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An inventory of studies on food security, calamities and their impact

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Preface

Food security is an issue of growing concern, as demand for agricultural products increases due to an increasing world population, changing diets and growing demand for energy crops. This might lead to a tightened supply-demand balance for agricultural commodities, in which fluctuations due to climatic, economic, and political factors have a magnified impact on food prices and availability. Increased variability in food production is likely to harm vulnerable groups and countries with insufficient buffering capabilities, but also currently wealthy nations with 'full control' over their economies and resource base may be severely affected directly or indirectly. In addition, the global food system may become less resilient to natural and man-made calamities.

The Steering Committee for Technology Assessment, an independent advisory committee to the Dutch Minister of Agriculture, Nature and Food Quality, has been concerned for some years about the resilience of the global food system to calamities. Therefore, Plant Research International of Wageningen University and Research Centre was commissioned to carry out an inventory study on the resilience of the European food system to calamities.

The impact of possible calamities on European food production was reviewed as the dependencies of Europe from food imports. The findings of this study suggest that the European food system is rather robust in terms of food availability with surplus home production and strong purchasing power to acquire food on the international market. One of the conclusions of the study is the high dependency of the EU of soybean imports. Based on the outcomes of this study a follow-up study has been conducted in which was looked specifically into the impact of a complete shortfall of soybean (meal) imports on meat production (Bindraban *et al.*, 2008).

We thank the Steering Committee for Technology Assessment for commissioning this assignment and their fruitful cooperation.

Prem Bindraban
Kees Burger
Foluke Quist-Wessel
Charlotte Werger

Wageningen, December 2008

Abbreviations and acronyms

ACP	African, Caribbean and Pacific Countries
ASEAN	Association of Southeast Asian Nations
BAP	Biodiversity Action Plan
CAP	Common Agricultural Policy
CAPRI	Common Agricultural Policy Regional Impact Analysis Model
CBD	Convention on Biological Diversity
CLUE-s	Conversion of Land Use and its Effects model
CRED	Centre for Research on the Epidemiology of Disasters
EAFRD	European Agricultural Fund for Rural Development
EC	European Community
EM-DAT	International Emergency Disasters Database
ENAPRI	European Network of Agricultural and Rural Policy Research Institutes
ESIM	European Simulation Model
EU	European Union
FAO	Food and Agriculture Organization of the United Nations
FAPRI	Food and Agricultural Policy Research Institute
GCM	Global Climate Model
GDP	Gross domestic product
GHG	Greenhouse gases
GMO	Genetically modified organisms
GTAP	Global Trade Analysis Project
HARM	Harmonised system of regions
HEI	High external input
IFPRI	International Food Policy Research Institute
IIASA	International Institute for Applied System Analysis
IMAGE	Integrated Model to Assess the Global Environment
IMPACT	International Model for Policy Analysis of Agricultural Commodities and Trade
IPCC	Intergovernmental Panel on Climate Change
LEI	Low external input
LEI	Landbouw-Economisch Instituut/Agricultural Economics Research Institute
LEITAP	Extended GTAP version implemented by LEI
MERCOSUR	Common market of the South
MNP	Netherlands Environmental Assessment Agency
MSA	Mean Species Abundance
NAFTA	North American Free Trade Agreement
NUTS	Nomenclature of Territorial Units for Statistics
OECD	Organisaton for Economic Co-operation and Development
OFDA	Office of Foreign Disaster Assistance of the US
SMP	Skimmed milk powder
SRES	Special Report on Emission Scenarios
toe	ton oil equivalent
UAA	Utilized Agricultural Area
UN	United Nations
UNFCCC	United Nations Framework Convention on Climate Change
WTO	World Trade Organisation

Summary

This study has analyzed the impact of possible calamities on the food security of Europe (EU-27) up to 2020 in a context of evolving globalization. It is hypothesized that Europe might be at risk at least for some basic food commodities if further globalization would lead to geographical specialization, and even more so under a scenario of trade liberalization, or with biofuel targets in place putting an additional demand for food crops.

