CHAPTER 5

Producing more or wasting less? Bracing the food security challenge of unpredictable rainfall

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ABSTRACT: A dramatic jump in the number of undernourished people around 2007/08 and conclusion at the World Food Summit, November 2009, to increase food production by 70% to 2050 are put in context. By the time decisions about a massive increase in production were in print, figures revealed that global food production had never been more impressive. Paradoxically, undernourishment increased alongside increases in production for an extensive period.

It makes little sense to increase production if the produce is not beneficially used. However, production, storage but also transport and marketing need to improve in areas where poverty and undernourishment co-exist. Despite an adverse climate with a highly unpredictable rainfall pattern in these areas, farmers occasionally produce bumper harvests. If the produce can be secured, especially during the good years, and if part of it could be transported and sold also outside local markets, devastating consequences of climatic variation could be reduced.

Food insecurity is a harsh reality for 1,000 million people. At the other end of the spectrum, overeating and food waste is common among 1,000 million plus people. Waste of food is waste of water and other resources. Availability of empirical data is one constraint to analyze the low efficiency in the food chain. Poor conceptualization is another.

Keywords: food losses, food waste, stochastic rainfall, carryover stocks of food, food chain, value chain

1 THE FOOD SECURITY CHALLENGE: CONTRADICTING TENDENCIES

Between 2007 and 2008, world cereal supply increased by more than 5% according to FAO (2009a). This may be compared with the current annual global population increase of about 1.2%. A record supply of $2{,}242 \times 10^6$ t [t = tonne = 1,000 kg] was due to a sharp increase in world cereal production and not the result of changes in the stocks of cereals[1]. Never before had so much food, in terms of cereals, been available on the world market.

[1] A word of caution is warranted about statistical information and terminology. Apart from a slight difference between tons and tonnes, information on food production, stocks, utilization, supply and consumption must be interpreted with care. It is often based on Food Balance Sheets compiled by FAO on data provided by countries. Many of the variables are difficult to define and measure and important data are derived from certain assumptions. In literature and in policy debates, differences between production and supply are seldom made. Losses in the field or during transport and storage are not recorded in any systematic statistical data base. Similarly, consumption, which is a key concept with regard to food security, is often estimated with reference to the amount of food produced in a country/other unit, plus import, minus export, non-food uses and assumed losses. Food waste is, however, not considered although it could be significant. The calculations are used as a proxy for food consumption, which invariably is quite different from food intake. See further below under: 5.5 *Food Security versus food supply and beneficial consumption*.

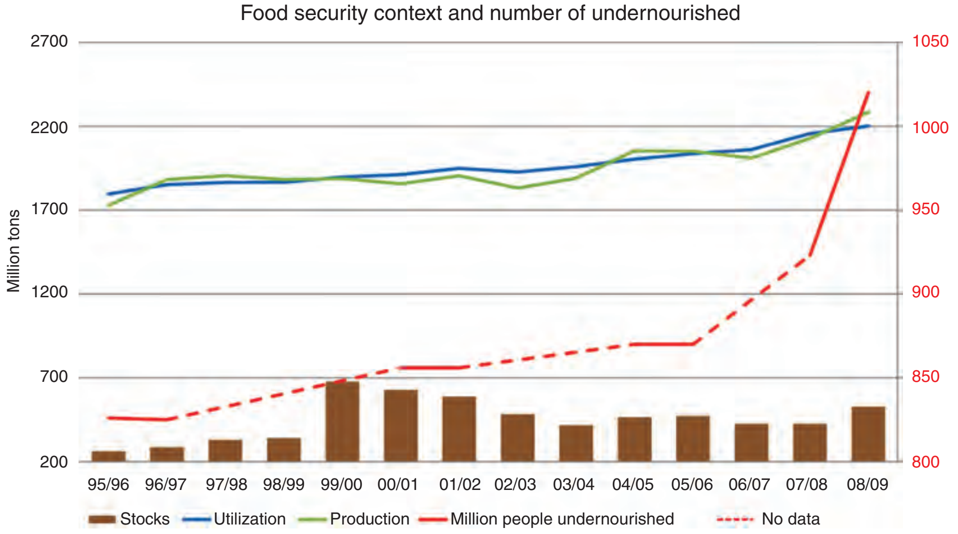


Figure 1. Global trends and variations in food production, supply and stocks (in 10^6 t), and number of people suffering from undernourishment (million).
Source: FAO: Food Outlook (FAO, 2009a); FAOSTAT.

Parallel with these optimistic calculations, dire figures about a dramatic increase in the number of people who were undernourished made headlines in the media. Human sufferings and discontent were demonstrated in the streets. Naturally, the areas and farmers who contributed to the record supply were far away from those who took to the streets. In food deficit areas, the political legitimacy and the capacity to handle riots were tested in countries across the globe, e.g. in Haiti, Egypt and Bangladesh. Export restrictions were rapidly imposed in more than thirty countries and in others, subsidies and price controls were tested (Evans, 2009). But this situation was not entirely new. The absolute and relative number of people who were undernourished had gradually slowed down since the end of the 1960s, when about 1,000 million people went hungry till the beginning of the 1990s. In 1995/97 the downward trend was broken and the number of undernourished started to increase. But it was the sudden and significant jump in 2008 from an estimated 850 million to about 1,000 million (FAO, 2009b) within months, i.e. an increase by some 15%, that renewed and augmented the concern (Figure 1).

It is relevant to underline that production and supply are very different from access and beneficial consumption. In literature and in policy, concepts and statistical information in these regards are invariably mixed as discussed later in this chapter. Poverty, conflict and adverse weather conditions are the main causes that prevent hundreds of millions of people to get access to food or to grow the food that they need. Recent price hikes on food for consumers have received much attention. Equally significant but much less discussed are the substantial increases on the price of inputs in agriculture, e.g. energy and fertilizers that the farmers need, and price on transport to the market. The prices on important inputs in food production are likely to remain high, which may be regarded as a new scourge that is added in the 21st century. Subsidies could distort the picture.

The international food price index has come down from a peak in 2008, but not for millions of people in Nigeria, Brazil, India and to some extent China, that is, for a major part of the world's population. They desperately need food at a price that they can afford, but the prices on the local markets have not come down (UN, 2009).

With the grave situation at hand, it is surprising that so little attention is paid to what happens to the food once it is produced. The losses and waste of the food[2] are largely ignored. The statistical information is quite limited but it is plausible to argue that the aggregate and cumulative losses and waste are in the order of 50% of the food that is produced albeit with different combinations and magnitudes of losses and waste in different countries and in different periods (FAO, 1981; Kantor *et al.*, 1997; Smil, 2000; Kader, 2005; Lundqvist *et al.*, 2008; Stuart, 2009). Losses and waste could be quite limited among small farmers. Leftovers, for instance, are used for feed. Paradoxically, losses could be high during good years (see Section 4.4). The estimate of 50% does not include overeating of food which may be perceived as another dimension of food waste. In terms of the number of people involved and affected, overeating is much more prevalent compared undernourishment. Similar to the throwing away of food, it implies a pressure on natural resources over and above what may be regarded as *sound* for food security.

