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HOW TO FEED THE WORLD'S GROWING BILLIONS

UNDERSTANDING FAO WORLD FOOD PROJECTIONS AND THEIR IMPLICATIONS

About this study
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Current postharvest loss levels are estimated at 20–50 %, with supply chain losses representing the dominant form of loss in developing countries and food waste at the retail and household levels dominating in industrialized countries. Inadequate infrastructure, such as of roads, transportation and storage facilities, is one important factor for postharvest losses in developing countries.

Preface

On 23 September 2009 the FAO released the results of its food balance projections until 2050. The main message of the FAO press release was that agricultural production has to increase by 70 % to feed the world in 2050.

The impact of this message on the political and public debate about hunger and malnutrition was and remains impressive. Without further background information, this 70 % figure provides an excellent argument to all those who would seek to focus the hunger issue on the need to intensify agricultural production. Briefly scanning the debate, one finds the 70 % production increase as an argument against organic agriculture, as an argument in favour of intense GMO use, and even as evidence to justify the intensification of European agriculture within the debate on the Common Agriculture Policy beyond 2013. In all cases the 70 % production increase figure cited by the FAO is cited in an appeal to an underlying moral responsibility: the world needs to be feed in 2050.

Thus, although the FAO may not have intended it, by publishing the results of their food balance projections the FAO shifted the debate on hunger away from all aspects of social justice and ecological sustainability. In the current debate, numerous salient questions are now overlooked, including: Why are more than one billion people hungry in a world which has for decades produced enough food to feed every person on this planet? What are the main factors driving people into hunger and poverty? How do consumer behaviour and agricultural policy in industrialized countries affect hunger and rural poverty worldwide? Who is going to manage the use of natural resources in the future and what does a sustainable agriculture system look like in times of decreasing fossil resources? All of these relevant questions, which are based on considerations stemming from human rights, ecological sustainability and social equity, have been absent from recent discussions.

WWF Germany and the Heinrich Böll Foundation hope to widen the debate with this paper. Our goals are threefold: First, we aim to provide a better understanding of the FAO world food balance projections by explaining the design of the FAO model as well as by outlining which assumptions have been included in the projection and which have not. As a consequence we hope to show how the projections have to be assessed from a political point of view. Second, we want to outline how the weak link between increasing world agricultural production and hunger. Third, we aim to discuss other possibilities to ameliorate food challenges other than the intensification of agricultural production, and, in this way, provide arguments to all those who seek to discuss the world food situation in a socially and ecologically sound way.

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Abstract

This study aims to clarify the methods used and the assumptions made in the FAO world food projections, which forecast the need for a 70 % production increase between 2005/07 and 2050, as well as to discuss the implications of this figure. We find that the FAO projections are based on solid analysis and an enormous amount of expert knowledge and country specific data, yet the assumptions and underlying methodology are poorly documented.

Furthermore, the FAO's strong focus on increasing production in contrast to other options for improving the world food balance, especially in the communication of the analysis to the public, is unbalanced. Alongside productivity increases, the reduction of political support for biofuel production, the reduction of postharvest losses and a less meat based diet in industrialized countries should be explored. Political support for first generation biofuels should be ended. This option could be easily implemented and would have direct and significant effects on the world food balance. A literature review suggests that there is significant scope and need for reducing postharvest losses in developing and developed countries. Current postharvest loss levels are estimated at 20–50 %, with supply chain losses the dominant form of loss in developing countries and food waste at the retail and household levels dominating in industrialized countries. Lowering meat demand in industrialized countries would have positive effects on human health and the environmental goods. Furthermore, it would result in lower climate gas emissions and ease the introduction of higher animal welfare standards. Finally, they would improve the world food balance and result in substantially lower meat prices but only slightly reduced cereal prices. Last but not least, it is important to note that the global availability of food is not the most relevant limitation in the reduction of undernourishment, but rather it is the persistence of poverty which causes undernourishment in a world which could feed 9 billion.

Key Results

Chapter 2: Understanding FAO World Food Projections

» The increase in global agricultural production and demand by 70 % between 2005/07 and 2050 is not what the FAO considers as desirable, but it reflects the increase in global demand which the FAO considers most likely to happen in the future, and the required increase in production that the FAO considers necessary and feasible to meet this demand. The projections are based on the assumption that about 290 million would still be undernourished by 2050.

» The FAO projections are based on solid analysis and a high amount of expert knowledge and country specific data. Furthermore, they are roughly in line with projections made by other institutions.

» Due to intransparent presentation and insufficient documentation of assumptions and methodology, it is almost impossible to reconstruct the results in light of the assumptions made. In addition, as many of the assumptions are unknown to the reader, it is impossible to evaluate their validity compared to any alternatives.

» Climate change is not included in the projections and is likely to put further pressure on the world food balance by 2050.

» On the other hand, GDP growth is assumed to run at 2.4 % annually for the period between 2030 and 2050, which is about 0.2 percentage points higher than observed between 2000 and 2010 and about 0.8 % higher than in the two decades prior. A more conservative estimate of GDP growth would reduce the pressure on the world food balance.

» FAO projections of the need for a 70 % production increase do not justify the claim that global agriculture in general should be intensified.

» The strong focus on the relevance of global agricultural production for fighting malnutrition and hunger in the communication of the results is excessively one-sided. Increasing global agricultural production is one option among others to improve the world food balance. And it is poverty, not the global food balance, which is the main cause of hunger.

Chapter 3: On the Interdependencies of Global Agricultural Production and Hunger

» Increasing the global availability of food, whether through higher production, changes in consumption habits such as lower meat consumption, or lower postharvest losses, is a necessary but not a sufficient condition for decreasing hunger.

» The most important factor for decreasing hunger is the reduction of poverty. The effects of higher global food availability on the reduction of hunger are rather indirect.

» An increase in agricultural production is of importance mainly within the regions subject to food insecurity. Here it can have a double effect, lowering prices and increasing food availability for food purchasers while also generating additional income for food producers. These regions should be the focus of investments in rural infrastructure and agricultural research, and efforts to improve governance systems and institutions which allow markets to work.

» What is needed most to fight undernourishment is poverty reduction by providing the poor with better access to education, employment, land and other options for income generation, as well as to public services such as social safety nets and medical care.

Chapter 4: Alternatives to Improving the World Food Balance

» Demand for biomass for energy production has a strong impact on the world food balance.

» Demand for first generation biofuels in the EU, US and various other countries is driven by narrow political interests and contributes to high global prices for agricultural products. This causes substantial indirect land use changes, as crop land use intensifies and expands worldwide in response to the increasing demand for biofuels.

Chapter 4.2 Reduction of Postharvest Losses

» Current postharvest loss levels are estimated at 20–50%, with supply chain losses dominating in developing countries and food waste at the retail and household levels dominating in industrialized countries.

» There is a significant need and considerable opportunities for reducing supply chain losses and consumer food waste due to the sheer volume of such losses. In contrast, there is only little evidence for the successful reduction of such losses through policy measures.

» Regarding the food security objective, the focus should be on reducing postharvest losses in food insecure regions, which would increase food availability and generate income along the supply chain at the same time.

» Without more systematic research on the extent of losses, measuring progress against any global reduction target is impossible. Despite this lack of reliable data, there are compelling arguments in favour of tackling postharvest losses.

Chapter 4.3 Changes in Consumption Patterns

Lowering meat demand in industrialized countries would improve the world food balance and result in substantially lower meat prices and slightly reduced cereal prices.

» The resulting effect of reduced meat consumption on food security, however, is likely to be small. This is because lowering meat consumption in industrialized countries leads to lower meat prices and causes more meat consumption elsewhere. The effect on basic staple food prices is therefore low.

» However, lowering meat demand in industrialized countries would have positive effects on human health and the environmental goods. Furthermore, it would result in lower greenhouse gas emissions, a less unequal per capita use of global resources, and ease the introduction of higher animal welfare standards.

1 Introduction

Despite the goal of halving the number of hungry by 2015 the prevalence of hunger has increased by 15 % since 1996

Globally, undernourishment is a disturbingly persistent problem: Although a target was set at the 1996 World Food Summit to reduce the number of undernourished by 50 % by 2015, the prevalence of hunger has increased by 15 % since that time and, after peaking at more than a billion in 2009, was at 925 million in 2010 (Figure 1.1).

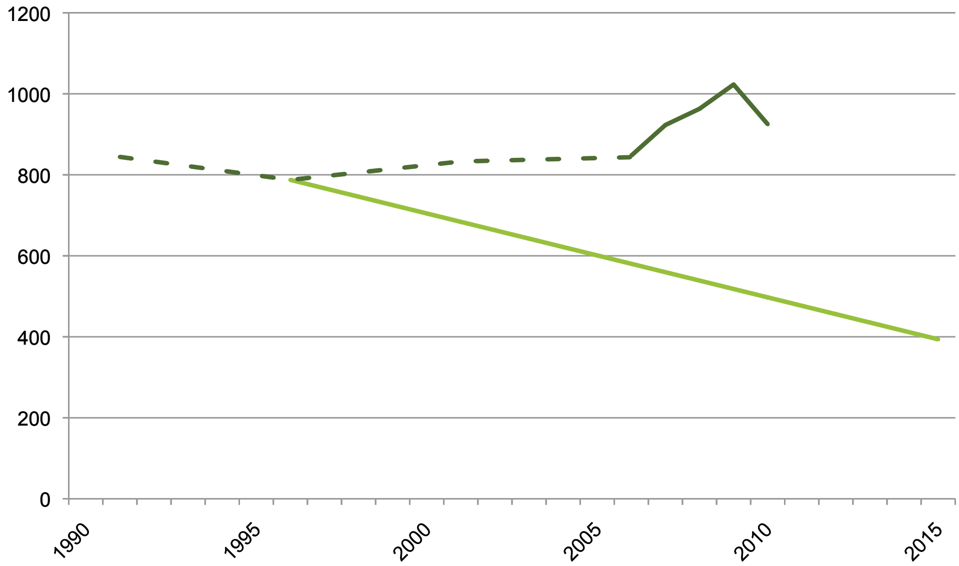

Figure 1.1: Number of Undernourished 1990–2010 (in millions)

Sources: FAO (various issues).

Number of undernourished

1996 World Food Summit Reduction target

In addition to the high prevalence of hunger that has persisted for decades, the world experienced a situation of high peaks in agricultural world market prices in 2007 and 2008 and again in 2010 and 2011. These have translated into an increasing number of undernourished, and many believe that they mark a change in the historical trend of declining real agricultural prices, which has been in evidence since early industrialization. Reasons behind this trend change include increasingly scarce natural resources such as land and water, strongly evolving non-food demand for biomass, mainly for the production of bioenergy, a continued high population growth, a shift in consumption patterns towards higher value foods and increasing energy prices.

Against this backdrop, projections regarding the world food balance are an important input for the political discussion on fighting undernourishment.

In 2006, the FAO published its “FAO Interim Report” (FAO, 2006), an update of an earlier report titled “World Agriculture: Towards 2015/2030 – An FAO Perspective” (Bruinsma, 2003). This Interim Report and some minor updates (Bruinsma, 2009) constitute the basis for the FAO estimate that global agricultural production must increase by 70 % by 2050 to meet global demand, a finding which was circulated at the World Food Summit in 2009: “In order to feed this larger, more urban and richer population, food production (net of food used for biofuels) must increase by 70 percent” (FAO, 2009a: 2). This figure was widely cited by the international press. In addition, several interest groups have used this figure with very different objectives, often to suggest a close link between global production and hunger reduction:

» In claims for more funds for development aid, e.g. by FAO (Financial Times, 2008).

» In claims for an intensification of agricultural production (AtlasFram Group, 2010).

» Use of GMOs (e.g. Brabeck-Letmathe, 2009; Bridges, 2008).

» In claims for a more intensive agricultural production in the EU in order to address global food insecurity (EU COM 2010).

» In criticism of organic agriculture (Syngenta, 2009).

But the isolated “70% production increase” figure (designated as “70 % PI” throughout this text) is not very meaningful without any accompanying information and inadequate to support the above mentioned claims. In particular, this figure does not justify the claim that global agriculture in general should be intensified. Furthermore, the excessively strong focus on the relevance of global agricultural production for fighting malnutrition and hunger is misleading.

Given this backdrop, this study has the following objectives:

» To clarify the methods used and the assumptions made in projecting the 70 % PI figure.

» To discuss the implications of the 70 % PI, especially whether and to what extent an increase of global agricultural production will contribute to reducing hunger.

» To analyze the extent to which changes in other variables (composition of food consumption, postharvest losses, use of biomass for energy production, etc.) – variables which are also subject to the impact of potential policies – may contribute to meeting the world wide increasing demand for food.

The study is organized as follows: Chapter 2 gives an overview of the background, methods used and assumptions made as well as the core results of the FAO projections. Chapter 3 discusses the interdependencies between agricultural production and undernourishment. Chapter 4 discusses and analyzes alternative options for improving the world food balance, in contrast to an isolated focus on increasing agricultural production. Two factors are especially highlighted in Chapter 4: the potential to decrease postharvest losses and the impact of lower meat consumption in developed countries. Finally, Chapter 5 draws some conclusions.

Growth in agricultural production has often been coupled with the unsustainable exploitation of natural resources. Agrochemicals, if not adequately used, have severe effects on natural resources like biodiversity and water.

2 Understanding FAO World Food Projections

2.1 Introduction

Several conditions are essential for understanding the 70 % PI and putting it into perspective:

» An understanding of the definition of the 70 % PI figure, including the units of measurement (such as area, calories, cereal units, value).

» An understanding of the assumptions made and methods used in the projections.

» A comparison of the results to those from other studies.

» An understanding of the political implications of the 70 % PI, especially with respect to its relevance for fighting world hunger. (Under which conditions are the 70 % PI valid? Why is the focus so much on 70 % PI instead of other options to improve the world food balance?)

The projected 70 % increase in production would imply an average increase of per capita calorie consumption of 11 % by 2050

Bruinsma (2009: 5) clearly defines what is meant by the 70 % PI: It is the increase in the value of global agricultural production in constant base period prices (1989–91 average world market prices in US$, FAO, 2006). This implies that the projected increase in global agricultural production has two components: (1) an increase in the absolute quantities of individual product categories (such as cereals by 49 %, meat by 85 %), (2) a change in the composition of product categories from low priced products (cereals, pulses, starchy tubers) to higher priced products (fruit and vegetables, animal products) (Bruinsma, 2009: 5). These two effects together are projected to lead to an increase in the value of global agricultural production by 70 %, equivalent to a 22 % per capita increase, taking into account population growth of 40 %, resulting in a world population slightly exceeding 9 billion by 2050. Expressed in calories the projected production increase in value would imply an average increase in per capita calorie consumption of 11 % by 2050 (ibid).

While 70 % appears on its face to be a clearly defined figure, it is difficult to know and understand the assumptions and methods that lie behind it. This is due to several problems:

The assumptions underlying the projected 70 % production increase are weakly documented

» The 70 % PI is based on several studies which are drawn together in a somewhat intransparent manner.

» The documentation of assumptions and methodological approach is spread over various papers which date as far back as 1995. In addition, the assumptions and methodologies are often drawn from papers which are not of direct relevance for the projections.

» A substantial portion of the assumptions are not or only in very general terms documented.

It is therefore almost impossible to trace the results in light of the assumptions made and as many of the assumptions are unknown it is impossible to evaluate their validity compared to any alternatives.

In order to ease the reader's access to the original sources, Figure 2.1 displays a timeline of relevant publications (lower part of the figure) and events (upper part of the figure).