The studies on the effects of various policy scenarios and climate developments show that agricultural trade patterns in the world will not show great changes in 2020 compared to the present. Present exporters will remain in that position and so will import countries. Europe will remain mostly self-sufficient, with small exports of cereals, and large imports of soybeans. Climate changes will not affect this pattern dramatically, though developed countries will gain relative to developing countries. Africa will be worse off in most climatic scenarios, while the trade scenarios do not offer much hope for Africa either. Northern regions in particular may benefit from global warming. Within the EU, southern regions will do a little worse. The EU agricultural sector as a whole will continue its path towards lower employment, and lower land use, particularly in the free trade scenarios. This would leave more room for natural habitats and/or cultivation of crops for feed and energy. The findings suggest that the European food system is rather robust in terms of food availability with surplus home production and strong purchasing power to acquire food on the international market.

A review of past calamities in Europe showed that the impact of the Chernobyl nuclear catastrophe damaged agriculture in Ukraine but left the food system in Europe at large virtually untouched. Similarly, extensive fire in Greece affected only 5% of the olive oil production that was compensated by a higher production in Spain. The drought in 2003 had a strong impact on the farmers concerned, but had little effect on the consumers, as reduction in production could be compensated for by purchases from the global market and the use of stocks. The occurrence of single calamities so far have not caused problems of food insecurity in Europe. A sequential occurrence of calamities, such as dry and hot spells or floods together with disruptions in the soy chains under a globalizing scenario with concentrated production areas, might have a bigger impact on the European food system. These accumulated effects have however, not been investigated in this study and need further attention.

1. Introduction

This document compiles the findings from studies that deal with factors that might affect the food security situation of Europe in the future. This introduction is elaborated in four sections. First, the general issues related to the resilience of the global food system to calamities are described. Subsequently, the relevance of these issues is placed in the European context. The objective, analytical framework and research approach of the study are described and the reading guide is finally outlined.

The global food system

Globalization of agriculture has started already during the colonial era with the transoceanic trade of agricultural commodities and introduction of non-native species. Trade volumes across and between continents have grown rapidly over the past decades and are likely to increase further in response to a reduction in trade barriers and an increase in food and feed demand. A production ecological analysis in the early 1990s on global food production and demand revealed the need for food supply from South America, Africa or Eastern Europe to Eastern and Southern Asian regions as these latter regions lack enough land and water to be self sufficient towards 2040. The flow of food and feed from South America to China has indeed increased dramatically during the past decade.

From an economic perspective, trade liberalization has been stimulated strongly over the past decades to allow countries with comparative advantages to benefit from global trade. This perspective is actively pursued through international agreements and negotiations, though regional self-interests have contained the speed of liberalization. Liberalization stimulates large scale production systems to benefit from economies of scale and might lead to regional concentration of agricultural production. Yet, changes may not be dramatic. For instance, due to suitable social-economic and natural conditions, over 90% of world's rice is produced in Asia and this has not changed much over the past decades. Soybean production has however, developed rapidly in South America over the past decade taking over the leading position of the USA. Together they produce more than 80% of all soybeans. Import demand and to a less extent export supply have become more concentrated in a few large countries. On the other hand, regionalization and even the call for autarky are gaining momentum as well. Europe, for instance, could be self-sufficient in food and feed. One development scenario might be the further geographical specialization of the agricultural production like an increased role of Brazil, due to globalization because of further trade liberalization and agricultural policy.

In addition to food (around 40% of all grains) and feed (around 45%), the demand for bio-energy has abruptly increased during the past years because of policies for compulsory blending of transport fuel and subsidies for the production of biomass for energy. Lack of foreign currency to purchase petrol on the international market had already led to the development of an ethanol sector in Brazil. Brazil could rely on its excessive land and water resources and the total energy use is rather small, while this is not true for most countries in the world. A number of concurrent global problems have fuelled the sense of urgency for bio-energy. CO_2 neutral energy from biomass would be an answer to curb climate change, as human induced emissions of CO_2 are perceived as the prime cause of climate change. Use of bio-energy would allow countries to comply with the Kyoto agreements. The dispersed production of energy throughout the world suits the current geopolitical strategies to reduce the dependence on few and unreliable suppliers of energy. Bio-energy fulfils this objective and at the same time would respond to the need for alternative and renewable energy sources, reducing the dependence on the presumed declining availability of fossil sources. Finally, bio-energy is seen as an attractive alternative crop, primarily in some developed nations. Europe will for instance, re-use its set-aside lands. Higher energy prices and policies may lead to more bio-fuel production reducing food supply and the acreage of natural biomes.