Global figures and trends are deceptive. However, in a globalised world it is noteworthy that a gradual deterioration in food security over several years has occurred parallel with an augmentation in the production and supply of cereals and other food items.

The lingering mismatch between trends in production and supply, and the number of undernourished is worrisome. In view of the high costs and stakes involved, it jeopardizes a stable and sound development. Increasing production to the level envisaged, i.e. by 70% till 2050 will most probably involve an expansion of agricultural land and a gradual increase in the pressure on finite and vulnerable water resources. High output agriculture presumes high inputs of fossil energy and nutrients, some of which are finite and cannot be substituted, e.g. phosphorous (Cordell, 2010). In spite of the additional efforts required, few well-informed analysts doubt that increases in yields are possible. They are conceivable. But without investments, additional inputs and well-functioning institutional arrangements, they will not be realized in areas and among people who most urgently need such improvements.

2 CONTENTS AND PURPOSE OF THE CHAPTER

The conventional approach to improve food security through an exclusive focus on production and supply is put in context. The purpose is to show that it is rational, even smart, to combine strategies that ensure that a larger fraction of the food produced will be secured and beneficially used parallel with efforts to increase production.

Reductions in losses and waste of food, as well as other agricultural commodities, will ease the pressure on water, land and other resources for a given amount of food that is available for beneficial consumption. The argument is not to totally eliminate losses and waste, since such a goal is not realistic. But losses can be reduced, for instance, through improved storage, transport and marketing arrangements of the food produced. The waste of food, i.e. the throwing away of food that is *perfectly fit for consumption* requires different policies as commented in footnote 2.

Reducing losses and waste improves the efficiency in the food chain, and is likely to generate significant and multiple gains. Foremost among these is an urgently needed opportunity to improve

[2] From an analytical point of view, it is useful to make a distinction between causes for and remedies to combat reductions in the amount of food that is beneficially used. In this chapter, losses refer to a reduction in the amount of food during the first segments of the food chain, i.e. during harvest, storage and transport, i.e. *from field to market*. Spoilage is used with reference to losses in quantity and quality during storage. Conversion is still another important dimension in the agricultural commodity and value chain, e.g. the use of cereals for feed. Waste refers to the throwing away of food that is "perfectly fit for eating" (WRAP, 2009a; 2009b), i.e. a dubious use of food in the latter segment of the food chain. The accumulated losses and waste refer to the entire food chain, *from field to fork* (Lundqvist *et al.*, 2008). The causes for losses and waste, respectively, differ and so do the remedies to deal with them. Reducing losses implies investments, technical and institutional arrangements. Reduction of waste can, in principle, be achieved at no cost, but with multiple benefits, i.e. it is a win-win-win option.

food security for a growing world population *without* a corresponding increase in resource pressure and environmental damage. Better storage and transport would lessen the risk for price collapses at local markets, enhance rural livelihoods and provide opportunities for a diversification of agricultural production and rural livelihoods. In addition to resource and environmental benefits, waste reduction is, arguably, the most cost effective and sensible effort with several winners. It is hard to envisage losers.

Some of the questions touched upon above will be discussed:

- In an era when considerable attention is given to climate change, it is relevant to discuss how the assumed increase of extreme climatic events and higher temperature will affect prospects for increased production and supply of food. To what extent and where will an erratic and unpredictable rainfall pose constraints on agriculture and what measures could be used to counter the consequences of an adverse climate?
- What are the resource implications from demographic trends and what seems to be a continuous improvement in purchasing power of large segments of the world's population, including a rapid growth in the urban population?
- What strategies are realistic and effective to achieve an improvement in food security, that is, in addition to efforts to increase production and supply?
- The discussion below will follow the food chain. The need to develop a systems perspective from *field to fork* and to pay more attention to what is happening to the food that is produced is emphasized.

3 REVIEWING THE EXCLUSIVE FOCUS ON INCREASED FOOD PRODUCTION

When the Millennium Development Goals (MDGs) were decided in 2000, the prospects for a continuous reduction in the number of hungry people seemed promising. The aggregate value of world agriculture including all food and non-food crops and livestock commodities had grown by 2.1–2.3% annually on average during the last four decades (Alexandratos *et al*., 2006; Bruinsma, 2009), i.e. faster than population increase. The number of undernourished had steadily been pushed back over several decades although the pace was not sufficient to reach the first MDG, i.e. to reduce the number of hungry people by half till 2015, from about 840 to 420 million. As shown in Figure 1, the positive trend in terms of a decline in the number of food insecure people turned upwards already in 1995/97.

With the recent dramatic acceleration in the number of people who are food insecure, the predominant response from policy makers and analysts has been to suggest increases in food production. At a high-level expert forum organized by FAO as an input to the World Food Summit in November 2009, about 300 leading experts from academic, non-governmental and private sector institutions from developed and developing countries, concluded that food production will have to increase by 70% till 2050 in order to feed another 2,300 million people, an increase from the current 6,800 to 9,100 million. A year earlier, the World Bank in its World Development Report argued that cereal production needs to increase by nearly 50% and meat production by 85% to meet the expected growth in demand by 2030. It was stressed that a renewed emphasis on agriculture would be a driver for development and poverty reduction (World Bank, 2008). Similar suggestions have been aired by highly esteemed colleagues. Norman Borlaug, Nobel Prize Laureate in 1970, argued that we must learn to produce three times as much food for the more populous and more prosperous world of 2050 (Borlaug, 2002).

Optimistic visions are important. Many of them have unfortunately not been achieved as solemnly envisaged. At the first World Food Conference, in 1974, Mr. Henry Kissinger, who was then Secretary of State in the USA, declared that no child would go to bed hungry within ten years (Economist, 2009). Few, if any, circumstances have changed in a direction to make this goal easier to accomplish today. Even if production and supply targets were achieved what is it that tells us that this would reduce the number of people who are undernourished (cf. Figure 1)?

However, as many colleagues emphasize, there is a significant yield gap in areas where food insecurity prevails, i.e. the yields are below the level that is realistic (Molden, 2007; World Bank, 2008; Adesina, 2009; Godfray *et al*., 2009). This is argued to be the case also in areas that are generally perceived as having a low potential, e.g. the Guinea zone in Africa, stretching over 400 million hectares of land, which is characterized as a *sleeping giant* (Morris *et al*., 2009), i.e. the potential is much higher as compared to the current output. The discussion about a yield gap raises an important question: if the potential is real and the most basic needs are not satisfied in the areas where it exists, why is it not realized more often?

4 VARIATION IN YIELDS AND PER CAPITA FOOD SUPPLY

The trends in yields during the past decades are disappointing in parts of the world where food security is already a serious challenge. Sub-Saharan Africa has experienced a declining trend in per capita cereal production since the 1960s. For many countries in the region, the level (in 2003–2005) is below 100 kg of cereal produced on a per capita basis, compared with e.g. India, 219 kg per capita; China, 313 kg per capita; Argentina, 914 kg per capita; the USA, 1,253 kg per capita (World Bank, 2008).