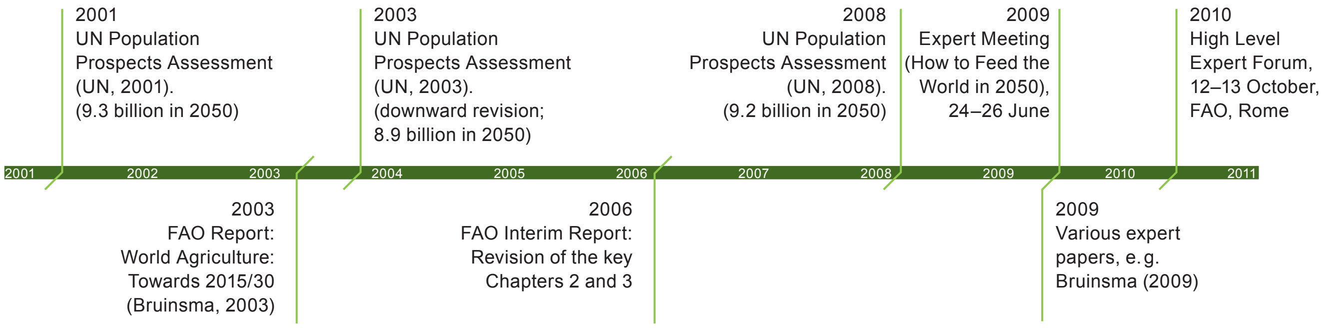

Figure 2.1: Timeline of the Important FAO Papers and Events

Source: Own composition.

The FAO has been engaged in generating projections of the world food situation since its foundation and has regularly published reports in this regard. The 70 % PI figure is based on three studies which are outlined in some detail in the paragraphs below:

» The FAO report "World Agriculture: Towards 2015/30", published in 2003 (Bruinsma, 2003).

» The FAO Interim Report "World Agriculture: Towards 2030/2050", including some updates and published in 2006 (FAO, 2006).

» Further updates to the projections published by Bruinsma (2009).

In 2003, the report "World Agriculture: Towards 2015/30 an FAO Perspective" (Bruinsma, 2003) was published. The report is a comprehensive study that documents projections of global agricultural production and the world food situation until 2030 in chapters 1–5. It also addresses several topics related loosely or not at all to the projections such as world forestry, globalization, agricultural trade liberalization, climate change and others. The methodology of the projections is described only rudimentarily in a short annex and reference is made to a publication by Alexandratos (1995), which adds little to providing a comprehensive documentation of the methodology used.

The so-called Interim Report (FAO, 2006) updates the projections from Bruinsma (2003) and extends the projection horizon to 2050. Reasons given for this update include: (1) the corrections of the UN population projections from 9.3 billion (UN, 2001) in 2050 to 8.9 billion (UN, 2003), (2) significantly higher projections of global crude oil prices and (3) insufficient progress with regard to the target of halving the number of undernourished by 2015, as avowed at the World Food Summit in 1996. A core finding of the Interim Report is a forecast that global agricultural production (in terms of production value at constant prices) will increase by 87 % between the base period (average of the years 1999–2001) and the year 2050 (own calculations based on FAO, 2006: 33). This figure has been communicated by FAO (FAO, 2008) and cited by the press frequently as the need for "doubling agricultural production by 2050" (Financial Times, 2008).

In preparation of the World Food Summit in 2009, projections were updated again. The most significant change was the consideration of new base data for agricultural production (2005–2007 instead of 1999–2001) (Bruinsma, 2009: 4). Therefore, the new projection period comprises 44 years (2005/07–2050) instead of 50 years (1999/2001–2050). Taking into account this difference in projection horizon, the new figures imply an almost identical annual increase in agricultural production as the former ones (in total 70 % instead of 87 %, with the projection horizon shortened by 6 years).

In the remainder of this chapter, Sections 2.2 and 2.3 present the methodological background of the most recent FAO projections underlying the 70 % PI and published by Bruinsma (2009), and the assumptions made to the extent that they could be extracted from the FAO sources. In order to ease the verification of FAO projections and underlying assumptions, Section 2.4 summarizes some key results, discusses the plausibility of their magnitude and compares them to those from other studies. Section 2.5 discusses the conclusions FAO draws from the 70 % PI, which are interesting especially in light of the strong political instrumentalization of this number shown above, and why the FAO puts such a strong weight on this figure in communicating the results of Bruinsma (2009) to the public. Finally, Section 2.6 draws some summarizing conclusions from the analysis of the projections.

2.2 Methodological Approach

FAO world food projections do not reflect what the FAO considers desirable to happen, but most likely to happen

FAO world food projections do not reflect what the FAO considers desirable to happen, but they reflect the increase in global demand that the FAO considers most likely to happen in the future, and the required increase in production that the FAO considers necessary and feasible to meet this demand. These projections thus do not imply a normative assessment of what should happen.

The projection of the world food balance is not based on the use of one quantitative economic simulation model, but rather consists of three subsequent steps, using an accounting framework and relying heavily on expert assessments. These steps are:

» Demand projections.

» Supply projections.

» The reconciliation of demand and supply projections at the national and global levels in order to achieve a balanced world food situation and plausible trade flows. This process is not price driven: real prices are assumed to remain constant.

1) Demand projections are based on available information from various sources such as other models, expert estimates and best guesses. Most important determinants include population growth, income growth, changes in income distribution, and autonomous trends in consumption patterns. As a result, the increase in effective demand for food products between the base period and the year 2050 is estimated based on calculations, and implies certain production increases. This increase in effective demand is not what the FAO considers as desirable, but what the FAO considers to be most likely to happen in the future based on currently available information. Especially important in this context is that this increase does not reflect the abolishment of hunger, but rather reflects the decline in hunger which the FAO considers likely to happen (see below).

2) Supply projections take into account the available resource base in the individual countries (land reserves, water for irrigation), expectations on technical progress (e.g. in yields per ha or feed use per unit of animal product output), and change in management techniques such as changes in cropping intensity.

3) Reconciliation of supply and demand: Initially, the FAO projections of demand and supply are generated independently, i.e. they do not necessarily balance out. National increases in supply would not necessarily match national increases in demand, and even if one allows for changes in the net trade balances for the individual countries, the aggregated increase in global supply would not necessarily match the aggregated increase in global demand. Therefore, as a next step in the projection process the global increase in supply is reconciled with the global increase in demand in an accountancy framework. This process of reconciliation is a rather resource intensive, technical and handmade procedure, involving per country modifications of supply and trade which is often based on the judgement of country and market experts. Important to mention is that this process does not involve the use of equilibrium models, which would allow for changes in relative prices in order to reconcile supply and demand changes, but rather assumes constant prices.

The FAO produces only one "baseline projection", but not any additional scenarios which may result under sets of different assumptions

The approach chosen by FAO has the advantage of allowing the inclusion of an enormous amount of country specific information on the natural resource base as well as socioeconomic and cultural conditions. This means that the results are validated against their physical feasibility and plausibility. A disadvantage, however, is that this approach does not allow for the simulation of changes in relative prices and the resulting feedback mechanisms. Furthermore, due to the missing market clearing price mechanism, the development of a scenario with supply and demand being balanced is enormously time consuming. As a consequence, the FAO produces only one "baseline projection" under a given set of assumptions and for a given projection horizon, but not any additional scenarios which may result under sets of different assumptions (Bruinsma, 2003: 381–382). Compared to projections based on a quantitative equilibrium model which equates demand and supply using the price mechanism, and typically finds changes in relative prices, the approach pursued by FAO does not necessarily result in less valid results. Thus, while the inclusion of an enormous amount of knowledge on biophysical restrictions and expert knowledge is an asset, the inflexibility in running alternative scenarios with different assumptions and sensitivity analyses represents a key weakness in the approach.

In the following section, we provide a description of the specific assumptions made in the projections to the extent that it is possible to extract this information from the respective publications.

2.3 Assumptions

A wide range of demand and supply factors are taken into account in the FAO projections and presented and discussed in detail in Sections 2.3.1 and 2.3.2. Table 2.1 gives an overview of these factors.

Table 2.1: Demand and Supply Factors Considered in the FAO Projections

Source: Own composition.

Demand Factors	
Factors included in FAO projections	**Factors not included in FAO projections**
Population growth	Price changes
Income growth	
Changes in food distribution (resulting from changes in income distribution)	
Socio-cultural factors	
Postharvest losses	
Improvement in feed conversion	
Changes in seed use and in industrial use	
Bioenergy demand	
Demand for fishery products	
Supply Factors	
Factors included in FAO projections	**Factors not included in FAO projections**
Change in agricultural area	Climate change
Increase in irrigated area	
Increase in cropping intensity	
Crop yield growth	
Production constraints resulting from resource availability	
Changes in animal numbers	
Increase in animal productivity and intensification (feed conversion, off-take rates, carcass weights, etc.)	

Price changes and climate change are not included in the projections

Price changes and climate change are not covered by the projections. Taking climate change into account would put even more pressure on the world food balance. It is very likely that climate change will negatively affect average global agricultural production in the future, and will likely lead to lower land productivity in tropical and subtropical climate zones and increased land productivity in temperate climate zones (Parry et al., 2004; Nelson et al., 2009; Moeller and Grethe, 2010; Fischer, 2009).

2.3.1 Demand Factors

The main factors determining food demand growth are increases in population and income as well as autonomous consumption trends:

» Population growth is based on the UN Population Prospects (UN, 2003), which predict world population to grow from 6.1 billion in the year 2000 to 8.9 billion by 2050, i.e. by 46 % (FAO, 2006: 16). As a result, population growth for the period for the latest projections between 2005/07 and 2050 would amount to 37 %.

» Average world per capita income growth for the period 2000–2030 is based on World Bank (2006) and amounts to a 2.1 % annual growth rate, and the FAO assumes a 2.7 % annual growth rate for 2030–2050 (FAO, 2006: 17). This leads to an income increase for the period of the latest projections between 2005/07 and 2050 of 180 %. Increases in income used in the FAO projections are country specific and the reaction of food demand to increases in income are also considered country-by-country. For example, FAO assumes the response in demand for meat products in India to income growth to be substantially lower than in many other countries with comparable income levels due to dietary preferences resulting from cultural and religious practices (FAO, 2006: 49). In the published FAO papers, projected income growth is reported by country group (e.g. Table 2.5 in FAO, 2006: 17), but not by country. The evidence on individual countries such as India is often anecdotal. Moreover, the income elasticity used in the projections are not documented.

» Changes in income distribution can have substantial effects on aggregate food demand: a more equal distribution of income results in higher food demand, as poorer parts of the population tend to spend a larger share of their incomes on food than higher income groups. The FAO projections do not explicitly take into account changes in income distribution. Based on World Bank projections of declining poverty, however, FAO projections are based on the assumption that coefficients of variation in food demand within developing countries will decline from a level in the range of 0.21–0.36 in the base period to 0.20–0.295 by 2050 (FAO, 2006: 21).

» Country and product specific consumption trends which are not driven by standard variables such as income or prices are often designated as “autonomous consumption trends”. Such trends may be driven by changes in consumers’ perception of food products, health issues and other factors. Such autonomous trends are sometimes taken into account in the FAO projections, but are not systematically documented in the reports.

» Increasing demand for fishery products is taken into account in the calculations of total food availability, but the exact amount is not specified clearly. The 2003 report states that “the global average per capita consumption could grow to 19–20 kg by 2030, raising total food use of fish to 150–160 million tons (97 million tons in 1999)”, with the bulk of the increase coming from aquaculture (Bruinsma, 2003: 22).

» The handling of demand forecasts for biofuels is quite intransparent. Bruinsma (2009: 2) states that the projections do “not deal with additional demand for agricultural products used as feedstock in biofuel production”. But obviously this refers to any additional demand for biofuels, which would add to that already considered in the Interim Report.

» The biofuel demand for coarse grains, especially corn, is mentioned several times in the Interim Report. In the section where the results are described, it is mentioned that “consumption of coarse grains should continue to grow, mainly for non-food uses (essentially animal feed, though use for the production of biofuels may assume some importance in the future)” (FAO, 2006: 41). Yet it remains open to what extent this has been considered in the projections.

The GDP growth rates assumed by FAO until 2050 are substantially above what has been observed in the past

» For vegetable oils, it is assumed that demand for non-food industrial uses will grow by 3.2 % annually until 2050, compared to human demand growing by 1.5 % annually. As a result, about 42 % of vegetable oil demand will be for non-food industrial use by 2050 (FAO, 2006: 57).

» For cassava, the Interim Report states that “In our projections for non-food uses we made some allowance for increased demand originating in the biofuels sector” (FAO, 2006: 60). Yet it remains unclear to what extent this was done.

» For sugar, it is assumed that demand for sugar in ethanol production will increase strongly in Brazil, Peru, Colombia, Central America, India, Thailand, Australia, South Africa and Zimbabwe. As a result, it is projected that industrial use of sugar will grow by 4 % annually up to 2050 (FAO, 2006: 62–63).

» The overall picture with regard to biofuels is unclear: the amount of vegetable oils and sugar use for biofuel production can be derived from the Interim Report, but this is not the case for cereals. The effect of biofuel demand on the global food balance is explicitly addressed in supplementary papers (e.g. Fischer, 2009).

Figure 2.2 graphically depicts the development of the two most important variables impacting food consumption: population and income

Figure 2.2: World Population and World Income (1970 = 100)

Sources: FAOSTAT (2011) for historical population data; IMF (2010) for historical GDP data, FAO (2006) for projections, own calculations.

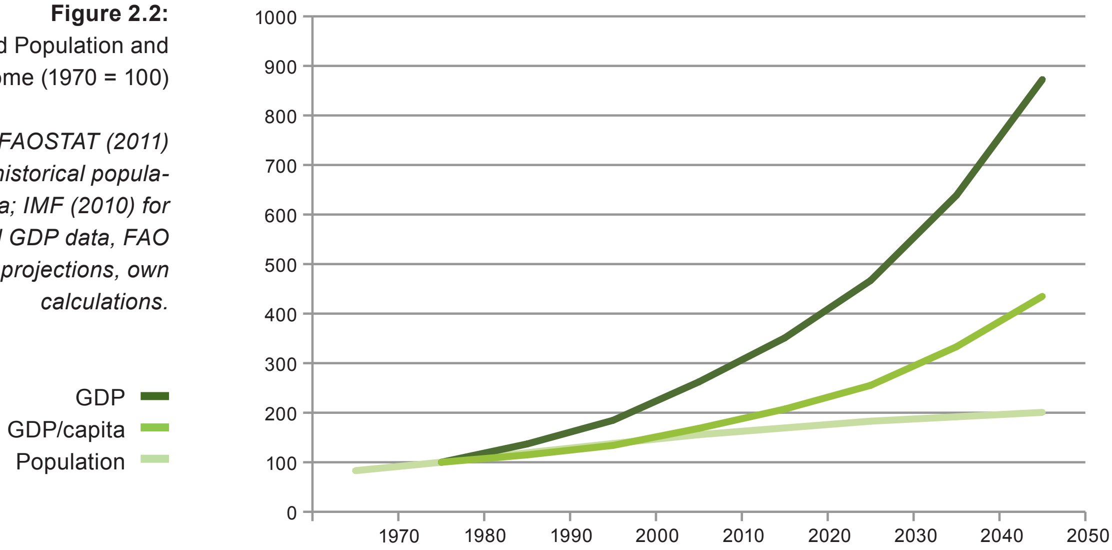

Figure 2.2 shows that world population is expected to grow slower than in the past (annual growth rate 2030–2050 = 0.5 %). In contrast, the GDP and per capita GDP growth rates assumed by FAO (2.1 % until 2030; 2.7 % until 2050) are substantially above what has been observed in the past (2.2 % annually from 2000 to 2010 and about 1.4 % in the two decades prior).

