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Saving Water: From Field to Fork

Curbing losses and wastage in the food chain

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Note to Reader

This report and the Side Event at CSD 16, May 5 – 16, 2008, are following up reports that have been prepared for two previous CSD meetings, "Water – More Nutrition per Drop" (2004*) and "Let it Reign: The New Water Paradigm for Global Food Security" (2005**). The topics addressed in the previous reports, and also in this report, are the links between water, food and development, which are high on the agenda for Swedish international development collaboration. This report highlights the magnitude of losses and wastage in the food chain, i.e. from field to fork. It is shown that a reduction of losses and wastage would save water and facilitate the achievement of multiple development objectives.

The views put forward in this report are expressed solely on behalf of International Water Management Institute, Chalmers University, Stockholm Environmental Institute and Stockholm International Water Institute.

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* http://www.siwi.org/documents/Resources/Policy_Briefs/CSD_More_nutrition_per_drop_2004.pdf
** http://www.siwi.org/documents/Resources/Policy_Briefs/CSD_Let_it_Reign_2005.pdf

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Executive Summary

Food Wastage is Water Wastage

We need to use our water prudently – no one will argue with this statement. But in fact we are wasteful. This need will become more pronounced, and the cost of bad water management will get higher in the future with increasing water demands from increasing population, cities, agriculture, and the environment. Moreover water management will become more difficult with climate change. New solutions and fast actions are required now.

Agriculture is the largest human use of water. Clearly, agricultural practices need to be targeted to reduce wastage of water. This has been the center of attention for water saving practices for years. But there are other ways to save water.

Food consumers and businesses have a key role. Losses of food between the farmers' field to our dinner table – in food storage, transport, food processing, retail and in our kitchens – are huge. This loss of food is equivalent to a loss in water. Reducing food loss and wastage lessens water needs in agriculture. We need to pay more attention to this fact.

Our Key Message:
Make the Food Chain More Efficient to Save Water and
Facilitate the Achievement of Multiple Development Objectives

Making the food chain more efficient means saving water that would have been used to produce that food. More than that, a reduction of losses and wastage can serve the interests of farmers, consumers and society at large.

The amount of food produced on farmers' fields is much more than is necessary for a healthy, productive and active life for the global population. Clearly, distribution of food is a problem – many are hungry, while at the same time many over eat. A hidden problem is that farmers have to supply food to take care of both our necessary consumption and our wasteful habits. This problem can be turned into an opportunity. Targeting losses and wasteful habits may generate multiple gains, including the saving of water.

As indicated in Figure 1, losses and wastage may be in the order of 50 percent between field and fork. Inefficient harvesting, transport, storage and packaging make a considerable dent in the potential availability of food. Additional and significant losses and wastage occur in food processing, whole sale, retail and in households and other parts of society where food is consumed. And agricultural water management practices could be much more productive.

It is important to recognize that agricultural products that do not reach our dinner plates are not necessarily wasted. Agricultural produce and residues are used for various purposes at farm level or within the agricultural system, – for feed, bioenergy and soil amelioration.

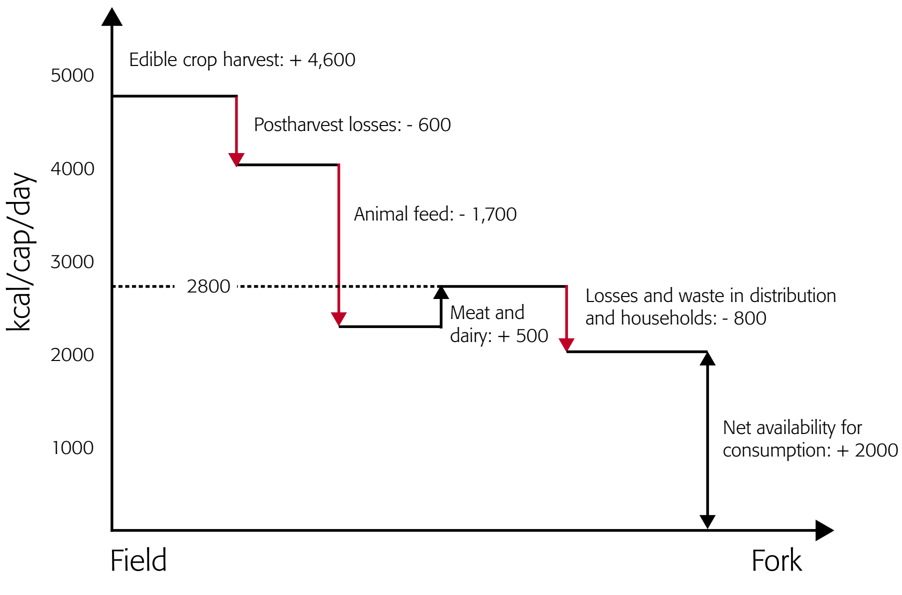

Figure 1. A schematical summary of the amount of food produced, globally, at field level and estimates of the losses, conversions and wastage in the food chain. Source: Smil (2000). Illustration: Britt-Louise Andersson, SIWI.

Situations differ from industrialized countries to those with weak economies and a strong agricultural base, and between rich and poor producers and consumers.

In fact, the entire picture is complex, and there is insufficient knowledge to guide policy. However, there is enough evidence, that the magnitude of food and water losses are large enough that we must pay close attention. Strategies that focus on reducing losses from field to fork can facilitate the achievement of multiple development objectives: food security, improvement of livelihoods of farmers, meet the growing demand for non-food agricultural products and safeguarding environmental resilience

A New Era for Water and Food Management

Warnings about severe water scarcity come at the dawn of a new era for agriculture. For an increasingly affluent world population the demand for a range of agricultural products is rapidly increasing, while the poor have to bear the brunt of price hikes and lack of access to food and water supplies. An estimated 1.2 billion people already live in areas where there is not enough water available to meet all needs from sectors of society, let alone the need of aquatic ecosystems.

Over the past 50 years, food supply has increased more rapidly than populations have, and under nourishment, a lingering threat throughout history, has been reduced. Until very recently, the real price of food has been fairly stable or declined, benefiting both national and household economies. The situation now is characterized by rapidly increasing prices on food with dramatic repercussions for the poor, rates of inflation and, generally, for the stability of society.

Several coinciding circumstances contribute to this quite serious situation, which may increase the number of people who are under nourished. Faced with this threat and with the escalating water scarcity and increased competition for land and water resources for a range of uses, increases in water productivity are necessary but it also makes sense to ensure that as much as possible of the food produced is also accessible for consumption across social groups of society.

Access to food is very much conditioned by socioeconomic circumstances in society. Under nourishment is largely perpetuated by poverty and conflict. However, with losses and wastage in different stages of the food chain, the overall food security in society is compromised One reason for losses in the food chain is an increasing distance between the places where food is produced and where it is consumed. Whereas in the past, many people produced their own food, now various parts of our meal come from food grown in many places in the world. Parallel and closely associated with this trend, is the involvement of a growing number of actors and interests along the food chain. Apart from farmers, transporters, store keepers, food processing industry, shopkeepers, supermarkets, among others, are involved. We therefore need to look at the stakeholders and drivers in various segments of the food chain and to what extent interests coincide or at odds across major groups. Enhancing efficiency in one part of the chain, e.g. in production, can be nullified if losses and wastage occur, or increase, in other parts of the chain.

All of these changes have implications on water resources. More food is likely to come at a cost of more water use in agriculture. Futher, distance to market, and a more complicated food chain, open the possibility of more food and water wastage. Water will be a key constraint to food production, unless we change the way we think and act about water resources.

Key Issues for Policy Debate

Support to Farmers

Actions are needed to support farmers, especially small farmers, to curb losses of water and food and to facilitate that their produce meets the growing demands for food as well as other agricultural commodities. Growing expectations on the agricultural sector is an opportunity that needs to be properly harnessed through:

- Improved harvesting technologies, better transport and storage.
- Innovative ways to capture and beneficially use the rain falling on farmers' fields to increase the fraction of the rains that can be productively used and to lessen stresses on rivers and groundwater. With current practices and strategies, a large fraction of the rainfall is lost in terms of unproductive evaporation in many parts of the world.
- Financial and institutional arrangements to realize productivity improvements.
- Co-management of land and water management, preferably in a basin context is much needed. In many cases, government institutions do not integrate these two sectors.

Food Processing and Supply

The business community should take action to minimize water wastage through reducing food wastage in their processing and transport:

- Benchmarking standards should be set by industry to indicate water use, including water use in the entire food chain, not just in their factory.

- The business community should take action to minimize water wastage through food wastage in their processing and transport systems.
- Businesses can raise publicity about their water use, and the need to save water.

Sensitize Consumers

Raise awareness amongst consumers about the water implications of their diets, overeating and food wastage. We as consumers need to be careful about food wastage in our homes. Over eating and throwing food away is like leaving the tap running:

- Raise awareness amongst consumers about the water implications of their diets, overeating, and food wastage.
- Incentives and practical guidance and well designed campaigns may be required to reduce food wastage in our homes and how to combine home economics with sound food habits. Concrete examples of how to avoid or reduce the throwing away of food need to be used.
- Explore the opportunities to include information of losses and wastage as part of a labelling system or as information on strategic consumer food items.

Basic Data and Information

We lack factual information about different types, size and implications of losses and wastage of food. An important step is therefore to improve knowledge:

- International organizations, businesses and agencies for research at national and international levels should initiate studies that will reveal the different types and magnitude of losses and wastage in the food chain in different parts of the world, and identify steps that can be taken to minimize these.
- Quantify information on the costs of looses and wastage as well as what are the benefits and who will benefit with a reduction in losses and wastage. Costs and benefits should be estimated in monetary terms but also in terms of water savings, environmental aspects and other suitable parameters.

A Strategy for Action

Governments, international organisations and NGOs have major roles to play to drive the policy agenda and its implementation. Following the call from World Economic Forum in January 2008, it is appropriate that the resources represented by the businesses are part of a coordinated action. A suitable next step is the forming of a broad collaboration across the business community and between the research community, the private sectors, NGOs, civil society and government.

A consortium of policy makers, representatives from industry, academia and civil society could lead the way to design effective, acceptable and practical actions to reduce losses and wastage by half by 2025.

1. Drivers of Food Demand

1.1 Water Costs of Past Achievements

Remarkable improvements in food security have been one of the most positive characteristics of development in large parts of the world over the last half a century. At the dawn of the Green Revolution, at the beginning of the 1960s, the average global crop yield was about 1.4 tonnes/hectare. Thirty years later, in the mid-1990s, it had doubled to about 2.8 tonnes/hectare (Molden et al, 2007 a). In the mid-1960s, total global cereal production was about 0.9 billion tonnes, and in 1995 about 1.7 billion tonnes. The 2 billion tonne mark was passed in 2004, when total cereal production was estimated at 2254.9 million tonnes (FAO, 2005).

Largely as a result of these developments, the number of undernourished people in the world has been reduced, in relative and absolute terms, although there are signs of setbacks (FAO, 2006; von Braun, 2007). One reason for a slight increase in food insecurity recently is persistent and extreme poverty in parts of sub-Saharan Africa and Latin America (Ahmed et al., 2007, cited in von Braun, 2007).

These achievements have come at a cost. Increased pressure on freshwater resources, due in large part to the rapid expansion of irrigation systems, has had repercussions on aquatic ecosystems (Falkenmark, et al., 2007) and for people in downstream areas. River basins around the world are closing, that is, there is no more water for additional water allocations, because water has already been fully allocated, or even over-allocated (Falkenmark and Molden, 2008). But demand and competition for water continues to increase unabated, and concerns are being heard from key people and organizations, including from the UN Secretary-General and representatives of industry.[1]

1.2 Income Improvements and Changing Diets

Poverty reduction remains the number one development goal. Economic development promotes poverty reduction and the prospects for this today are very bright. In the year 2000, 800 million people lived in regions with a mean annual GDP per capita above USD 10,000. Economic growth projections based on so called demographic dividend projections, where economic behavior is linked to age composition, foresee about 7 billion people, or about 80 percent of the world's population, living in such regions by 2050 (Malmberg, 2007; Lind & Malmberg, 2007). If the envisaged massive economic growth will unfold, a significant reduction of poverty is possible. It will make considerable public and private investments in infrastructure, research and human development conceivable. It is an opportunity to build a better future for broad groups of people. A vital question, however, here is how can the associated growth in demand be met and still reconciled with the concomitant increased pressure on natural resources and the environment during the coming decades? And how will the poor, who may still be counted in hundreds of millions, be faring in a context of increasing resource pressure and competition? Experience tells us that even at higher levels of income and consumption, people tend to want more, knowingly or unknowingly about the implications for natural resources and the environment. Apart from poverty alleviation, sustainable lifestyles are increasingly an issue. Changes in diets towards an increasing demand for meat and seafood is one of the vital issues in such discussions (Jackson, 2008, Halweil and Nierenberg, 2008).