The combination of low yields and high rates of poverty implies a low food supply, and a high risk for food insecurity. In countries and for people with an economic strength and/or political influence, a low domestic food production can be compensated through imports and a reliance on stocks, which *smoothen* the trends as shown in Figure 1. Several distinguishing differences between the food supply in Western countries and NICs, the *Newly Industrialized Countries*, on the one hand; and many developing countries on the other, are shown in Figure 3. The fraction of animal calories in the supply, for instance, varies from a few percent to about a fifth. Another worrying difference is the steady increase in food supply for the former group of countries whereas the fluctuations over time are considerable in many developing countries.

The graphs illustrate that the food supply, at national level, varies from about 1,800 to about 3,800 kcal/day per person in 2005.

The trends shown in Figure 2 refer to the aggregate regional situation and the columns in Figure 3 show the situation at national level. Both Figures conceal the fact that the situation is often more dramatic at sub-national levels and during individual years and seasons.

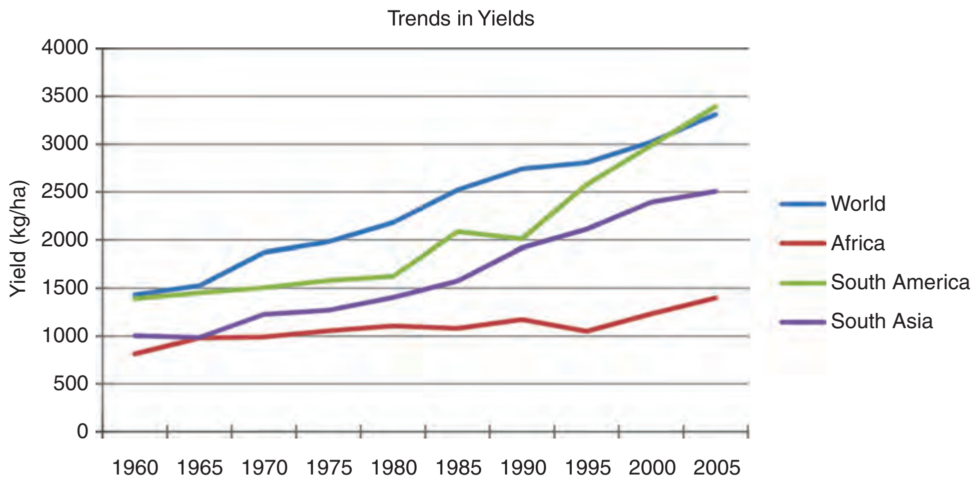


Figure 2. Trends in yields for major world regions 1960–2005.
Source: FAOSTAT.

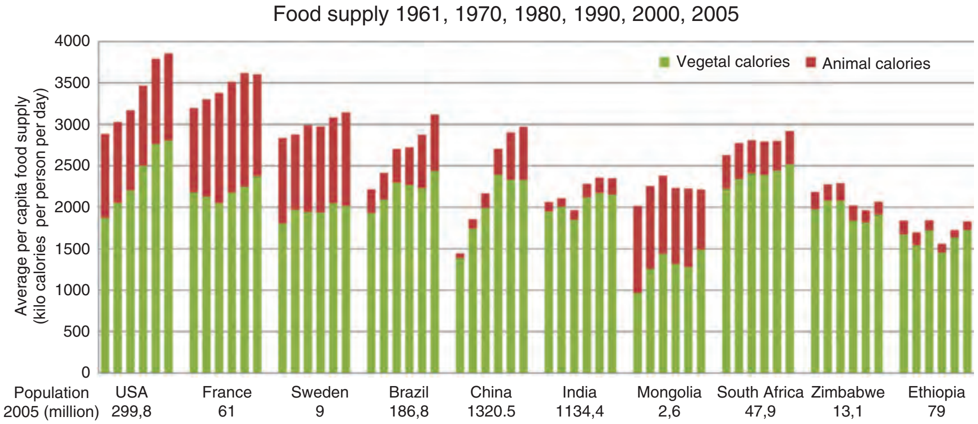


Figure 3. Per capita food supply per day, 1961–2005, separated into vegetal and animal calories.
Source: FAOSTAT.

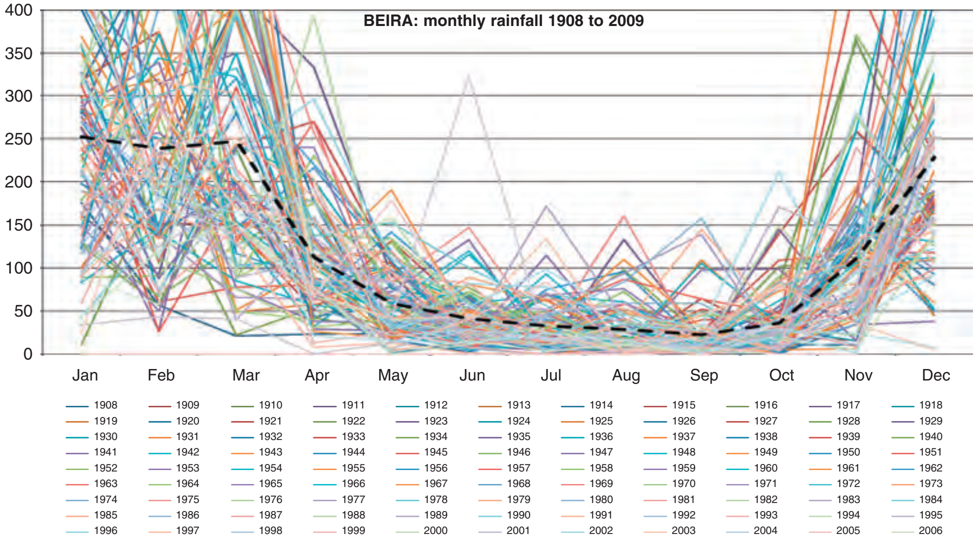


Figure 4. Monthly rainfall in Beira, Mozambique, 1908–2009.
Reproduced by kind permission from a presentation made by Jean-Marc Faures, FAO, at World Water Week in Stockholm, August 2009.
Source: FAO (2009d).

4.1 *Unpredictable rainfall*

A number of circumstances contribute to low yields and insufficient domestic food production: a high ratio between population size and resource endowment, adverse climate and impoverished soils, poor access to high quality seeds and sources of nutrients, expensive and limited agricultural credit, inferior transport to markets and small holdings with uncertain tenure. For this chapter, it is relevant to point at the challenges that climate imposes in terms of water scarcity and particularly the risks and implications of a highly erratic rainfall pattern.

