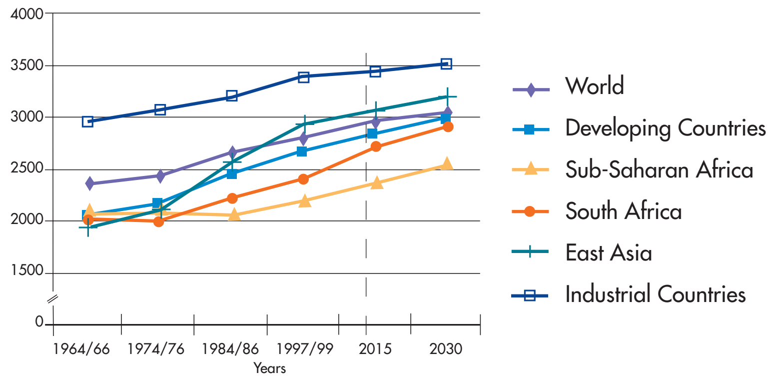

Figure 4.6. Projected per capita food consumption in kcal per person per day, from 1964 towards 2030. Source: [5]

What Can Be Done?

An important message in the discussion above is that social-economic-political circumstances on the trade and consumption side are most important in terms of the size and orientation of food production. These circumstances are key in explaining why some 850 million people are undernourished and a similar number overweight and obese. Currently, it is thus not only the physical resources context which dictates how much and what kind of food is produced, nor where it is produced.

However, as discussed in Chapters 3 and 5, it would be fallacious to overlook the tremendous challenges in terms of resource endowments and environmental implications to produce the required amounts of food. Trends in consumer food preferences, demographic trends and legitimate claims for food security for all, will substantially increase the pressure on the earth's biological production capacity. Food policies must increasingly consider what a proper composition of the diet entails.

Figure 4.6 illustrates that the trends in food intake, in terms of calories, are increasing on all continents according to projections made by FAO [5]. A projected daily per capita intake of about 3,000 Kcalories around 2030 is quite high from a nutritional requirement point of view. Equally important, it implies an accelerated pressure on land and water resources. Suggestions about what constitutes a proper and sound energy intake and diet composition vary. The international norm of a daily per capita intake of 2,700 Kcalories is often used as a reference. With this level as a general norm, it is assumed that the variation in food intake that exists in a country will ensure that also the people who are below the norm would still not risk being hit by undernutrition. Substantially lower levels are used in some contexts. For urban India, it is assumed that 70% of this norm, i.e. a calorie intake of 1,890 Kcal/person, day, is still regarded as acceptable from a nutritional point of view for an "urban consumer unit", i.e. a weighted average for an urban dweller [39, 42].

Social-economic-political circumstances on the consumption side are most important in terms of the size and orientation of food production.

Obviously, the pressure on the world's land and water resources is very much related to the average food intake. With an increasing number of consumers and with an increasing purchasing power, the related augmentation in the demand for food items and the associated implications must be analysed. Current trends in the overconsumption of many food items are likely to result in additional public health problems. They also contribute to an increased resource pressure in a situation which is already alarming in many parts of the world.

Since food production is, increasingly, geographically and otherwise separated from consumption, the role of the wholesale and retail trade and food processing industries is very important. The dynamic growth of these organisations is part of the globalisation of the food production and consumption pattern. While this provides opportunities for both exporting and importing countries, it also entails new and tough conditions for the small-scale, unorganised food producer. It also implies that consumption is geographically separated from the environmental implications from production.

Consumption is geographically separated from the environmental implications from production.

All in all, a conclusion is that a much more integrated perspective is required of the linkages and the driving forces between production, trade and processing and consumption of food.

5. Towards an Ecologically Sustainable Food Production

Photo: Mats Lannerstad

Main Message

Overuse of river flow and groundwater aquifers, i.e. the blue water resources, already occurs in much of the world, and continues. Prevailing water abstraction is the consequence of a focus on direct water requirements of humans while overlooking the water requirements of ecosystems. Policies for the required changes to secure ecosystem goods and services include:

- A system for water allocation monitoring for all uses, including for environmental flow requirements and protection of biodiversity
- Design of economic incentives and regulatory arrangements for allocation and use(r) rights
- Systems for valuing water from all different aspects, including social, economic and ecological values
- Education programs for improved understanding of the ecological implications emanating from changes in the quantitative and qualitative features of water flow

Maintaining Ecological Sustainability Has Four Main Aspects

Achieving ecologically sustainable food production requires the development of better ways to cope with a crucial set of challenging phenomena:

- Plant growth involves a biophysical process of consumptive water use, whereby huge amounts of water move from the soil to the atmosphere
- Semiarid climates have particular challenges to meet water requirements for unimpeded grain production; drought and dryspell protection by irrigation, either large-scale or small-scale, is crucial
- Many tropical soils are particularly vulnerable to erosion, crust formation and salinisation
- Since soil nutrients taken up by plants are carried away with the produce, they have to be replenished through fertilisation

Intensive crop production implies high pressure on water resources and risk for an undermining of the productive potential of the soil. If unchecked, this undermining threat-