Even if rates of poverty are reduced, a very large segment of the world's population is still poor or extremely poor. Recent price hikes on food is a most serious change for them. For the billion plus of people who are forced to survive on the equivalent of an average per capita income of a dollar per day, a very large part of their disposable money and resources are spent on food and other basic necessities of life. For them, even comparatively small increases in the price of food are causing extreme hardship. On the other hand, a growing middle class in various parts of the world contribute to increasing the demand for a range of goods, including food and other agricultural products. Prices of commodities are naturally affected and what food items are produced. People who are well off are comparatively less affected by price hikes on food. To avoid widespread social unrest and negative repercussions on inflation and the economy it is vital for Governments and international organizations to consider the interests and concern of the population as a whole. At the recent National People's Congress in Beijing, Premier Wen Jiabao promised that the government would boost production of daily necessities such as grain, vegetable oil and meat and/or increase imports of consumer products that are in short supply (Wang 2008), with the twin objective to reduce threats of inflation and dam up against social grievances.

With rising incomes and urbanization, demand for food will increase. Furthermore, consumers' tastes are changing towards more nutritious and more diversified diets, which tend to boost the consumptive use of water. A shift in consumption patterns among cereal crops and away from cereals toward animal products and high-value crops can be anticipated (see Molden et al., 2007 a,b). For example, in South East Asia rice supply peaked at around 120 kg/capita/year during the 1980s while per capita

[1] Water scarcity was a major issue at the World Economic Forum, Davos, January 2008, with no less than nine events addressing various consequences of worsening water stress. UN Secretary-General, Mr Ban Ki-moon, told the meeting: "What we did for climate change last year, we want to do for water and development this year" Andrew Edgecliffe-Johnson, Financial Times , 25 January 2008 http://r.smartbrief.com/resp/jCoccSoRcsixtWCiaKqZvlHE?format=standard

wheat demand more than tripled between 1961 and 2002 and is still increasing. Meat demand grew by a factor of 7, from 6 to 40 kg/capita/year. Demand for high-value crops – such as fruit, sugar and edible oils – also increased substantially and projected increases in demand vary from 70 percent to over 100 percent (Fraiture et al., 2007).

Changes in food habits as incomes rise are illustrated in Figure 2. The general trend is in favor of more nutritious and more diversified diets with a higher proportion of animal products and high-value crops and away from "traditional" cereals, e.g. various varieties of sorghum. There are pronounced regional and cultural differences. While changes in diets as a result of income growth follow similar patterns, regional and cultural differences are pronounced – and may remain so for some time (Lundqvist et al., 2007). For example, meat demand in (mostly vegetarian) India rose much slower than in China, for comparable income increases, but demand for milk products increased more rapidly (Figure 1). Per capita supply of meat in India seems to remain relatively low, projected at 15 kg/capita/year by 2050, while China is projected to supply six times more (Molden, 2007); China's meat demand is projected to be 83 kg/capita/year by 2050 (de Fraiture et al., 2007).

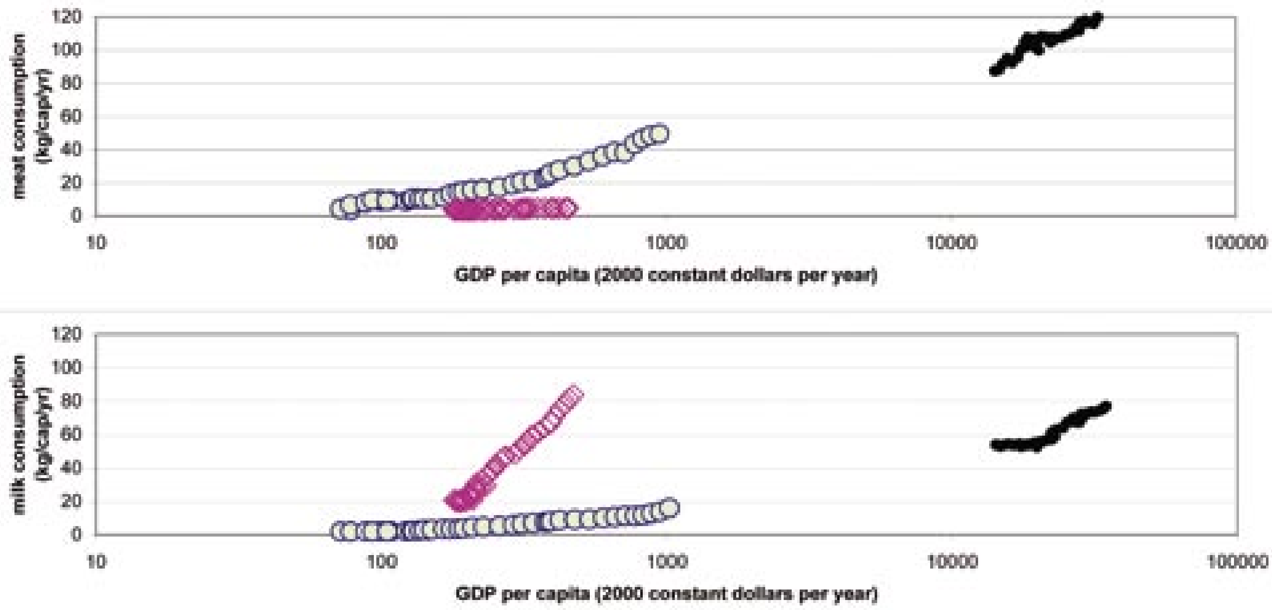

Figure 2. Trends in meat and milk demands and GDP per capita in China, India and the USA (1961–2000).
Source: GDP data from World Bank WDI online; consumption data from FAOSTAT.

Cereal demand projections are in the range of 2800–3200 million tonnes by 2050, an increase of 55–80 percent compared with today. Much of the future increase will be fed to animals to satisfy the demand for meat (Fraiture et al., 2007). Today some 650 million tonnes of grain – nearly 40 percent of global production – is fed to livestock, and this may reach 1100 million tonnes by 2050.

Although general trends toward more diversified and meat-based diets are well documented (e.g. Molden, 2007 a; Steinfeld et al., 2007), considerable uncertainties remain regarding some of the major factors driving future food composition and feed requirements. Projections for world meat demand are uncertain, varying from 375 to 570 million tonnes by 2050, that is, an increase of 70–160 percent compared to 2000 (Fraiture et al., 2007). Environmental concerns and emerging health problems related to obesity may promote counter trends, particularly in high-income countries. But the problem of overweight and obesity is increasing in other parts of the world, too.[2] Outbreaks of diseases such as mad cow disease and avian flu, together with the industrial nature of meat production, may deter some people from increasing meat consumption.

Much uncertainty surrounds the feed grain requirements per kg of meat, milk and eggs. In many parts of the world there is the potential to increase the efficiency of feed systems (Peden et al, 2007; Wirsenius et al., forthcoming). Livestock are fed by a combination of grazing, crop residues, and feedstuffs (primarily grains). In OECD countries, where cattle are raised largely on feed grains, two-thirds of average grain production is devoted to cattle feed, some of which is imported. In contrast to an industrial character of agriculture that is expanding in many parts of the world, in sub-Saharan Africa and South Asia a

[2] Reliable statistics are hard to find about the situation and trends of overweight and obesity and their causes. In a newspaper article in 2007, almost 40% of the population of Malaysia are obese according to the Health Minister Mr Chua Soi Lek. In an effort to deal with the epidemic, the Government is considering a "sin tax" on junk food in line with the tax on alcohol. International Herald Tribune, 16 February 2007. http://www.iht.com/articles/ap/2007/02/17/asia/AS-GEN-Malaysia-Fast-Food-Ban.php

large part of the livestock is typically fed on crop residues, grazing lands and by-products from local sources, with less than 10 percent of grain supply is used for feed. This kind of integration between the cropping system and animal rearing, which is a characteristic feature in many small holder systems, contributes to diversity of social and natural resource use systems and can therefore be benign both with regards to resilience and efficiency. These kinds of aspects must be considered in discussions of how livestock will be fed in the future (Peden et al, 2007).

In addition to uncertainties and opportunities on the supply side, projections about the drivers of demand, like the growth in GDP and income vary widely. The four emission scenarios of the Intergovernmental Panel on Climate Change (IPCC, 2000), use estimates of GDP growth during the 21st century that vary from a tenfold to a massive twenty-six-fold increase compared to 2000 – a staggering multiplication in size of the world economy. Similarly, there is a 2.5 times difference between the most optimistic and most pessimistic income projections for 2050 in the Millennium Ecosystem Assessment (2005).

Admitting that the pace and magnitude of economic growth cannot be predicted with a high degree of certainty, there is still a widespread view that the world economy, including most economies in Asia, Latin America and large parts of Africa, will continue to expand (Lind and Malmberg, 2007). Even if GDP projections are based on purchasing power parity calculations, the future effective demand for food and the mix of food items is extremely difficult to assess. It is, however, plausible that the economic factor is potentially a more forceful driver than population growth *per se*.

1.3 Diets and Water

What kind of food is demanded and how much, determine to a large extent how water for agriculture is allocated and used. As elaborated in chapter 3, it is most relevant to also make a distinction between the amount of food demanded and bought, or otherwise acquired, on the one hand, and the amount of food actually eaten, on the other. Food supply directly translates into consumptive water use, that is, how much water is transpired and evaporated from the field during the production of a specific amount of food (see Molden et al, 2007b for a discussion). Unlike water use in industry, the high proportion of consumptive use in agriculture means that this water is effectively lost for re-use or re-circulation in society, that is, until it returns as precipitation. Consumptive use means that the ability to respond to water demand for other activities is inevitably reduced. Generally, water resources in areas located downstream of a consumptive use area are negatively affected.

What do the envisaged changes in diet mean for water demand? While estimates of water requirements for crop and livestock products vary widely, most studies agree on the main points. Higher value crops, such as sugar and vegetables, typically require more water per calorie than staple cereal crops. Meat and dairy production is more water-intensive than crop production. For example, 500–4000 liters of water are evaporated in producing one kilogram of wheat, depending on climate, agricultural practices, variety, length of the growing season and yield. However, to produce one kilogram of meat takes 5000–20,000 liters, mainly to grow animal feed. In terms of the energy content of food, approximately 0.5 m^3 of water is needed to produce 1000 kcal of plant-based food, while for animal-based food, some 4 m^3 of water is required (Falkenmark and Rockström, 2004).

The production of meat from animals fed on irrigated crops has a direct impact on water resources, much more so than if the meat is derived from grazing animals and animals fed on residues. Irrigation water, withdrawn from rivers or other water bodies and returned back to the atmosphere by crop consumptive use, will not be available for cities, industry or the environment. As noted above, projections suggest a doubling in the amount of grain used for feed upto 2050 from rainfed and irrigated systems. The amount of cereals used today for feed varies between regions, ranging from 20 percent in sub-Saharan Africa to 70 percent in OECD countries (FAOSTAT, 2000).

Food preferences, such as the ratio between plant- and animal-based products, vary greatly between countries at the same level of GDP/capita (Figure 3). This means that there are very different implications for water demand in different countries.