Figure 4 provides a visual presentation of the tremendous variability in monthly amounts of rainfall measured at a station in Beira, Mozambique, over a hundred year period. The challenges

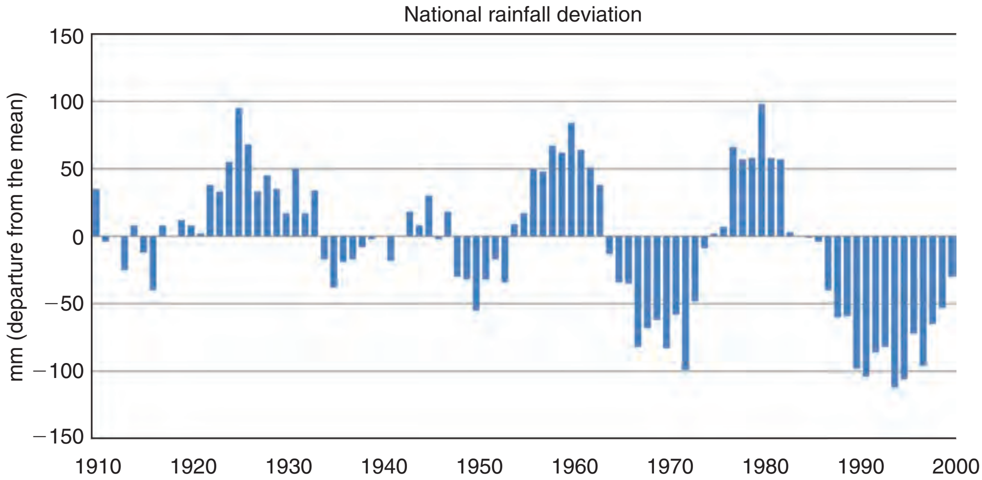


Figure 5. National rainfall deviations in millimeters from the long-term mean, 1910–2000, Zimbabwe. *Source*: GRID-A based on data from Zimbabwe Department of Meteorological Service. [www.grida.no/zw/climate/vitalafrica/english/02.htm].

are often compounded by a high intensity in rainfall and the associated rapid flows of water, overland and back to atmosphere. Figure 5 gives an indication of an increased amplitude in the deviation from the mean national rainfall value in Zimbabwe. The Figure also shows that positive and negative deviations, respectively, tend to last for a number of consecutive years.

Torrential rainfall during short periods has devastating consequences in arid and semi-arid areas. For vulnerable communities in the Sahel region, the situation is described as *ground zero*, and the need for effective adaptation measures is obvious (UN-IRIN, 2008; 2010).

The significant variation in the amount of precipitation between seasons and years and the deviations from an average, as illuminated in Figures 4 and 5, are the reality for farmers in many parts of the world. This is, for example, the case in monsoon areas where an unpredictable rainfall is part of human history. Lannerstad (2009) compiled information of incidences of failures of the monsoon and the related human sufferings in Southern India during a hundred year period from the beginning of the 19th century. ". . . scarcity, desolation and disease" were rampant at 18 occasions with a duration of one or a couple of consecutive years. For individual years, like 1808, failure of both monsoons "carried off half the population". With the huge population in the region today, the scale of the challenge is mindboggling. For the 540 million people living in the Ganges-Brahmaputra-Meghna Basin, 50% of the annual precipitation falls in 15 days and 90% of runoff is in 4 months (Grey & Sadoff, 2009). Yet, the magnitude of the challenge is increasing.

The association between a *difficult hydrologic legacy*, including a highly unpredictable rainfall and insecurity, is found in many parts of the world (Grey & Sadoff, 2007; Brown & Lall, 2006). The situation was quite bad in Africa around 1910 with droughts in both East and West Africa. The beginning of the 1980s was the culmination of a few decades of diminishing rainfall. The magnitude of the problem in Africa is less in quantitative terms when compared to Asia but devastating for those who are affected. In semi-arid and dry sub-humid Sub-Saharan Africa, about 250 million people today depend on rain fed crop farming as their primary source for food and income (Enfors, 2009).

4.2 *Lack of water where and when it is needed*

The rainfall pattern and the high temperatures are together resulting in a high risk for agricultural droughts, i.e. moisture deficits in the root zone during critical stages of the cultivation season.

The amount of water that is available to the roots of the crops, i.e. the size of the green water resource, depends on the amount of rainwater that infiltrates through the soil surface. In areas with an impermeable layer on top of the soil, farmers must break up the crusts through ripping or some other land management practice (Enfors, 2009; Molden *et al*., 2010; Rockström *et al*., 2009).

Otherwise, there will be no water where it is needed, i.e. in the root zone. Vulnerability and risk are often amplified by a low water holding capacity of the soil in tropical areas, the faction of rainwater that permeates into the soil is accessible to the roots of the plants only for a short period of time. The risk associated with rain fed systems in semi-arid parts of the world without any supplementary irrigation is very high (Molden, 2007).

Through their experience from this harsh reality and in the absence of insurances and *risk capital*, farmers in this context naturally apply a precautionary strategy with the result that experiments, innovative land and water use and new crops are seldom tried. The yield gap remains.

4.3 *Rainfall pattern decisive for lean and fat years across the globe*

Extreme weather conditions are experienced also in major food producing and export oriented countries. Starting in 2002, Australia experienced the worst multi-year drought in a century (Evans, 2009). For part of the country, e.g. in the Murray Darling basin, a dramatic reduction of the inflow into the river was observed and the water situation is still problematic, especially in the Murray river (Michael Moore, Stockholm International Water Institute, 2010, pers. comm.). More or less during the same period, droughts and other adverse weather conditions affected other important export countries, e.g. Russia, Ukraine and Canada, with the result that world cereal production fell by 2.1% in 2006 (Evans, 2009) and cereal stocks diminished (cf. Figure 1).

A reduction in world cereal production during one or a couple of years will hit various countries quite differently, primarily because adaptation capacity differs. Stimulated by the wave of food export restrictions, which distort international trade, the leasing of land in other countries has recently become a state driven strategy to secure access to food on a long-term basis. Individual farmers have always bought or leased lands in other countries. However, no poor country with a large fraction of its population being undernourished, or facing such a risk, is in a position to enter into such lease contracts. Nor can they access adequate amounts of food through trade. Equally problematic, food aid tends to undercut prospects for domestic farmers to sell their produce since food aid is *free* and the price on imported food is artificially low due to subsidies in exporting countries. Conversely, for wealthy people and politically powerful countries access to food is not an issue that cannot be overcome.

For local communities in most parts of Africa, the occurrence of bad years dominates. Enfors (2009) found that rainfall is highly unpredictable in semi-arid parts of Sub-Saharan Africa. In areas with an average annual rainfall below 600 mm, the farmers experienced critical dry spells (defined as no rain during 21 consecutive days, or more) during 60% of the seasons or more. Farmers in areas with an annual rainfall of 400 mm, or less, experienced dry spells almost every season. Even without dry spells, 400 mm is close to the margin for the successful cultivation of many crops in this climatic context. In northern Tanzania the conditions have become worse with a doubling in the frequency of dry spells during the last 60 years (*ibid*.).