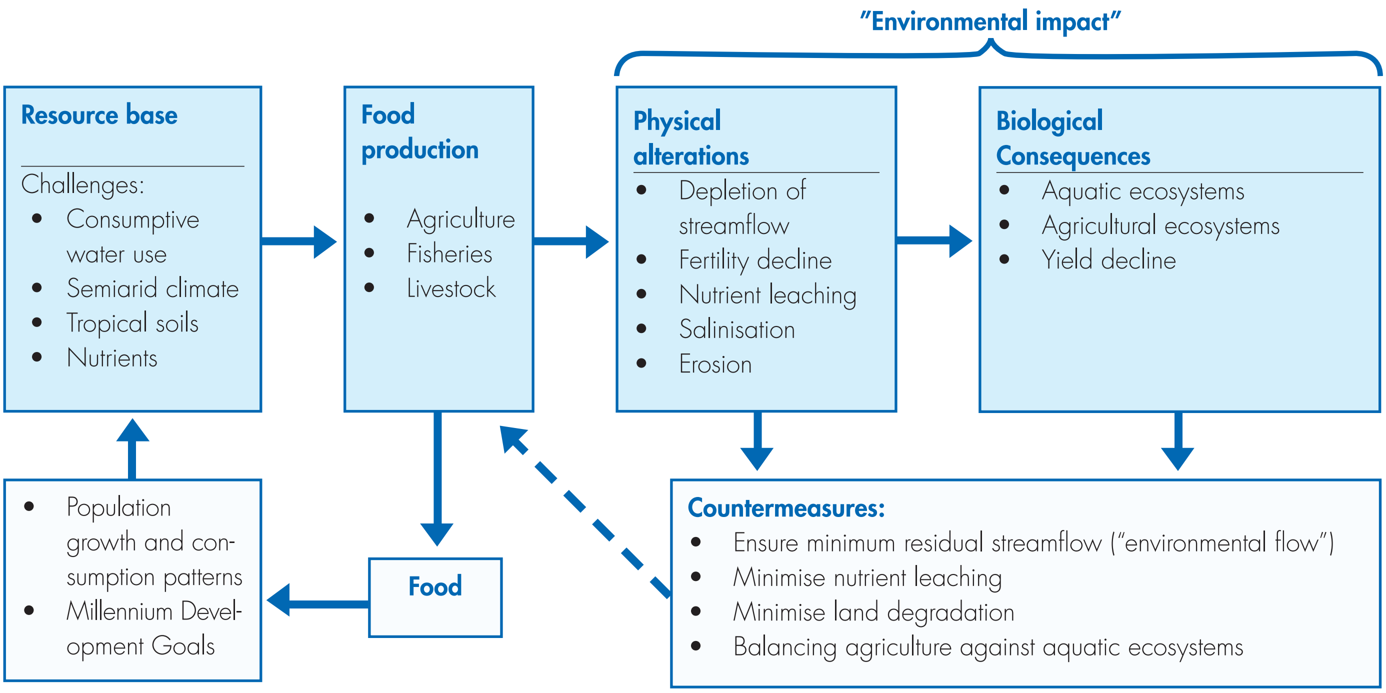

Figure 5.1: Links between food production to meet global food needs; environmental impacts generated by agricultural practices; and possible countermeasures towards environmental sustainability.

ens the ecosystem's ability to provide goods and services and has four main manifestations: streamflow depletion, groundwater overexploitation, nutrient leaching and land productivity decline by erosion and salinisation.

Reduction of River Flow by Consumptive Blue Water Use in Irrigated Crop Production

Large consumptive water use in irrigation-dependent areas causes widespread streamflow depletion (Box 5.1). The consequences are particularly evident in closed lakes – the most notorious examples being the Aral Sea and the Dead Sea. Where water inflow to marshes is reduced, as in the Sultan Marshes in Turkey, a complete drying out may occur. Dropping water levels cause considerable damage to wetland habitats, flora and fauna.

Overexploitation of Groundwater for Irrigation in Small-scale and Large-scale Farming

Groundwater is depleted wherever withdrawals exceed the natural recharge, with the effect being decreased

Four main problems: streamflow depletion, groundwater overexploitation, nutrient leaching and land productivity decline by erosion and salinisation.

Box 5.1

River Depletion

River depletion reduces river flow, in some cases from perennial to intermittent. Consumptive water use by irrigation is the major reason [51]. Streamflow reduction also reduces dilution capacity and leads to reduced quality. Dropping river flows may imperil societal development, increase competition between upstream and downstream users, and threaten freshwater and coastal ecosystems.

The clearest example is the Aral Sea, which was once the world's fourth largest. Irrigation along the tributary rivers Amu Darya and Syr Darya has reduced this inland sea's area by half and volume by three-quarters. Disappearing deltas hastened the decline of habitat and endemic species. A collapsed fishing industry and human health problems are among the societal effects [52].

The water in the Colorado River supports irrigation of 800,000 hectares and supplies drinking water to 25 million people. Since 1960, discharges to the California Gulf have been rare [53].

The naturally perennial Indus River irrigates 14 million hectares in Pakistan. During on average 81 days of the dry season and 26 days of the wet season, there is no outflow to the Arabian Sea. Just 21% of historic dry season flow reaches the delta ecosystems [54].

In 1972 the Yellow River mouth dried up for the first time. In 1997 the dry-up lasted 226 days and reached 700 kilometres upstream. Reduced dilution of industrial effluents threatens the health of millions. Little or no flow also leaves the fertile delta plains without irrigation water and cause extensive siltation, posing a threat to river dikes during flooding [55]. Efforts are ongoing to improve and maintain downstream streamflow.

Dropping river flows may imperil societal development, increase competition between upstream and downstream users, and threaten freshwater and coastal ecosystems.

During the 1960s and 1970s, Gujarat coastal farmers experienced a tube well economy boom. Now saline sea water intrusion in depleted aquifers reaches 7 kilometres inland and causes socio-ecological collapse in many villages.

Box 5.2

Groundwater Overdraft

Since 1950, the development of geological knowledge, well drilling, pump technology and rural electricity infrastructure has enabled extensive groundwater exploitation [56]. Estimated global groundwater use in 1995 was more than 800 km^3[22]. Two-hundred cubic kilometres (200 km^3) is overdraft of non-recharged groundwater and sufficient to produce 180 tonnes of grain, or about 10% of the global harvest. The major groundwater depleting nations during the mid 1990s were India (104 km^3), China (30 km^3) and the USA (14 km^3) [1].

Seckler estimated that a quarter of India's harvest relies on groundwater overdraft [57]). In North Gujarat 30 years ago bullock-bailers lifted water from wells which were 10–15 metres deep. Today, tube wells often pump fluoride contaminated groundwater from 400 metres depth. During the 1960s and 1970s, Gujarat coastal farmers experienced a tube well economy boom. Now saline sea water intrusion in depleted aquifers reaches 7 kilometres inland and causes socio-ecological collapse in many villages (Shah et al 2000).

The Ogallala aquifer underneath the U.S. Great Plains covers an area of 453,000 km^2 and waters one-fifth of the USA's irrigated land. The annual overdraft is estimated at 12 km^3. In 1978 Ogallala irrigation peaked at 5.2 million hectares. Due to falling water tables only 60% is projected to stay irrigated by 2020 [1].

The North China Plain has a population of 200 million, embraces 64% of the national farmlands and produces half of China's wheat crop and one-third of its the maize [58, 57]. The groundwater table under Beijing has fallen 59 metres since 1965 [59], and the Chinese Ministry of Water Resources is concerned that, unless reduced to sustainable levels, there are risks of "effectively destroying the groundwater dependent agriculture base, massive subsidence and sea water intrusion, virtual elimination of groundwater as a water resource for many cities and countless households and the loss of 'insurance' water for the future generations" [59].