Assuming a reduced annual per capita GDP growth rate of 1.4 % leads projected growth in food demand by 2050 to drop from 75 % to 50 %

A quick back of the envelope calculation shows that the increase in population and income assumed by FAO alone would result in an increase in the value of consumption on the order of magnitude projected by FAO: Assuming an income elasticity of total food demand of about 0.21 and a population elasticity of total food demand of 1, the resulting increase in food consumption would be about 76 %. If, instead, per capita GDP growth rates observed between 1980 and 2000 are assumed to prevail in the future (i.e. 1.4 % annually), the resulting increase in food consumption would only be 50 % instead of 76 %.

A final factor which impacts the future of the global food balance is the postharvest losses that occur along the food supply chain and at the household level (see Section 4.2 below). In its projections, the FAO estimates of postharvest losses (called "waste" in the reports) exclude losses at the household level (FAO, 2006: 14), but the figures used for the base period and the projections are not published in the FAO reports. Based on published FAO statistics which are used in the projections (Supply Utilization Accounts; FAOSTAT, 2011), we can conclude that even if losses at the household level are neglected, losses used in the projections seem low compared to the estimates for losses along the supply chain reported in the literature, which are about 15 % for cereals in developing countries (see Section 4.2.4 below). This conclusion can be derived as follows:

» The updated projections of the Interim Report only include the categories "food" and "all uses", whereby "all uses" minus "food" would include feed, industrial use, seed and waste (e.g. FAO, 2006: 40, Table 3.3).

» Figure 3.9 in the original FAO report (Bruinsma, 2003: 75) shows the development of "other uses" for cereals, including industrial use, seed use and waste, which declines from about 10.4 % in 1997/99 to 9.4 % by 2030.

» According to FAO commodity balances (FAOSTAT, 2011), waste accounted for 4.5 % of global cereal production in 1997/99, seed accounted for 3.6 % and industrial utilization for 2.3 %, yielding the 10.4 % figure found in Table 3.9 in Bruinsma (2003).

Postharvest losses assumed in the FAO studies are far below other estimates

Thus, postharvest losses assumed in the studies are far below other estimates. Second, we can try to understand how FAO projects postharvest losses to develop until 2050:

» The FAO assumes a slight decline in the aggregate total for industrial use, seed use and waste of about one percentage point by 2030, yet one can only guess as to the composition of this decline.

» According to FAO data, seed use has declined substantially in the past, whereas waste has been quite stable. For this reason, it appears FAO projections for a decline in the aggregate are based on declining seed use instead of declining waste (see Figure 2.3).

[1] *An income elasticity of demand of 0.2 means that demand for the respective product increases by 0.2 % if income increases by 1 %.*

35 % of US corn production is used for bio-ethanol production

Figure 2.3 includes data on total non-feed and non-food use up to 2007, when these categories totalled at 11 %, as well as FAO projections of this aggregate up to 2030. This total includes seed use, industrial use and waste. In addition to showing a decline in seed use and stable food loss percentages, Figure 2.3 highlights the strong increase in the industrial utilization of cereals witnessed since the mid-90s. It seems that this use category has reversed the declining trend of the overall aggregate "non-feed and non-food use". The main driver of the industrial utilization category is the use of cereals for bioethanol production. For example, the use of corn for bioethanol production in the US increased from 10 mil. tons in 1995 to 116 mil. tons by 2009. The latter figure represents 35 % of US corn production or 5 % of world cereal production (ERS, 2011; FAOSTAT, 2011). Whether and to what extent demand for cereals for ethanol production has been considered in the projections is unclear (see below).

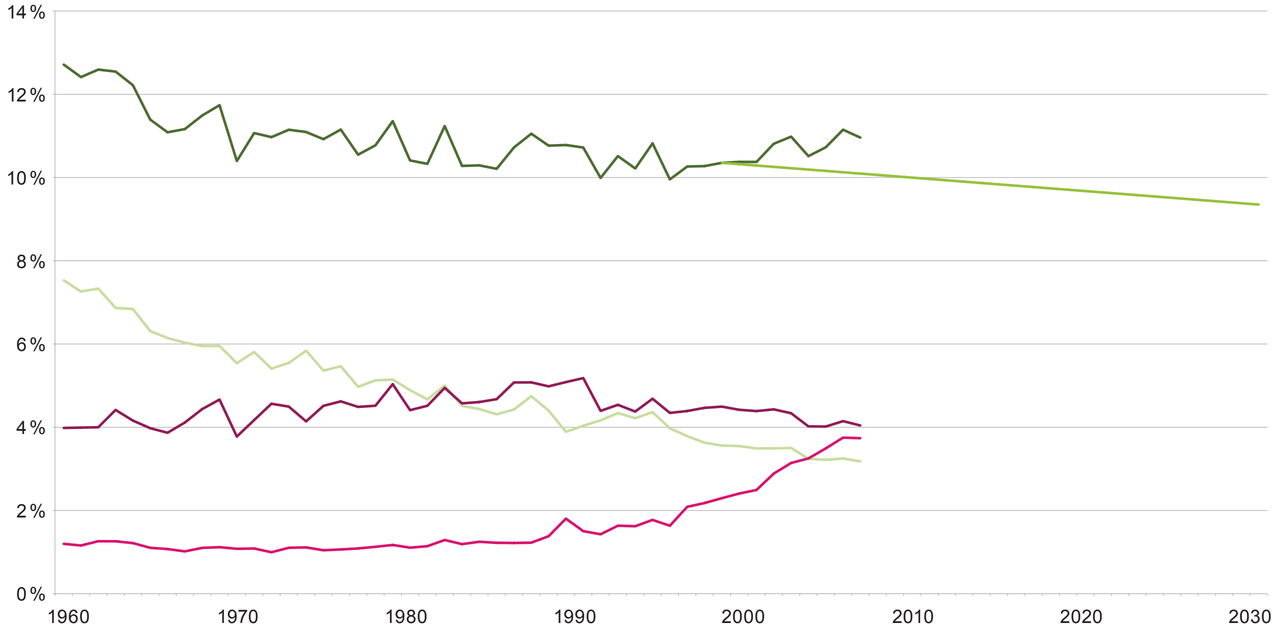

Figure 2.3: Non-Feed/Non-Food Cereal Use as a % of Global Production

Sources: FAOSTAT (2011) for historical data; Bruinsma (2003) for projections, own calculations.

Total non-feed & non-food
Total non-feed & non-food projections
Seed
Waste
Industrial utilization

2.3.2 Supply Factors

There are essentially two factors that can lead to higher crop yields: an increase in cultivated area and an increase in the productivity of land. Increases in the productivity of land improved may stem from several factors, including enhanced complementary inputs (irrigation, fertilizer), improvements due to crop breeding, or improved farming techniques. For the FAO projections the following assumptions are made about average global developments (Bruinsma, 2009: 2–6):

» Total arable land will increase by 5 %, reflecting a decline in industrialized countries and an increase in developing countries.

» Irrigated land will increase by 17 % and land equipped for irrigation will increase by 11 % (all of this increase is forecasted to occur in developing countries).

» Cropping intensity, which is defined as the frequency of harvests on a given land unit, will increase by about 9 %.

» Average crop yields will increase by 42 %.

For animal production, supply increases may be achieved with an increase in animal numbers or with productivity increases caused by factors such as shorter production cycles and higher carcass weight or milk and egg yields (Bruinsma, 2003: 164).

Bruinsma (2003) presents information on the projected growth rates in meat producing animal numbers between 1997/99 and 2030 (Bruinsma, 2003: 165, Table 5.3) as well as assumed developments in carcass weight. Information on other underlying productivity parameters is not specified in the report. Based on the increase in animal numbers (Bruinsma, 2003: 165, Table 5.3) and the projected increase in animal production (Bruinsma, 2003: 89, Table 3.11) between 1997/99 and 2030, the growth rates in animal productivity that underlie the assumptions in FAO projections to 2030 can be reconstructed:

» Beef production will increase by 1.3 % annually (= 51 % between 1998/99 and 2030) of which 0.6 % (21 %) can be ascribed to advances in productivity and 0.7 % (25 %) to increasing animal numbers;

» Pork production will increase by 1.1 % annually (42 % in total) of which 0.5 % (17 %) can be attributed to productivity improvements and 0.6 % (21 %) to the increase in animal numbers;

» Poultry production will increase by 2.7 % annually (135 % in total) of which 1.1 % (41 %) is attributed to productivity increases and 1.6 % (66 %) to the increase in animal numbers.

Moreover, feed demand for cereals for overall livestock is specified, but no information is published on changes in feed conversion rates. Total feed demand for cereals is expected to increase by 89 % between 1999/01 and 2050, which is equivalent to 1.28 % p.a. (1.6 % p.a. between 1999/01 and 2030 and 0.8 % between 2030 and 2050; up from 0.8 % p.a. in the 1990s).

This can be compared to an increase in the production of all livestock products (including meat, eggs and milk) of 1.6 % p.a. between 1999/01 and 2030 and of 0.9 % p.a. from 2030 to 2050, equivalent to a total increase of 92.6 % over the period 1999/01–2050. Thus, total livestock production and total feed demand for cereals increase by about the same rate. From these figures, however, one cannot conclude that feed conversion rates remain constant, as they combine various effects: improvements in feed conversion, a changing composition between different livestock products, and changes in the composition of feed rations.

Figure 2.4: Arable Area, Area Equipped for Irrigation and Crop Yield (1970 = 100)

Sources: FAOSTAT (2011) for historical data; FAO (2006) for projections, own calculations.

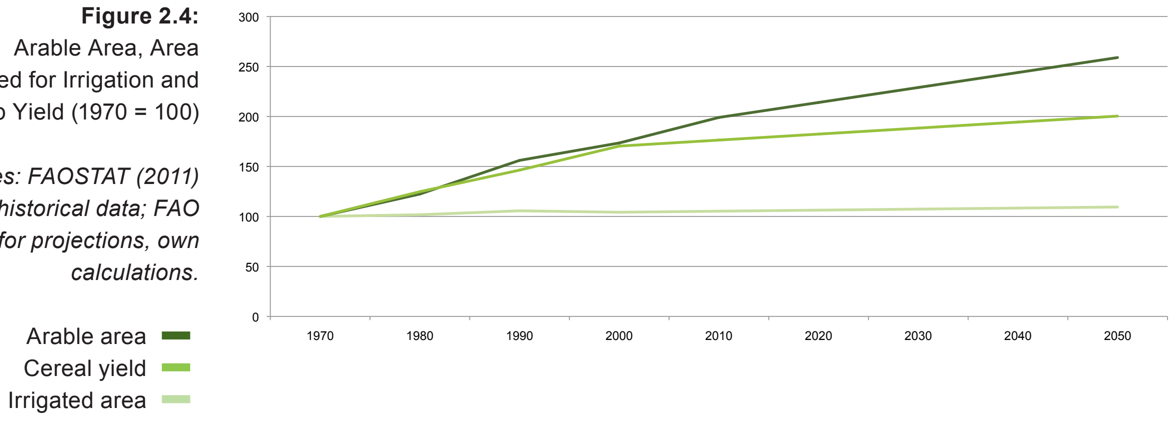

Figure 2.4 graphically depicts trends in the most important variables impacting crop production: arable area, area equipped for irrigation and cereal yields.
Figure 2.4 shows the limited potential for increases in arable area, the strong decline in the absolute increases of irrigated area and the declining growth rates of cereal yields, which were above 2 % annually in 1970–1990, declining to 1.2 % in 1990–2010 and are projected to further decline to 0.6 % by 2050.

2.4 Results of the FAO World Food Projections

FAO projects agricultural production to increase by the percentages displayed in Table 2.2 over the 44 year period from 2005/07 to 2050. For product groups with a comparable value per quantity unit, such as cereals and meat, the increase is reported for the development of the total quantity. For other product groups, which comprise products with very different per unit values (such as "crops"), increases are expressed in terms of total production value at constant world market prices at constant 1989–91 world market prices in US $ (FAO, 2006: 31).

Table 2.2: Increases in Agricultural Production

* In value terms, aggregated with constant world market prices of the years 1989–91 in US $.

Sources: Bruinsma (2009: 5), own calculations.

	1961/63	2005/07	2050	1961/63 to 2005/07	2005/07 to 2050
		(observed)	(projected)	(observed)	(projected)
World			Millions of tons		Change in %
Total agricultural production*				148.0 %	70.0 %
Total crop production*				157.0 %	66.0 %
Cereal production	843	2,012	3,009	138.7 %	49.6 %
Livestock production*				136.0 %	76.0 %
Meat production	94	249	461	164.9 %	85.1 %
Developing countries					
Total agricultural production*				255.0 %	97.0 %
Total crop production*				242.0 %	82.0 %
Cereal production	353	1,113	1,797	215.3 %	61.5 %
Livestock production*				284.0 %	117.0 %
Meat production	42	141	328	235.7 %	132.6 %
Developed countries					
Total agricultural production*				63.0 %	23.0 %
Total crop production*				64.0 %	30.0 %
Cereal production	490	900	1,112	83.7 %	23.6 %
Livestock production*				62.0 %	17.0 %
Meat production	52	108	133	107.7 %	23.1 %

Table 2.2 shows a total increase in agricultural production of 70 % in value terms, which results from a 97 % increase in developing and 23 % increase in developed countries. Globally, meat products experience the strongest growth (85 %), followed by the aggregate of livestock production (76 %), aggregate crop production (66 %) and cereal production (nearly 50 %). In developing countries, growth in total livestock products and meat production increase by a higher percentage than crop production. In developed countries, by contrast, the increase in animal production is lower than that in crop production.

The 70 % growth in total agricultural production results in a 22 % per capita increase when taking into account global population growth of 40 % to 9 billion by 2050. Expressed in calories, such an increase in value would imply an average increase in per capita calorie consumption of 11 % (Bruinsma, 2009: 5). Based on assumptions of a more equitable distribution of food within countries by 2050 (FAO, 2006: 21), the FAO estimates that the absolute prevalence of undernourishment in developing countries will decrease from 813 million in 2000/2002 to 290 million by 2050, a decrease equivalent to 64 %.

Growth rates observed in the past are more than twice as high as those projected for the future

In order to put the projected increases in agricultural production into perspective, Table 2.2 also presents the historical increases for an equally long 44 year period: 1961/63 to 2005/07. A comparison shows that for agriculture as a whole as well as for most product groups, the growth rates observed in the past are more than twice as high as those projected for the future, although they started from a much lower absolute level, of course. Looking more closely at the calculations underlying the projections described above, these declining growth rates reflect lower demand growth mainly due to weaker population growth (population has more than doubled during the historical 44 year period and is projected to increase by only 38 % over the forecast period). On the supply side, declining growth rates in arable area, irrigation and the productivity of land assumed, and are sufficient to satisfy the increase in demand. Furthermore, it should be taken into account that past growth rates in agricultural production was often accompanied by the unsustainable exploitation of natural resources (e.g. Bruinsma, 2003: Chapter 12).

Past growth rates in agricultural production has often been accompanied by the unsustainable exploitation of natural resources

Finally, the FAO projections can be put into perspective by comparing them to projections of the world food situation made by other institutions and author teams. Major alternative sources are projections published by the International Food Policy Research Institute (IFPRI) based on the partial equilibrium simulation model IMPACT. As discussed above, simulations based on such a model allow for the simulation of price changes and the straightforward formulation of scenarios based on alternative assumptions that can be analyzed quickly. A major IFPRI publication based on the IMPACT model is "Global Food Projections to 2020" (Rosegrant et al., 2001). Due to the relatively dated nature of these projections, however, we also compare the FAO projections to Msangi and Rosegrant (2009), who project the development of world food balances up to 2050.