Over the past decades, fluctuations in supply and demand, due to climatic, economic and political factors, have been buffered by food stocks, preventing major famines. In Europe and the USA production volumes have been controlled through a wide range of agricultural policy measures, including set-aside policies and quotation. With the dramatically increasing demand for virtually every commodity due to population growth, changing diets and vast growth of some large economies, and with the novel demand for bio-energy, an even larger buffering capacity may be needed to prevent calamities. This is even truer if climate variability was to increase due to climate change, further increasing risks because of the tightened supply-demand balance.

Variability in food production is likely to harm vulnerable groups and countries with insufficient buffering capabilities. Also current wealthy nations with 'full control' over their economies and resource base may be severely affected directly or indirectly due to the tightening supply-demand balance. The frequency and severity of droughts and floods are expected to rise with climate change. Simultaneous outbreaks of animal diseases in large-scale production units and regions, through either natural events or bioterrorism may place a temporary but severe shock on the global food system, as will sudden dents in the supply-demand chain due to social unrest and war. Collapse of the internet jeopardising information exchange may curtail trade flows. A nuclear disaster may have unprecedented sudden, but even long-term implications on food availability.

These sudden events along with the likely geographical concentration of agricultural production will affect global and regional food systems. The impact on regions and people will depend on the robustness to respond to such calamities and the resilience of the systems to recover. Stability of demand for food depends crucially on the flexibility with which shifts can be made to other sources of feed or food, distinguished either by type of product, or by origin.

The European perspective

Characterised by insufficient food production and insufficient work and income, especially in rural areas after the Second World War, Europe heavily stimulated its agricultural production. A number of policy measures were simultaneously taken to that aim. Research and technology development was encouraged and new agricultural industries e.g. for the production of tractors and other mechanical equipment, and agro-chemicals were stimulated. Stable market conditions were created through subsidies, guaranteed prices and purchasing mechanisms. The strategy was successful and Europe turned from a net importer into a net exporter during the early 1980's. The share of the EEC in world agricultural exports, excluding intra-EEC trade, exceeded 50% for eggs, reached almost 50% for butter and cheese, and between 10-20% for sugar, beef and wheat (Balassa, 1988). In order to cut spending on agriculture and to comply with WTO regulations, surplus production is constraint, trade barriers reduced and subsidies are being relocated from production to income support so that Europe moves towards liberalization.

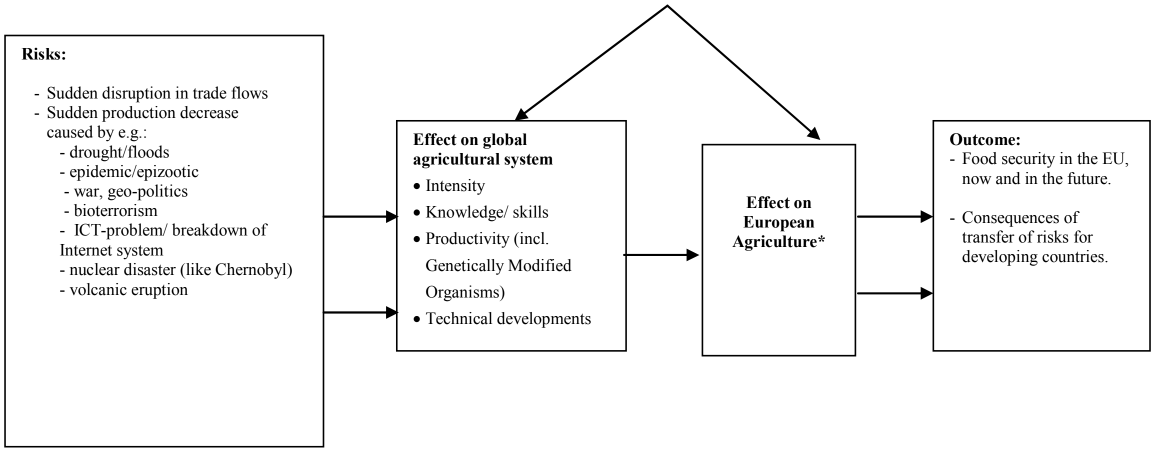
Europe will therefore be increasingly engaged in and dependent on the global food system. While this implies overall economic benefits, it might inherit unacceptable risks, such as the insufficient availability of food in case of calamities, as reasoned in the previous section. In order to safeguard its food security, Europe will put a claim on food from the international market and could, while doing so, transfer adverse externalities to the food security situation in other global regions.