Groundwater development on the Northeastern China Plain has been key to the huge economic growth of the region and the achievement of self-sufficiency in food production.

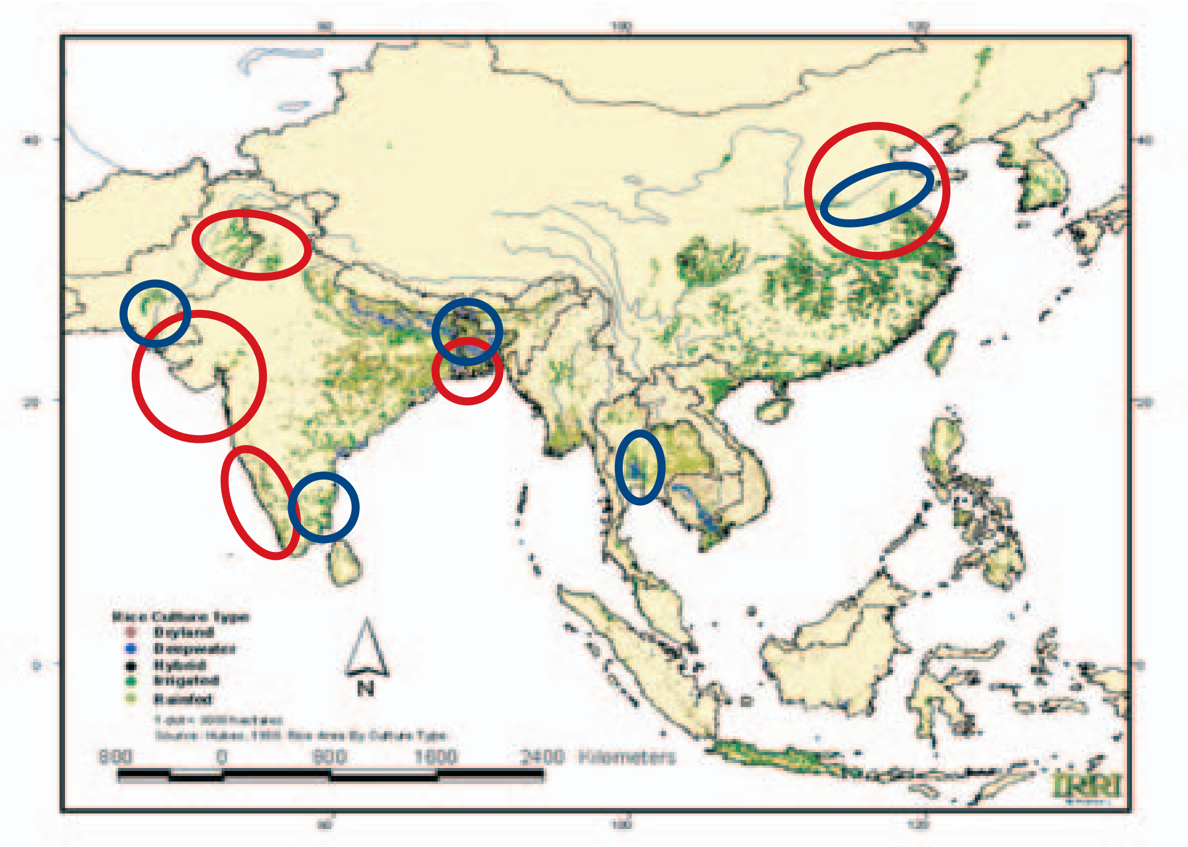

Figure 5.2: Major hot spots of groundwater depletion (red circles) and reduced river water flows (blue circles) in Asia. Source: [26]

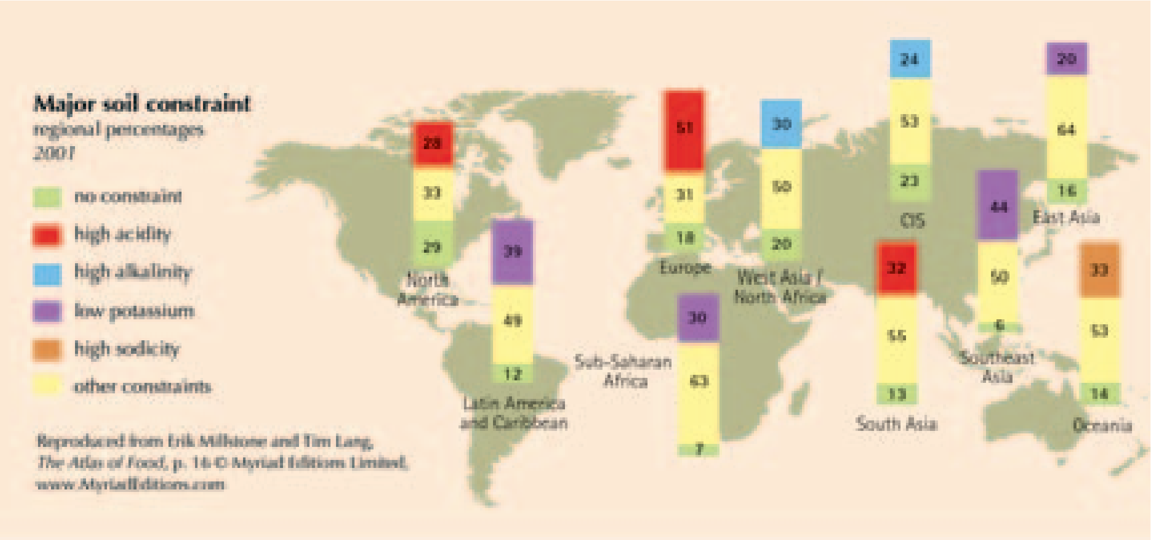

Figure 5.3: Main types of soil fertility problems and their relative importance. From Millstone & Lang, 2003.

Where nutrient loss is not compensated by fertiliser application or by shifting cultivation, nutrients are depleted, a kind of "soil mining".

water tables. Significant declines have been noted in several Indian states (Haryana, Tamil Nadu, Rajasthan and Gujarat), stimulated by an electricity subsidy policy. The scale of the current groundwater mining on the North China Plain has been assessed at some 10 km^3/yr; in Mexican aquifers it is circa 5 km^3/yr [56] (Box 6.2). Groundwater development on the Northeastern China Plain has been key to the huge economic growth of the region and the achievement of self-sufficiency in food production [60]. Here, one of the largest aquifer systems in the world has contributed to large socio-economic benefits, which in return has resulted in a massive and continuing water table decline, hundreds of thousands of dry wells, sea water intrusion, land subsidence over vast areas and groundwater salinisation. This is a potentially disastrous problem since at the current rate of extraction, the groundwater resource will be depleted within a few decades.