Generally speaking, world food projections tend to be quite much in line, as Figures 2.5 and 2.6 show. These figures contain contain FAO projections (Bruinsma, 2003; FAO, 2006), IFPRI projections (Rosegrant et al., 2001) and different scenario results from the Millenium Ecosystem Assesment (MA) (2005), which are also based on the IMPACT model at IFPRI.

Corn is one of the most important staple foods worldwide. Adequate conservation and storage techniques are needed to reduce postharvest losses.

Figure 2.5:
World Cereal Production
1960–2050

Source: IAASTD (2009: 295).

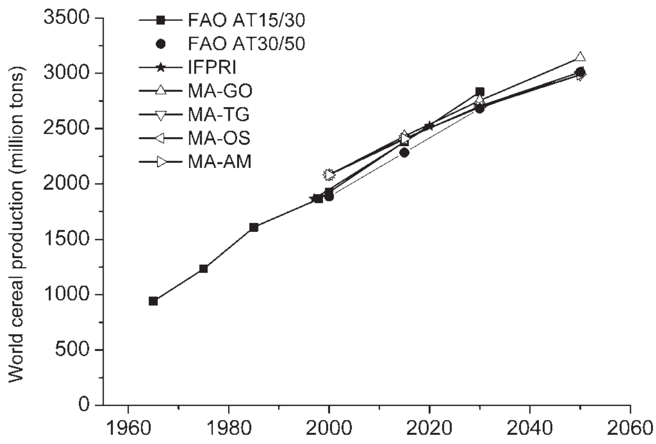

Figure 2.6:
World Meat Production
1995–2050

Source: IAASTD (2009: 297).

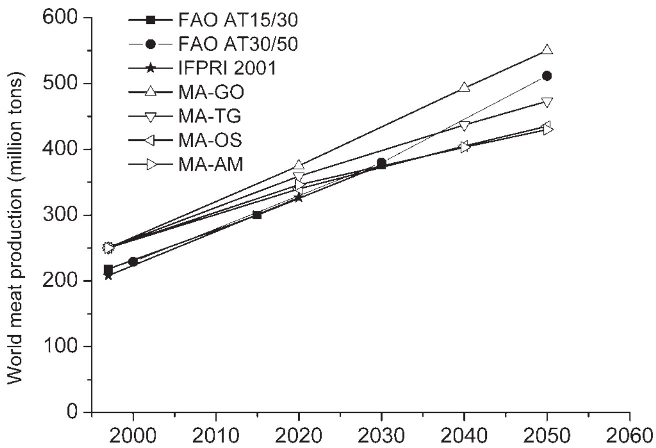

Figure 2.5 and 2.6 show that deviations between the IFPRI and FAO projections are very small. Deviations among the MA scenarios are somewhat larger, especially for meat, which is because of strongly differing scenario assumptions, including substantial differences in per capita income, which has greater impacts on meat than on cereal consumption.

More recent projections based on the IMPACT model foresee a total increase in cereal production between 2000 and 2050 by 48 % (own calculations based on Msangi and Rosegrant, 2009: 30, Figure 3), being equivalent to an annual growth rate of 0.79 %. This is a slightly more moderate estimate than FAO projections (Bruinsma, 2009), foreseeing an increase of cereal production by 49.6 % between 2005/07 and 2050, being equivalent to an annual growth rate of 0.88 %.

2.5 Political Conclusions Drawn by FAO from the Results

The FAO reports are quite modest with regard to policy conclusions. The initial report (Bruinsma, 2003), for example, has no chapter focussing on conclusions with policy relevance, and most conclusions formulated in the individual chapters on world food projections are rather technical. One conclusion with strong political implications is that it is very unlikely that the World Food Summit target of halving undernourishment by 2015 would be met, even by 2030 (FAO, 2006: 4).

Bruinsma (2009) contains more pronounced conclusions: he sees an improvement in the global food balance by 2050, and asserts that the world as a whole could produce enough food for all by that time. But he also hints at the remaining regional disparities which will leave large population groups in many countries undernourished (Bruinsma, 2009: 3). Furthermore, Bruinsma highlights the importance of increasing agricultural production within food insecure countries in order to match local demand due to often limited import capacities (ibid: 29). It is also stressed that "the projected increases in yields, land and irrigation expansion will not entirely come about spontaneously (i.e. driven by market forces), but require huge public intervention and investments, particularly in agricultural research and in preventing and mitigating environmental damage" (ibid: 3). Investment requirements have been quantified by Schmidhuber et al. (2009), who estimate that of the investments required to maintain the capital stock of the years 2005/2007, an additional 65 % will be needed by 2050 to reach the projected 70 % PI.

Despite the rather modest and technical policy conclusions made by the FAO, the projections have been used to argue for a tenfold increase in agricultural development aid by Jacques Diouf, Director General of the FAO (Financial Times, 2008), as well as to argue for more investment in agriculture. Moreover, the projections are often cited in the public debate over hunger reduction (e.g. FAO, 2009b).

Ultimately, it appears that the FAO may have taken the position of arguing for a 70 % increase in production as it seems to be a less controversial position than calls for alternate or additional measures to reduce hunger, and is likely to have few opponents and strong supporters. Other policy recommendations such as those for income redistribution, better governance in countries with a high prevalence of food insecurity, changes in diets in industrialized countries, the reduction of postharvest losses or bioenergy subsidization would have been likely to raise more opposition.

2.6 Conclusions from the FAO World Food Projections

It is not clear to what extent the FAO takes into account increasing demand for bioenergy

The FAO projections are based on solid analysis and an enormous amount of expert knowledge and country specific data. Furthermore, they are roughly in line with projections by other institutions. Due to the intransparent presentation and insufficient documentation of assumptions and methodology, however, it is almost impossible to trace the results in light of the assumptions made. As many of the assumptions are unknown, it is impossible to evaluate their validity compared to any alternatives. For example, it is not clear to what extent FAO takes into account increasing demand for bioenergy.

The assumed average global income growth rates for 2030 to 2050 are high compared to the past and may result in an overestimation of future demand. On the other hand, the effects of climate change are not yet considered in the projection of global supply. Climate change may put further pressure on the world food balance.

3 On the Interdependencies of Global Agricultural Production and Hunger

FAO communications and media coverage surrounding the world food projections have strongly focused on the need to increase global agricultural production in order to assure world food security. In this study, however, we discuss other measures which could be implemented to increase global food availability: the reduction of postharvest losses, the limiting of policy support for bioenergy in industrialized countries and the lowering of meat consumption in industrialized countries. Such efforts would help to improve the global food balance and prevent global food prices from increasing to a level that would result in increasing food insecurity and poverty for people who spend a high share of their income on food.

But is the link between the global availability of food and undernourishment really that strong? Amartya Sen formulated the relevance of food availability for food security three decades ago as follows:

"Starvation is the characteristic of some people not having enough food to eat. It is not the characteristic of there being not enough food to eat. While the latter can be a cause of the former, it is but one of many possible causes" (Sen, 1981: 1).

Undernourishment is not a problem of global food availability, but of access to food. Poverty is the main reason for food insecurity

This notion has become widely accepted and is reflected in mainstream access-based definitions of food security as "[a situation in which] all people, at all times, have physical, social and economic access to sufficient, safe and nutritious food that meets their dietary needs and food preferences for an active and healthy life" (FAO, 2010). This definition stands in sharp contrast to earlier definitions which focused on the availability of food, but not on individual access to food, with food security being defined as: "availability at all times of adequate world food supplies of basic foodstuffs to sustain a steady expansion of food consumption and to offset fluctuations in production and prices" (United Nations, 1975).

In conclusion, undernourishment is not a problem of global food availability, but of access to food. And in the overwhelming majority of cases, it is the economic access to food that stands in the way of food security: Poverty is the main reason for food insecurity. The following facts underline the observation that food availability at a global level is not the main problem at all, but rather that hunger is a problem of economic access to food, and thus of its distribution:

Daily per capita food consumption was at 2789 kcal in 1999/2001 – The FAO estimated undernourishment threshold is 1840 kcal

» Per capita food consumption was 2789 kcal/person/day in 1999/2001 (Bruinsma, 2009: 8) which was more than 50 % above the FAO estimated undernourishment threshold of 1840 kcal/person/day (ibid: 15).

» Per capita food consumption is projected to reach 3130 kcal/person/day by 2050 (Bruinsma, 2009: 8) which would be 64 % above the FAO estimated undernourishment threshold of 1913 kcal/person/day (ibid: 15).

» Periods of high "global availability" of food are reflected in low world market prices, as was seen, for example, in the mid-1980s and late 1990s. Yet even during such periods, hunger was not significantly reduced but the number of people suffering from hunger remained at a level above 750 million (FAO, 2010: 9).

Increasing agricultural production, reducing losses or decreasing demand in regions with a low prevalence of undernourishment has only indirect and limited impacts on the prevalence of hunger

Thus, increasing agricultural production, reducing losses or decreasing demand in regions with a low prevalence of undernourishment would only have indirect and limited impacts on the prevalence of hunger. Such measures lead to lower world market prices (provided the region concerned is integrated into world markets). This, in turn, lowers the import bill of net food importing countries and, if prices are transmitted to regions with a high prevalence of undernourishment, improves the food status of net food buying households. This assertion, however, needs to be qualified for several reasons:

» The overall effect is likely to be low. If, for example, cereal production in industrialized countries increased by 10 %, this would be equivalent to an increase in global production by 3.7 % (production shares as projected for 2050 in Bruinsma, 2009). Assuming an own price elasticity of global supply of 0.5 and of global demand of -0.2, the resulting decline in world market price would be about 11 %. This is a small price movement compared to the observed cereal price variations over the last few years, which have fluctuated between 90 US $/t and about 250 US $/t for wheat on an annual average (FAOSTAT, 2011).

» The relationship between international prices and prices at the household level in food insecure regions is often not very direct (see Winters, 2002, for a framework to analyze the linkages between international prices and poverty and Winters et al., 2002, for a summary of the empirical evidence). The transmission of world market prices to domestic prices and to remote regions within countries is in particular often far from perfect.

» It is not only that net food purchasing households are positively affected by lower prices, but also that net food selling households are negatively affected. Empirical evidence suggests that the majority of poor households are net food buyers, but this does not hold for all countries/regions (Ivanic and Martin, 2006; Aksoy and Isik-Dikmelik, 2008).

The main bottleneck for food security is the reduction of poverty

In conclusion, improving the global availability of food is only a very indirect means of reducing hunger. The main bottleneck to food security is instead the reduction of poverty. What is needed is investment in rural infrastructure, agricultural research and public services, as well as efforts to improve governance systems and institutions which allow markets to work within food insecure regions. Finally, efforts focussing on poverty reduction are most important, including improving the ability of the poor to access education, land, employment and other income sources as well as to public services such as social safety nets and medical care (von Braun, 2007; Heidhues, 2008).

An increase in agricultural production is of importance mainly within the regions subject to food insecurity and mainly among those affected by food insecurity – namely, agricultural smallholders.[2] Here increasing production can have the dual effect of lowering prices and increasing food availability for food purchasers, and of generating additional income for food producers. The relevance of food production within food insecure regions is also emphasized in the various FAO studies (e.g. Bruinsma, 2003: 45-50, Chapter 8). But even here the focus must be on poverty reduction: if higher incomes from agriculture accrue to only a few landowners with little trickle down effects, higher agricultural production may have little effect on reducing hunger.

[2] *Agricultural smallholders are estimated to constitute about 50% of the hungry (IFAD, 2010: 1).*

The reduction of postharvest losses in food insecure regions increases food availability for food buyers as well as income for food sellers

These arguments hold not only for the effects of increasing agricultural production on hunger, but also for the effects of any measure affecting the global food balance. More specifically:

- A decline in postharvest losses in food secure regions (see Section 4.2) is likely to have only a modest and indirect effect on global undernourishment, just as a decline in meat consumption (Section 4.3) or a decline in bioenergy production (Section 4.1) in food secure regions.
- In contrast, the reduction of postharvest losses within food insecure regions is likely to have stronger effects on undernourishment: it increases food availability for food buyers as well as income for food sellers.

Different crops have different postharvest characteristics: grains and pulses (durables) can have a storage life of several years, roots and tubers (semi-perishables) have a shelf life of weeks to several months. For fresh fruit and vegetables shelf life can be very short.

4 Alternatives to Improving the World Food Balance

4.1 Introduction

There are two strong arguments in favor of searching for alternatives to increasing global agricultural production in the effort to improve the world food balance. First, exploring additional options will increase the overall potential for improving the world food balance. And second, increasingly scarce natural resources such as water, land, biodiversity, and fossil energy suggest that an exclusive focus on increasing agricultural production is problematic.

Many options to improve the world food balance exist, both on the demand and supply side. One option which could be easily implemented and would have direct and significant effects would be to abolish the policies to enhance demand for first generation liquid biofuels in the EU, US and other countries. Furthermore, other policies that enhance the demand for biomass for energy production should be strongly narrow political interests. Moreover, indirect many cases policies which are currently in place are motivated by interests of vested lobbies and indirect effects on land use and the global food situation are not sufficiently taken into account. We do not discuss the reduction of biofuel subsidies in detail, as it has been addressed in many papers recently. Nevertheless, we consider the revision of bioenergy policies as a self-evident option for improving the global availability of food. The following points summarize key findings of recent literature:

» Demand for biomass for energy production has a strong impact on the world food balance. This impact is expected to increase, mainly due to ongoing political efforts to increase demand for biofuels.

» Increasing demand for biofuel has the potential to strongly contribute to higher global prices for agricultural products (Rosegrant, 2008; Banse et al., 2008; Banse and Grethe, 2008; OECD, 2006; Fischer 2009).

» Higher world market prices cause substantial indirect land use changes as crop lands expand around the world as a response to the increasing demand for biofuels (Fischer, 2009).

» It has been found that the production of certain forms of bioenergy such as liquid fuels in the US and EU could even increase global GHG emissions if direct land use effects are taken into account (Searchinger et al., 2008; WBGU, 2008).

» Overwhelming scientific evidence suggests that the political support for first generation biofuels should be ended (Wissenschaftlicher Beirat beim BMELV, 2007; WBGU, 2008).

A more equitable distribution of income has a high potential to decrease hunger

Furthermore, a more equitable distribution of food, which could be achieved with a more equitable distribution of income, has a high potential to decrease hunger. Bruinsma (2003) shows that at an average national consumption level of 2300 kcal/person/day, a reduction in the coefficient of variation[3] of food distribution from 0.3 (a typical value for developing countries with high inequality) to 0.2 (a typical value for industrialized countries) has the same effect on the reduction of undernourishment as an increase in average national calorie availability by 14 % (own calculations based on Bruinsma [2003: 44]; coefficients of calorie distribution from FAOSTAT [2011]).

[3] *The coefficient of variation is a dimensionless statistical measure which relates the standard deviation to the mean of a data set. The higher the coefficient of variation, the more unequal the distribution.*

Two options to improve the world food balance are highlighted in sections 4.2 and 4.3 below: the reduction of postharvest losses and the reduction of meat consumption in industrialized countries. The reduction of postharvest losses, including losses along the supply chain as well as waste at the household level, are relevant due to the high share of up to 50 % in global agricultural production, and due to their potentially very direct effects on food security that would result from a reduction of losses within food insecure regions. The reduction of meat demand in industrialized countries is of special interest as reduced meat consumption would have supplementary beneficial effects for human health, the environment, climate change and animal welfare.