1.4 A Bleak Water Future?

If diet continues to be correlated with income, as in Figure 3, water requirements will increase significantly in the future as a result of GDP growth. Researchers agree that per capita food supply and the share of animal-based food items in the food basket are both increasing (e.g. Bruinsma, 2003; Fraiture et al, 2007; Steinfeld et al., 2007, McMichael et al., 2006). In rich countries, food supply is currently close to 3500 kcal/capita/day with an animal food fraction of about a third, whereas the global average food supply is about 2800 kcal. In poor countries, both food supply and the fraction of animal-based foods are significantly lower (FAO, Food Balance Sheets).[3]

[3] http://faostat.fao.org/site/502/default.aspx

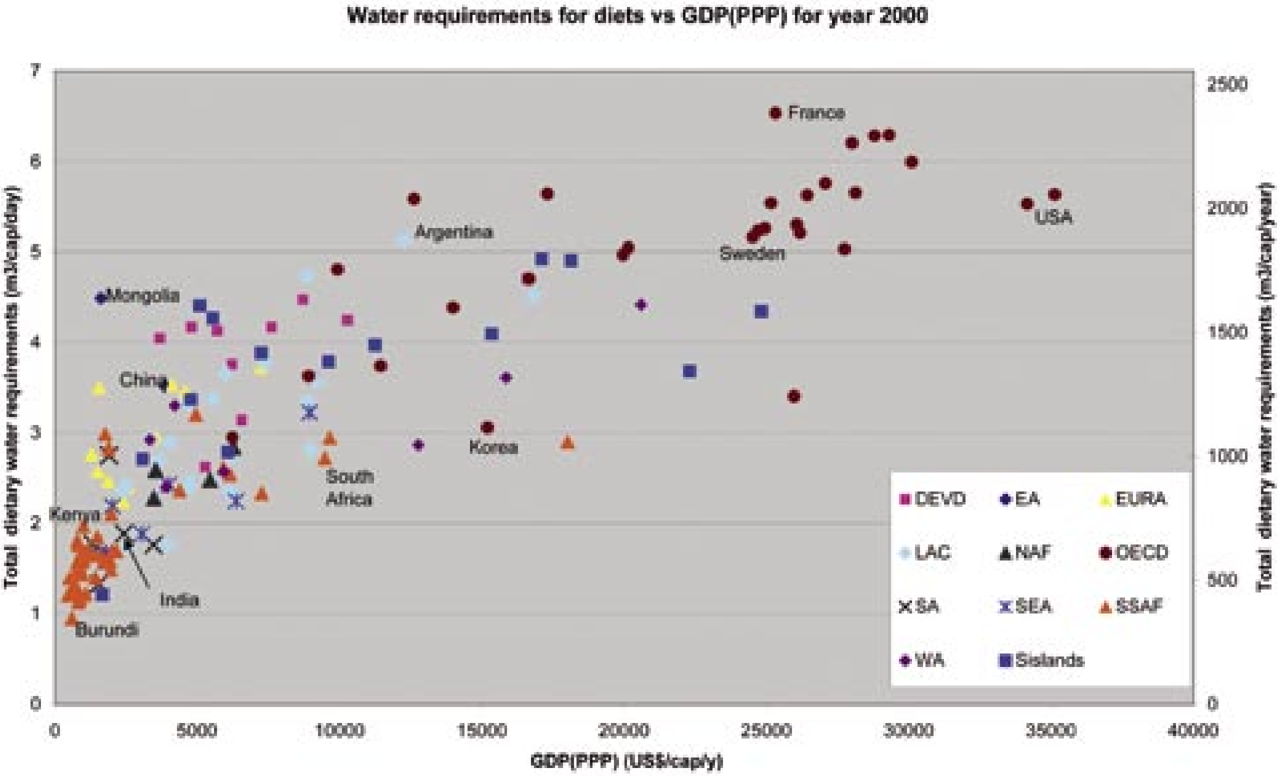

Figure 3. Consumptive use of water for food supply as a function of GDP (Lundqvist et al., 2007). PPP: purchasing power parity. Source: GDP data from the World Bank (2006); food supply data from FAOSTAT (2006).

Regional groups: DEVD=transition countries Europe, EA=East Asia, EURA=transition and developing former USSR, LEC=Latin America and Caribbean, NAF=North Africa, OECD=Members of the Organisation of Economic Cooperation and Development, SA=South Asia, SEA=South-East Asia, SSAF=Sub-Sahara Africa, WA=West Asia, Sislands=Small Islands.

It takes enormous amounts of water to produce our food. Yearly some 7000 km^3 of water[4] are evaporated and transpired in connection with the production of crops to meet the global food demand at the beginning of this century. Assuming a projected high level of average food supply of 3000 kcal/capita/day, with 20 percent animal and 80 percent plant food, the consumptive water use will be above 3 m^3/capita/day – 1300 m^3/capita/year, (Falkenmark and Rockström (2004). Similarly, the Comprehensive Assessment (CA, 2007) estimated that cereal and water demands could both double with present production practices by the year 2050. Considering water scarcity constraints, it's vitally important to consider what are realistic levels of food production and the desirable levels and composition of food consumption. Depending on how food is produced, and assumptions on population and diet, future water requirements to meet food demand by 2050 have been estimated at between 10,000 to 13,500 km^3/year (de Fraiture et al., 2007; Lundqvist et al., 2007).

The increase in water needed to meet the demand for food is a major concern given the growing water scarcity and related environmental problems in many parts of the world. Already 1.4 billion people live in places where water is physically scarce (CA, 2007). Another 1.5 billion people live in places where water is available in nature but infrastructure to access it is lacking.

It's probable that if today's food production and consumption and environmental trends continue, crises will occur in many parts of the world (CA, 2007). The challenges become even greater when we include newly emerging issues such as climate change and its implications for water variability and scarcity, and the demand for agricultural produce for bioenergy and industry.

Improvements of water productivity, and agricultural productivity in general, are therefore urgent and necessary. Similarly, reductions of losses and wastage in the food chain could significantly contribute to ensure a reasonable diet for a growing population over the next 50 years, given the available land and water resources

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[4] Each year, on average about 110,000 km3 of rain falls on the earth's surface. A large part of this infiltrates and forms the green water resource (see Box 4) and another part results in about 40,000 km3of streamflow, which is a major part of the blue water resource, Geographic and temporal variation is considerable. The fraction of streamflow that can be withdrawn depends on a number of circumstances and development objectives. Currently some 4,500 km3 are withdrawn with about 2,700 km3 for irrigation systems. This can be compared with an estimated 7,000 km3 or slightly more that are evapotranspired in the process of total food production, i.e. from irrigated and rainfed land.

2. A New Type of Water Scarcity

2.1 Climate Change Amplifies Water Scarcity

Climate change will radically change conditions for cultivation. In the context of rising populations and fast-growing economies, these changes need to be considered in the quest for food and water security.

Agricultural production will be significantly affected by a combination of changes in the pattern of rainfall and higher temperatures (IPCC, 2007). Even small temperature increases (1–2°C), will reduce potential yields and overall food production in the tropics and sub-tropics. IPCC scenarios suggest that climate change will affect 75–250 million people in Africa, where potential yields in rainfed systems in some areas may decline by up to 50 percent by 2020 (IPCC, 2007). Agriculture in countries in Central, South and South East Asia, which are largely dependent on river water for irrigation will be hit by a projected drop in river levels (IPCC, 2007).

Scenarios do, however, vary in the literature and in official statements. For densely-populated areas in South Asia and southern Africa, Lobell et al. (2008), estimated that sizeable reductions in yields of major crops are likely if no effective mitigation or adaptation measures are implemented. For instance, if agricultural practices do not drastically change, reductions in maize production may be in the order of about a third by 2030. In areas that are already susceptible to food insecurity and where population will continue to grow, this is a drastic scenario. Dr Jacques Diouf, Director-General of FAO[5], has recently warned of a 5 percent decline in cereal production in many developing countries by 2020, and that some countries may lose a much higher percentage of their cereal harvest. According to Dr Diouf, 65 countries, representing about half of the world's population, will experience falls in cereal production. Among the most severely hit will be India, losing 18 percent of its current cereal harvest.

At the same time, yields are far below their potential in many areas of sub-Saharan Africa and South Asia. A major climate change adaptation measure is to harness this potential through improved integrated land and water management practices and to regain the momentum of support to agricultural research and activities. In this manner the predicted negative effects of climate change could be countered.

On the other hand, in temperate zones, a temperature increase of 1–3°C may improve conditions for agriculture (IPCC, 2007). Climate change is therefore likely to accentuate regional differences in preconditions for agricultural production and food security.

Food security can be achieved through a combination of local and domestic production and imports in combination with a more efficient food chain management. Given the above scenarios, local and national food self-sufficiency will be increasingly difficult unless effective measures are implemented. The possibility to produce food for a growing population will be significantly curtailed. Rockström et al. (2008) have assessed how many countries will be able to produce food for their populations at 3000 kcal/capita/day (20 percent animal and 80 percent plant food) by 2050. The assessment was based on a dynamic global vegetation and water model (Gerten et al. 2004) and the IPCC's A2 scenario[6] (IPCC, 2000). About one-third of the projected population of 10.5 billion will be living in water-abundant countries where such production levels would be possible. But most will be in countries suffering various degrees of water constraint. More than half the population could be in countries with severe water constraints (too dry and with difficulties of expanding irrigation). These water-constrained countries include China, India, Ethiopia, Egypt, Iran, Jordan and Pakistan (Rockström et al., 2008). We therefore need to consider realistic levels of future food supply with regard to production constraints, on the one hand, and consumption requirements, on the other.

2.2 Variability in Water More Pronounced

Climate change will increase risk and unpredictability for the farmer. Extreme events will occur more often and high temperatures will speed up the flow of water back to the atmosphere, disrupting the water balance. But variability is nothing new to farmers. Throughout history, the monsoon in Asia has had devastating effects and the climate has dictated livelihoods in the tropics and sub-tropics. Box 1 gives an account of serious water scarcity in two districts of Tamil Nadu, southern India that resulted in famine, sickness and death 17 times over 100 years from 1804.

2.3 Water Scarcity: Competition and Environmental Concerns

Present production patterns are unsustainable in many places: for instance, they involve overexploitation of groundwater, and appropriation of stream flow resulting in widespread river depletion and damage to aquatic ecosystems, fisheries and biodiver-

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[5] Statement by Dr Jacques Diouf at a conference organized by the Swedish International Development Agency "Climate change, food security and poverty reduction. Ensuring food security by adapting to climate change" (http://www.fao.org/english/dg/2007/sida.htm).

[6] The underlying theme of the A2 storyline is self-reliance, a continuously increasing global population and relatively slow per capita economic growth (IPCC, 2000).

Box 1. In the Farmer's Field, There is No Such Thing As an Average
At the global, regional, and local level, water availability and rain is usually given as an average value. However, the average isn't usually the real water availability that the farmer has to deal with. In tropical monsoon climates, in particular, the average often conceals considerable annual or seasonal variations; an example being agriculture in Coimbatore and Erode Districts, in Tamil Nadu, southern India. The area relies mainly on the unpredictable and erratic northeastern monsoon of October–December, characterized by cyclones, and short and heavy downpours. In historical records the area is described as "of exceptional dryness" where the marked variation in rainfall resulted in a situation where "not less than two-thirds of the seasons" were "unfavourable" (Madras Presidency, 1902).

During the years 1804–05, 1806, 1808, 1812, 1813, 1823, 1831, 1832, 1834, 1836, 1861, 1866, 1876–78, 1891–92, 1892–93, 1894–95, 1904–05 and 1905–06 the area experienced serious water scarcity and these years were described as times of "scarcity, desolation and disease" or "famine, sickness and death". In 1808 failure of both monsoons caused a famine "that carried off half the population", while the "The Great Famine" in 1876–78 is described as "more disastrous in effect than any of its predecessors" (Madras Presidency, 1902; Balinga, 1966 p. 17). Famines continued to occur during the first half of the 20th century.

Immediately after independence in 1947 the new National Government sanctioned the construction of the Lower Bhavani Reservoir (capacity 900 Mm3) across the Bhavani River. The river is the only reliable, perennial surface water resource in the area and the dam is supposed to even out variation in flow and hold sufficient water for one year. But as shown in Figure 4, the river flow and thus the inflow to the reservoir vary greatly. Over time, there is a tendency of reduction in average flow/inflow. Despite the reservoir, a large part of the farmers in the Lower Bhavani Project Command Area (84,000 ha) do therefore not receive the amounts of irrigation water they were supposed to get. In fact, they regularly receive less water than they had planned (or hoped) for. Over the last 90 years (before and after dam construction), the flow at the reservoir site shows that there is no such a thing as an average in terms of river flow for an individual year. Even during years with the same annual flow, monthly and daily variations can result in peak inflows that overflow the reservoir, with less water available to distribute over the cropping year than the average would seem to imply.