Massive Leaching of Agricultural Chemicals to Rivers, Groundwater and Coastal Waters

Leakage of nitrogen (N) and phosphorous (P) from agricultural systems causes major environmental problems. Should present trends continue, global N-fertilisation would increase annual fertiliser usage by 60% by 2025 and 170% by 2050 [61]. Great quantities of N and P from fertiliser and animal wastes enter surface and groundwater systems. Nitrogen is lost largely through drainage, and phosphorous both through drainage and erosion.

In semiarid climates with little groundwater recharge, small nitrate losses nonetheless cause high levels of nitrate in groundwater. In Europe, leaching of nitrate-N has increased in parallel with the increased use of inorganic fertilisers. Similarly, the use of large amounts of manure is associated with high risk for large leaching losses.

Massive Reduction of Land Productivity in Both Irrigated and Rain fed Agriculture

More than 80% of the world's arable land suffers soil degradation, reducing its productivity [62]. While an erosion of 10 tonnes/hectare per year is considered an absolute limit for sustained agriculture, erosion in semiarid tropical areas with intense seasonal rains may be as high as 30 tonnes/ha-yr. Where nutrient loss is not compensated by fertiliser application or by shifting cultivation, nutrients are depleted, a kind of "soil mining". For the past 30 years, nutrient levels have declined steadily in Africa. More than 10% of irrigated land is severely degraded by accumulation of salt; almost three times as much are affected by salinisation and water logging [63].

In the inflow-depleted Lake Ichkeul in Tunisia, salinity has increased and severely affected the vegetation.

In Australia, European-style agriculture was ill suited to the old and fragile soils, leading to land and water degradation problems by erosion, dryland and river salinisation, soil acidification and biodiversity decline. Dryland salinity adversely affects agricultural or pastoral yields on some 3.3 million hectares, while ultimately 17 million hectores are at risk in 50 years. Also here, salinisation is a frequent problem on overirrigated land when appropriate drainage is absent.

Effects on Aquatic Ecosystems*

Water is the determining factor in aquatic ecosystems. As such, river flow, groundwater modifications and increased pollution are important contributors in the

*examples from www.iucn.org

Photo: Michael Moore

large-scale degradation of aquatic ecosystems, which is often the combined response to river depletion, nutrient leaching and water pollution. There are also river fragmentation effects due to damming and physical alterations in rivers. The broader importance of ecological systems means that ecosystem effects have socio-economic consequences, more or less severe.

Rivers

Streamflow depletion generates ecological effects that primarily hit downstream stretches and delta ecosystems. In the lower reaches of Spain's Ebro River diversions upstream have decreased the flow to the mouth by some 40%. Reduced sedimentation rates and a lack of accretion are leading to coastal retreat and land subsidence. With modern agriculture the delta faces the threats of pesticides and eutrophication. In the Indus, the floodplains and wetland ecosystems of the delta have been severely degraded. Streamflow depletion in Lower Moulouya in Tunisia has decreased by 66% and silt flow been reduced to only 7% due to dam silting. The river delta is now retreating sharply at an average of 10 metres per year. Increased water and soil salinity has caused agricultural land to be abandoned. Lost fishing, aquaculture and shellfish opportunities in the lower course means lost revenue.

The soil nutrient losses in Sub-Saharan Africa are an environmental time bomb.

Wetlands and Lakes

Groundwater-fed wetlands are vulnerable to groundwater extraction. The Aamiq Wetland, a Ramsar site in Lebanon which used to be flooded throughout the year, is now reduced to a few small pools for half of an average year. In the Sultan Marshes in Turkey, socio-ecological effects have followed from the damaged reed systems. More than 80% of the surrounding population have been cutting reeds to earn income from export to Northern European countries. In the inflow-depleted Lake Ichkeul in Tunisia, salinity has increased and severely affected the vegetation. The reed belts disappeared together with the rushes, which were the main food of wintering birds. A bird population which numbered some quarter of a million no longer has any nesting cover in the vegetation. The water salinity became too high for many fish, and catches collapsed.

Coastal Waters

Streamflow depletion, nutrient loads and altered silt flows generate alterations of coastal habitats. The result may be major ecological effects on coastal ecosystems. Eutrophication, overfishing and aquaculture are major threats to marine biodiversity [61]. In the global assessment of key environmental problems performed by the Global International Waters Assessment (GIWA), moderate or strong impact is caused by eutrophication in 31 out of altogether 88 coastal waters, and by water scarcity/streamflow depletion in 30 regions (GIWA). Agricultural nutrient pollution has led to increased blooms of toxic algae in many coastal systems and to large dead zones in, for example, the Gulf of Mexico, the Black Sea and the Baltic Sea.

Effects on Agro-ecosystems: Decreasing Yields

The soil nutrient losses in Sub-Saharan Africa are an environmental time bomb [64]. Unless these disastrous trends are reversed, the future viability of African food systems will be imperilled with severe socio-economic effects.

The problem originates from the abandonment of shifting cultivation, which in Africa resulted in an agrarian crisis [6]. While in the temperate zone, this phase of agricultural development was solved through nutrient transfer from animals and later fertilisers, now with yields of 6–10 tonnes per hectare, the nutrient loss in Africa has not been compensated for by a new management strategy for soil fertility. The farming systems have therefore dropped down to a lowered agro-ecological level, resulting in a "one-tonne-per-hectare agriculture". African farmers often abandon degraded pastures and cropland and move to new lands as a response to declining soil productivity with yields low. From the economic point of view, it is cheaper for them to move to new land and exploit those resources rather than stay and rehabilitate already degraded lands.

What Can Be Done to Minimise Environmental Degradation?

Secure Minimum Residual Streamflows

Countermeasures to minimise environmental degradation include securing a minimum residual flow (so-called environmental flows), flood release and adequate flows for fishery. The environmental flow requirements consist of ecologically relevant low-flow and high-flow components and depend on the objective in terms of the acceptable conservation status (natural, good or fair) (Box 5.3) [65]. Due to the conflicts of interest, acceptable minimum flow is, however, essentially a political decision. South Africa has assessed such flows for all its more important river basins, and determined that some 20 to 30% of natural streamflow was necessary. In the Sabie River in South Africa, a sophisticated, participation-based methodology was used to determine desired river recommended flows. These were then divided into low and high flows for maintenance and drought years. In the Mekong, the downstream countries require river flows to continue close to natural levels in order to maintain fisheries and rice production in the Delta and prevent salinity intrusion. One of the first milestones faced by the environmental flow assessment efforts in the Mekong was a World Bank requirement that guidelines to ensure flows be incorporated in the Mekong Agreement 1995 and be in place by July 2004.