Objective, analytical framework and research approach

The components to be considered in the analyses are structured in Figure 1.1. The ultimate aim of the research is to analyse whether Europe will be subject to possible risks in overall food availability or in some major food items, such as cereals, meat or soybean, resulting from calamities, and to identify the transfer of possible adverse externalities on third countries when it will safeguard its food security. These outcomes will depend on the reactions of the global and European food systems to calamities such as extreme events like drought and floods, epidemics, geopolitical instability, bioterrorism and so forth. The number of combinations or scenarios to analyse these effects can be numerous and should be rationally selected aimed at testing the hypotheses. Two overall hypotheses are defined that have been broken down into partial components (Table 1.1).

Overall conditions: (Assume constant values for these factors, consider sensitivity analyses)

- Continuation of EU-27 (possible expansion)
- Climate change scenario
- Population growth and economic growth determining change in food consumption patterns
- Food security in the rest of the world; transfer of risks to third world countries is not acceptable*)
- Space for biomass and nature (or: (1) price scenarios/energy scenarios, (2) obligatory share of biofuel)



NB. * Assess for each risk what the consequence is for the EU agricultural system (e.g. drought: no soy available, price of animal feed increases).

* The consequences on the food security of developing countries due to the coping strategies of the EU to address calamities should be assessed.

Figure 1.1. Research structure with components to be considered in the study: 'Resilience of the global food system to calamities'.

To focus on the relevant issues to be analyzed, the scope of the research should be clearly defined. Here, a globalization scenario will be further studied whereby some variables will be derived from existing analyses and not further modified. These include the political stability of the EU suggesting no further expansion, population growth, climate change, a certain demand for biofuels and space for natural ecosystems.

Obviously, the complexity of the research questions is extremely high and has to be disentangled in sub-research questions for a sensible analysis. Therefore, this research is set up in a step-wise approach that gives flexibility to effectively guide the research. At least two research phases are distinguished (Figure 1.2). The aim of phase I is to review existing analyses and reports on current food availability and trade and about future developments following the analytical framework. It describes the scope of the research and sums the major risks to be considered for analysing the effects on the global agricultural system in general and on the European system in particular. These insights should lead to the identification of the implications of these factors to European food availability and the consequences of European policies on third countries when they will safeguard their food security. This framework will be used to systematically pull out the answers to the research questions from the reports during phase I. The information gathered will form the basis for scenarios that will serve as a starting point to further analyze plausible future developments for research phase II.

Table 1.1. Hypotheses 'Resilience of the global food system to calamities'.

Hypotheses 'Resilience of the global food system to calamities'
The following hypotheses will be researched in this study: 1. In case of further geographically specialization (as a result of increasing globalization) the vulnerability of the (global agricultural system) increases due to following calamities such as drought and floods, pests and diseases, bio-terrorism, disruption of trade flows (e.g. as a result of war),collapse of the internet system and nuclear disaster (accident in nuclear plant) 2. Food security in the EU will not be endangered overall, but the availability of some basic food items will be at risk, such as cereals, soy and meat. In order to test these two overall hypotheses, the (possible) consequences of the evolving process of globalization will be studied first along the following partial hypotheses 3. The expected evolution of globalization will result in increasing geographically specialization of agricultural production. For instance: in each climate and energy scenario Brazil's share in global agricultural production will at least triple (Food and feedstock). 4. This trend is accelerated by liberalization of trade and agricultural policy. 5. Climate change does have an impact on geographical distribution of agricultural production, but not on the degree of geographical specialization. 6. Higher energy prices and policy measures result in increasing agricultural production for bioenergy and therefore decrease food security and area dedicated to nature.