A 20 % postharvest loss has to be offset with a 25 % production increase, a 40 % loss with a 66 % increase

4.2 Reduction of Postharvest Losses

4.2.1 Introduction

The challenge of feeding a growing population is commonly framed in terms of the need to increase production. However, there is another route to increasing food availability – the reduction of postharvest losses. In fact, a greater production increase than loss reduction is necessary to achieve the same level of food availability, since any production increase also suffers losses. For example, a 20 % loss has to be offset with a 25 % production increase, a 40 % loss has to be offset with a 66 % increase and so on (Bourne, 1977). For this reason, loss reduction is regarded as the more sustainable, economical way to increase food availability by many experts (Bender, 1994; Bourne, 1977; Grolleaud, 2002). While often overlooked, postharvest loss trends are an essential component to any world food projection.

Postharvest usually designates the period between completion of harvest and consumption (e.g. Bourne, 1977; NAS, 1978; Parfitt et al., 2010). **Postharvest losses** occur during threshing, grading, packaging, transport, storage, processing, distribution and marketing. Throughout this study, we use the term of **food waste** to distinguish the losses beyond the point of purchase, i.e. at the consumer level, which are not included in the FAO projections (Bruinsma, 2003; FAO, 2006) from the supply chain losses occurring between the farm and retail levels (the term **supply chain losses** is used this way by, inter alia, Parfitt, 2010; Ambler-Edwards, 2009; and Knight and Davis, 2009).

Food losses can be further subdivided into quantitative losses – a disappearance of food because of spillage or consumption by pests – and qualitative losses in edibility, nutritional quality, caloric value, consumer acceptability (Bourne, 1977; Grolleaud, 2002; Kader, 2004). While quantitative losses can be measured by weight or volume, qualitative losses are much more difficult to assess. Nonetheless, nutritionally inferior or contaminated food can lead to poor health and lowered productivity and thus affect a country's economy as a whole (NAS, 1978; FAO, n.d.). The negative effects of micronutrient deficiencies on human capital and economic productivity are well known (Hoffmann, 2009). Studies have found that micronutrient deficiencies – so-called "hidden hunger" – are much greater than protein or calorie deficiencies (Bourne, 1977; Hoffmann, 2009).

This subchapter begins with the introduction of the major causes of postharvest losses. In the following, an overview of the current extent of such losses and expected future trends is provided. Finally, the validity of the assumptions made by the FAO as well as potential alternative assumptions are discussed.

4.2.2 Causes of Postharvest Losses

Food is biological material that naturally degrades to the simple inorganic compounds from which it was produced. Technology can slow down this process but cannot stop it. After the harvest, food is subject to a complex of biological, climatic, economic, social, cultural and political conditions (Bender, 1994; Grolleaud, 2002; Parfitt et al., 2010). The causes of postharvest losses can be classified as immediate or primary causes and underlying or secondary causes that cause or influence the immediate causes (see Figure 4.1).

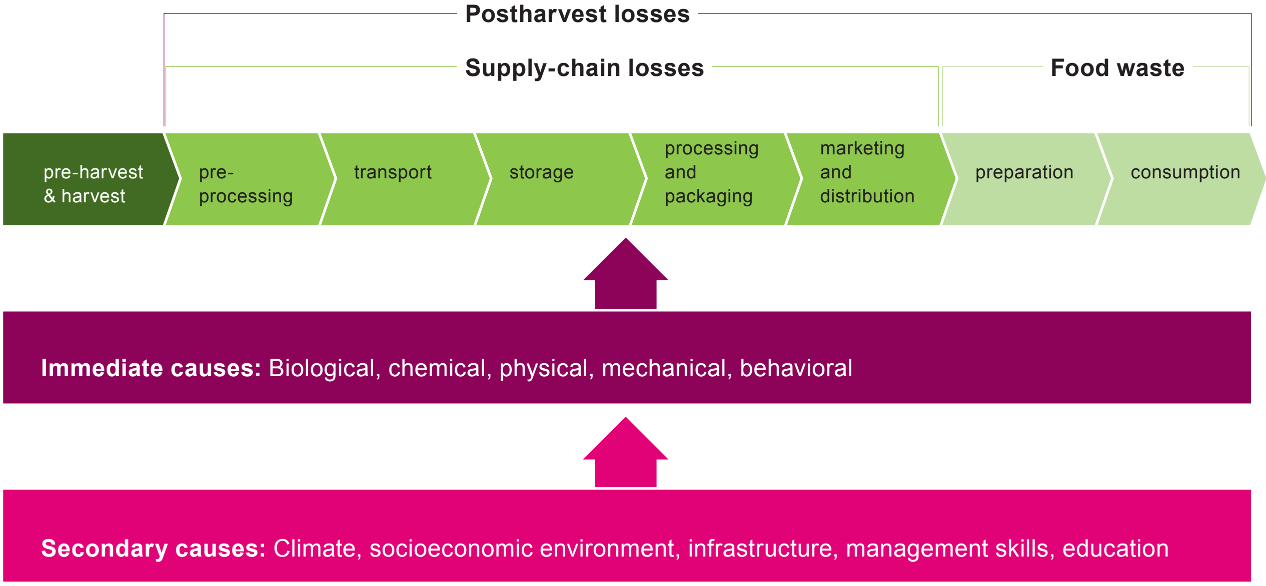

Figure 4.1: Losses Along the Food Chain

Source: Own composition.

Immediate causes include biological, chemical, physical and mechanical factors such as attack by insects or microbes, inherent metabolic processes, contamination with harmful substances, mechanical damage and injuries, and improper atmosphere, temperature, light or humidity which can interact in various ways (Lundqvist et al., 2008; Bourne, 1977). Underlying causes can be classified into the following categories:

» **The natural environment (climate):** High temperatures speed up chemical reactions, respiration and spoilage, and lead to water losses; climates that are regularly moist and warm foster the reproduction of insects and micro-organisms (yeasts, moulds) that attack harvest and stocks (Aidoo, 1993; Bourne, 1977; Grolleaud, 2002; Lundqvist et al., 2008); the season (rainy or dry) can also play an important role (Grolleaud, 2002).

» **Properties of the crop:** The type of crop and the condition of the crop after harvest (e.g. moisture content; potential damage during harvesting) are important factors. Different crops have different postharvest characteristics: grains and pulses (durables) can have a storage life of several years; roots and tubers (semi-perishables) have a shelf life of weeks to several months; in the case of fresh fruit and vegetables shelf life can be very short; some highly perishable foods (e.g. milk, meat, fish) it can become inedible in a matter of hours (Grolleaud, 2002; Parfitt et al., 2010).

Many traditional varieties have good postharvest qualities. Improved high yielding varieties are often more vulnerable

Furthermore, there can be important differences in storage life between different varieties. Traditional varieties have usually been selected for their good keeping qualities (e.g. hard endosperm, good husk cover which protects them against insects), while improved high-yielding-varieties are highly vulnerable to pests and damage in postharvest handling (Bourne, 1977; Boxall, 2001).

- **Socioeconomic and cultural factors** create the conditions in which primary causes occur and may hinder the implementation of technological solutions for postharvest losses. These causes are highly correlated with the general economic and institutional development process and include:

  - Inadequate infrastructure such as roads, transportation and storage facilities (Kader, 2004; FAO, n. d.; Aidoo, 1993; Lundqvist et al., 2008; Boxall, 2001).

  - Inadequate technology that is not adapted to or incompatible with local conditions and existing practices, customs and available materials (Parfitt et al., 2010; Bourne, 1977, NAS, 1978; IAASTD, 2009).

  - Lack of information/knowledge and managerial skills – most postharvest handlers have little or no appreciation of the need for or how to maintain quality (Dixie, 2005; Kader, 2004). Scarcity of research on postharvest problems (Kelman, 1989; Smil, 2004; Wirsenius et al., 2010; Lundqvist et al., 2008) and inadequate extension services (Aidoo, 1993; FAO n. d.; Boxall, 2001) contribute to these problems.

  - Underdeveloped institutions and lack of or inadequate government regulation (Kader, 2004; Bourne, 1977; Boxall, 2001; World Resources Program, 2001).

  - Lack of political attention and neglect by the international community; lack of funding (Smil, 2004; Boxall, 2001; Bourne, 1977; Kelman, 1989; Lundqvist et al., 2008).

  - Lack of access to financial resources; low returns from agricultural production (Mittal, 2007 cited in Parfitt et al., 2010). Improving postharvest methods is often costly and can only be justified if it is profitable (Dixie, 2005). Peasant farmers are not squandering their harvests unnecessarily (Grolleaud, 2002). The cost of an improvement including maintenance (!) is the deciding factor in its adoption (World Resources Program, 2001; Boxall, 2001; NAS, 1978).

Food waste is found to be higher in more advanced economies due to changes in consumer attitudes

These factors tend to increase supply chain losses in developing countries relative to developed countries. In contrast, food waste is found to be higher in more advanced economies due to changes in consumer attitudes, values, behaviours and knowledge that accompany rising incomes (Parfitt et al., 2010; Lundqvist et al., 2008; Ambler-Edwards, 2009). Since affluent consumers spend only a small proportion of their income on food, its value is less appreciated and waste seems harmless. Concerns about food safety, demand for quality, high expectations in terms of food cosmetics and a growing disconnect between consumers and food production lead to edible, but imperfect food items being outgraded and thrown away before they are sold (especially in industrial countries, but also among the more wealthy in developing countries).

4.2.3 Current Extent of Postharvest Losses

Overall average losses are not known with certainty. Many of the numbers for developing countries that are cited in the literature date back to quite limited studies carried out in the 1970s and 1980s. Since then, there has been technological progress and changes in markets and distribution systems. Thus there is little consensus on the current global level of food losses and waste (Parfitt et al., 2010). Estimates vary widely from 10 to 50 % overall, 10 to 25 % for cereals and from 1 to 50 % for roots, tubers, fruits and vegetables, depending on the location, crops and keeping conditions. (Bourne, 1977; World Resources Program, 2001). There are important differences in climate, economic development, postharvest systems and causes of losses between different countries and even within countries. Furthermore, a universally applied method for measuring losses does not exist and a wide variety of approaches are used in different studies (Grolleaud, 2002; World Resources Program, 2001).Therefore, it is difficult to draw conclusions about overall averages and it is advisable to be cautious about over-simplified results (Grolleaud, 2002).

Postharvest losses between farm and retail are higher in developing countries. Food waste at the retail and household levels is higher in more advanced economies

In light of all the studies reviewed for this report, a very conservative estimate for cereal losses in developing countries, excluding marketing, distribution and consumer losses, would be in the range of 15 %. Worldwide postharvest losses in fruits and vegetables could be estimated at around 30 % in developed and developing countries in the whole supply chain including food waste at the household level. It should be kept in mind that these figures are averages over a great variety of regions and conditions – losses for single locations and crops or varieties could be much larger or smaller.

Although accurate data are not available there is general agreement that postharvest losses are heaviest in developing countries (Kelman, 1989). However, if losses at the consumption stage are taken into account, the picture might be different. Kader (2004) estimates that total postharvest losses for horticultural crops in both developing and developed countries are about 32 %, but they occur at different points after harvest. Ambler-Edwards et al. (2009) report that 50 % of the food produced may be lost after harvest in the UK (including consumer waste) according to work done at Cardiff University. While in developing countries the bulk of losses occur in the first part of the postharvest system (between farm and retail), in developed countries they occur in rather late stages (retail and consumption) (Kader, 2004; Lundqvist et al., 2008; Nellemann et al., 2009). In the UK one-third of all food purchased is discarded by consumers, according to a study carried out by the waste and resources action programme (WRAP, 2008), an amount equal to 6.7 million tonnes worth an estimated £ 14.5 billion. 61 % of this waste, worth £ 10.2 billion, is avoidable, meaning it could have been eaten if prepared in time or was thrown away while still in date. Kantor et al. (1997) estimate that consumers wasted 26 % of the edible food purchased in the United States in 1995, cautioning that this was an underestimate. More recently Hall et al. (2009) estimate that consumers wasted 40 % (or 1400 kcal per capita) of the food available in the United States in terms of caloric energy. Assuming a wastage rate of about 25 % for the most affluent countries seems appropriate. Consumer waste in developing and transition economies seems to be significantly lower. Pekcan et al. (2006) find waste rates of 8.9 % for Turkish households, and Sibrián et al. (2006) estimate a household waste of 9 % for the Philippines based on secondary data from 1978. Two studies from the 1970s suggest that waste was much lower in the UK at that time, equal to about 10 % and 6.5 %, respectively (Dowler, 1977; Wenlock et al., 1980).

A wastage rate of about 25 % for the most affluent countries seems appropriate

Yet in addition to the poor empirical evidence for quantitative food losses, there are very few datasets on qualitative losses, with the existing studies in this area focussing on losses during storage. Measurement here is even more problematic than for quantitative losses (Parfitt et al., 2010). However, some data for single countries or sectors that are available could give an idea of their order of magnitude. While conservative estimates of losses in horticultural crops during transport, processing and storage amount to 10–15 % in terms of quantity, they could amount to 25–50 % in terms of economic value because of quality reductions (Lundqvist et al., 2008).

In conclusion, both supply chain losses and consumer food waste seem to be correlated with the level of economic development and incomes, however in different directions. We would expect supply chain losses to drop with higher levels of development and thus higher levels of development, as higher levels of technology become affordable, and food waste to rise with higher disposable incomes. The total effect of economic development on overall postharvest losses in the absence of policy interventions is therefore ambiguous.

4.2.4 Postharvest Losses in the Course of Economic Development

It is often argued that in the course of economic development industrialized food chains achieve better resource efficiency and lower losses, but research suggests that these benefits are negated by growing consumer waste for various reasons (Parfitt et al., 2010).

Low food prices in relation to disposable income encourage wasteful behavior

1. **Rising incomes and changing consumer attitudes:** According to Ambler-Edwards (2009), increasing food waste is concomitant with the transition to a more affluent diet. Higher incomes result in increasing consumption and thus higher food wastage (Nellemann et al., 2009; Sibrián et al., 2006; Wirsenius et al., 2010). With growing incomes, qualitative factors become more important and foods that may have been acceptable before may become "lost" now because they do not meet the new higher standards (World Resources Program, 2001). IAASTD (2009) expects the demand for products with high quality and safety standards to further grow in developed countries. Furthermore, low food prices in relation to disposable income encourage wasteful behaviour (Sibrián et al., 2006; Lundqvist et al., 2008). Bender (1994) finds that overconsumption and consumer food waste are already very large, with rates of 30–60 % of food requirements in high income countries, and will increase rapidly with rising incomes in developing countries, as well. According to Parfitt et al. (2010) and Hall et al. (2009), there is strong evidence for the increase of consumer food waste over the past decades. But overconsumption is not only a problem in developed countries. Wasteful food habits and excessive consumption are spreading among the better-off segments of the population in many middle- and low-income countries. For example, there are unprecedented levels of obesity in China, and in Shanghai alone more than 1000 tonnes of food a day are thrown out (Ambler-Edwards, 2009; Parfitt et al., 2010; Smil, 2004). However, while the link between income and food waste is strong, cultural differences and differences in consumption styles can influence waste generation in unpredictable ways (Thøgersen, 1996).

2. **Dietary transition:** In addition to the direct effects of higher income on food waste, there is an indirect effect resulting from changes in the composition of diets: the proportion of luxury foods increases relatively to staples (Bender, 1994; Parfitt et al., 2010). According to Parfitt et al. (2010), there is a shift in consumption patterns towards more vulnerable foods with shorter shelf-lives. A higher proportion of perishable food items increases the risk of losses and wastage (Lundqvist et al., 2008). The rapid expansion of the fresh fruit and vegetable sector in transitioning countries is likely responsible for significant supply chain losses due to inadequate infrastructure. Perishables also constitute the largest part of household food waste (Parfitt et al., 2010), and there is evidence that varied consumption styles generate more waste than "pure" forms (Rathje, 1984, cited in Thøgersen, 1996; Sibrián et al., 2006).