In already overappropriated rivers, minimum streamflow has to be secured through:

- Producing the same amount of food with less evapotranspiration and allocating saved water to rivers, or through fallowing land
- Reducing evaporation from soils, water bodies and high water tables
- Reducing flows to sinks such as saline aquifers or drainage flows directed away from river systems and into the sea

One of the biggest misconceptions is that increasing the efficiency of irrigation from 40% to 60% could save enormous quantities of water.

One of the biggest misconceptions is that increasing the efficiency of irrigation from 40% to 60% could save enormous quantities of water. In river basins, drainage flows are often not wasted but can be reused. Efforts for water savings thus need to be redirected at the three points above. More precise irrigation methods like drip irrigation may not lead to real water savings (unless evaporation is reduced) but can boost yields and water productivity, with less fertiliser leaching.

Due to the conflicts of interest, acceptable minimum flow is, however, essentially a political decision.

Another countermeasure to reduce the ecological impacts from consumptive water use in agriculture is short-term flood releases [66], advocated since the 1980s. In the Lower Indus, it is recognised that water demand management needs to be implemented so that water for the express purpose of flooding the Delta can be released. In the Senegal River, controlled release from the Manantali Dam was used during a transitional period to give riparian communities which were responsible for cultivating 50,000 hectares time to move from "recession" agriculture to full-scale irrigated agriculture. Through artificial flooding over the past eleven years of the Diawling delta in Mauretania, a dramatic ecosystem recovery has taken place,

Box 5.3

Ecological Water Requirements

Ecological water requirements, known as "environmental flows", are commonly defined as the flows in a river that are necessary to sustain aquatic ecosystems and the valued goods and services that they provide such as fisheries, ecotourism, flood plain agriculture and natural purification of passing waters. Assessing the environmental flows of rivers and investigating the correlation between flows and fish catch form essential components of decisions regarding water resource allocations at a river basin scale. A flow assessment should take into account not only the quantity of water needed to maintain socially acceptable levels of ecosystem health, but also other important characteristics of the natural flow regime, such as frequency of flows, timing and duration of flow events and rates of change

There are many difficulties, however, facing further assessment and implementation of environmental flows, including the lack of understanding among decision makers of the socio-economic benefits associated with flows, a lack of political will to implement flow scenarios, the relatively new and complex tools for assessing water requirements, and the need for technical support and scientific data for effectively determining flow scenarios for each unique river system. Despite these challenges, future management of water must continue to work towards achieving a sustainable balance between water for agriculture and water for natural ecosystems that are dependent upon adequate river flows.

Future management of water must continue to work towards achieving a sustainable balance between water for agriculture and water for natural ecosystems.

Maintenance of soil organic matter is a delicate task in tropical agriculture.

Wastewater reuse in agriculture is also increasing. It is estimated that up to 10% of all irrigation water used in developing countries is reused wastewater.

A whole set of success stories have been reported in an International Water Management Institute (IWMI) study on so-called "bright spots".

Through artificial flooding, a dramatic ecosystem recovery has taken place, allowing market gardening and drinking water provision.

allowing market gardening and drinking water provision. Fish catches have increased by two orders of magnitude. The Mauretainian authorities are even planning to establish a biosphere reserve [67].

Minimising Nutrient Losses

Water and nutrient use efficiency for a good crop yield demands optimisation of the factors simultaneously; too much water may lead to nutrient loss, especially nitrate, through leaching, while for phosphorus it is the erosion that is the serious problem [68]. Methods are needed to efficiently close the nutrient cycle from soil to livestock and back to agricultural soil. In terms of fertiliser use, split applications balanced to the current need of the crop improves both yield and net loss of nutrients and are fairly easy to introduce. Drip irrigation gives especially favourable conditions for such applications as the fertiliser can be dissolved in the irrigation water.

Wastewater reuse in agriculture is also increasing. It is estimated that up to 10% of all irrigation water used in developing countries is reused wastewater. In Addis Ababa, a system of public toilets is being tested to facilitate use of urine and faeces in agriculture. On the positive side, this use of wastewater and nutrients contributes to livelihood opportunities; conversely, it imposes health risks.

In Europe, catch or cover crops have been used as a countermeasure against nitrate leaching. The catch crop can take up considerable amounts of nitrogen after harvest of the main crop in the autumn, and thereby reduce leaching considerably. Methods that reduce soil erosion – ground cover, conservation tillage, etc. – will reduce the transport of phosophorus to rivers and lakes. Planting shelter belts along open water bodies may also reduce water-carried losses of phosphorus to acceptable levels.

Minimising Land Degradation

Numerous programs and nongovernmental organisations (NGOs) are promoting adoption of organic and low external input methods of soil fertility replenishment, including the incorporation of leguminous trees and shrubs into improved fallow systems, planting of leguminous cover crops, application of manure and compost, and biomass transfer [69]. Maintenance of soil organic matter (SOM), which has quite a number of functions in soil, is a delicate task in tropical agriculture. Net losses of several hundred to thousand kilograms of carbon per hectare per year are common in tropical countries. Strategies that improve SOM levels include: no or minimum tillage, improved fallow using leguminous species, meticulous caretaking of crop residues and manure, inorganic fertilisers increasing crop residues and yield, and agroforestry.

Encouraging results from agro-ecological approaches have been achieved in Africa. One example is the Senegal Regenerative Agriculture Center (SRAC), which promotes sustainable agriculture based on soil regeneration for small-scale farmers. The cropping system is legumes intercropped with cereals, and compost used to restore soil fertility. There are, however, also constraints: they are very labour intensive (e.g., composting, manuring, biomass transfer) and transporting such bulky and low-value inputs is time consuming and costly.

A whole set of success stories have been reported in an International Water Management Institute (IWMI) study on so-called "bright spots" [70]. Some 11 million farmers working a total area of 32 million hectares increased yields by 60%. Key elements were the reduction of drought risk and adoption of innovative practices to reverse soil degradation while maintaining or enhancing food security. While community-based projects were generally catchment-oriented development projects where leadership, social capital and community participation were the three most important elements, technology-driven cases were generally led by individual farmers with secure access to land. However, without external support (financial and otherwise), the ability to replicate and scale up these successes will be restricted.