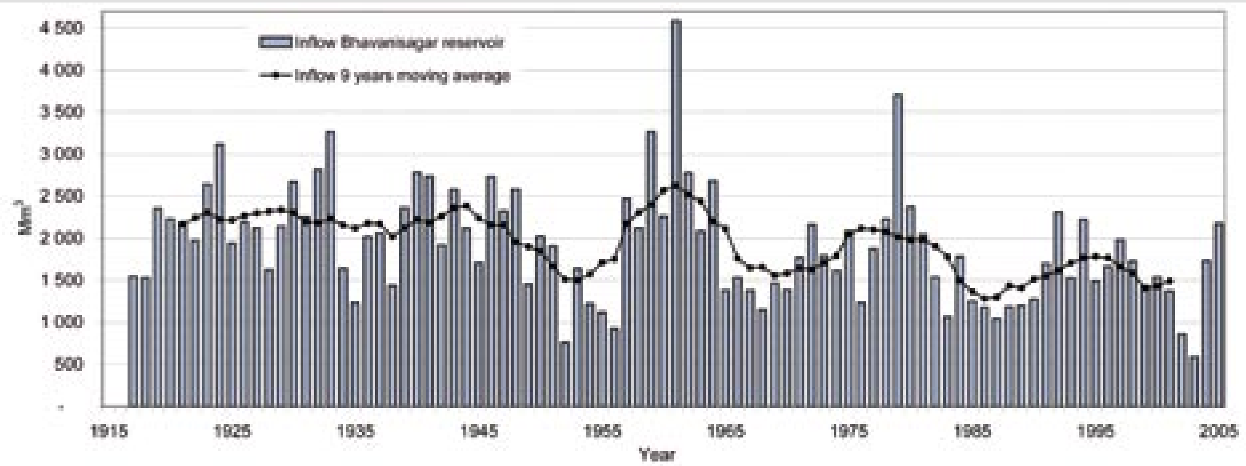

Figure 4. Flow at the site of Lower Bhavani Reservoir, Tamil Nadu, India (1917–2005). Sources: pers. comm. Executive Engineer, PWD (Public Works Department), Bhavanisagar, Tamil Nadu, India, 2004-2006; Government of Madras (1965).

sity (CA, 2007, Postel, 1999). About 1.4 billion people live in closed basins, that is, where all water flow (for an average year) is already committed and where environmental flow is not considered. In addition, pollution from agricultural chemicals and hormones, water logging and salinization pose threats both to the environment and to crop production.

Reduction in water bodies and changes in water flow affect aquatic ecosystems in several ways (Smakhtin et al., 2004; Smakhtin and Anputhas, 2006; Falkenmark et al., 2007; Molle et al., 2007). River depletion and changes in hydrologic regimes by dam building disrupt downstream aquatic ecosystems. Groundwater over-exploitation damages groundwater-dependent ecosystems. Overuse or unwise use of nutrients and agricultural chemicals affect both aquatic and terrestrial ecosystems due to polluted return flow from crop lands. Drainage of wetlands for agricultural use leads to loss of habitat and affects ecosystem characteristics such as fisheries, flood retention and groundwater recharge. Changes in these characteristics can have severe consequences for the poor who depend on ecosystems for their livelihoods.

Growing water scarcity increases competition. With rapid urbanization, the agricultural sector will increasingly compete for water with the urban sector. Substantial trans-basin diversion schemes have been planned or are being constructed (e.g. Three Gorges in China, or the Linking Rivers project in India). Competition for water from the urban sector means increasing water stress for farmers and the rural sector since economic, social and political arguments for increasing supply to urban areas will be hard to counter. At the same time, urban expansion intensifies demand for food and other agricultural produce. Growing numbers of urban dwellers enjoy increased disposable incomes, part of which will be spent on food and other agricultural produce. The demand for agricultural products will not only accelerate but will also be more varied. Apart from food, the urban sector demands raw materials for industry, commercial products and bioenergy. All of these demands present the receptive farmer with new opportunities. Some of these new products fetch a higher price than staple food crops, so these new opportunities may stimulate investments in rural areas, although not necessarily for food.

2.4 Land and water for bioenergy and other non-food produce

Although we think of food as the most important agricultural product, there is a marked increase in demand for other products, which will compete for land and water resources, investments, manpower, etc. With the price on oil already well above the 100 dollar per barrel level, the "peak oil" discussion, and geopolitical and climate change concerns attached to a reliance on fossil fuels, an increased demand for bioenergy is expected (Berndes 2002). For farmers, a more diversified and increasing demand is an opportunity in the face of a long period of falling prices paid on staple food items.

Biomass is an important source of energy in developing countries, mainly combustion of wood and agricultural residues, with severe negative impacts. The combustion in confined spaces leads to indoor air pollution to which women and children are primarily exposed with severe health consequences, including respiratory illnesses and premature death (WHO 2002). There is a strong motive to substantially improve and increase the supply of energy services in developing countries (Takada and Porcaro 2005, UNDP 2005).

One of the consequences of an expansion of bioenergy is a significant increase in the pressure on land and water resources (see Box 2). During the coming decades, the water requirements for bioenergy may add substantially to the total water requirements. Latin America and sub-Saharan Africa are among the regions commonly suggested to become major biofuel suppliers on a prospective global biofuel market. It is well motivated to investigate the consequences of large biofuel production levels in these regions (Figure 4).

It is relevant to note that although bioenergy may become a major component in the future pressure on land and water resources there are other important drivers as well. As discussed above, the demand for animal based food products is significantly adding to overall water pressure. Concerning the bioenergy sector, there are considerable uncertainties about its role in the future. The biomass use for energy[7] assumed in Figure 4 is not very high compared to the supply potentials reported in various resource assessments focusing on land rather than water as the constraining factor.

An important question is also where the production of biomass for energy purposes can and will expand. Depending on the type of feedstock, it is possible to cultivate biomass for energy purposes in areas where conventional food production is not feasible, for instance, due to water constraints. Such a strategy is, for example, being attempted in parts of India where about 13 million hectares of wasteland are being earmarked for cultivation of feedstocks that can grow in areas with a low rainfall, e.g. Jatropha and sweat sorghum (Wani, pers. Com. 2008). Another important option is efforts to promote multi-functional production and social systems. In Brazil, for instance, efforts are made to combine crops for bioenergy, sugarcane, and other agricultural produce, e.g. milk production through arrangements for small farmers (Sparovek et al., 2007). For farmers and rural communities, an enhanced demand for their produce provides an opportunity and could stimulate investments in rural development. Tenure, access to credits and markets to cater for social development objectives will be very important.

Social and environmental challenges and opportunities must be continuously identified and evaluated. For example, analyzing the water implications of increased production of biofuels for transport for selected countries/regions (de Fraiture et al., 2008) found that globally, irrigation is not likely to be a major water source for biofuel production (at the assumed production levels, which varied among regions and globally reached 7.5 percent of transport fuel use by 2030). But locally, it could cause severe water stress. Using irrigation for biofuel production would add significantly to the water stress in contexts where water availability is constrained but where food cultivation is possible.

Other non-food crops (such as cotton) occupy only 3 percent of the cropped area, and 9 percent of the irrigated area (Molden et al. 2007 b). Even if the importance of cotton and other non-food crops were to increase in the future, which might be good for the farmer, in terms of resource pressure these crops are comparatively much less significant than food, feed and biomass for energy purposes.

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[7] About 86 EJ per year (EJ, or exajoule, is equal to 10^{18} joules), which can be compared to the 390 EJ (60 GJ/capita) of fossil fuels that were commercially traded globally in 2005 (BP 2007).. Projections about energy demand in the future vary substantially: for 2050 ranging from about 800 EJ to 2,000 EJ. Modelling studies of long range energy system development commonly see biomass use for energy reaching several hundred EJ per year (BP 2007. Statistical review of world energy 2007. (http://www.bp.com/statisticalreview)

Box 2. Bioenergy, Food and Water Pressure
The present global energy system is dominated by the use of fossil fuels with environmental effects such as eutrophication, acidification and climate change. Around the world, food production also relies to various degrees on fossil fuels and petroleum-based chemicals, including synthetic fertilizers.

Concerns about human-induced climate change and oil/gas import dependency drive the search for radical changes in the global energy system. There are compelling arguments for keeping atmospheric CO2 concentrations below 400 ppm. Assuming a global population of 10 billion people in 2100, average global emissions would need to drop to about 0.2 tonnes of carbon per capita per year. This is below the prevailing level in India today. At the same time, global energy consumption is expected to more than double during the 21st century.

Possible future energy sources include solar and wind energy, bioenergy, nuclear fission and fusion, and fossil fuels with carbon capture and sequestration. Bioenergy ranks as one of the few technological options capable of tackling climate change today. However, it is not the panacea for solving future energy systems.

Biofuels for transport (mainly ethanol and biodiesel) at present use traditional starch, sugar and oil crops. Second generation biofuels (e.g. Fischer Tropsch fuels, dimethyl ether and lignocellulose-based ethanol) will become increasingly competitive when more abundant and cheaper lignocellulosic feedstocks become available.

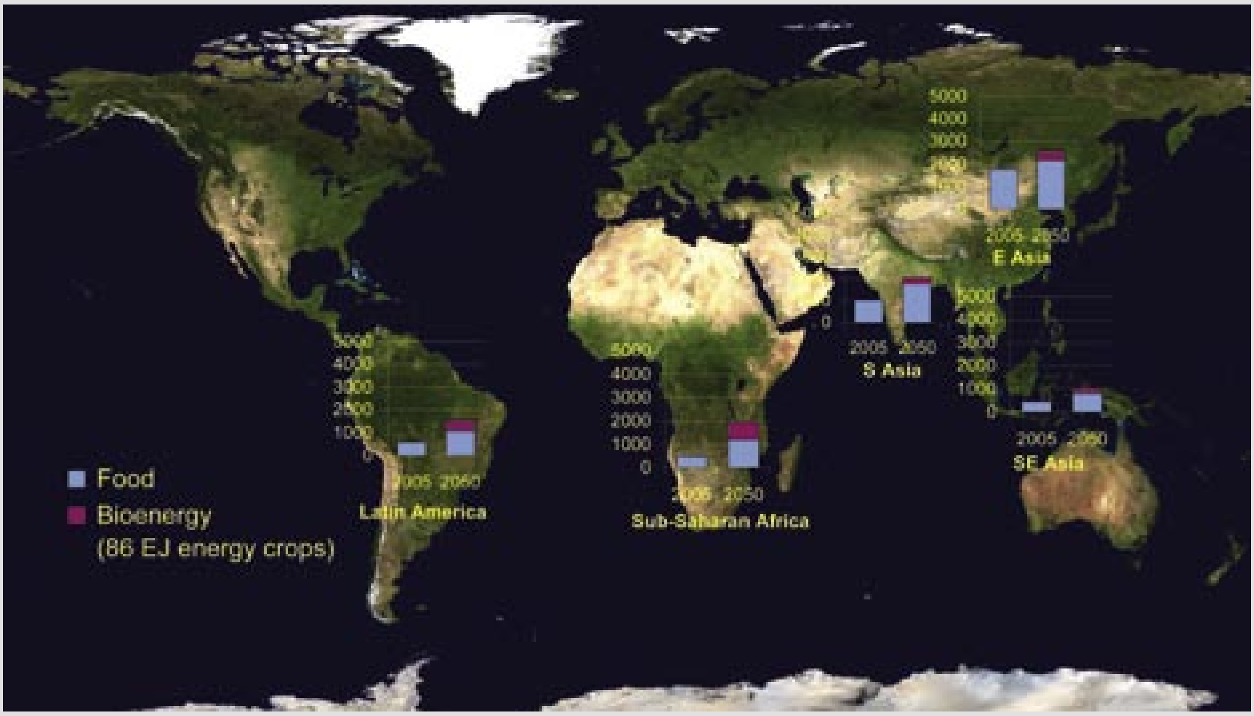

Figure 5. Estimated water requirements for food today and hypothetical water requirements for food and bioenergy around year 2050. The vertical axis is crop evapotranspiration in km3/year. It is assumed that lignocellulosic crops will mainly be used for bioenergy with an average water use efficiency (WUE) of 2.5 kg biomass per m^3 of evapotranspiration. This is a high average WUE compared to that presently achieved for agricultural crops. However, calculations are based on a possible situation almost 50 years ahead, when WUE will likely be higher than today as a result of plant breeding and improved agronomic practices. See Lundqvist et al. (2007) for further information.