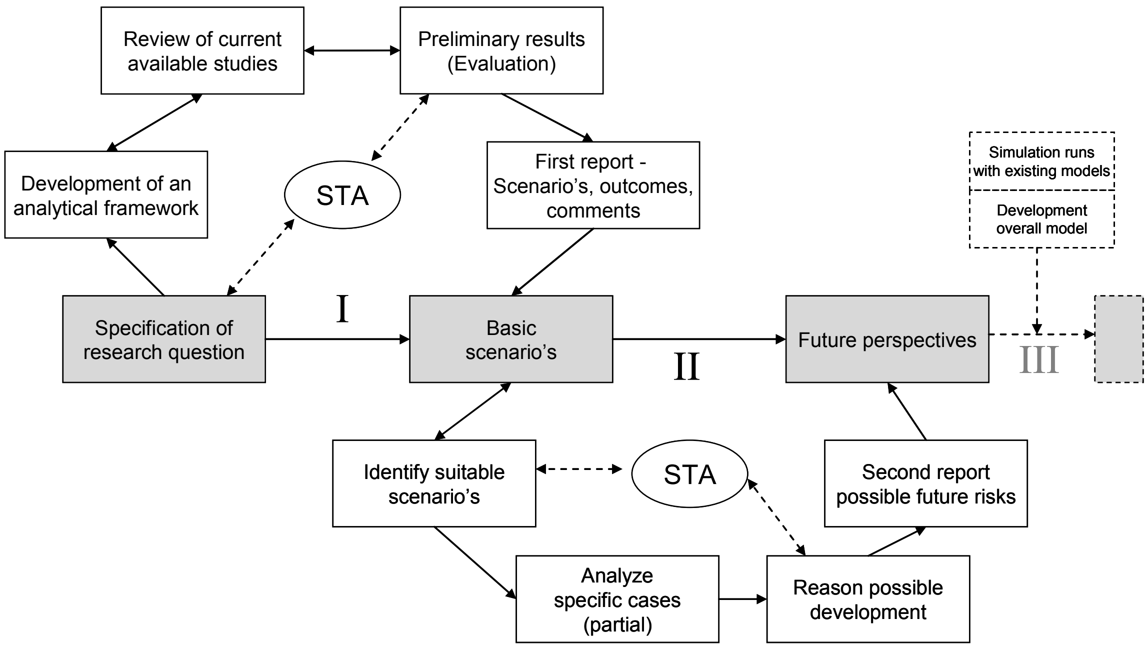


Figure 1.2. A two-step-approach is proposed to delineate desired answers to the research questions. Third and subsequent phases may evolve from the findings in previous phases. The temporal order of the boxes is clock-wise for phase I and anti-clock-wise for phase II.

Plausible future development pathways will be elaborated during phase II. Comprehensive models could be used to this aim, or a logical train of thought could be followed. We recommend pursuing the second possibility first, as comprehensive analyses are very costly and may not necessarily lead to better results, and such analyses can always be undertaken in a third phase. For the second approach, lessons learned from specific cases on regional and global food balances will guide the logical reasoning, such as the impact of the El Niño and La Niña on rice in Asia, recent outbreaks of animal diseases, current rust epidemics in soybean and wheat. Model analyses that look into specific components of the European food system could provide basic quantitative information. Future perspectives can be reasoned for each scenario based on these lessons and quantitative information. Milestones could also be identified that may cause sudden changes in development, such as the green revolution, the IT revolution, breakthrough in energy technologies etc., which may lead to a range of plausible outcomes for each scenario. The insights gained from phase II, will be used to provide recommendations as to what strategies the EU ought to pursue to safeguard its food security and to reason the possible implications of these strategies to third countries.

Report outline

This document reports about phase I of this study. First, an overall situation of the global and European food system and expected trends are presented in Chapter 2 and 3, respectively. Chapters 4 and 5 elaborate expected future developments based on the review of a number of quantitative trade and biophysical analyses. Special attention has been paid to the introduction of biofuels in Chapter 6. Shocks in the food systems, as have been experienced in the past due to several calamities, and global governance of food, including the control of food stocks, as a means to control food situations are described in Chapter 7. The main findings are summarized in Chapter 8 that includes suggestions for a base scenario for the second phase to analyse the impact of calamities in a globalizing world to the food situation of the EU and third countries.

2. Global present situation and base projections

2.1 Demographics

The growth of the world population is mainly determined by the developments in birth and death rates. At a regional level, net migration is an additional factor that affects population development. Global population growth rate is expected to fall to about 1% in the coming ten years, which is due to declining birth and fertility rates (Nowicki *et al.*, 2006).