Photo: SIWI

Infrastructure development should also be enhanced. Increasing credit to farmers or cost sharing as a short-term strategy should be considered if capital is the major constraint [71]. Some experts suggest that the debate on (selective) subsidies for fertiliser and even soil conservation measures that are a net benefit to society should be reopened. Research and technical assistance programmes that will investigate and promote use of fertiliser and other inputs must also be explored [69].

Balancing Agricultural Production Against Protection of Aquatic Ecosystems

A strategy for the integrated management of land, water and living resources, developed with stakeholder participation, will have to address the challenges of resolving conflicting interests between fisheries and various sectors concerned with human development and environmental conservation, according to the Penang Statement in January 2004. An interesting case of balancing water needs between food production and aquatic ecosystems is the Murray-Darling basin in Australia [72]. This case reflects a dramatic shift in community values, and involves satisfactorily resolving difficult issues of common interest, and the decision to adopt a vision of a healthy river system.

This Australian catchment shares a number of features with other arid catchments around the world, including problems with water productivity, water quality, soil salinity, rising water tables and interactions between surface and groundwater. Management of water resources in the regions requires a rigorous understanding and application of hydrology combined with economic, policy and legal aspects of water management. The tools include innovative hydrologic, economic and community education tools developed by the Commonwealth Scientific and Industrial Research Organisation (CSIRO) for natural resources management. These models and community participation activities are readily transferable to other parts of the world. They are being used in the Yellow River in China, and the Indus River. There is considerable interest in applying them in South African catchments.

Awareness Raising

Although it is increasingly felt that ecosystems should be seen as forming an important component of "water infrastructure", water decisions have in many cases proved to be financially and economically insufficient [73]. Ecosystem degradation leads to declining future profits, increasing future costs and additional remedial measures for water investors. Economics remain a powerful factor in decision making. Payments for ecosystem goods and services can be useful to highlight the linkages between upstream and downstream uses and impacts. Quantification of ecosystem benefits allows comparisons to other economic sectors and activities. Economic valuation can thus provide a convincing argument for placing ecosystems on the water and development agenda, alongside other considerations in decision making.

In the case of the Vomano River in Italy, an environmental scorecard was developed to quantify and compare the environmental performance of different policies. In Australia, when scientists were able to tell policy makers that land and water degradation were a billion dollar problem, notice was taken at the highest level of government.

Educating school groups of all ages is particularly important [74]. They are the future water users and will soon be the ones making a difference and making decisions. In Australia, CSIRO experts have developed an extensive program for school visits, putting focus on learning in a creative, illustrative and interactive fashion, and often with hands-on components.

Co-ordinate Land and Water Governance

Since practises upstream directly influence the flows downstream, and thus wetland ecosystems and delta regions, an integrated approach will be needed for the entire river basin. Integrated Water Resources Management (IWRM) is recognised as a fundamentally important approach in order to pursue sustainable development. In the efforts to restore the degraded Sultan Marshes in Turkey, there is no alternative to an integrated management approach but to restore the ecosystem. Securing the environmental flows needed for the marshes is, however, complicated since it is not in the hand of one single decision-making body. A difficult challenge is also the translation of the environmental objective into a well-defined and quantitative measure that can be used in mathematical modelling and optimisation tools to evaluate the effect of different management policies. Such translation would be helpful to inform negotiators and policy makers on environmental flow requirements and measures to provide them.

In Australia, land degradation and water issues have achieved a political high profile, which has led to a range of innovative policy, administrative, scientific and economic responses. Motivated to act by prospects of declined terms of trade, farmers have been willing to adopt scientific and technological solutions to stay in business. Landcare, Bushcare and Coastcare programs mobilise communities into action at local levels to address erosion, salinity, acidification and biodiversity decline, and encourage localised best-practise management solutions. Landcare operates in rural Australia, involving 40% of the farmers who manage 60% of the land.

When scientists were able to tell policy makers that land and water degradation were a billion dollar problem rather than a tens of million dollar problem, notice was taken at the highest level of government in Australia.

Landcare, Bushcare and Coastcare programs mobilise communities into action at local levels.

An interesting case of balancing water needs between food production and aquatic ecosystems is the Murray-Darling basin in Australia.

Securing the environmental flows needed for the marshes is, however, complicated since it is not in the hand of one single decision-making body.

6. Links, Synergies and Trade-offs

It is important to identify links and synergies as well as build awareness of possible, and often unavoidable trade-offs.

Main Messages

In pursuit of the human livelihood improvements identified in the UN Millennium Goals (MDGs), the co-ordination of efforts in many areas is crucial.

- By co-ordinating efforts for food and nutrition security, substantial synergy is possible
- Political and collective will and commitment must be combined with management ingenuity and entrepreneurship

In recent decades, high-level policy recommendations have underscored the importance of placing development and security in a wider perspective. Commonality has been a recurring theme. The Brundtland Commission emphasised work towards a "common future". The Palme Commission preached "common security", and the Brandt Commission elaborated on the "common crisis". A principal message throughout has been that development and security are complex phenomena which cannot be achieved unilaterally within conventional and narrow perspectives.

Ensuring food and nutrition security is a basic challenge in the MDG targets, but securing livelihoods and sound development will continue to be a huge task beyond 2015.

This wider principle approach permeates today's global development roadmap as reflected in the Millennium Development Goals (MDGs) and their associated targets (Box 4.2). The MDGs recognise that improvements in human livelihoods cannot be effectively accomplished or sustained by improvements in individual sectors alone. Each goal needs well-defined packages of technologies, incentives and services. Yet, it is important to identify links and synergies as well as build awareness of possible, and often unavoidable trade-offs between the various packages.

Ensuring food and nutrition security is a basic challenge in the MDG targets, but securing livelihoods and sound development will continue to be a huge task beyond 2015. Fierce and mounting competition for the natural resources of water and fertile land, threats from pollution, loss of biodiversity and general ecological degradation do not manifest themselves in statistics on Gross Domestic Product, and are only indirectly considered in the Human Development Index. Nevertheless, they are very real circumstances and have implications on the factual opportunities to reduce hunger and provide sustainable livelihoods for millions and millions of people on a long-term basis.

Photo: FAO/19848, SIWI, FAO/11764/W. Gartung, SIWI

Synergy and Trade-offs Between MDG Commitments and Development

The sufferings caused by undernutrition and overnourishment on human beings are immense. They cripple not only those who are affected, but also their families. They drain the pocketbooks of families and societies. They rob from those who could contribute to development the ability to do so.