The dynamic links between adverse weather conditions, agriculture and limited options for alternative livelihoods for an increasing population pose significant challenges. A low and uncertain return on hard work under a burning sun and a high incidence of food insecurity is common for a large number of the about 1,500 million people who depend on smallholder agriculture (World Bank, 2008). With low and uncertain yields the *one-acre dilemma* is a huge challenge, socially and in terms of resource pressure (Lannerstad, 2009). Is the exclusive focus on increases in production the most promising strategy among this group of food producers?

4.4 *Losses increase during good years*

Occasionally, the weather and other conditions are favorable. Like elsewhere, yields in the semi-arid area in Northern Tanzania are sometimes much higher than the prevailing low output. In 2006, yields increased to about 3,000 kg/ha, and with conservation tillage yields could reach 4,800 kg/ha (Enfors, 2009). When farmers are able to produce high yields, they are left with a couple of choices. They can try to sell the surplus or they can store it. Some may use it for feed. Selling the surplus during a good year is however likely to be frustrating. With a lack of transport and poor market access, it is only local markets that are accessible. When many farmers want to sell, the result is invariably market shocks and the collapse of prices as noted for different parts of Africa (Adesina, 2009). In the communities studied in Northern Tanzania, farmers choose to store the surplus for later consumption. Unfortunately, pests destroyed most of the crops that were stored (Enfors, 2009). Drastically falling prices at local markets and inferior storage are not peculiar to semi-arid parts in Northern Tanzania and Africa, but is also a significant problem, for instance, in China (Dinghuan Hu, Chinese Academy of Agricultural Sciences, 2010, pers. comm.).

A paradoxical situation is experienced by millions of farmers caught up in the context just described. Farmers face considerable risks related to the vagaries of an adverse climate. Yields are low and so are total production and income. When they are fortunate and produce high yields, there is an imminent risk that a large part of the surplus will be lost, or alternatively, that the price at local markets collapses. Conversely, with low yields, farmers will, of course, use the harvest judiciously and losses may be insignificant.

In this kind of situation, which is common for poor households in smallholder communities and in areas where food insecurity is rampant and where a stable level of production from year to year cannot be expected, efforts to increase production must be combined with investments in post harvest technologies and marketing arrangements. As aptly formulated in an FAO report (1981:2): “It is distressing to note that so much time is being devoted to the culture of the plant, so much money spent on irrigation, fertilization and crop protection measures, only to be wasted about a week after harvest”.

4.5 *Carry-over stocks of water or food?*

This sensible argument has been left without attention for decades. To overcome the consequences of unpredictable rainfall on food production and rural livelihoods, it is necessary to balance the deficiencies during bad years with the surplus during good years. Water storage in reservoirs together with lifting of groundwater has been one important strategy to reduce the risk of water deficits during cultivation seasons. The strategy is certainly important but it is increasingly costly, financially and in energy and environmental terms. There are few sites left where carry-over stocks of water from rainy seasons or years can be impounded in surface reservoirs at reasonable expense. Similarly, the energy cost to lift water must be covered by the user or society. Storing rain water in the soil is very important but presumes better coordination between land and water management (Falkenmark & Rockström, 2004). In areas with frequent dry spells, supplementary irrigation from various types and sizes of water storages is important to reduce the high risk associated with rain fed cultivation.

In this kind of situation it seems rational to make arrangements for storing food as a complement to storing water from the good to the bad years, i.e. facilities that could help the farmers to save part of the agricultural produce when conditions are favorable for use at a later occasion or for a staggered sale (Lundqvist, 2009a).

Improved storage, transport and marketing arrangements for food, and other agricultural commodities, are likely to bring multiple benefits. In addition to a reduction of losses of the crops currently cultivated and more stable prices and, hence, income, these kinds of improvements will enable the farmers to produce other crops for which there is a demand outside the local market. Local food processing could generate opportunities for farmers to grow sensitive crops that cannot be transported over long distances in an unprocessed form. This is, for example, the case with fruits which can successfully be grown in Northern India and sold in cities far away or even abroad (Paul Appasamy, Karunya University, India, 2009, pers. comm.; Narendra Kumar Tyagi, Department of Agricultural Research and Education –ICAR–, New Delhi, 2009, pers. comm.).

Table 1. Comparison of population increase, growth of GDP and water withdrawals, 1800–2000 with projections for 2050. Population figures from UN population statistics.

	Population (million people)	GDP (10^3 million US$, 2005 PPP)	Water Withdrawals (km^3)
1800	<1,000	913[1]	–
1900	1,650		700
1950	2,500	7,006	–
2000	6,000	56,593	3,500
2050	9,100[2]	193,318[3]	Increase by 10–15%[4]

[1] Figure refers to 1820.
[2] UN medium projection.
[3] Trend growth projection (Hillebrand, 2009). PPP refers to Purchasing Power Parity.
[4] Various projections have been made. Increase of this magnitude is used in FAO reports.

5 INCREASED PURCHASING POWER AND URBANIZATION

Low yields and missed opportunities to increase and stabilize the income for the farmer and deliver food and other agricultural produce to the market are obstacles to a sound development. It also implies a low efficiency in resource use and in the food supply chain (Nellemann *et al*., 2009). A high efficiency in resource use in connection with production will be of limited value if the food produced is lost or wasted as eloquently formulated in the 1981 FAO report (quoted above). A glance at the demand side dynamics reveals that strategies that link production with demand and beneficial consumption must be developed.

For the future, the significant change in the food and water linkages will be related to the combination of an urban expansion and an increase in purchasing power rather than to population size *per se*. Socioeconomic and demographic dynamics is concentrated in urban settings, but the implications are, to a very large extent, in rural areas. For example, the demand for food and many other goods and services is largely driven by urban interests and it is in urban centers that a larger and larger fraction of consumption, and waste, takes place.

The figures in Table 1 show that GDP has historically grown faster than population. But a new situation is unfolding. Population increase has slowed down and may reach a replacement level in a generation or two, whereas economic growth is projected to continue unabated. In the contemporary setting and for the future, the growth of GDP is significantly faster than population increase. Between 2000 and 2050, world population increase is estimated to be about 50%, a staggering 3,000 million, while the global GDP is expected to expand by some 400% (Hillebrand, 2009). Purchasing power will thus be relatively more important than population size. For the poor and undernourished, an improved purchasing power is certainly desirable. For society as a whole and with regard to the natural resources and environmental situation the combined effect of demography and economics in terms of the character of the increased demand is important. If the demand for water intensive products increases heavily, which it currently does, and if a large share of the procured products are lost and wasted, the future and the prospects for sustainability appear bleak.

However, the number of people living under various levels of poverty is still staggering. About 880 million people had less than 1 US$ a day to spend in 2005, estimated in terms of Purchasing Power Parity (PPP), and 2,600 million had less than 2 US$ a day, 13% and 38% respectively of the world's population. It is also mindboggling that 5,150 million, i.e. 77% of the world population, have less than 10 US$ a day to spend (Shah, 2009). The vast majority of the world's population is thus far from wealthy. But it is reasonable to assume that all people, even those who are better off, have an ambition to earn more. And spend more, with implications for resource pressure.