Urbanization results in longer food supply chains which increase the risk of losses

3. **Urbanization and demographic changes:** Urbanization results in longer food supply chains (Parfitt et al., 2010; Adhikari et al., 2006) which increase the risk of losses as food has to travel longer distances, be kept fresh for longer periods of time and is handled at many stages and by many different actors, such as processors, brokers and wholesalers. Kantor et al. (1997) report that a typical food item in the US has already been handled 33 times on average before it is displayed for consumers in the supermarket. An ageing population and the growth of single person households in developed countries lead to higher wastage rates. Studies have found that large households waste less per person than smaller households and singles throw away more per capita. Adults waste more than children and young people waste more than older people. However, this is likely to change in the future because today's young are tomorrow's elderly and unlikely to change their attitudes and behaviours towards food. Whereas today's elderly might still have experienced hunger and scarcity, many younger people grow up in affluence (Parfitt et al., 2010).

4. **Technological progress:** Technological progress not only decreases supply chain losses but also affects food waste. However, technological advances do not automatically result in consumer waste reductions. The relationship between refrigeration and food loss, for example, is complex and depends on factors such as lifestyle and attitudes to food (Garnett, 2008). Mercado-Villavieja (1976) found Mexican households with refrigerators tend to waste more food than those without (cited in Parfitt et al., 2010). Better packaging can significantly reduce food waste but leads to higher solid waste (Beede and Bloom, 1995).

5. **Vertical integration:** Arrangements such as contract farming and vertical integration can significantly reduce postharvest losses within supply chains, however, more often than not at the cost of excluding small farmers and firms (Goletti, 2003, Parfitt et al. 2010, Mrema and Rolle, 2003).

Next to these factors which are closely related to economic development, two more factors may substantially affect future trends in postharvest losses: increasing real food prices and climate change. Long term price trends would affect postharvest losses. Food prices have been decreasing for a long time, and despite recent price hikes, food is still relatively cheap. Food price is recognized as the most important factor in determining consumer choices. Thus, except for the very poor, many consumers have little incentive to change their wasteful behavior (Lundqvist et al., 2008). However, anecdotal evidence suggests that the economic crisis has stimulated a shift in consumer attitude to food waste. In the long run, resource limitations are likely to increase the value of food. This might lead to a more efficient postharvest system and consumer waste reduction (Parfitt et al., 2010).

Finally, alongside food production, climate change will also affect the postharvest system. Extreme weather events could affect transport and storage infrastructure, and rising temperatures place greater demand on refrigeration, with the poor likely hardest hit (Garnett, 2008). Introduction of new pest species and the exacerbation of existing pest problems are also likely to increase with climate change. Warmer winters will allow the expansion of insects and diseases over wintering ranges – this has already happened for some plant pathogens (Garrett et al., 2006; Rosenzweig et al., 2001; Baker et al., 2004; all cited in IAASTD, 2009). Current strategies for pest control could loose their effectiveness and reduce the flexibility of pest management in the future. Higher temperatures could also lead to the deactivation of resistance genes in plants, thus increasing their vulnerability. Furthermore, crops could become increasingly susceptible to nematode attack with higher temperatures (IAASTD, 2009).

4.2.5 Potential for Loss and Waste Reduction

4.2.5.1 In Developing Countries

In developing countries supply chain losses are more important than consumer food waste. Therefore, actions to reduce postharvest losses should focus on the first stages of the postharvest system. However, it is advisable to keep in mind that with rising incomes food waste could increasingly become a problem that should be addressed as well.

The first World Food Conference in 1974 identified reducing postharvest losses as a key strategy for addressing hunger and set a reduction goal of 50 % by 1985

The first World Food Conference in 1974 identified reducing postharvest losses as as a key strategy for addressing hunger and set a reduction goal of 50 % by 1985. Since data on the initial loss level and subsequent progress are missing, it is not possible to say what advances were made (Parfitt et al. 2010). Although most authors agree that there is significant scope for reducing supply chain losses, concrete figures on reduction potential are rare. According to a study carried out in the ASEAN region, 10 % of the losses during handling, storage and processing of grains could be avoided (Grolleaud, 2002). The grain storage losses accepted by farmers in developed countries are very low at about 0.75 to 2 %, according to Grolleaud (2002). Bourne (1977) sees the average storage losses of 0.249 % in wheat in Australia in the 1960s and 1970s as a reference figure for an achievable goal. Lundqvist et al. (2008) find a 50 % reduction in postharvest losses, including consumer losses, to be realistic.

Although the evidence base is scarce, all studies reviewed agree that there is significant scope and need to reduce supply chain losses in developing countries, and that increasing production without addressing the postharvest system bears the risk of exacerbating the situation. There are compelling arguments in favour of tackling postharvest losses, despite the lack of reliable data.

Only 5 % of funding for agricultural research are devoted to post-harvest systems. Yet internal rates of return from post-harvest research are high

Heyes (2003) argues that internal rates of return from postharvest research are high. The internal rates of return on investments to reduce postharvest losses in fruit were 21–48 % per year, according to the Australian Centre for International Agricultural Research. An impact study on research concerned with the large grain borer found that the benefits in Ghana and Tanzania alone outweighed the costs of all large grain borer research expenditures undertaken by all aid organizations (Goletti and Wolff, 1999). Although these are only a few examples for the high positive impact of postharvest research, they suggest that the current lack of attention to these issues is not justified. Currently, only 5 % of funding for agricultural research and 4 % of agricultural researchers are devoted to postharvest systems (Parfitt et al. 2010, IAASTD, 2009).

Furthermore, investment in the postharvest sector helps to achieve multiple goals. In addition to improving food and nutrition security, a growing postharvest sector can foster rural development and create rural employment opportunities, thus contributing to the development of the wider economy via production and consumption linkages, while reducing migration to urban centers. Improved postharvest practices can improve competitiveness and facilitate access to lucrative export markets. Furthermore, support to the postharvest sector has the potential of enhancing gender equality and increasing employment opportunities for women, since they have traditionally played an important role in food processing, handling and preparation. In addition, reducing postharvest losses can address environmental and sustainability issues, easing unnecessary pressure on natural and financial resources by reducing overproduction (Goletti, 2003). The public good character of many investments in the postharvest sector – including those in research and extension, transportation and infrastructure, and improved institutions – justifies government intervention.

After increased international attention and action in the 1970s and 1980s, the topic of postharvest losses seems to have slipped off the agenda. In the late 1990s and early 2000s some international organizations, including FAO, started addressing the issue again with the information network on postharvest operations (Inpho), a global postharvest forum (phAction) and a global postharvest initiative (GphI). However, the information gathered by these initiatives did not include any original research, and mostly dates from the 1970s and 1980s. Furthermore, there has not been any activity since 2002.

4.2.5.2 In Developed Countries

In developed countries, food supply chains are quite efficient, with low losses. Waste by consumers and food services are relatively more important and have become a significant problem in some affluent countries.

Nellemann et al. (2009) sees scope for increasing food system efficiency by 30 to 50 % through reducing and recycling food waste. One suggestion is to use food waste as a substitute for animal feed. However, such practices are limited by current feed safety regulations, such as those in the European Union. Bender (1994) sees the largest opportunities for consumer waste reduction in high income countries and expects savings from a reduction of losses in marketing and distribution in developing countries to be small.

There are large variations in wastage rates among countries of similar income levels. The Netherlands, Finland, Japan and Sweden waste only about 60 % of the amount of food that is wasted in the USA, Belgium, Switzerland and Italy

Intercountry comparisons show that there are large variations in wastage rates among countries of similar income levels. For example, the Netherlands, Finland, Japan and Sweden waste only about 60 % of the amount of food that is wasted in the US, Belgium, Switzerland and Italy. In some countries food demand could conceivably be reduced by 50 % to a level that is found in "best practice" countries. Bender calculates that "A reduction in food waste from 50 % of [...] [consumed food products] to 35 % would directly result in a minimum of a 10 % decrease in global food supply requirements" (Bender, 1994: 389). However, it is unclear to what extent increased efficiency is economically feasible.

Sibrián et al. (2006) report that knowledge on food safety and quality issues was the most important factor determining the quantity of household food wastage in several studies. Increased awareness and behavioral change could have significant impacts on consumer waste (Parfitt et al., 2010; Garnett, 2008). However, the large number of actors makes it difficult for policies to influence consumer behavior (Lundqvist et al., 2008; Garnett, 2008). There is significant scope to improve labelling and the understanding of labelling by consumers (Granett, 2008; Parfitt et al., 2010). Research by WRAP (2008) in the UK suggests that there is significant scope for consumer waste reduction as most waste would be avoidable with better housekeeping, planning and clearer labelling. WRAP is currently taking action to reduce waste at the consumption and retail levels. If successful, these programmes could be a model for other developed countries. Packaging technology that improves shelf life of perishables could help to reduce consumer waste (Garnett, 2008; Parfitt et al., 2010). However, this waste reduction has to be traded off with higher packaging waste (Beede and Bloom, 1995). Another important consideration is that if people wasted less food, they might use the money saved to consume more resource-intensive luxury food products or more non-food products with high environmental impacts. If policies are not aware of possible knock-on effects, changes in one aspect of consumption behaviour will simply shift the problem to another area (Garnett, 2008).

Furthermore, Bender (1994) cautions that in many countries with particularly high consumer food waste, farmer subsidies and supply management measures make it unlikely in the short run that policies for food waste reduction will gain political support.

4.2.6 Conclusion

All of the cited authors agree that there is a significant need and considerable potential in reducing supply chain losses and consumer food waste due to the sheer size of such losses. Regarding the objective of achieving food security, the focus should be on reducing postharvest losses in food insecure regions. This would have the additional benefits of increasing food availability and generating income along supply chains.

Investment in research as well as postharvest loss reduction policies is too low

Currently, investment in research as well as policies to reduce postharvest losses is too low. Without more systematic research on the extent of losses, measuring progress against any global reduction target is impossible (Parfitt et al., 2010; Lundqvist et al., 2008). Furthermore, successfully implemented measures to reduce losses are needed in order to establish precedents that allow an estimation of the potential for reducing global food waste as one answer to the challenge of feeding nine billion people by 2050.

The potential for reducing of postharvest losses to improve the world food balance is illustrated in Table 4.1 in a small example.

Table 4.1: The Link Between Cereal Production and Availability in Developing Countries Under Different Waste Assumptions (in millions of tonnes)

	2005/07	2050	
		Scenario 1	Scenario 2
Postharvest losses	15 %	15 %	7.5 %
Production	1,113	1,797	1,651
Food/feed availability*	946	1,527	1,527
Increase of production		61 %	48.4 %

*at the wholesale level.

Production data in Scenario 1 from Bruinsma (2009). Own calculations.

Bruinsma (2009) projects a 61 % increase in cereal production between 2005/07 and 2050. If we assume a 15 % loss rate (see Section 4.2.4 above), food/feed availability at the wholesale level would be 946 million tonnes a year in 2005/07, and 1,527 million tonnes in 2050 (Scenario 1). If losses could be reduced by half to 7.5 % (Scenario 2), a cereal production of 1,651 million tonnes by 2050 would be sufficient to achieve the same level of food/feed availability as in Scenario 1. This translates into a 48.4 % production increase over the production of 1,113 million tonnes in the base year. In other words, if losses could be reduced by 7.5 percentage points, a production increase of less than 50 % would be necessary to reach the same level of food/feed availability, as opposed to the 61 % that would be necessary if losses remain constant.

If average meat consumption in OECD countries were to decline by 30 %, approximately 30 million hectares of crop land could be set free for alternative food production such as cereals.

4.3 Changes in Consumption Patterns

4.3.1 Introduction

The future world food balance will not only depend on overall production and overall calorie intake, but also on the composition of the average human diet. Agricultural production depends on various resources that will become more scarce in the future (land, water, energy). As meat-based diets are on average more resource intensive than plant-based diets (Marlow et al., 2009; Pimentel and Pimentel, 2003), the amount of animal products consumed per person plays a vital role in the average resource use of a human diet. Within this context, the sustainability of current meat consumption in developed countries has gained broad attention in the media (ScienceDaily, various issues; MailOnline, 2010) as well as in the scientific debate (Stehfest et al., 2009; Rosegrant et al., 1999; Wirsenius et al., 2010; Pimentel and Pimentel, 2003; Nonhebel, 2004; Marlow et al., 2009; Elferink and Nonhebel, 2007; Aiking, 2011; Fiala, 2008). Decreasing meat demand in industrialized countries could represent one part of a solution to ease future resource pressures. As a side effect, decreased meat consumption would be likely to lower agricultural prices, and, in turn, enhance food security by reducing the food cost for net food buying households. Political measures could contribute to achieving such a demand shift, including the introduction of a consumer tax on meat and consumer awareness campaigns in developed countries.

Decreasing meat demand in industrialized countries could represent one part of a solution to ease future resource pressures

The following Section 4.3.2 presents a short summary of past and projected livestock sector developments. Section 4.3.3 describes the competition between food and feed production. Next, Section 4.3.4 introduces potential motives for political measures to reduce meat consumption. Section 4.3.5 presents a literature review and some of our own calculations on how reduced meat consumption in OECD countries may affect the world food balance. Finally, Section 4.3.6 draws some summarizing conclusions.

4.3.2 Past and Future Livestock Sector Developments

4.3.2.1 Consumption Trends

During the past decades, and especially since the 1980s, per capita consumption of animal products experienced an immense upsurge. Due to the already high level of consumption in developed countries, growth rates have been modest in the developed world. By contrast, in the developing countries, average per capita growth rates have been immense. Table 4.2 illustrates the changes that happened between 1980 and 2005. The impressive growth of past decades is not at all evenly distributed among developing countries. Instead, the lion's share of the increase can be attributed to a small number of countries/regions, with major increases in East and Southeast Asia (Pica-Ciamarra and Otte, 2009). China in particular witnessed immense increases, in per capita meat consumption growing by more than 4 times from 1980 to 2005. For other regions changes have been more moderate, and in Sub-Saharan Africa levels have even slightly decreased (FAO 2009c).

With average per capita meat consumption of 82 kg, developed countries consume 40 % of world meat while representing only 20 % of world population

The gap between average consumption in developing and developed countries remains wide: With average per capita meat consumption of 82 kg, developed countries consume 40 % of world meat while representing only 20 % of world population. As consumption levels in developing countries are much lower – 31 kg per capita, on average – there is immense potential for consumption levels to increase. Whether past trends of growth will continue will be determined crucially by the development and distribution of future income growth in low income countries (FAO, 2009c). The FAO projections foresee a growth of per capita meat consumption in developing countries to an average of 44 kg/capita by 2050. Still, growth rates are projected to be significantly below those of the past: FAO projects an annual global increase in meat consumption of 1.7 % between 1999/01 and 2030 and 1 % annual growth between 2030 and 2050, in contrast to the annual increases of 3 % from 1961 to 2001 (FAO, 2006: 47, Table 3.7). As a result, meat consumption is expected to increase by 85 % overall between 2005/07 and 2050 (Bruinsma 2009: 5, Table 1). In contrast to the FAO assumptions, Keyzer et al. (2005: 194) figures higher levels of future demand: "per capita demand for India of 11.8 kg per year (8.9 kg) in 2015 and 17.9 kg (13.8 kg) in 2030 for the High Growth (Low Growth) scenario", which "differs substantially from what is implied for India by Bruinsma (2003) or explicitly projected by IFPRI (2001) in their baseline scenario (7.4 kg)". Due to India's high share of world population such deviations imply large quantities.