There is "no such thing as a free lunch". Investment needs are staggeringly high in view of the budget constraints in both developed and developing countries. Achieving the goals of the 1996 World Food Summit – to halve the number of chronically hungry by half, i.e. the same as the MDG No. 1 – will cost USD 24 billion annually from public coffers [31]. Investments, however, should be seen in the wider view: an annual increase in GDP of USD 120 billion is a likely result of longer, healthier and more productive lives. To reduce child malnutrition by half, it is estimated that the level of investments need to be increased from about USD 430 billion to USD 592 billion between 1995 and 2015 (Figure 6.1) [46].

A reluctance to honour the pledges that have repeatedly been made is not rational. The consequences of not acting and doing what can be done are infinitely more troublesome than the enormous efforts which, no doubt, are required to improve the situation.

Synergy and Trade-offs Between Water Sectors

Water is often treated sector by sector: drinking water supply, sanitation, irrigation, hydropower, fisheries, etc. Sector policies are important and necessary, but it is vital to recognise that there is significant synergy potential between the sectors. The attention paid to drinking water and sanitation is usually motivated by the fact that these are a sine qua non for a productive and dignified life. Recent discussions about nutrition security highlight the close connection and synergy between households access to safe water and real food security (Box 4.2).

Synergy Between Green and Blue Water in Development

About 60% of the world's cereals are produced in rain fed areas [6]. The current yield in semi-arid, less developed regions is quite low, as is income. Irrigated agriculture is less significant in terms of food production, although it clearly plays a very important role in many countries, particularly those in Asia. Farmers engaged in irrigated agriculture have better market access and benefit from various kinds of societal support. Their incomes, thus, are generally higher than those of their cousins in rain fed agriculture.

Historically, agricultural policy and investments designed to increase food production have focused on irrigated and high potential rain fed areas. Today, studies show that the return on public investment in rain fed and other less favoured areas in China and India can be equal to that of irrigated areas [22]. For Africa, a substantial enhancement of water and land productivity in rain fed agriculture is possible [15]. With an integrated set of crop, land and water management efforts, the current unproductive, non-beneficial evaporative losses of water can be shifted to productive transpiration; more food can be produced without withdrawing additional blue water from competing uses.

But humans do not live on bread alone. And there are both producers and buyers of bread. The role of water in the "income generation equation" and liveli-

To halve the number of chronically hungry by half will cost USD 24 billion annually from public coffers.

The consequences of not acting and doing what can be done are infinitely more troublesome than the enormous efforts which, no doubt, are required to improve the situation.

Nutrition security highlights the close connection and synergy between households access to safe water and real food security.

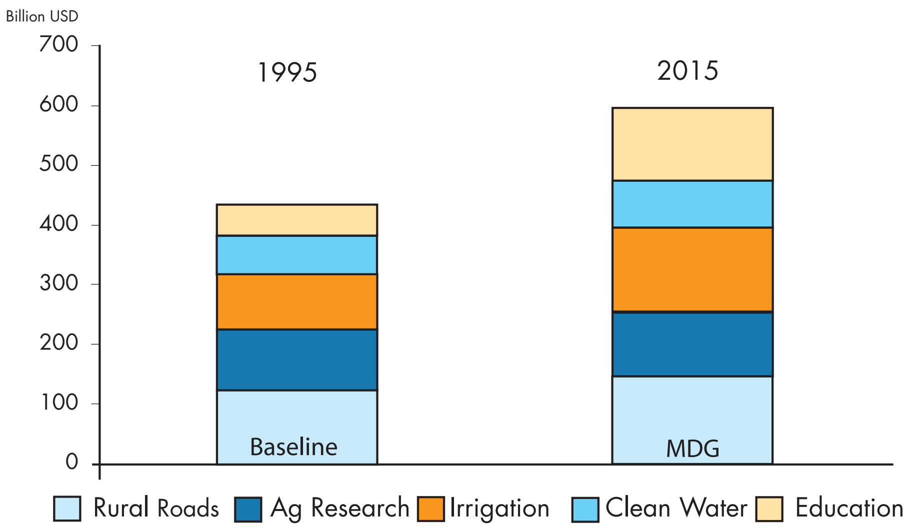

Figure 6.1. Cost estimates in billion USD for investments in the period 1995-2015 to implement the baseline (i.e. business as usual), and MDG Scenario for child malnutrition, 2015, Developing Countries. Source: [46].

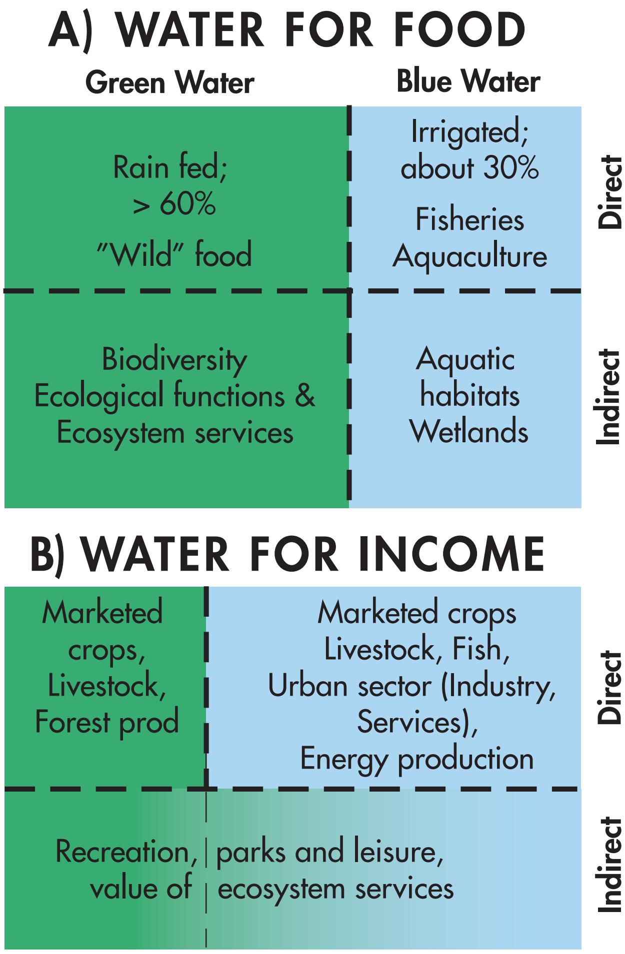

Figure 6.2 The complementarity and synergy between green and blue water resources. In terms of food production, green water is of paramount importance, while blue water plays a significant role in GDP and, generally, in income-generation activities. Modified from [6].