2.5 Under Nourishment and Over Eating: Changing Perspectives on Food Security

Discussions about food security refer either to the amount of food supply, usually at national level, or the nutritional requirements. The common denominator is the objective to minimize the risk of undernourishment. According to the 1996 Rome Declaration: "Food security exists when all people, at all times, have physical and economic access to sufficient, safe and nutritious food to meet their dietary needs and food preferences for an active and healthy life." (FAO, 1996). Naturally, the food requirements vary depending age, physical activity etc. The most commonly used international norm for food security refers to a food supply where the energy requirements of the national populations are supposed to be met. In addition to the energy requirements, a proper diet must contain essential proteins and micro-nutrients. Figures about dietary energy requirements vary in literature, but a common reference is to a national average food supply of 2,700 kcal/capita/day. Slightly higher figures have also been used, 2,800 (CA, 2007) and 3,000 (Bruinsma, 2003).

An analysis of food supply data[8] and the incidence of undernourishment in the world reveal a direct and linear reduction in the number of undernourished people with increased food supply. The risk that some of the population may be undernourished is very low if food supply is approaching 3000 kcal/capita/day (SEI, 2005); this comparatively high level of food supply corresponds to projections in FAO reports (Bruinsma, 2003).

While the risk of undernourishment is reduced with increasing supply of food – provided that access is ensured – the risk for over eating and wastage is likely to increase when food becomes more abundant in society. It is therefore important to make a difference between figures that refer to food supply and figures that refer to intake or consumption of food. Generally, the amount of food produced must be higher than the amount of food supplied, which in turn must be higher than food consumed. From a nutritional point of view, food intake should be about 1900–2200 kcal/capita/day (FAO, 1996; Schäfer-Elinder, 2005; Smil, 2000; MSSRF, 2002). If it is lower, the risk of undernourishment increases[9] and if it is higher, the risk of overweight and obesity increases . Consequently, level of food supply and composition of diets have direct consequences for water pressure and the environment as well as for public health. It is therefore very important to look at the critical link between production and supply and the actual food intake (please see chapter 3)

Food supply refers to the amount of food available on the market, and also to food supplied through other channels, including schools, hospitals and other public distribution systems. Socioeconomic factors mean that access can vary significantly between groups of people, also within a household. Even if there is sufficient food available in society, for many people access is restricted mainly because of poverty and conflicts in society. In countries or regions where lack of water or other factors prevent food production, access can be secured through imports, i.e. if the means and conditions make imports possible. Poverty implies that purchasing and bargaining power is limited.

An estimated 830–850 million people in the world are undernourished (FAO, 2006) primarily because members of the household do not have the means to buy food or are unable to grow the food they need. There is a striking correlation between areas with a high proportion of undernourished people and a high proportion of the population who are extremely poor, indicating that poverty means that people do not have the means to produce for themselves nor can they afford to purchase the food they need (Lundqvist 2008). Similarly, there is a correlation between areas with an dry climate and water scarcity and the level of undernourishment (Falkenmark and Rockström, 2004).

Surprisingly, food insecurity is most prevalent among rural populations (von Braun, 2007), that is, in areas where food is, or could be, produced. Even with a public distribution system in place and food available in stores, there may be people who are food insecure. This is the case in India where food grains have accumulated in the godowns of the Food Corporation of India. In the Public Distribution System, there is currently a problem managing a food surplus rather than a shortage, while at the same time there are large numbers of undernourished people (Gaikwad et al. 2004).

At the other end of the spectrum, the number of overweight and obese people is an increasing problem, not only in developed countries but also in developing countries. Globally, there are roughly 50 percent more people who are overweight and obese (1.2 billion) than there are malnourished (860 million). Over eating together with wastage of food contribute to natural resource depletion and has environmental implications, for instance, in terms of green house gas emissions. As discussed in sections 3.2 to 3.5 below, it is important to recognize that all food that is produced, whether it is consumed, wasted or not, has consumed water and contributed to pressure on other natural resources. Overeating leads to poor health and increased costs to individuals, family and society. Food security is thus not only a matter of food production or food supply.

Discussions about food security must rightly focus on access to food. It is relevant to address the problems related to the proportion of the food from cereals and other plant based foods and food derived from animals. While livestock products and fish are important in a nutritious diet, in many countries the consumption of livestock products, sugar and oil is significantly higher than what is required for human health. In other countries, this part of the diet is quite low (McMichael et al., 2007). Apart from the high consumptive use of water for livestock products, they also contribute significantly to the generation of greenhouse gas emissions (Steinfeld et al., 2007; McMichael et al., 2007).

Emerging challenges related to sustainable resource management and changing perspectives on food security mean that a narrow focus on production and food supply is no longer valid. A broader view incorporating the full chain from food production to consumption is warranted.

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[8] The most comprehensive database for such calculations is FAO's Food Balance Sheets (see note 3), which provide information for individual countries on production, net exports or imports and non-food use of food. Quality of data depends on reports from the individual country. These sets of data can be used to estimate the supply of food on a country basis. They do not, however, show how much food is lost, wasted or eaten.

[9] For the poor and undernourished, the need of increased access to and intake of food up to a certain basic level is an overriding issue. Attempts have been made to estimate what is the Minimum Dietary Energy Requirement. According to FAO, for instance, these estimates vary from 1,730 to about 2000 kcal/capita/day for various countries (http://www.fao.org/es/ess/faostat/foodsecurity/Files/MinimumDietaryEnergyRequirement_en.xls). In MSSRF (2002) it is mentioned that an average food intake that is 70% of the international norm for food security, i.e. 0.7 x 2700 = 1890 kcal/capita, day may be acceptable. What is generally acceptable must be related to nutritional and medical criteria. It is also related to the age and occupational structure of the population, among other things. Smil (2000) provides examples showing that food intake at levels below 2000 kcal/capita/day have not resulted in documented signs of under nourishment.

3. Taking a Food Chain Perspective: From Field to Fork

The emerging challenges facing the food sector include growing water scarcity, unacceptably high levels of undernourishment, and at the same time the proliferation of people who are overweight or obese and of food that is lost or wasted in society. All these challenges mean that a narrow perspective on food security in terms of production and supply is no longer sufficient. It's time to take a broader perspective incorporating the steps from growing crops in the field to consuming a meal at home, that is, a field to fork perspective.

3.1 Stages and Actors in the Food Chain

There are many stages and actors in the chain from producing crops in the field to consuming a meal at home or in a restaurant (Figure 6).

At the beginning of the chain are the farmers producing the crops. Crop production takes place under many different climatic and socioeconomic regimes, so the efficiency of water use (irrigation and rainwater) varies enormously. At the next stage the crops are harvested, where a range of harvesting techniques are used, from manual to highly mechanized. A significant stage in the food chain consists of converting vegetal feed items into livestock products. The production of animal-based produce, such as meat and milk, requires different amounts of water depending on the particular animal and the feeding strategy. Different animal species have different conversion rates. Producing 1 kg of beef meat requires roughly 8 kgs of feed, while 1 kg of chicken meat requires only a couple of kgs of feed. As a global average, about 40 percent of total global cereal production is fed to animals to produce meat, milk, cheese and other foods derived from animals. Converting vegetal to animal foods means a substantial overall 'loss' of energy.

6a	Food Production		Processing and Distibution		Food Supply	Consumption Unit
Activities	Crop cultivation	Harvest	Vegetal foods Feed animal foods	Storage, transport, processing, packing Storage, transport, processing, packing	Access: Food exposure, Food purchase; Food outlets and super- markets	Storage, Cooking, Consumption, Throwing food away
Tpe of Loss	Water losses	Crop Losses	Conversion losses	Distribution losses and spoilage during storage and processing	Spoilage and Wastage	Wastage, Overeating

6b	Food Production		Processing and Distibution		Food Supply	Consumption Unit
Key Issue for Policy	Water and land manage-ment practices	Technical and management issues	Choice of production of animal foods or vegetarian foods	Technical infrastructure	Business marketing, Food regulation, Consumer behavior	Individual and collective consumer behavior

Figure 6. Schematical overview of losses and wastage in the main stages of the food chain (6a) , and factors contributing to these losses and wastage (6b).

Storage is necessary to balance supply and demand over time and to withstand the climate and other factors, such as pests and trade limitations, which can influence food availability in a country or region. A characteristic feature of economic development and urbanization is that, increasingly, food is not consumed in same place as it is produced. A decreasing fraction of the world's population are involved in the primary food production, i.e. at farm level (SIWI et al. 2005). In developing countries, food is typically transported over relatively short distances. With globalization and with decreasing transport costs, food is increasingly transported around the world, involving different transport companies using different modes of transport. Another trend is the development of food industries, meaning that food often goes through several processing steps in different factories (Reardon et al. 2003, Dugger, 2004). In rural areas of poor countries, households themselves process food for immediate or later consumption.

Rising incomes, urbanization and the felt need for conveniency in food preparation and the quest for variety, have promoted the role of food-processing industries, and increased the importance of packaging. With an increasing distance from sites of production to where food is marketed, it becomes rational to prolong the life span of perishable products and ensure that the quality and appearance of food items will correspond that what consumers have come to expect. Once food is processed and packaged, it is marketed in local shops and supermarkets. Big supermarkets offer the consumer a wide range of foods, but not all perishable products can be sold before their expiry date. With consumers increasingly concerned about food safety and demanding high quality fresh produce, this inevitably leads to food being thrown away even before it's sold and often while it is still perfectly fit for eating. This is a bigger problem in developed than in developing countries. However, with improved living standards and changes in attitudes, habits and living conditions, and with more food outlets like supermarkets, the problem is increasing in developing countries, too.

The final stage in the food chain is a combination of consumption at home, in restaurants and in institutions (such as schools, offices and hospitals) and a discard of part of the food in terms of through aways.

Because more and more of the world's population are moving out of agriculture and into urban centers, the food chain is becoming longer and more complex. The increasing complexity in distribution and supply systems and the increasing geographical distances between production and consumption are natural and driven by consumers' expectations of variety and convenience. At the same time, the increasing demand for animal products, fruits, vegetables and other sensitive and perishable food items, leads to an increased risk of loss, in both quality and quantity. For many food items that are in increasingly high demand, it may be a matter of days before quality declines and they become less attractive. Apart from being less attractive, other concerns, such as public health, environmental and ethical issues, are becoming increasingly important in the food chain. Stricter rules and labeling of food in combination with consumers' increasingly exacting standards mean that part of the food supply will remain unsold or be withdrawn (Box 3).

Production by farmers will, of course, continue to be a vital precondition for food supply to meet increasing demand, but due to resource constraints and the demand for land and water for other types of agricultural products, it is essential that the field to fork chain is as efficient as possible.

For a proper analysis of food security, the complexity of the food chain may be reduced to four important levels:

- the amount of food produced, that is, at the field level
- the amount of food available on the market, that is, the produce "at the field level" minus losses before the food reaches the shop or supermarket, losses during conversion from vegetal to animal foods, plus/minus changes in stocks, that is, the food supply
- the amount demanded or bought by households, public institutions and other buyers
- the actual intake of food, that is, the amount of food eaten.

The first level refers to the amount of food in terms of edible crops. Since about 40 percent of the crops are used for feed, and some are lost through poor harvesting technologies, transport and storage deficiencies, the supply of food to the market is much less than the food at the field level, but it is typically more varied than the produce at the field level. Because of wastage in the retail chain, and in restaurants and households, the amount of food that people actually eat is much less than that produced.