5.1 *Disposable income, dietary preferences and water pressure*

An increase in disposable income will increase the demand for food among other things. In combination with urbanization the composition in food preferences is changing, sometimes referred to as a *nutrition transition* (Schmidhuber & Shetty, 2005). As noted above, the demand for meat products may increase by something like 85% till 2030 (World Bank, 2008). Some of the increasing demand will be for meat. However it is important to recognize that the composition in the demand for various meat and animal products varies and that the consequences and benefits are quite different between various categories. More cattle mean an increased demand for feed, which translates into a demand for land and water. Instead of direct human consumption of grain products, about 36% (738×10^6 t in 2005 according to FAOSTAT) are used for feed to cattle. This fact has, however, received much less attention as compared to the significantly much smaller use of cereals for bio-energy production, which is about 5% or some 120×10^6 t in 2008/09 (FAO, 2009c).

One of the most rapid transformations in socioeconomic terms takes place in China with significant repercussions on water pressure and the environment. After the cultural revolution (1966–1976) and in pace with the rapid economic growth after the economic reforms at the end of 1970s and together with the demographic dynamics, the demand for food items has increased rapidly, totally and on a per capita basis. Farmers have been stimulated to increase production to meet the growing demand. Initially, the demand for cereals grew, but from around the mid 1980s a shift in the demand pattern towards high quality food items became obvious, i.e. an increased demand for animal products, vegetable oils, vegetables and fruits (Liu & Savenije, 2008). This is an important development in terms of nutritional improvements and quality of life for hundreds of millions. It is also in line with the progress to reach the MDGs. However, it also meant that the pressure on water resources increased rapidly as illustrated in Figure 6.

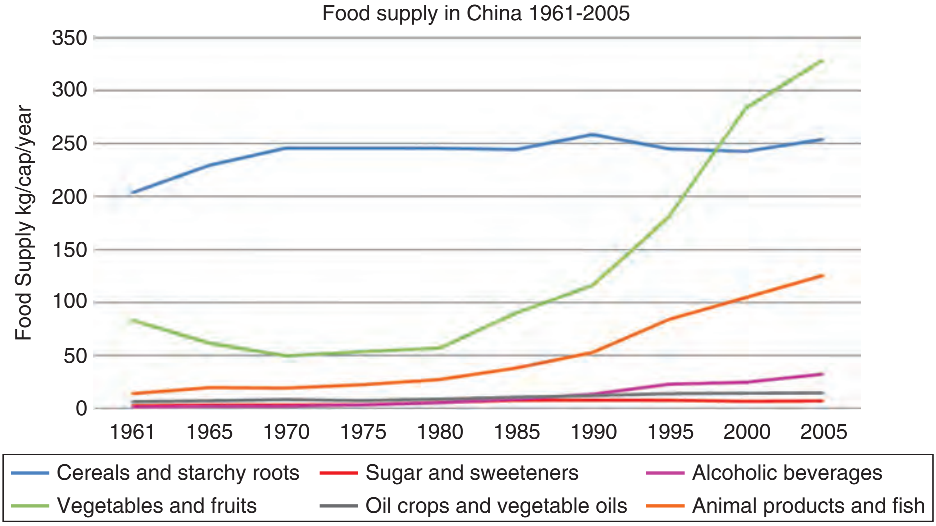
5.2 *Nuances in the meat debate*

Most colleagues would agree that animal products have a much higher impact on water resources and the environment as compared to cereals and other food items as illustrated in Figure 6. However, it is important to recognize a few points.

The virtual water content in different meat products varies. Generally, it is much higher for red meat as compared to white meat, whereas pork is somewhere in between. The circumstances under which meat products are produced, also need to be considered. Grazing of cattle in areas that cannot be used for crops or other agricultural production and where no irrigation water is used is quite different compared to raising cattle in feedlots. Parts of Southern Africa, for instance, are suitable for wild animals, which produce high quality meat. These areas are not suitable for crop production. Cattle raised in feedlots with fodder coming from irrigated fields or feed grown in areas where alternative land use is possible naturally have a different impact on resource systems.

A third important feature refers to the role of animal husbandry in rural livelihoods in many poor countries. Rearing of different animals alongside with other agricultural activities helps millions of farmers to diversify agricultural production and to obtain their income from various sources (Peden *et al.*, 2007). For many communities, cattle represent an important part of their capital as well as an integral part of their culture and livelihood. On the demand side, this corresponds to the fact that people obtain a range of high quality food and other items from animals, e.g. milk and other dairy products, blood and fat apart from meat. Multipurpose benefits are thus derived from animals especially for many poor communities.

However, it is relevant to observe that a high or very high per capita animal food supply tends to be associated with an intake of animal based food items in excess of what is motivated from a medical and nutritional point of view. Similarly, the environmental implications of livestock are considerable (Smil, 2000; McMichael *et al.*, 2007; Steinfeld *et al.*, 2006). In addition to these circumstances, we should also realize that animal based food items are quickly and easily degraded in quality, which increases the risk of waste particularly if supply is excessive (Lundqvist, 2009b) as discussed in next section.



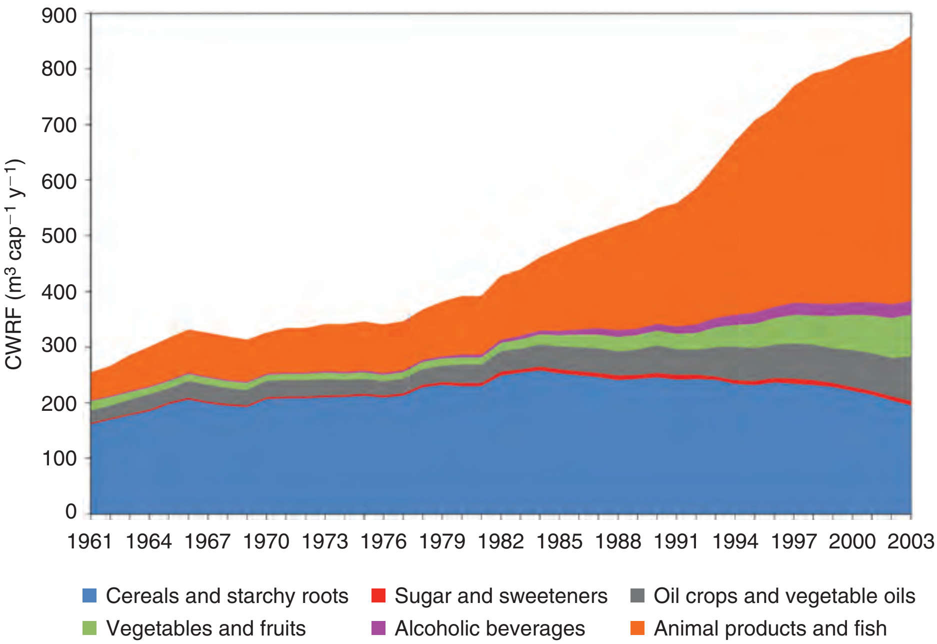


Figure 6. The top diagram illustrates the increasing supply of different food items and the diagram below shows the water footprint associated with food supply in China, 1961–2005.
Source: Modified from: Liu & Savenije, 2008; Liu *et al*., 2008; FAOSTAT.