FAO projects world meat consumption to increase by 85 % overall between 2005/07 and 2050

Besides the trend towards higher overall consumption levels there has been a shift between different meat categories. While bovine meat consumption increased by 1.1 % per year, pork and poultry consumption increased by 2.9 % and 5.1 %, respectively, from 1981 to 2001. According to FAO projections, future growth rates will decrease and converge again, with annual percentage increases in demand for pork falling slightly below the levels of beef demand, and demand growth for poultry remaining higher (FAO, 2006: 47, Table 1).

Table 4.2: Per Capita Consumption of Livestock Products in kg/year by Region 1980 and 2005

Source: FAO (2009c: 11).

	Meat			Milk			Eggs		
	1980	2005	% change	1980	2005	% change	1980	2005	% change
Developed countries	76.3	82.1	7.6 %	197.6	207.7	5.1 %	14.3	13.0	-9.1 %
Developing countries	14.1	30.9	119.1 %	33.9	50.5	49.0 %	2.5	8.0	220.0 %
East and Southeast Asia	12.8	48.2	276.6 %	4.5	21	366.7 %	2.7	15.4	470.4 %
Of which China	13.7	59.5	334.3 %	2.3	23.2	908.7 %	2.5	20.2	708.0 %
Latin America and the Carribean	41.1	61.9	50.6 %	101.1	109.7	8.5 %	6.2	8.6	38.7 %
South Asia	4.2	5.8	38.1 %	41.5	69.5	67.5 %	0.8	1.7	112.5 %
Of which India	3.7	5.1	37.8 %	38.5	65.2	69.4 %	0.7	1.8	157.1 %
Near East and North Africa	17.9	27.3	52.5 %	86.1	81.6	-5.2 %	3.7	6.3	70.3 %
Sub-Saharan Africa	14.4	13.3	-7.6 %	33.6	30.1	-10.4 %	1.6	1.6	0.0 %
World	30.0	41.2	37.3 %	75.7	82.1	8.5 %	5.5	9.0	63.6 %

4.3.2.2 Production Trends

Due to their more industrialized types of production, better feed conversion rates and relatively shorter lifecycles compared to ruminants, which allow for faster productivity improvements, the supply response to increasing meat demand has been greater for monogastrics (especially poultry) than for ruminants (Bouwman et al., 2005; FAO, 2009c; Naylor et al., 2005). In addition to the shift from ruminants to monogastrics, a movement from extensive land-based towards intensive production systems has occurred. Most of the production increases in recent decades have occurred within intensive systems (Naylor et al., 2005; Gold, 2004). One major aspect of these systems is that they depend to a lesser extent on local feed production, because feed use shifts from low-value crop residues and natural pastures towards concentrate feeds that consist of feed crops (mainly cereals) and high-quality agro-industrial by-products (mainly oilmeals). In contrast to pasture and low-value plant residues, these are traded on domestic and international markets and can be sourced by animal producers at the lowest prices. As a result, production becomes more independent from the local land base (Naylor et al., 2005; FAO, 2009c). Increasing industrialization in animal production has been especially strong for pork and poultry. About 75 % of world poultry production, more than half of pork, and over two-thirds of all egg production now takes place in large-scale intensive production systems[4] (FAO, 2009c: 27; Naylor et al., 2005). This is mainly because of higher feed conversion rates with poultry and pork production than with cattle (Naylor et al., 2005; FAO, 2009c; Koning et al., 2008) and because of the feed requirement of cattle for roughage that has to be provided locally. Consequently, the share of cattle production in intensive systems has remained at a rather low level (FAO, 2009c: 26, Table 7).

4.3.3 Competition Between Food and Feed

Livestock production can make use of resources without alternative use options (marginal lands), improve the utilization of agricultural by-products and yield a range of other beneficial effects (see for example Bradford, 1999). Nevertheless, livestock production increasingly relies on resources which can also be used in food crop production (Steinfeld et al., 2006; Keyzer et al. 2005). This is true not only with regard to monogastric production in industrialized systems (which use large amounts of cereals as feed) but also with regard to beef and milk production. The potential to expand pasture area into marginal lands has practically reached its limits, and already today vast areas of pasture land are being established to the detriment of valuable and important natural ecosystems. Livestock production is the primary driver of deforestation. Additionally, where land expansion potentials are limited, growth in livestock production has often lead to the degradation of grazing areas due to overgrazing (Asner et al., 2004; Keyzer et al., 2005; Steinfeld et al., 2006). Furthermore, the increasing share of animal products in the human diet will contribute to less low-value there will be less low-value plant residues available as animal feed (Keyzer et al., 2005). As a consequence of the scarcer availability of natural grazing area and plant residues, and with the growing industrialization of the livestock sector, it appears that the majority of additional production will rely on feed inputs that use the same resources (e.g. land and water) that could instead be used for crop production or serve other important ecosystem functions. Worldwide, an estimated area of 470 million ha has recently been devoted to feed crop production, which amounts to about 33 % of the world's total cropland (Steinfeld et al., 2006). Alongside increasing demand for oilmeals, there will be huge demand increases for cereals, especially maize (Bruinsma, 2009).

Livestock production is the primary driver of deforestation

Worldwide, an estimated 470 million ha has recently been devoted to feed crop production, which amounts to about 33 % of the world's total cropland

[4] *Intensive systems are defined as systems in which less than 10 % of the dry matter fed to animals is farm-produced, and in which annual average stocking rates are above ten livestock units per km² (on average at the census unit level) (Steinfeld et al., 2006).*

Moreover, while a downward trend in cereal growth rates has been witnessed in the past, leading to reduced grain/meat ratios, this trend is expected to reverse (FAO, 2006: 51).

The increasing importance of cereals for use as feed is also pointed out by Keyzer et al. (2005), who assert that many projection models may underestimate future cereal demand. Keyzer et al. believe that cereal/meat ratios in developing countries will increase during the next decades rather than fall, as is commonly assumed in many projection models, because traditional sources of animal feeds such as crop residues and household waste are becoming more scarce.

In conclusion, there will be pressure to intensify crop and pasture production (Wirsenius et al., 2010), with associated negative environmental effects. A reduction in meat consumption in developed countries could be an option for increasing food availability without putting additional strains on the environment and/or animals.

A reduction in meat consumption in industrialized countries may have several positive effects

4.3.4 Reduction of Meat Consumption in Developed Countries

4.3.4.1 Benefits from Reduced Meat Demand in Developed Countries

There are several considerations that support efforts to reduce meat consumption in OECD countries. Major considerations include the following:

Consumer health: In 2005/07 average per capita meat consumption (including only poultry, beef and pork) in OECD was around 225 g/day (82.1 kg/year) (calculation based on FAOSTAT, 2011) and is projected to increase further. From the perspective of human health, however, significant reductions in meat consumption in the OECD would instead be preferable (Pimentel and Pimentel, 2003; Gold 2004; McMichael et al., 2007). The recommended maximum daily protein intake for an average person is around 50–60 g protein per day from a mixed diet (Aiking, 2011). In light of average daily meat consumption levels of 225 g and assuming protein content in meat of 20–30 % (Stehfest et al., 2009; Aiking, 2011), daily protein intake of meat alone already roughly covers the recommended protein intake level. Together with the protein intake from other animal and plant products that are being consumed, average protein intake is way above the recommended level. As a comparison, the World Cancer Report Fund recommends around 300 g meat per week (approx. 45 g meat/day) (EPHAC, n.d.). Curbing meat consumption in OECD countries may lead to health benefits for the majority of the population and reduce social costs triggered by the negative health effects of meat consumption (see for example Barnard et al. 1995, who calculate the medical costs in the US that can be attributed to meat consumption). This would probably not be the case in developing countries, where average consumption levels are still low.

Environmental sustainability: Livestock, including feed production, contributes to environmental problems which are hardly reflected in the prices of animal products. Due to increasing trade of meat and feed, environmental externalities do not necessarily occur where the end products are consumed (Naylor et al., 2005). Instead, increasing demands for feed and meat in one country can cause increasing environmental resource pressures and foster unsustainable land used in another country (Steinfeld et al., 2006). Von Witzke and Noleppa (2010) show that EU net imports of “virtually traded land” have increased substantially over the last decade, mainly because of soybean imports used in animal feed. A decrease in meat consumption in one part of the world may therefore ease resource pressures and environmental degradation on a local as well as global level (e.g. less deforestation in the Amazon due to decreasing feed and meat demands in developed countries).

In 2005/07 average per capita meat consumption (including only poultry, beef and pork) in the OECD was around 225 g/day (82.1 kg/year) (calculation based on FAOSTAT, 2011) and is projected to increase further.

Global warming: There is increasing evidence that the livestock sector and especially cattle production contribute significantly to global GHG emissions, though estimated amounts differ over a wide range (Steinfeld et al., 2006; Goodland and Anhang, 2009; Fiala, 2008).

Animal feed is increasingly competing with the production of food crops that could be used for direct human consumption

Global food security: As described in Section 4.3.3, rising meat production as well as the shift in feed use towards concentrate feed lead to a situation in which the production of animal feed is increasingly competing with the production of food crops that could be used for direct human consumption (FAO, 2009c). This has the effect of increasing food prices for animal as well as plant products (as analyzed in detail in Section 4.3.5 below).

4.3.4.2 Taxing Meat Consumption

In Section 4.3.5, we analyze the potential effects of a 30 % decrease in OECD meat consumption levels. Such a demand change could be reached via changes in consumer attitudes, which could be supported by political measures such as consumer awareness campaigns and nutritional education in schools, as well as price policies such as consumption or production taxes. In the long run, factors such as the development of more attractive meat substitutes may also make a contribution (Smil, 2002).

If the main aim of reducing meat consumption is to improve human health, a consumer tax would have two important advantages over a producer tax: First, it addresses the issue of "health effects" more adequately, as it would not allow for switching from more expensive home produced (and taxed) products to non-taxed imports. Second, it is likely easier to implement.

A producer tax, on the other hand, would be a more adequate instrument in order to internalize external costs that arise from negative environmental effects connected with livestock production that are not reflected in the current price levels. A producer tax would, however, result to some extent in foregone production in industrialized countries being replaced by imports which would lead to a lower achievement of policy objectives related to global environmental goods such as a reduction in GHG emissions.[5] On the other hand, one should take into account that animal production today is substantially more supported in most industrialized countries than crop production (OECD, 2010), which results in animal production being distorted in favour of producers in developed countries.

Several authors have discussed a tax on livestock products (or production): Goodland (1997) suggests that a differentiated tax scheme on animal products could improve the diets of the rich, increase food availability for the poor and reduce adverse environmental impacts such as the excessive use of resources and pollution inherent to livestock production. Wirsenius (2008) proposes the introduction of a differentiated consumption tax on animal products as a climate policy instrument. Gonzáles-Zapata et al. (2009) discuss a tax on "obesity-promoting foods" within the context of fighting obesity in Europe. Though they do not mention the taxation of animal products specifically, it can be assumed that certain animal products, being high in saturated fats, are among those that contribute to obesity, as suggested by Preker (2002). A report by Goodman (2006) includes a critical evaluation concerning the effectiveness of a tax to reduce the consumption of saturated animal-based fats in order to reduce obesity. The report includes a short overview of some modelling studies that analyzed the effectiveness of economic instruments to influence food consumption.

[5] *For options to compensate for such a replacement of domestic by imported production see Grethe (2007).*

Lelieveldt (2010) illustrates how the option of a "meat tax" in order to combat Green House Gas Emissions has so far been received among politicians, the media and public.

In considering whether it is preferable to achieve changes in meat consumption via taxes or via changes in consumer awareness, it has to be noted that human food consumption involves complex behavioural processes and that efforts to induce consumption changes in food bear risks. Meat products do not only contain health damaging components, but contain important nutrients and vitamins in highly concentrated forms. In order to achieve positive health effects from lower meat consumption, it is important that substitution takes place with food that is healthy and nutritionally adequate to compensate for the forgone meat consumption (Haddad, 2003; Powell and Chaloupka, 2009). Research is needed to analyze the effectiveness of pricing health adverse food categories (Thow et al., 2010). Most preliminary research suggests that a mixture of different political instruments might be the way to steer consumption changes in a desired direction. These may include the combination of food taxes on health adverse food categories (Powell and Chaloupka, 2009; Thow et al., 2010) and other measures such as consumer information campaigns and health labelling, or the introduction of healthy meals in public institutions such as schools (Tukker et al., 2009).

Lower meat demand in OECD countries, would involve lower global meat prices, less global meat production, more meat consumption in developing countries, less feed demand and lower global feed prices

The effects of lower meat demand in OECD countries, which are analyzed in the following section, include lower global meat prices, less global meat production, more meat consumption in developing countries, less feed demand and lower global feed prices, as well as more consumption of crop products in developed countries and potentially also in developing countries.

4.3.5 Quantifying Effects of Lower Meat Consumption in Developed Countries on Global Food Balances

4.3.5.1 Literature Review

Several studies have tried to assess the effects of lower meat demand in developed countries on global food markets based on spreadsheet calculations or quantitative simulation models. Analyses differ widely due to discrepancies in the employed base period, projection horizon, model type and scenario specifications. As a result, they are difficult to compare.

Rosegrant et al. (1999) project developments on global agricultural markets up to 2020 based on the partial equilibrium model IMPACT. In addition to a reference scenario, they run a scenario in which they assume an exogenous decline in meat demand in developed countries by 70 % compared to the reference scenario in 2020. In addition, an exogenous increase in cereal consumption is assumed in order to keep the overall energy balance of consumers in developed countries constant. Results of the study compared to the reference scenario show a decline in global meat prices by 20–30 %, a decline in global meat supply by 13 %, and an increase in meat demand in developing countries by 13 %. Due to falling feed demand, coarse grain prices decline by up to 10 %, but the rice price stays constant and the wheat price even increases by 1.5 %. Finally, per capita demand for cereals in developing countries remains almost constant. In conclusion, the effect on average calorie consumption in developing countries is positive (+0.8 %) but small.

Two other studies project effects of a shift towards less meat focused diets and base their reference scenarios on FAO projections: Stehfest et al. (2009) and Wirsenius et al. (2010). Both studies display effects on changes in area use, but not on food consumption and food security.

Stehfest et al. (2009) use the IMAGE modelling framework and simulate a scenario in which they assume a globally uniform meat diet of about 93 grams of meat per capita per day (~34 kg/yr), leading to an increase in consumption levels in developing countries and a decrease in developed ones.
In total, global meat consumption decreases by 37 % by 2050 compared to the reference situation. Total agricultural area use declines by 42 % for pasture land and by 9 % for crop land.

Wirsenius et al. (2010) use the Albio model to simulate a scenario in which about 20 % of global ruminant consumption is replaced by poultry and pig consumption. As a result, total agricultural area use declines by 14 % for pasture land and by 2.3 % for crop land, compared to a reference scenario which includes a higher productivity of livestock production than FAO projections. Additional scenarios include a reduction in total meat consumption, but are combined with reductions in postharvest losses such that results cannot be attributed to the reduced meat demand alone.

In conclusion, these studies suggest that a reduction in meat, and especially beef consumption, lowers the demand for agricultural area, even if calorie consumption is kept constant. They also find strong effects on pasture area and comparably low effects on cereal area. Only the Rosegrant et al. (1999) study assesses the effects on global agricultural prices and food demand in developing countries and finds the effects on calorie availability in developing countries to be small, but positive. This is because the effects on prices for cereals are small. In contrast, price effects for meat are substantial and lead to a higher protein availability from meat in developing countries.