Many food demand projections and major food databases such as FAOSTAT does not distinguish between these four phases. Consumption or "national average apparent food consumption" are often-used concepts when, in fact, food supply would be the appropriate term. The figures used are usually derived from Food Balance Sheets and refer to food supply rather than actual food intake (e.g. in Bruinsma, 2003). Yet, because of the losses along the food chain, quantities coming from the field are very different from quantities supplied, which, in turn, are different from the amount of food actually consumed.

3.2 Losses, Spoilage, Conversions and Wastage

Reductions in the amount of food between the field to the fork are of quite different kinds. In the literature, various concepts are used for these kinds of reductions.

Losses generally refer both to quantitative and qualitative reductions in the amount of and the value of the food. In this report, we have also argued that part of the rain water resource that is potentially available for food production is lost from the field as unproductive evaporation. At the field level, part of the crop is lost due to rodents, pest and diseases. Similarly, a part of the produce is lost during transport and storage due to the same type of problems. Poor water and land management will increase the risk for water losses and the lack of effective harvesting, transport and storage technologies will augment the losses at the farm level and during latter stages in the food chain.

Spoilage is another term used to highlight problems with transport, storage, processing and packaging.

Conversion refers to the use of cereals and other plant based products as feed to produce animal foods.

Wastage generally refers to the deliberate discarding and through away of food that is "fit for purpose and perfectly good to eat" (Knight & Davis, 2007). This occurs in the latter part of the food chain, in food companies, wholesaling, retailing and households.

Generally, a hot and humid climate will increase the risk for these types of losses. Vulnerability of food increases with the trend towards high-value food items and greater transport distances.

Figure 7 depicts a gross estimate of the global picture of losses, conversion and wastage at different stages of the food chain. As a global average, farmers produced the equivalent of 4600 kcal/capita/day in the late 1990s (Smil, 2000), i.e. before conversion of food to feed. Counting down the losses, conversions and wastage at the various stages, roughly 2800 kcal is available for supply (mixture of animal and vegetal foods) and, at the end of the chain, 2000 kcal on average is available for consumption.

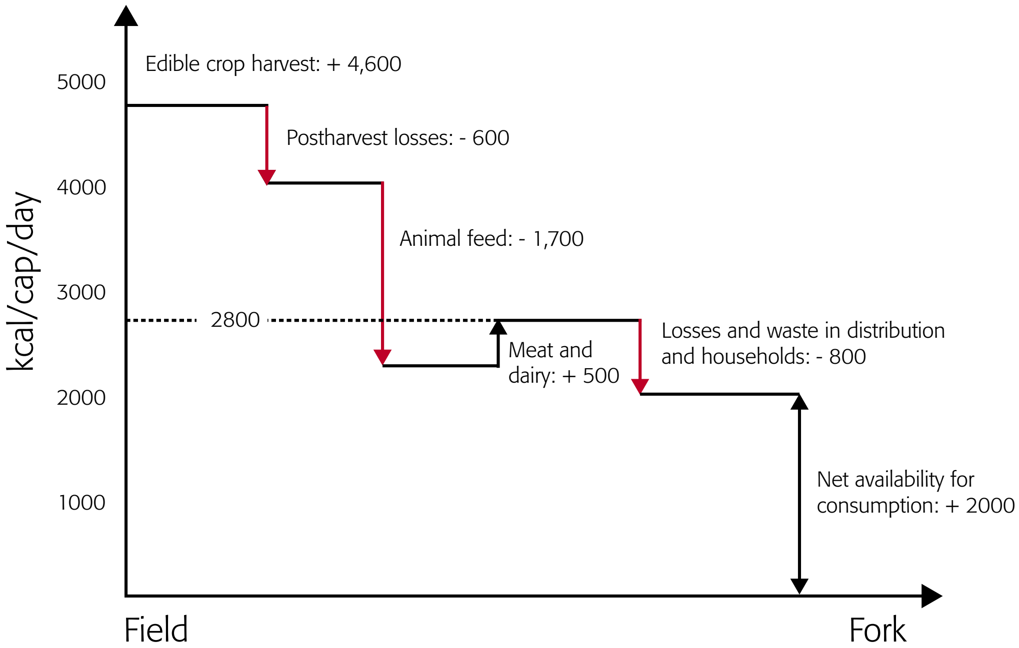

Figure 7. Energy losses, conversions and wastage in the food chain. Source: Smil (2000).
Illustration: Britt-Louise Andersson, SIWI.

The orders of magnitude of losses, wastage and spoilage differ by location and stage of the food-chain. Very broadly speaking, in developing countries most losses occur at the beginning of the food chain: in the field due to poor harvesting technologies, and as a result of poor storage and transport facilities. In hot and humid regions especially, losses of food, including a deterioration in quality, are most pronounced during the first part of the food chain.

In developed countries, harvesting, transport and processing are often comparatively efficient, but with significant variations between different crops. However, towards the end of the food chain significant amounts of food are wasted in wholesaling, retailing and among consumers – who tend to throw away a significant fraction of the food they have paid for and taken home. As incomes in middle-income and less developed countries continue to rise, and the distance from the site of production to places where food is prepared and eaten increase, the energy losses associated with converting grains into livestock products will become more important as diets shift from vegetal to animal foods.

According to Kader (2005) losses in the field (between planting and harvest) could be as high as 20–40 percent of the potential harvest in developing countries due to pests and pathogens (Figure 8). Losses in processing, transport and storage are conservatively estimated at 10–15 percent in quantity terms, but could amount to 25–50 percent of the total economic value because of reduced quality (Kader, 2005). Lastly, substantial losses and wastage occur during retail and consumption, due to discarding excess perishable products, product deterioration and food not consumed.

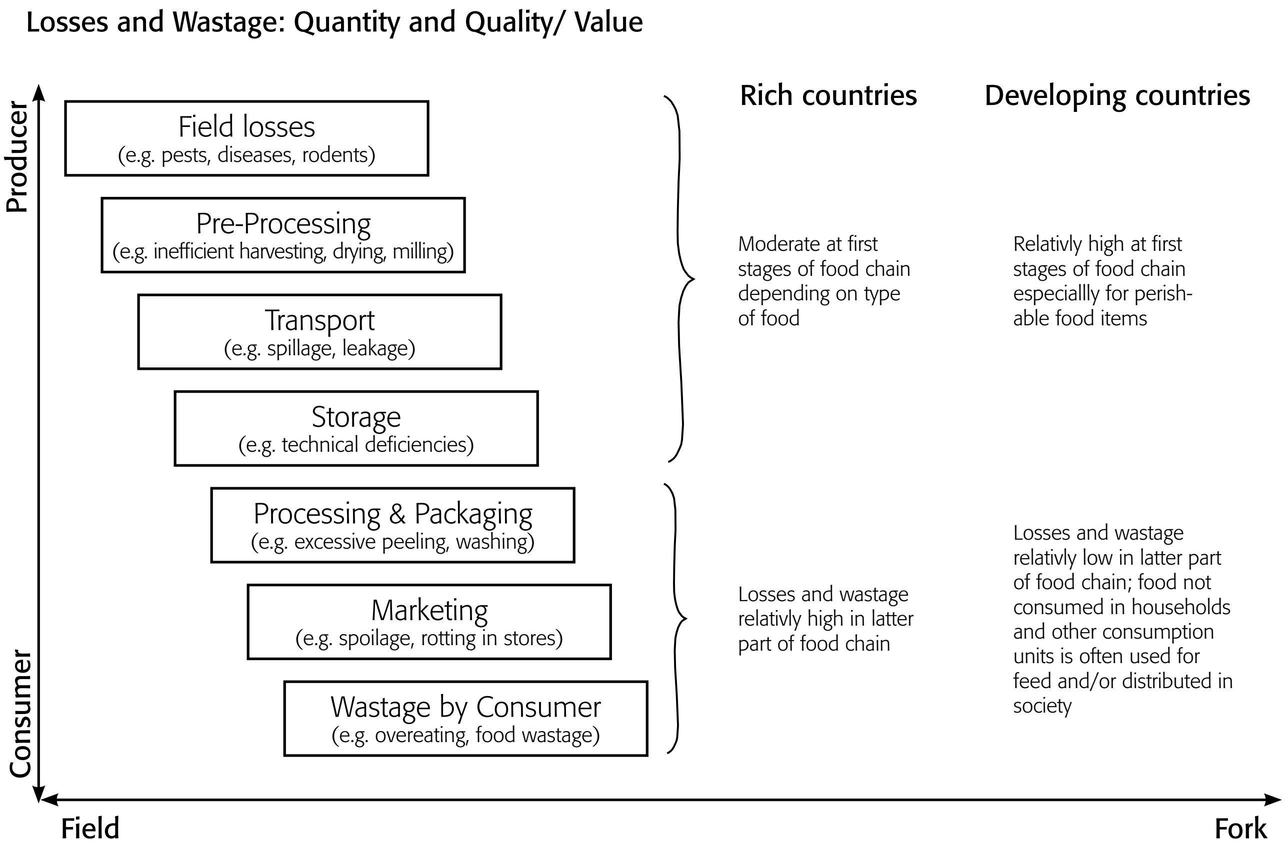

Figure 8. Main types of food losses and wastage. Illustration: Britt-Louise Andersson, SIWI.

3.3 Significant Losses and Spoilage in Less Developing Countries

Many factors contribute to substantial losses and wastage of food. In many of the less developed countries, the adverse climate, with high humidity and high temperatures, and attacks from rodents, insects, mold and other agents constitute a significant problem. Many poor farmers have to rely on inefficient harvesting, transport and storage facilities, with substantial losses. Swaminathan (2006) mentions that the post-harvest infrastructure is weak in large parts of India "… even now, paddy is spread on the roads drying in many places. The spoilage can be as high as 30 percent in the case of vegetables and fruits". Losses for grains and oil seeds are lower, about 10–12 percent, according to the Food Corporation of India. Some 23 million tonnes of food grains, 12 of fruits and 21 of vegetables are lost each year, with a total estimated value of 240 billion Rupees. A recent estimate by the Ministry of Food Processing is that agricultural produce worth 580 billion Rupees is wasted in India each year (Rediff News, 2007).

Inferior and inefficient technologies do, of course, present difficulties when planning the supply chain. The challenge is greatly compounded by poverty, both at the level of the small producer as well as the consumer. In India, the Public Distribution System has been organized to ensure food supply to the needy outside ordinary market channels. Recent reports show that food grains have been accumulating in the godowns of the Food Corporation of India, far beyond the prescribed buffer stocks, with the result that a considerable proportion is lost.

Available figures from Africa reveal similar problems and relative losses. In many countries the post-harvest losses of food grains are estimated at 25 percent of the total crop harvested. For some crops such as fruits, vegetables and root crops, being less hardy than grains, post-harvest losses can reach 50 percent (Voices Newsletter, 2006). Economic losses in the dairy sector in East Africa and the Near East due to spoilage and waste could average as much as US$90 million per year (FAO, 2004). In Kenya, each year around 95 million liters of milk, worth around USD 22.4 million, are lost. Cumulative losses in Tanzania amount to about 59.5 million liters of milk each year, over 16 percent of total dairy production during the dry season and 25 percent in the wet season. In Uganda, approximately 27 percent of all milk produced is lost, equivalent to US$23 million per year (FAO, 2004). In Ghana post-harvest losses can account for 35 percent of total agricultural output (Ghana Business News, 2003).

Without proper storage and transport facilities, perishable food items are particularly vulnerable in hot and humid climates. The high losses in developing countries are mainly due to a lack of technology and infrastructure as well as other intrinsic and extrinsic factors such as high insect infestations, unwanted microbial growth, injuries and blemishes due to improper handling or transportation and prevailing high temperatures and humidity during growth and harvesting (Buys and Nortje, 1997).

3.4 High Rates of Losses and Wastage in Developed Societies

Food losses in rich countries are different to those in the developing parts of the world. Generally, the kinds of losses in developed countries are referred to as wastage, i.e. food is discarded even if it's "perfectly good to eat".