The world population of 6.7 billion in 2007 is expected to grow to 7.7 billion in 2020 and reach 9.2 billion in 2050 according to UN medium variant projections (UNPD, 2007). Despite decreasing growth numbers, the absolute annual increments continue to be large. Most of this growth will occur in developing countries. Table 2.1 shows, that between 2007 and 2050, the population of the more developed regions will remain largely unchanged at 1.2 million inhabitants, but the population of the less developed regions is projected to rise from 5.4 billion in 2007 to 7.9 billion in 2050. At the same time, the population of the least developed countries is projected to more than double from 804 million in 2007 to 1.7 billion in 2050. Consequently, by 2050, 86% of the world population is expected to live in the less developed regions, including 19% in the least developed countries, whereas only 14% will be living in the more developed regions.

Table 2.1. World population in 1950, 1975, 2007, and projections for 2020, 2040, 2050 according to medium variant of the UN. With distinction in major development groups and major areas.

Major area	Population (million)			Population (million) Projection, medium variant		
	1950	1975	2007	2020	2040	2050
World	2,535	4,076	6,671	7,667	8,824	9,191
More developed regions	814	1,048	1,223	1,254	1,257	1,245
Less developed regions	1,722	3,028	5,448	6,413	7,567	7,946
- *least developed countries*	200	358	804	1,075	1,527	1,742
- *other less developed countries*	1,521	2,670	4,644	5,338	6,039	6,204
Africa	224	416	965	1,271	1,765	1,998
Asia	1,411	2,394	4,030	4,596	5,148	5,266
Europe	548	676	731	722	687	664
Latin America and the Caribbean	168	325	572	660	750	769
Northern America	172	243	339	379	427	445
Oceania	13	21	34	39	46	49

Source: UNPD, 2007.

Figure 2.1 shows that Asia will remain the most populous region, and Africa will house an increasing part of the global population. The share of world's population in Latin America and the Caribbean and Oceania stabilizes, while the share of population in North America and Europe decreases.

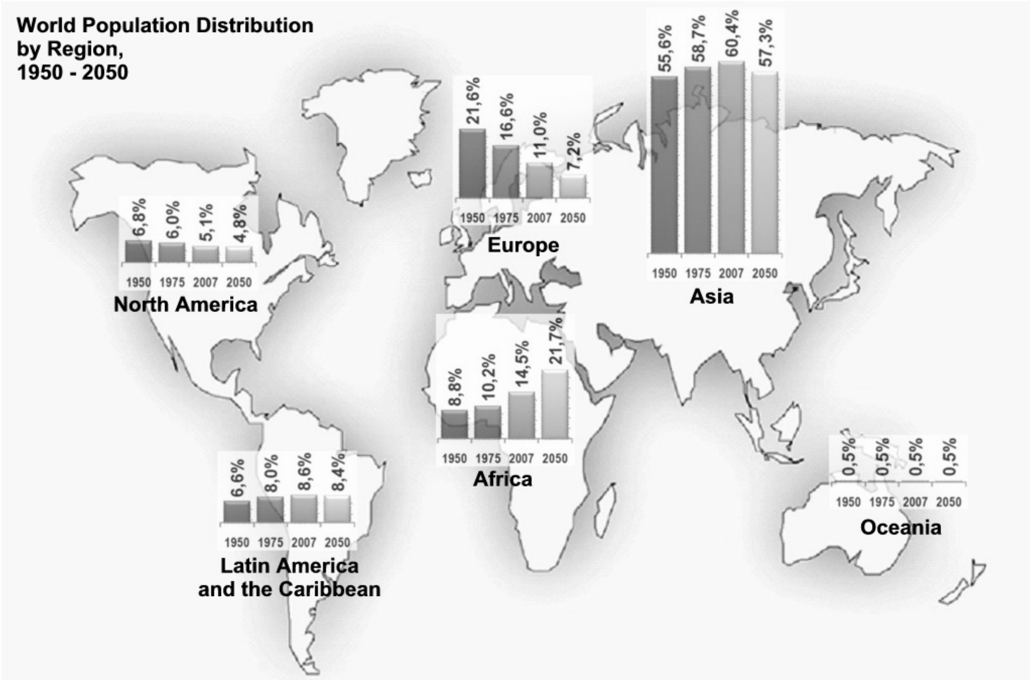


Figure 2.1. World population and distribution by region, 1800-2050. Source: UNPD, 2007.