5.3 *Increased vulnerability and impacts of food systems*

Many of the food items for which demand is increasing with growing prosperity are both water intensive, environmentally dubious and vulnerable, that is, they will easily and quickly degrade in quality. Without proper handling, storage, cold or chilled transport, animal based products, fruits and vegetables will start to deteriorate after days or even hours. As a comparison, cereals can be kept for long periods and presume less sophisticated treatment during storage and transport. In urban societies and perhaps particularly among people who are far away from food production, physically and in terms of comprehension, there is a tendency to perceive blemishes and cosmetic appearance of food e.g. on fruits and vegetables as a sign of poor quality (Stuart, 2009; Godfray *et al*., 2009). Safety standards and a fear among consumers about health risks associated with eating food that is proven to be –but often rather suspected to be– of inferior quality adds to the vulnerability of the food systems. Reports reveal that other types of food waste can be significant but largely unnoticed. This is e.g. the case with supermarkets and restaurants (Stuart, 2009). Finally, the recall of huge quantities of beef in the wholesale segment of the food chain is documented (Rano, 2008; Lundqvist *et al*., 2008).

5.4 *The food chain is also a value chain*

Since expenditure and efforts are made in different segments of the food chain, in farms, in transport and storage, processing, marketing, etc., the accumulated investments and value are higher towards the end of the food chain. Similarly, the accumulated energy input increases in the food chain per unit of food. Of the total energy used from production to consumption of food items, a large part of it refers to the last part of the food chain, i.e. in households where especially cooking means a high energy use per food unit. Situation varies between countries, but the general picture seems to be that the economic value and inputs increase along the food chain. Consequently, wasting food and especially food that is prepared and ready to eat incurs higher accumulated costs as compared to the loss of food at the beginning of the food and value chain.

An additional perspective is relevant: when food that is prepared and ready to eat is tossed, a range of actors who have been involved in various activities in the food chain have already been paid for their efforts. The GDP has increased while, ironically, the benefits of the product itself are foregone. When food is lost in the field or at the beginning of the food chain, on the other hand, it is primarily the producer who is deprived of an income, and society, at large, will not get access to these commodities. In both cases, water and other resources have been used to produce the commodities that are used as well as those that are lost and wasted.

Based upon the assumption that about half of the food available *in the field* is lost or wasted and thus not beneficially consumed, a conservative estimate of the water that is used in vain is about 1,350 km^3 (Lundqvist *et al*., 2008). This is half of the water that is estimated to be withdrawn from rivers, lakes and aquifers and used for irrigation, i.e. it does not include any reference to the water used in rain fed systems. Other relevant calculations are made about e.g. impacts of food waste in terms of green house emissions (Nellemann *et al*., 2009; WRAP, 2009a) and the "Livestock's Long Shadow" (Steinfeld *et al*., 2006).

5.5 *Food security versus food supply and beneficial consumption*

The laudable increases in global food production and supply have resulted in a situation where food security should not be a problem. On a per capita basis, much more food is produced and also supplied, as compared to what is required for the world population to lead an *active and healthy life*. But as we all know, what *could be* is different from *what is*. And it is different from commitments made at various meetings. Hundreds of millions of children still go to bed hungry. This is not to say that commitments made at various meetings are not seriously intended. It rather illustrates that the reality is extremely complex.

It is relevant to relate the discussion above to the definition of food security: "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, *italics* added). In connection with the World Food Summit, November 2009, the following sentences were added: "The four pillars of food security are availability, access, utilization and stability. The nutritional dimension is integral to the concept of food security". The most widely used definition on food security is thus about the combination of availability, i.e. production and supply, and access. It is also about the use of food. The notion of *sufficient* is one key word in the definition. For about 1,000 million people the harsh reality is that they do not have access to what is sufficient. Paradoxically, the number of people who overeat and suffer from overweight and obesity is considerably higher. Obviously, *food preferences* and human behavior deviate from what is sufficient.

It is interesting to compare the bars in Figure 3 with figures on food intake requirements for *an active and healthy life*. Food intake requirements usually refer to dietary energy contents of food, expressed in kcal or Joule per person and day. For good nutrition, proteins, vitamins, fat, etc. are required in addition to the energy contents of food. The average energy intake requirements, which allow light activity, is estimated to range between 1,720 to 1,840 kcal/day per person, for different developing countries with the current age structure and increase to 1,820 to 1,980 kcal/day per person by 2050 as a result of changes in age composition (Alexandratos *et al*., 2006). With increasing physical activity, the requirement is naturally increasing. In medical and nutritional literature, an average intake of 2,000–2,200 kcal/day per person is considered adequate (Schäfer-Elinder, 2005; Smil, 2000). Lower intake levels are seen as acceptable (MSSRF, 2002). Interestingly the intake is comparatively low for some groups in many different societies, e.g. the USA, Canada and in Africa (Smil, 2000). For food security, a common international norm is that food supply at a *national level* should be in the order of 2,700 to 2,800 kcal/day per person (Molden, 2007). This level of supply is supposed to be adequate to ensure that the *individuals* may have a food intake in line with the definition quoted above.

As shown in Figure 7, the food supply is much higher in many countries as compared to the international norm and substantially much higher as compared to the food intake requirements. If a comparison is made between the amount of food produced in the field and food intake requirements, the gap is even wider since losses and conversions are substantial. These kinds of distinctions are rarely, if ever, made in literature and policy. The notion of food consumption, for instance, is not used with reference to food intake requirements, which would be natural from a semantic point of view. National average food consumption is a proxy that is based on figures in National Food Balance Sheets (FBS). The FBS include figures on production, trade and estimates of losses, but not waste at household level. As noted by Alexandratos *et al*. (2006), waste can be significant. In other words, figures on food consumption, sometimes called *apparent consumption* (*ibid*.), convey deceptive information about food intake requirements and they mask considerable waste of food.