But there are also significant losses in the first segments of the food chain in the rich countries depending upon what food is being produced. For instance, quite significant volumes of food are lost and wasted in the US. According to Jones (2004), losses at the farm level are probably about 15–35 percent, depending on the industry. For the fresh vegetable industry, losses are naturally higher at 20–25 percent. For fruits like apples and citrus losses vary around 10–40 percent. The retail industry has comparatively high rates of loss at about 26 percent, while supermarkets, surprisingly, only lose about 1 percent. "Overall losses amount to somewhere around USD 90 to USD 100 billion a year" (Jones, 2004) and "…households alone, in the US alone, throw away USD 48.3 billion worth of food each year" (Jones, 2006).

Kantor et al. (1997) estimated the US total retail, foodservice, and consumer food losses in 1995 to be 23 percent for fruits and 25 percent for vegetables. Fresh fruits and vegetables accounted for nearly 20 percent of consumer and foodservice losses, from product deterioration, excess perishable products that are discarded, and food not consumed by the purchaser (Kader, 2005). In the US, losses of fresh fruits and vegetables are estimated at 2–23 percent, depending on the commodity, with an overall average loss of about 12 percent between production and consumption sites (Kader, 2005).

Similar levels of food losses and wastage are reported from Europe. In the UK, for instance, Knight and Davis (2007) estimate that "…about 5 million tonnes of food goes into household waste". Other UK studies estimated "...total consumer and industrial food waste reaching 17 million tonnes [annually]". A part of this, or about 4 million tonnes, is still "fit for purpose and perfectly good to eat". An assessment made in 1997 of the monetary value, or annual cost of food wasted by supermarkets and catering outlets in the UK was £ 386 million (Knight and Davis, 2007 p.4).

Reports on food waste in Sweden suggest that families with small children throw away about 25 percent of the food they have bought and carried home and that total losses and wastage in the food chain are close to 50 percent (KSLA, 2007; Ennart, 2007). Figures are, however, uncertain. Other studies suggest lower wastage in households, whereas wastage in units for collective food consumption, such as schools and hospitals, is comparatively large (Naturvårdsverket, 2007).

The figures quoted here give an indication of the average annual losses and wastage of food. In addition to the generally high levels of losses and wastage, incidents involving huge losses or wastage regularly occur. Due to strict safety standards, animal food items are especially vulnerable. The recall in the US of about 65 million kg of raw and frozen beef products at the beginning of February 2008 (see Box 3) highlights several important characteristics of the food sector (Rano, 2008). Even with a recall of such magnitude, there were no reported shortages. This shows that a tremendous volume of food is available in rich countries. Since the recall was to ensure the safety of the meat supply, the example also shows that the fear of the transmission of mad cow disease or other pathogens harmful to human health, may significantly affect both supply and, as in this case, demand.

Box 3. Water Costs of Beef Recall

Earlier this year, the Hallmark/Wetland Meat Packing Company, California, voluntarily recalled approximately 143,383,823 pounds or about 65 million kgs, of raw and frozen beef products, following an investigation by USDA's Food Safety and Inspection Service (Rano 2008).

What reached the headlines were stories of the undercover investigation by the Humane Society of the United States, and the resulting footage of plant employees mistreating cattle. The video led to fears that the use of crippled cattle could increase the risk of human exposure to mad cow disease or pathogens such as E. coli.
The news has spurred fiery debate amongst industry and consumer safety groups, with the latter claiming that the incident supports growing consumer fears that the US government is not properly regulating meat safety.

The unreported side of the story is about the water wastage of this and similar incidents. As mentioned in chapter 1 of this report, the consumptive use of water to produce beef varies significantly between countries and production systems, but a conservative average is about 5 to 10 tonnes of water per kilo beef. To produce the 65 million kgs of beef, will thus require an estimated of 650 billion liters of water that is evaporated and transpired, mainly to grow the fodder for the animals. This is enough water to irrigate about 100000 ha of dry land for a year, or supply more than enough for Las Vegas annual supply (the present demand is 870 liters per capita per day, BBC news, Vegas heading for 'dry future' , July 29, 2005) which extracts about 350 billion liters from Lake Mead (from Wekpedia).

3.5 Implications and Dimensions of Losses and Wastage of Food
Losses and wastage are important in other respects than from a pure food security perspective. It is important to recognise that losses and wastage look quite different depending upon socio-economic and other conditions (Figure 9). For the farmer, shop owner and consumer, the economic implications are significant. For the producer, income is reduced, while for the consumer it means higher than necessary spending on food. From a natural resources and environmental perspective, it's important to recognize that food production is resource intensive and has significant environmental consequences. Few people seem to be aware of the fact that agriculture is associated with a high proportion, about 22 percent, of all greenhouse gas emissions. This is at about the same level as industry but higher than the transport sector. Livestock production alone accounts for about 18 percent of total global greenhouse gas emissions (McMichael et al., 2007; Steinfeldt et al., 2007), so the beef recall was also a loss in terms of the added cost of greenhouse gas emissions (Box 3).

These figures refer to the environmental consequences of production. In addition, there are substantial environmental costs associated with subsequent stages of the food chain. Transport, storage, processing, packaging and improper disposal of discarded food must also be considered for a proper understanding of the total food bill. If discarded food is used for landfills rather than being properly disposed of, for instance, in composts or for biogas production, the organic content will generate gases, including methane, which is a very potent greenhouse gas (Knight and Davis, 2006). Importantly, the public understanding of the magnitude and the consequences of the food waste is poor. According to studies done by wrap (2008), the very majority of people in the UK describe the amount of food they throw away as "some, a little, hardly any or none" as compared to the actual through aways that are eaquivalent to about a third of the food bought, most of which could have been eaten. The worth of this wasted food is more than 8 billion pounds retail value (about 12 billion USD). Similarly, the consumers do not recognize the green house gas emissions that are generated both in connection with growing, transport, processing and storage. Almost 6 mt of food waste annually generated in UK homes, out of 6.7 mt are used for landfill. Altogether, it is estimated that some 15 mt of CO_2 are generated from food that could have been eaten. Instead of wasting food, a sensible option would have been to consider how much food needs to be produced or imported.

It's time we moved beyond thinking how we meet quantities, and start looking at the type of foods we produce and how we benefit from them. As food consumers, we all play a role.

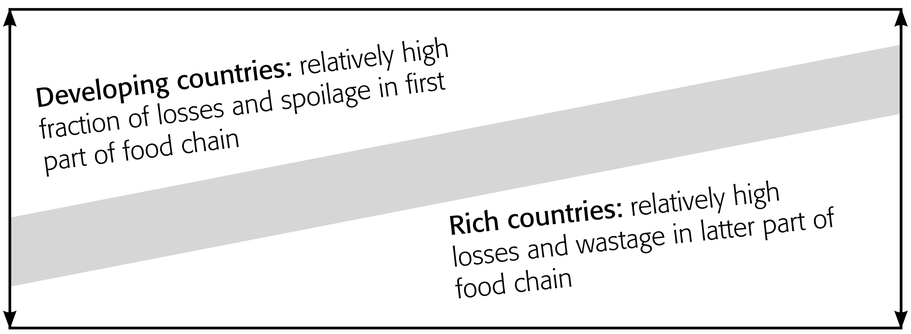

Figure 9. A schmatical presentation of the combination of losses and wastage in different contexts.
Illustration: Britt-Louise Andersson, SIWI.

4. The Smart Approach to Water Saving

4.1 The Need to Act on a Broad Scale
Recent global price spiral on food and repeated reports about palpable social unrest in a large number of countries and fears of an 'agflation' (Economist, 2007) reveal the strategic and basic importance of the agricultural sector for social and economic stability and for environmental sustainability. Given its fundamental role in society, prime importance should be placed on taking all necessary steps to ensure sustainable use of water resources. Challenges now are different from a few decades ago. Climate change will make water availability more variable and scarce. Environmental concerns become increasingly more urgent and costly (The Economist of 15 March 2008 estimates that environmental damage in China may be as much as 10 percent of its GDP). The need for reducing pressure on water resources is real. On the other hand demand for biomass and agricultural products is increasing because of increased income and demand for a range of food as well as non-food products.

So far, the discussion on reducing water demand has centered on how to produce more food with less water, without questioning if the food produced can be used more efficiently. Expressed in kilocalories, global food production at the field level is about double that required to meet the " … dietary needs and food preferences for an active and healthy life of all people at all times" (FAO, 1996). A promising pathway to reduce the need for an increase in gross food production – and therefore water – is minimizing losses and wastage along the food chain. Together with measures to produce food with less water, enormous amounts of water can be saved for other uses and the environment. Less waste in the food chain saves water, money and increases consumers' disposable incomes. It's time to take a broad perspective on water savings and to explore the scope for improvements along the entire food chain, from field to fork. We propose a two-pronged approach combining water savings in the field by producing more food with the same or even less water with measures to reduce losses and wastage of food produced in the various stages of the food chain , and thus ease pressure on water resources.

4.2 More Food with Less Water: Reducing Unproductive Losses of Rainwater

Large quantities of water are lost in the field. Roughly there are two ways of capturing this water. First, capturing a larger share of the rainfall and make it accessible for productive transpiration. This strategy might however impact negatively on downstream water users. Upstream runoff generation is only a loss to the upstream farmer, while it may be used beneficially by downstream ecosystems or water users. Second, changing the way water is used in crop production by maximizing the benefits per unit of water consumed in

Box 4. Reducing Unproductive Losses of Rainwater

The renewable potential freshwater resource is equal to the total amount of precipitation over land. As precipitation reaches the ground, it is split into a number of flows (Fig. 10). One fraction is aboveground and groundwater flows; these contribute to the blue water in lakes, rivers, reservoirs and the acquifer. Another fraction of the precipitation infiltrates the soil and is stored in the soil profile, forming the green water resource.

In all agricultural systems, some of the potential water resource is inevitably lost as non-productive evaporation. The fraction of rainfall available for productive transpiration is generally less than 30 percent, but varies between agroecological systems and climatic zones (Rockström, 2003). In arid regions with little rainfall, only some 10 percent of the total rainfall is consumed as productive transpiration, while most of the precious drops are lost as non-productive flows (Oweis and Hachum, 2001). In semi-arid parts of sub-Saharan Africa, this may be in the order of 15–30 percent. In temperate regions, productive transpiration is around 45–55 percent of rainfall (Rockström, 2003). An overriding challenge in sub-Saharan Africa and other areas suffering from water scarcity is to increase the fraction of rainwater available for productive transpiration.

Non-productive water losses can be minimized by mulching, weed and pest management, early plant vigor, optimal planting density and no-tillage systems. Crop choice can also influence plant water uptake capacity and thus water productivity.

It's important to recognize that cropping under pure rainfed systems is fairly risky and yields tend to be low. In many of these areas, conventional irrigation is not feasible, either because it is too costly or simply because water availability is a constraint. In these situations it can, however, be done with some kind of supplementary irrigation, such as from water harvesting systems, for instance a small hand-dug dam. Such systems have been successfully used in small-scale agricultural systems to bridge dry-spells. If local run-off is applied to the plants during dry periods, the risk of crop failure is substantially reduced. The aim of supplementary irrigation is not to meet the plant's full water demand, but to ensure that the plant gets enough water during critical growth stages. In combination with fertilizers, small amounts of additional water can lead to high yields and water productivity, particularly where yields are low (Rockström et al., 2007).