4.3.5.2 Quantitative Analysis

In order to get an impression of the extent to which declining meat consumption could enable additional food production, we analyzed the impact that a reduction in meat (beef, poultry and pork) consumption in OECD countries by 30 % would have on world food balances. Such a reduction could be attained through various measures, including the implementation of a consumption tax on meat along with consumer awareness campaigns. For simplicity, these illustrative calculations are done for the years 2005/07, the base year of the FAO projections.

The daily average meat intake (only accounting for poultry, pork and beef) in OECD countries in 2005/07 was ~225 g/day, which amounted to an annual meat consumption of around 102 million tonnes. We assumed a 30 % demand decrease for each meat category resulting in a total meat reduction of 30.6 million tonnes per year and a reduction of per capita meat consumption by about 70 grams per day (Table 4.3).

Table 4.3: OECD Base Year (2005/07) Meat Consumption and Consumption Change

Source: FAOSTAT (2011), own calculations.

	Beef	Pork	Poultry	Total Meat
Base consumption (million tonnes/year)	27.9	37.6	36.5	102.1
Consumption change (million tonnes/year)	-8.4	-11.3	-11.0	-30.6
Base consumption (g/capita/day)	61.5	82.8	80.4	224.7
Consumption change (g/capita/day)	-18.4	-24.8	-24.1	-67.4
Percentage change	-30 %	-30 %	-30 %	-30 %

Based on assumptions concerning feed rations and crop yields (see Table 4.4), the estimated amount of feed and corresponding areas that are set free by the reduction of meat production can be calculated. These effects are, however, reduced when considering that the reduced meat consumption is offset by an increase in other food products in human diets. It is assumed here that offsetting occurs through by higher demand for plant products (pulses, cereals, roots and soybeans), ensuring that the decrease in protein and energy intake from meat is roughly compensated for. Milk and egg consumption levels are assumed to be constant.

A 30 % decrease in meat consumption in OECD countries would set free 30 million ha of cropland

The net effect of reduced meat production, taking into account additional food crop production for dietary compensation, is illustrated in Table 4.4. The main effects on crop production arise from changes in cereals (around 85 million tonnes) and oilmeals (around 25 million tonnes) which make up the main part of concentrate feed. For pulses, roots and soybeans the additional demand for human consumption exceeds the reduced demand in feed (this, however, depends on the assumptions regarding substitution in human diets), resulting in higher land use.

Table 4.4: Assumed Feed Demand per kg of Meat, Crop Yields, Changes in Crop Demand and Crop Land Set Free

Sources: Feed demand: own composition based on Banse et al. (2005); Bouwmann et al. (2005); FAOSTAT (2011); Steinfeld et al. (2006). Crop yields: FAOSTAT (2011). Changes in human demand and area: own calculations. For more detailed information see Duman (2011).

	Cereals	Soybeans	Pulses	Roots	Oilmeals
Human Demand Change (million tonnes/year)	6.813	6.813	9.084	9.084	0
Ratio of feed (kg) to meat (kg)	3.080	0.000	0.054	0.190	0.887
Feed Demand Change (million tonnes/year)	-94.294	0.000	-1.642	-5.814	-27.159
Net Demand Change (million tonnes/year)	-87.482	6.813	7.441	3.270	-27.159
Crop Yields (tonnes/ha)	5.500	2.500	1.700	27.000	1.400
Area Set Free (million ha)	15.906	-2.725	-4.377	-0.121	19.400

When adding up the area change resulting from the change in crop production as illustrated in Table 4.4, one can conclude that approximately 30 million ha of crop land would be set free that could be used for alternative food production. This would correspond to about 2 % of global arable and permanent cropland. This finding, however, is subject to several qualifications:

Land set free from decreased feed demand for cereals, pulses and roots can be used for alternative food production purposes. But this is not the case for oilmeals which are a co-product of plant oil production. Both oilmeal and plant oil production yield similar revenues (while 1 kg of soybeans yields around 20 % oil, the oil price per kg is about 3 times that of 1 kg of oilmeals). (Nonhebel, 2004). Supply reactions in oilseeds will therefore depend on demand for plant oils. As a consequence, a decrease in demand for oilmeals by a certain percentage will not translate into the same percentage change in oilcrop production. In the case of low demand elasticities for plant oils (low price reactions by consumers) and continued strong demand for vegetable oils it is likely that the supply quantities of oilmeals will not be affected much and only little area would be released for alternative uses. Due to a lower feed demand, however, prices for oilmeals would drop and the share of oilmeals in feed rations might increase. This effect may further reduce the demand for other feed crops such as cereals that are in direct competition with resources used for food production.

One important aspect not considered so far is the effect on permanent pasture aarea. This effect, however, is difficult to estimate. There are great variations in pasture qualities, yields and use intensities (Bouwmann et al., 2005; Steinfeld et al., 2006), but there are only very limited data (Wirsenius et al., 2010). However, a significant amount of pasture area is hardly suitable for food crop production. Steinfeld et al. (2006: 37) classify 60 % of all pasture land as "extensive pasture in marginal areas". In developed countries, this category comprises even 80 % of pasture area. Thus, a substantial part of the pasture area calculated to be "set free", but having no other lucrative use options, might therefore still stay in animal production. This would increase the share of forage in the average feed rations and thus reduce the use of other feed crops in ruminant production. Moreover, to some extent these marginal areas could serve other valuable purposes not directly related to food production. Stehfest et al. (2009) estimate that around 50 % of global extensive and intensive grassland area could constitute important carbon sinks if reverted from managed grazing land to natural vegetation such as forests, woodland, savannah or scrubland.

More generally, it has to be said that predicting and quantifying effects from reduced meat demand is not as straightforward as the previous calculations would suggest. Effects are complex and strongly depend on supply and demand interactions. Therefore, the results illustrated in Table 4.4 cannot do more than give an indication of their order of magnitude.

There are numerous complex and interrelated adjustment processes, for example:

» Substitution processes in human demand play a significant role in determining the effects of reduced meat consumption. For example, if it is assumed that milk and eggs play a role in compensating for reduced meat consumption, the resulting effects are smaller.

» Reduction rates may differ among meats: If the meat reduction percentage is assumed to be greater for ruminant meat and smaller for monogastric meat, the resulting changes on resource use are larger, as ruminant meat needs relatively more feed and land per kg of output.

» OECD countries are not isolated from the rest of the world and agricultural production and consumption is part of a global system in which market forces come to play. A decrease in meat demand in OECD countries has effects on international food commodity and agricultural input prices, which in turn induce global changes in demand as well as in production processes for various agricultural products.

In order to address these shortcomings to a certain extent, an economic equilibrium model with fully elaborated supply and demand functions can give further insights. Such a partial equilibrium model in a very rudimentary form has been developed for this study. It consists of isoelastic supply and demand functions for five plant and five livestock products and market clearing conditions (for a full documentation see Duman, 2011).

The plant products covered are cereals, roots, pulses, oilmeals and grass. Feed demand functions are specified for all plant products; human demand only exists for cereals, roots and pulses. Animal products comprise beef, poultry, pork, eggs and milk. The world is divided in two country aggregates: OECD member states and an aggregate of all other countries, called "rest of the world" (ROW). The model is calibrated to correspond to FAOSTAT (2011) data for the three year average of 2005/07. Time is not considered and the model solves comparative static equilibria for the base situation 2005/07. In order to simulate the effects of reduced meat demand, a tax is imposed on all meat products in OECD countries at a level such that demand decreases for each of them by 30 %. Due to a system of symmetric cross price elasticities, higher meat prices result in more plant product consumption such that overall calorie and protein intake is maintained. Core results compared to the base situation comprise:

- **World market prices** for pork and poultry decrease by 13 % and for beef by 18 %; cereal and root prices fall by 10 %, while the price of pulses increases by 11 %.

- **Consumption changes in the ROW:**
  - Due to lower world meat prices, overall meat consumption rises by 5 % (~4 % in pork and poultry and 7.5 % in beef).
  - Cereal demand increases by 2.6 % and root demand stays constant. Consumption of pulses falls by abaut 5 %.

- **Consumption changes in the OECD:**
  - The 30 % meat demand reduction is compensated for by an increase in cereal (5 %), root (6.5 %) and pulse (160 %) consumption.

- **Change in aggregate world production:**
  - Meat production falls by 9.6 % (11.1 % in poultry, 8.7 % in pork, 9 % in beef).
  - Cereal production decreases by 1 %, production of pulses increases by 5.3 % and that of roots decreases by ~1 %.

Thus, a main conclusion is that the 30 % decrease in meat consumption in OECD countries results in lower world market prices for meat and thus increased meat demand in the ROW. Therefore, not all cereals which are theoretically set free by consumption changes in the OECD according to our previous calculations (Table 4.4) will be available for direct human consumption. As a consequence, the effect on cereal prices and increased cereal consumption in the ROW are small, which is in line with the simulations by Rosegrant et al. (1999). ROW consumers do, however, benefit from higher protein supply from meat products. Moreover, with world production of meat decreasing by almost 10 %, environmental pressures would be reduced.

4.3.6 Conclusions

Lower meat consumption in developed countries would substantially impact the 70 % PI figure for two reasons:

- The FAO study forecasts a quantitative increase in global meat production of 85 %. This makes a significant contribution to the overall 70 % increase in two ways: First, the 85 % increase is disproportionately large in magnitude. Second, meat products are of higher value than most other food commodities. Due to this, a change in meat consumption would have a larger impact on the necessary production increase than a same quantitative change in plant products.

- Moreover, alongside less meat production there would be less crop demand, in the event the value increase in food crop demand is smaller than the value decrease resulting from decreased feed demand. This would decrease the necessary increase in crop production until 2050 and further reduce the projected increase of 70 %.

In order to show the effect of lower meat demand in developed countries on the required increase in global meat production, Table 4.5 illustrates the required meat production increases to 2050 when meat demand is reduced by 30 % relative to 2005/07 in developed countries compared to the reference scenario developed by Bruinsma (2009).

Table 4.5: Effect of a 30 % Meat Demand Decrease in Developed Countries on 2050 Meat Balance

Source: own calculations base on Bruinsma (2009), FAO (2009c), Alexandratos (2009).

	2005/07	2050			
		Scenario 1 (FAO)		Scenario 2	
			Change relative to 2005/07		Change relative to 2005/07
Per capita meat demand in developed countries (kg/yr)	77.1	95.7	24.0 %	57.5	-25.4 %
Total meat demand in developed countries (million t)	103.0	130.0	26.6 %	78.0	-24.0 %
Global meat demand (million t)	249.0	462.0	85.0 %	412.0	65.6 %

The effect of lower meat demand in developed countries on the global world food balance would be substantial. But the effect on food security in developing countries would be relatively small

FAO projections foresee an increase in per capita meat demand in developed countries by 24 % between the base year and 2050. Assuming instead that per capita meat demand based on 2005/07 levels will decrease by 30 % and remain at this level up to 2050 would result in 40 % lower meat demand in developed countries (78 million t instead of 130 million t) than foreseen by the FAO for 2050. Thus, instead of 462 million t of meat, only 412 million t would have to be produced globally (without considering that part of the demand change in developed countries might be counterbalanced by increasing meat demand in developing countries, as described in Section 4.3.5.2). As a consequence the global meat balance would be improved, with necessary meat production growth by 2050 of 65.6 % instead of 85 %.

In conclusion, the effect of lower meat demand in developed countries on the global world food balance would be substantial. But the effect on food security in developing countries would be relatively small, because crop prices would fall only slightly due to increasing meat demand in developing countries as a response to lower prices.

Curbing meat consumption in OECD countries may produce health benefits for the majority of the population and reduce social costs associated with the negative health effects of meat consumption. This would probably not be the case in developing countries, however, where average consumption levels are still low.

5. Conclusion

Concerning the first objective of our study – namely, to clarify the methods used and assumptions made in projecting the 70 % PI figure – we conclude that the FAO projections are based on solid analysis and a high amount of expert knowledge and country specific data. Furthermore, they are roughly in line with projections by other institutions. Due to the intransparent presentation and insufficient documentation of assumptions and methodology, however, it is almost impossible to trace the results in light of the assumptions made. As many of the assumptions are unknown, it is impossible to evaluate their validity in comparison to any alternatives. For example, it is not clear to what extent the FAO takes into account increasing demand for bioenergy.

Assumptions on average global income growth rates for 2030 to 2050 are high compared to the past and may have resulted in an overestimation of future demand. On the other hand, the effects of climate change are not yet considered in the projection of global supply, and these effects are expected to put further pressure on the world food balance. Our second objective was discuss the implications of the 70% PI, especially whether and to what extent an increase in global agricultural production would contribute to reducing hunger. We conclude that undernourishment is not a problem of global food availability, but rather of access to food. Furthermore, in the overwhelming majority of cases it is economic access to food that stands in the way of food security. Clearly, poverty is the major reason why food insecurity persists.

Poverty is the main reason for food insecurity.

Nonetheless, improving the global world food balance is of importance in order to prevent global food prices from increasing to a level that leads to increasing food insecurity and poverty for people who spend a high share of their income on food. In tackling this objective, efforts to increase global production should be complemented and balanced with other strategies for improving the world food balance, including eliminating bioenergy subsidies, reducing postharvest losses and reaching a lower meat share in food consumption in developed countries.

Thus, increasing agricultural production, reducing food losses or decreasing demand in regions with a low prevalence of undernourishment are only likely to have indirect and limited impacts on the prevalence of hunger. An increase in agricultural production or reduction in postharvest losses is of importance mainly within the regions subject to food insecurity. In these regions it can have the dual benefit of lowering prices and increasing food availability for food purchasers while also generating additional income for food producers. Thus, what is needed is investment in rural infrastructure, agricultural research and public services, as well as efforts to improve governance systems and institutions which allow markets to work within food insecure regions. Finally, efforts focussing on poverty reduction are most important, including improving the ability of the poor to access education, land, employment and other income sources as well as to public services such as social safety nets and medical care.

Our third and final objective was to analyze the extent to which changes in other variables (composition of food consumption, post harvest losses, use of biomass for energy production, etc.) – variables which are also subject to the impact of potential policies – may contribute to meeting increasing global demand for food. We conclude that the opportunities for alternative or complementary measures are manifold. The reduction of subsidy-supported biofuel demand, minimization of postharvest losses and consumption of less animal products in industrialized countries should also be considered and may be more sustainable measures for improving the world food balance.

The production of certain forms of bioenergy such as liquid fuels in the US and EU has significant indirect land use effects and could even increase global GHG emissions if these effects are taken into account. Political support for first generation biofuels should therefore be ended. This could be easily implemented and would have direct and significant effects on the world food balance.

Various studies suggest that there is significant scope and need for reducing postharvest losses in developing and developed countries due to the sheer volume of such losses: Current postharvest loss levels are estimated at 20–50 %, with supply chain losses representing the dominant form of loss in developing countries and food waste at the retail and household levels dominating in industrialized countries. Regarding the objective of achieving food security, reducing postharvest losses in food insecure regions. This, in turn, would increase food availability while also generating income along supply chains.

Without more systematic research on the extent of losses, measuring progress against any global reduction target is impossible. Nonetheless, there are compelling arguments in favour of tackling postharvest losses, despite the lack of reliable data. Lowering meat demand in industrialized countries would have positive effects on human health and environmental goods. Furthermore, it would result in lower climate gas emissions and ease the introduction of higher animal welfare standards. Finally, reduced meat consumption would improve the world food balance and result in substantially lower meat prices and slightly reduced cereal prices.

The resulting effect on food security, however, is likely to be small since lowering meat consumption in industrialized countries leads to lower meat prices, which in turn triggers more meat consumption elsewhere. The effect on basic staple food prices is therefore low.

Livestock, including feed production, contributes to environmental problems to an extent hardly reflected in the prices of animal products.

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