In 2005, nearly half of the world's population that reached 6.6 billion lived in urban areas; for more developed countries and less developed countries urban population represented 74.1 and 42.9% resp. of total population. For the coming decennia, population growth is expected to occur especially in urban areas in less developed countries.

2.2 Global GDP development

Table 2.2 shows the projections of global GDP development as provided by MNP (2007). Global GDP (gross domestic product) is expected to triple during the coming 5 years with China and India playing a significant role. By 2040, these two countries are expected to have a bigger share and larger influence in the world economy compared to 2005, as China will be the largest economy in the world and India taking a fourth position just following the EU. Currently, economies of China and India, but also Brazil, are indeed experiencing spectacular growth.

Table 2.2. Global GDP development.

	GDP 2005		GDP 2040	
	(billion $)	(%)	(billion $)	(%)
EU	9,590	20	18,460	12
USA	10,040	20	24,020	16
China	7,140	15	34,060	22
India	3,040	6	15,740	10
Brazil	1,280	3	3,190	2
World	49,130	100	151,660	100

GDP in billion dollars, 1995 value. Source: MNP, 2007.

Since total GDP development depends on population developments, it is also important to look at GDP per capita developments for different regions. Figure 2.2 presents past and projected developments in GDP for the period 1970 up to 2040. Especially East Asia will experience growth in GDP per capita, which is partially due to the strong economic growth of China. Although GDP per capita is expected to grow for all regions, South Asia and Sub Saharan Africa are the regions lagging behind and experiencing the least growth.

Income growth between 2005 and 2020 is about 2% yearly for the EU-15 and 3.8% yearly for the EU-10. Combined with an annual population growth of 0.3% for EU-15 and -0.2% for EU-10, this results in an increasing per capita income (Nowicki *et al.*, 2006), which suggests that Europe will maintain its wealthy position.

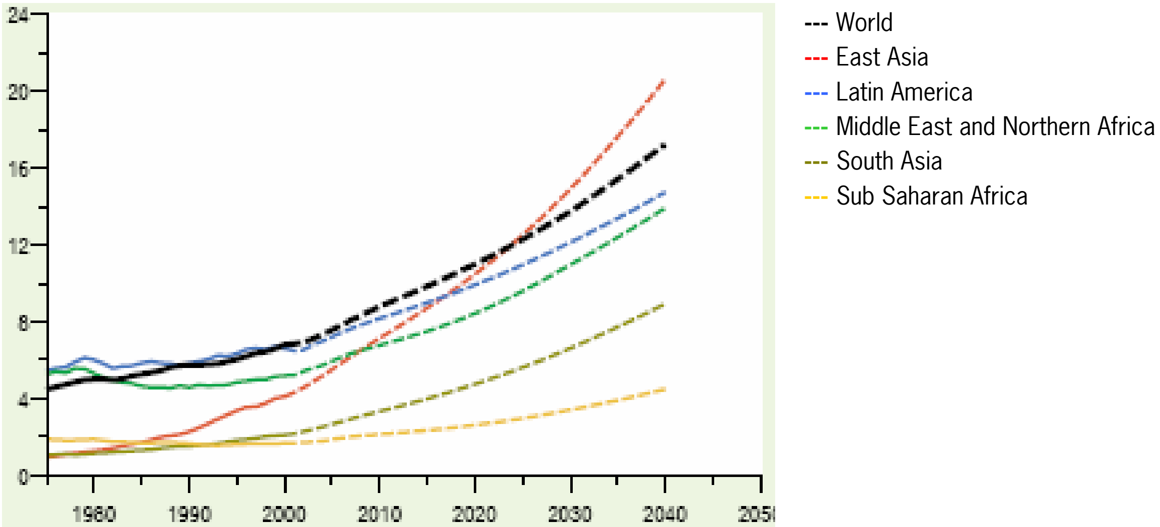


Figure 2.2. GDP per capita (1000 dollar, 2000 value). Source: MNP, 2007.