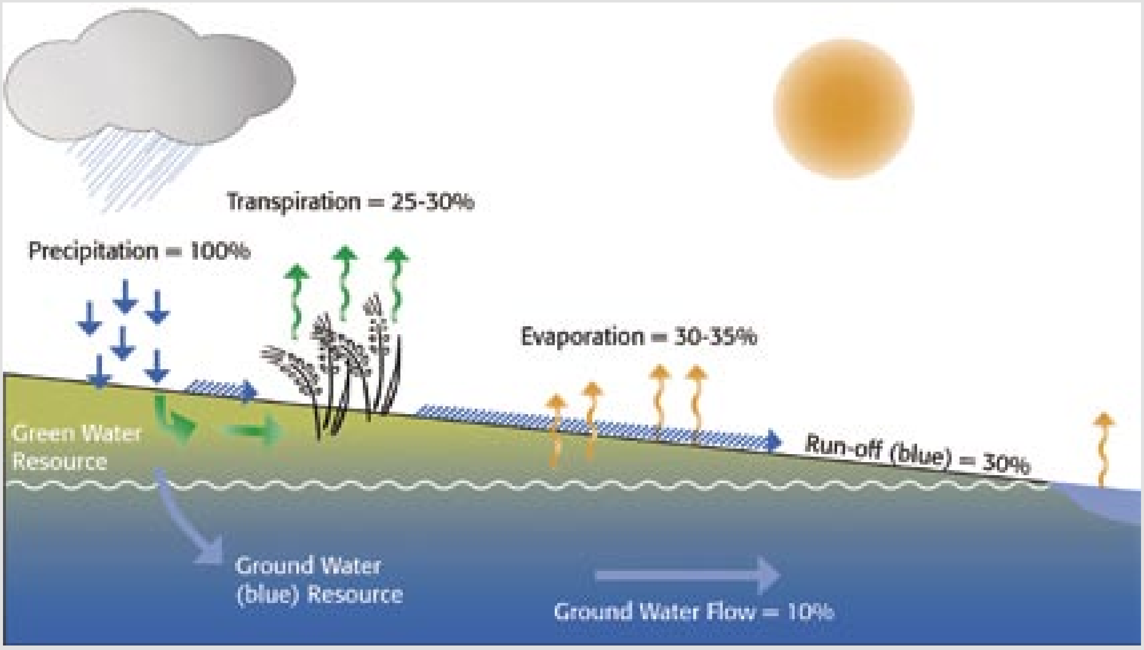

Figure 10. Green and blue water resources and flows in the landscape. Illustration: Britt-Louise Andersson, SIWI.

Box 5: The Need for a Green Revolution in Africa
The Green Revolution is a much misunderstood and maligned process of agricultural intensification. It has, for example, enabled India to feed its population which grew from some 450 million people in the 1960s to more than a billion today, and it has allowed a number of previously food-deficient Asian countries to become net exporters of food. Asian cereal production doubled between 1970 and 1995 while the total area under cereals only increased by 4 percent (Evensen ad Gollin, 2003). Yield improvements are important. They have, for example, had a dramatic conservation effect in that they have limited agriculture's intrusion into marginal lands and hence preserved wildlife and biodiversity.

This has been partly due to new technologies – high-yielding crop varieties, inorganic fertilizer and irrigation – and the green revolution has commonly been seen as 'merely' a technology package. In reality it went far beyond technology. The Asian green revolution was a state-driven, market-mediated and smallholder-based strategy to increase national self-sufficiency in food grains. Supported by international crop research, governments took the lead but (unlike in China and North Korea) did not eliminate private traders. The technologies offered were suitable for smallholders and were backed by massive support systems including credit, subsidies, price policies, extension services and infrastructural investments, e.g. in schools, roads and canals (Djurfeldt et al. 2005).

Initially based on high-yielding, semi-dwarf varieties of rice and wheat, the Green Revolution is sometimes described as a one-shot-intervention. Since the 1960s, the Green Revolution has evolved to encompass a wide variety of staple crops (e.g. maize, beans, bananas, cassava) and the Consultative Group on International Agricultural Research (CGIAR) has released more than 8000 improved crop varieties during the last 40 years. Improvements are not limited to yield increases but also include characteristics such as drought tolerance, pest resistance, and fast maturation – innovations that make varieties suitable for other regions, too, notably sub-Saharan Africa where agricultural productivity is still low (Holmén 2006).

Gaps between potential and actual yields are considerable among African smallholders even within the same local area, that is, within a similar land and water context, indicating that there is the potential to increase yields, even with the effects of climate change. Actually, output could double if poor farmers were given incentives to adopt existing technologies, including better water management already used by their better-off neighbors. Hence, an African Green Revolution would need to concentrate on the supportive measures. Implementing a Green Revolution in Africa would also, in theory, make room for considerable acreage to be devoted to bioenergy crops without jeopardizing food security or marginal lands.

rainfed and in irrigated agriculture (Molden et al 2007). For example, rapid rates of evaporation mean that a considerable fraction of rainfall is lost as return flow to atmosphere without being beneficially utilized. Several strategies to improve the water productivity, or "crop per drop", are available. Related to this option, it will be increasingly important to have a strategy for where food is best produced. Climate change and the associated escalated water scarcity will make agricultural production very difficult or very costly in large parts of the world whereas opportunities will be improved in areas blessed with a water abundance of dependable water availability.

It is, however, very important to increase food production also in areas where needs and demands may increase the most. For large parts of Africa, prevailing levels of production and productivity are low and quite uneven, indicating that there is a potential to increase production with the right incentives and supportive measures (Box 5). Trade can help mitigate water scarcity if water-short countries can afford to import food from water-abundant countries. Cereal trade from rainfed areas in the temperate zones (USA, EU, Argentina) to arid areas (Middle East) reduces current global irrigation water demand by 11–13 percent. But political and economic factors are stronger drivers and barriers than water.

Generally, only 30 percent of rainfall that hits the ground is converted into productive transpiration, necessary for crop growth and food production. By shifting non-productive evaporation to productive transpiration through an integration of crop and soil management, more food can be produced with the same amount of rainfall (Falkenmark and Rockström, 2004). This is an important opportunity to improve agriculture through better utilization of local rainfall. The crucial challenge is to reduce unproductive evaporation losses so that the impact on downstream water users is as small as possible (Box 4).

4.3 Water Savings Potential Throughout the Food Chain

The sheer magnitude of losses, wastage and over-consumption means that we have the ability and options to reduce gross food demand and agricultural water supply without affecting food security. Most losses occur after food is produced in the field. As water has already been evaporated, successive losses down the food chain add up to considerable unproductive water use. Globally, the amount of water withdrawn to produce lost and wasted food could fill a lake of 1300 km^3, about half the size of Lake Victoria. In the US, food production consumes about 120 km^3 of irrigation water. People throw away an estinmated 30 percent of this food corresponding to 40,000 billion liters of irrigation water, enough water to meet the household needs of 500 million people. The amount of water that can be saved by reducing food waste is much larger than that saved by low-flush toilets and water-saving washing machines. It's time for us to move beyond thinking about how we meet quantities, and to start looking at the type of foods we produce and how we benefit from them.

This is by no means easy. There are many stages and many actors from field to fork, such as farmers, agricultural workers, truck drivers, shopkeepers, government officials and consumers. Individually, some actors have little or no incentive to improve efficiency when the waste in their segment of the chain is relatively small and the costs or efforts of improvement outweigh the benefits. Other actors, like small farmers, would benefit from a reduction in post-harvest losses, as it could increase their income and food security. Too often, however, they lack the financial and other resources to make the necessary investments in improved technology.

With increasing disposable income, urban lifestyles and the influence of the food industry and supermarkets, the stages in the food chain beyond production are evermore important. Yet measures and policies to influence consumer behavior are controversial and notoriously difficult to implement. Despite recent rises in world market prices, food is still a relative cheap commodity except for the very poor, and many consumers have little incentive to change their wasteful behavior.

Studies carried out at the University of Arizona revealed that people living in cities in the US display an alarming level of ignorance with regard to food-related issues. Most urban consumers who were interviewed did not realize that meat, dairy and fruit come from living things that use natural resources to grow (Jones, 2004 and 2006). With increased distance between farms and food consumption sites and commoditization of food, the level of ignorance may only increase, and unaware consumers are less likely to question and change their behavior.

A combination of policy measures will be necessary: investment support in post-harvest technologies, scrutiny of the role of the food-processing industry and supermarkets, as well as pricing mechanisms and strategic efforts to visualize and educate the public on practically contributing to reducing food wastage. Schools and public institutions could be focused entry points for such a strategic effort, as general awareness campaigns have proved to be rather ineffective.

To successfully address losses in the food chain it will be necessary to involve various sectors and actors in the efforts to develop measures to adapt to the new type of water scarcity.

4.4 Involve Stakeholders

The Business Community

The business community increasingly sees the need to protect water resources to safeguard future production. Earlier this year, serious concerns about water scarcity affecting the industrial sector were expressed at the World Economic Forum. Attention was drawn to its potential negative ramifications on future economic wealth and political security. Special concern was raised to limits of sustainable water use being reached or breached in many world breadbasket regions. The meeting concluded with a “call for action” (Box 6). Several business leaders see a triangle of related issues critical to the sustainability of their businesses: climate change–water–food.

Box 6. Call to Action from Davos

Significant business disruptions due to water scarcity – across all sectors and geographies, and with all the associated technical, economic, political, environmental and social implications – are a reality today, and are projected to worsen in the future, as a result of changes in climate and demographics. Governments play an important role in helping to mitigate and adapt to the challenge, but so does the private sector, through individual company actions and through innovative public–private and multistakeholder partnerships. CEOs are called to catalyze holistic water management actions up and down their respective supply chains and throughout the existing and new networks of which they are a part.

The focus of actions should include:

- Water governance for transparent/fair allocation to users and sound incentives for efficient water use
- Water for agricultural use (“more crop per drop”; 70 percent of water withdrawn worldwide)
- Water for industry (water efficiency within operations)
- Water for energy (the deepening link between water resources and climate change)
- Water for human purposes (sustainable and affordable access to safe drinking water and sanitation)
- Water for the environment (to ensure sustained ecosystem security).

To assist the development of this set of actions, the signatories of this paper encouraged the Davos community to establish a wide coalition of businesses across different sectors. This coalition should create and collaborate with innovative partnerships on water management involving the research, development, farming, international non-governmental organizations (INGO) and government communities (World Economic Forum 2008).

Consumers

With an increasing distance between field and fork, consumers are losing touch with farm practices, and often do not realize that food production comes from living things that require natural resources to grow. Food is undervalued as a commodity, and waste seems harmless. Awareness-raising and environmental education are crucial, with target groups such as schools, hospitals and offices a good point to start.

Price incentives also have a role to play. Recent hikes in food prices (due to increased demand from strong growing economies such as China and the demand for bioenergy) raise concerns related to food security, particularly for poor consumers who buy food in the market. On the other hand, price increases are beneficial to farmers and send a clear signal to consumers that food is valuable and should not be unnecessarily wasted. It's time to curb wasteful behavior, and as consumers we all have a role.

Policymakers

A first step is getting inefficiencies in the food chain onto the political agenda. In the 1970s and 1980s there were several studies conducted on global and regional post-harvest losses (Pariser, 1978) but the topic now seems to be off the agenda. There are relativly few people who deal with these issues. Recent studies are scarce and often refer back to older works, but sketchy evidence shows huge losses. To effectively reduce food losses, information on where, how much and why losses occur is essential. Without awareness backed up by good estimates, policy design will be difficult.

5. Conclusion

For an integrated and innovative strategy for saving water, a reduction of losses and wastage of food from field to fork is sound and rational. Reducing losses and wastage will ease pressure on water and other resources and free up land and water for other purposes than food production. A number of benefits are within reach for a cross section of people and interests in society. Livelihoods of producers could be enhanced, supplies to industry could be improved and consumers could benefit. Reducing losses of water and produce in the field and on the road to the market, presents tangible opportunities for farmers and their customers. Multiple gains across many sectors and at low cost are conceivable.

We need to set a target to reduce food losses and wastage. With reference to the targets for MDGs and with due consideration to the magnitude of losses and the potential gains, a reduction by 50 percent of losses and wastage in the entire food chain from field to fork – including agricultural and post harvest practices – seems realistic. As outlined in the policy suggestions, a number of actions will be necessary to achieve such a goal.

At this point in time, this cannot be effectively done, because we are lacking the factual information about different types, size and implications of losses and wastage of food. Consequently, informed decisions and effective policies are not possible. A major step to start the process for an effective strategy is to put the issue of losses and wastage on the political and research agenda. New and systematic knowledge about the food chain in academic curriculum and training programs for people in, for example, food industry and trade are needed. With more and more people living far away from sites where food is produced, with food being processed and packed in various types of wrappings, and with growing affluence, this information becomes essential.

By improving knowledge and through political initiatives, the necessary resources and driving forces for food and water security in a world of increasing water stress and competition need to be mobilised and set in motion.

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