For Africa, a substantial enhancement of water and land productivity in rain fed agriculture is possible.

hood in society at large must also be recognised. For instance, the blue water is indispensable in virtually all urban-related activities such as energy production, recreation and, of course, to meet the daily water needs in households. The direct and indirect contribution of these sectors to GDP and to domestic income is significant and an important driver of resource allocation and usage, also in rain fed agriculture (Figure 6.2).

The role of water in the "income generation equation" and livelihood in society at large must also be recognised.

Synergies Between Productivity Improvement and Ecological Protection

Food production in agriculture will have to be managed with an eye on its impacts, for instance on biodiversity. It has been shown that it is possible to design, construct and manage irrigation systems to maintain and in some instances even enhance biodiversity. A high degree of biodiversity can and does exist in irrigated landscapes. Similarly, aquaculture and paddy cultivation can successfully be combined [25].

Supplementary irrigation, based on harvested rainwater or local runoff, to upgrade rain fed agriculture in semi-arid regions may result in alterations in the availability of water in downstream areas. Enhancing production and yields requires a management strategy that converts the unproductive evaporation from agricultural lands to productive transpiration by plants, as elaborated in Chapter 3. Such a strategy is necessary to achieve the synergy of increased production (and income) and ecological sustainability.

As the competition for blue water resources intensifies, a system of water allocation will be needed which involves negotiation between different user groups. The key challenge is to increase overall benefits while protecting and sustaining aquatic ecosystems. At a minimum this means safeguarding ecologically important sites in the river valley – economically important wetlands, for example – with activities such as fishery, grazing, food gathering and farming. The greater the river depletion, the higher up in the river the saltwater will rise, altering the ecological conditions. Streamflow quality will be as relevant in these negotiations as quantity [75].

Management of rivers should be based on minimum criteria for both quantity and quality, starting from the downstream end. The "bottom line" will be the minimum outflow necessary to keep the river mouth open to protect its wetlands and avoid the disappearance of migratory birds, and to avoid seawater intrusion into the groundwater. Each segment of the river can then be allocated an inflow from upstream and be responsible for leaving a certain outflow for the downstream neighbour.

Such a process has worked in the Australia's Murray Darling basin as described in Chapter 5.

Synergy and Trade-offs Between Food Consumption and Production

Food production is the basic aim of agriculture and fisheries. Agriculture is also producing for the industrial sector. Today there is a mismatch between food production and consumption patterns in two respects. One is that even though enough food is produced to make it possible for everybody to "lead a healthy and productive life", about 15% of the world's population is undernourished. Most disturbingly, this figure has increased recently [31]. The other problem refers to problems with the composition of the diet among segments of the population. About the same number of people are malnourished, including the overweight and the obese, as are undernourished [32, 33, 34]. The pressure on water and land resources is intensifying because of an increasing demand for meat and dairy products.

More and better information about the resource implications from consumption patterns is necessary. The linkages between food production, food and nutrition security and environmental sustainability need to be scrutinised and subject to massive education and awareness programmes. An improved public awareness is a pre-requisite for changes in policy and for an adherence to it.

The Necessary Time Perspective and the Vital Political and Collective Will

All or most of the efforts discussed in this report are time consuming. Human development efforts are a long-term obligation, and the changes in perceptions and understanding are a tricky, sensitive and ongoing process. Similarly, the research findings take years if not decades to materialise in the farmers' fields.

It is often stated that political will is vital but, unfortunately, often lacking. The challenges involve more than "just" opening the purse and spending money. Similarly, the challenges call for demanding change among the large populations of poverty stricken farmers who often suffer from undernutrition themselves; for decades they have been alienated from active and responsible development work [39]. "There is something other than capital, technology, and trade that drives economic progress. Call it collective will, pride, social cohesion, trust or culture. ...Perhaps it is time to think concretely about the role of culture, the social contract between citizens of a country and the importance of collective will" [76].

If the will and commitment of political leaders and food producers alike are not flexible and paired with the courage and openness to innovative thinking, the money and the energy are likely to be ill spent. Similarly, if consumption patterns continue to move in a direction where the earth's productive capacity is arrogantly disregarded, a robust and sustained development remains a rhethorical slogan.

Today there is a mismatch between food production and consumption patterns.

Research findings take years if not decades to materialise in the farmers' field.

If consumption patterns continue to move in a direction where the earth's productive capacity is arrogantly disregarded, a robust and sustained development remains a rhethorical slogan.

Photo: Mats Lannerstad

In dry climate tropics, agricultural yields may double by dryspell mitigation, based on supplementary irrigation, water harvesting and small-scale storage tanks.

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Let it Reign:
The New Water Paradigm for Global Food Security

The food security issue is alarming: food needs are increasing, and food consumption is moving towards more water-intensive items. Irrigation possibilities are limited and agricultural land is shrinking. In pursuit of the human livelihood improvements identified in the UN Millennium Goals (MDGs), however, co-ordinating efforts in sectors can generate substantial synergies at a time when globally food consumption patterns are changing rapidly.

Co-ordination is needed since today food consumption drives food production, which is dependent on water. Consumer food preferences in combination with new patterns in the processing and trade of food items are changing the consumptive use of water for food production and impacting the already-stressed water resources, ecosystems and the water available for other societal uses. Yet food production will always be highly water consuming, from both the "green" and "blue" water perspectives. For the projected per capita human diet of 3000 kcal/day, water needs are 70 times greater than for basic household water needs.

Co-ordination is also needed since undernourishment is trending upwards – 852 million people are hungry today. Paradoxically, overnutrition is equally rampant. These public health threats hinder people from fighting hunger, poverty and disease.

This is the dilemma, and the opportunity. Eliminating undernourishment by 2025 may require as much additional water as is already withdrawn (often unsustainably) today for agriculture, industry and domestic uses; improved green water use and irrigation are crucial. Improved access to food, and the resource implications of trends in food consumption patterns also warrant due attention.

This report highlights key facts, conditions and trends regarding water aspects of food production, consumption and ecological sustainability. It presents policy recommendations within governance, capacity building/awareness raising and financing in order to improve water productivity and increase the possibility to produce the food needed, improve diets, and raise consumer awareness – all in an equitable and ecologically sustainable manner.

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