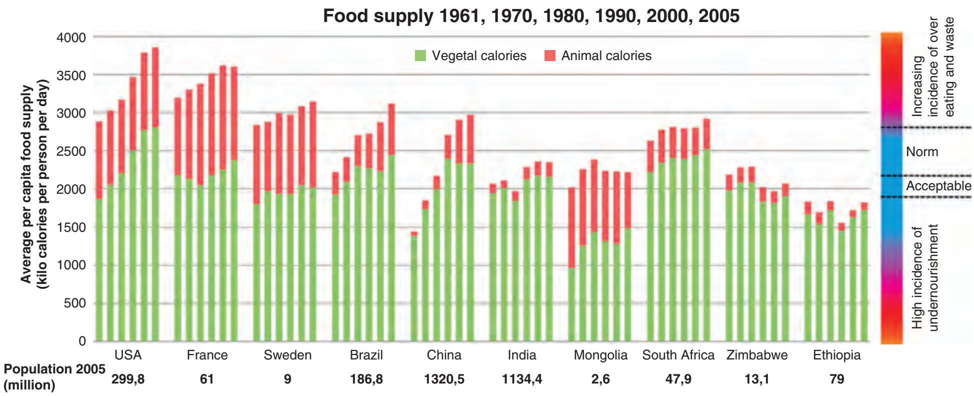


Figure 7. Comparison between the variation and trends in food supply and norms and recommendations to reach food security and national and individual levels.
The columns in green and red show daily per capita food supply in selected countries (cf. Figure 3). The column to the right illustrates interpretations of food security in terms of average energy intake requirements at the individual level and food supply at the national level. An intake of 1,980 kcal/day per person corresponds to the minimum requirement, and 2,200 kcal/day per person to an *acceptable level*. For food supply at national level, reference is made to the international norm, which is usually set at 2,700/2,800 kcal/day per person. For details, see comments in text above.

6 THE MULTIPLE COST OF LOSSES AND WASTE OF FOOD

It may be discussed whether the definition on food security should only refer to what is *sufficient* in terms of energy and nutrient contents, or whether it should also refer to the implications when supply and intake increase. Keeping in mind that the objective of food security is to ensure that *all people at all times* may lead *an active and healthy life*, it is logical to recognize that overeating is associated with overweight and obesity and thus curtails the ability to lead an active and healthy life. In an interesting study recently published, the relationships between food supply, intake and food waste in America have been analyzed. Calculations imply a steady increase in body weight among USA adults over the past 30 years and a progressive increase in food waste, from 900 to 1,400 kcal/day per person between 1974 and 2003 (Hall *et al.*, 2009). When supply of food increases and food is perceived as relatively cheap and easily accessible, the risk for a dual problem increases: the public health situation deteriorates and the waste increases with negative repercussions on resource pressure, environment and productivity in society.

The waste of food is significant in affluent societies with multiple costs. Detailed studies in the UK show that households throw away about a third of the food that they buy and that some 60% of this is perfectly fit for consumption. The annual avoidable waste is about 70 kg per person. A similar level of waste is found for Scotland (WRAP, 2009 a; 2009b). Studies made in other OECD countries show partly similar figures, but also that the magnitude of waste varies significantly. Norway has about the same level of waste as the UK, i.e. 71 kg/yr per person (Hanssen & Olsen, 2008). For Holland, Thoenissen (2009) reports that 8–11% of edible food is wasted (43–60 kg) and that this corresponds to US$ 364–539 per household, annually. Ca. 20% of all the food bought is thrown away. In the USA, the estimates vary significantly from about 25 to 50% (Jones, 2006; Schiller, 2009) and in Australia an average household annually throws out an estimated AUD$ 239 per person, or US$ 222 (Baker *et al.*, 2009); the corresponding figure for UK is £ 430 or US$ 659 (WRAP, 2009a). The surprisingly large differences between societies that seemingly have similar socioeconomic and cultural characteristics may partly depend on methodological differences and difficulties to define the boundaries for the measurements.

A common finding is that most people are not aware of the magnitude of the waste and they have vague and sometimes faulty notions of the consequences of food waste for resource pressure and environmental damage. For instance, the generation of methane from sites where food waste is improperly disposed is not known among people in the UK (WRAP, 2009a). Convenience and time constraints in relation to expenditure on food presumably play a major role in the level of waste. Cultural norms and social habit play their part. Household expenditure on food is typically about 10% or slightly more of household budgets in many OECD countries, which, however, is a misleading figure. An illusion of an abundance of cheap food is perpetuated in many societies. To the price paid in the shop, people pay for their food via their tax bills and indirectly in terms of environmental and other social costs. The expression that "there is no such thing as a free lunch" is more valid than ever but not internalized in the minds and habits of most people.

7 CONCLUSIONS

A dramatic and sudden jump in the number of people who are undernourished triggered vivid debates and activity around 2007–2009. Many countries were severely affected. Protests and grief from those who were affected were displayed in real time through the media. Export restrictions were hastily introduced in some thirty countries. Distortions in trade and access to food were the result of, or resulted in, price hikes on inputs in production as well as price on food in the market. This chapter has elaborated on the conclusion issued at high level meetings that food production must increase substantially. Reports and decisions talk about the need to increase cereal production by 50% to 2030 and 70% by 2050. For animal based food products, the corresponding figures are higher.

The focus on increased production is noteworthy. By the time these analyses and decisions were in print, figures started to show that global food production and supply had never been more impressive. Comparing the global trends in food production and supply reveals, strikingly, that increases on the supply side are no guarantee for a desirable improvement among those who need improvements. For individual societies or countries, a worrying association is rather between a progressively increasing food supply and an increasing number of overweight and obese people. In addition, high supply levels seem to be linked to high waste rates with associated costs in resource and environmental terms. Most of these costs are *unnecessary* and function as hindrances to sustainability.

What happens with the food once it is produced and how much of it will reach various social groups in society and how much will be beneficially used is, unfortunately, not an issue in the policy discussion nor in literature.

With a highly unpredictable rainfall as a result of an adverse climate and other problematic preconditions, increasing production *to the extent proposed* is a tremendous challenge. To stabilize production is even tougher. If production is increased in other areas than where food and improved income are needed, the prospects for reduction of undernourishment and poverty are limited. However, sometimes farmers are fortunate and produce bumper harvests also in areas that, generally, show low yields. If the produce can be secured, and especially during the good years, for years with low production and/or if some of it could be transported and sold also at places and to customers outside local markets, the devastating consequences of seasonal and annual climatic variation in many poor communities could be offset to some degree.

This chapter has elaborated on a few questions: to what extent may investments and institutional arrangements in post-harvest segments of the food and value chain improve food chain efficiency? To what extent can losses and waste of food be reduced and in what ways and to what extent would they help in feeding a growing world population, keeping in mind that some are more and more wealthy and some are trapped in extreme poverty?

Efforts to reduce losses and waste can be motivated from the point of view of water and other resources, environmental and public health. But reducing losses and waste is not easy. On the other hand, increasing production by 70% is not easy either. A mixture of production and supply and demand side strategies seems most promising. What other options would be easier and better to pursue if the objective is to feed the world without an undue pressure on natural resources and impact on the environment?

In an era when food insecurity is a tough reality for 1,000 million people and when resource scarcity and rainfall unpredictability together with environmental impacts cause widespread political and public concern, attention needs to be devoted to the food chain dynamics with its inherent complexities and opportunities. The relation between food security, our life support system, including scarce and unpredictable water resources, and human wellbeing is a key issue in this regard. Unfortunately, the availability of empirical data is an absolute constraint in analyses and policy development. Combined with a deceptive terminology, and a less-than-strict use of key concepts, the efforts to understand and effectively deal with this huge complex are thwarted.

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