2.3 Food consumption

Global food consumption is increasing due to population growth and increasing per capita consumption. Between 1970 and 2000 the world food demand doubled, which related to a per capita increase of approx. 20%. Higher incomes, urbanization and changing preferences are raising domestic consumer demand for high-value products in developing countries. The consumption of food budgets is shifting from the consumption of grains and other staple crops to vegetable, fruits, meat, dairy and fish. The present shifting patterns of consumptions are expected to be reinforced in the future (Braun, 2007).

Present production exceeds the economic demand for agricultural products. This might change in the future, as natural resources (land and water) per head of the growing population will continue to decline and yield growth potential is more limited than in the past (Bruinsma, 2003). Actually, today already, the production may not meet required demand to be food secure, as a large part of the world population is undernourished or has a 'low caloric diet' as they have no access to food due to lack of money to purchase food. As such, their (lack of) economic demand is not considered when compared to production volumes, i.e. food availability.

2.4 Agricultural production

MNP (2007) used a trend scenario approach, with the IMAGE-model, to make projections of the agricultural area required in 2040. The MNP study did not include the impacts of climate change and production of food crops for bio energy. These topics will be discussed in Chapter 5 and Chapter 6 of this report, respectively.

Presently, an area of 5 billion hectares (5 Gha) is used to feed the world population, of which 1.5 Gha is dedicated to arable crop production and 3.5 Gha is used as permanent pasture. One third of the arable land (0.5 Gha) is used for fodder production (MNP, 2007).

The future demand for meat will continue to put pressure on land use. Global per capita meat consumption increased with 40% between 1970 and 2000 while consumption of other agricultural products increased with 10%. Presently, the production of 1 kcal beef requires 80 times as much land as the production of 1 kcal of grain. This is mainly because cattle are kept on grassland. For non-grazing animal such as chicken, the production of 1 kcal meat requires 2.5 as much land as the production of 1 kcal grain. It is expected that livestock production systems will be intensified, therefore the area of pastures will not increase significantly, but land expansion is required for feed production. The area for soy production is expected to increase with 20% in the coming 40 years (MNP, 2007).

Table 2.3. Agricultural land per person in 2005 and 2040.

	Arable land (Gha)	World population (bio)	Land/person (ha)
2005	5	6	0.8
2040	5.5	9	0.6

Source: MNP, 2007.

As Table 2.3 shows, the average land per person is expected to decrease from 0.8 ha in 2005 to 0.6 ha in 2040, assuming that 5.5 Gha is used to feed 9 billion people in 2040. This implies that between 2005 and 2040, an increase in agricultural land of 10% would have to feed an increase in population of 50%. To this end, global productivity will have to increase with 43%. Such an increase in productivity is assumed to be feasible, as it has been proved over the last 4 decades when global average productivity increased with 55% between 1970 and 2005 (MNP, 2007). The increase in food demand will occur mainly in Sub Saharan Africa and South Asia. Increase in crop productivity is mainly expected in the less developed countries, because there is still a large gap between current and potential yield levels that can be closed. Expansion of land is most likely in the tropical areas of Latin America and Africa.

If the required increase in productivity will not be realized, further expansion of agricultural area is most likely to take place. Based on FAO data the MNP study calculated that if all land suitable for agricultural production would be used, 6 Gha could potentially be cultivated. Additionally 1 Gha is available for extensive grazing, and 2 Gha of low productive land could be used for forestry. The expansion of agricultural land will be at the expense of tropical rainforest and grassland. It has to be realized that in this case all potential nature, including tropical rainforest, has been converted into agricultural land.

2.5 Agricultural trade

Table 2.4 shows the relative importance of agricultural trade for selected countries. Agricultural exports and imports are expressed as a percentage of total merchandise exports and imports. For the developed countries, like the EU-25 and the USA, agricultural trade is relative less important at rates below 10% than it is for least/less developed countries like in Africa. This suggests that changes in global agricultural trade patterns will affect domestic agricultural markets of African countries more than it will affect those in Europe. This table also reveals the countries with a major share for agricultural products to the total export. These are Brazil, Argentina, New Zealand and to a lesser degree Australia.

Table 2.4. Share of agricultural imports and exports in economy's total merchandise trade of different countries, 2006.

Country	Percentage exports (%)	Percentage imports (%)	Value of exports (million dollars)	Value of imports (million dollars)
USA	8.9	5.4	92,664	103,648
EU-25 [1]	6.4	7.3	95,308	123,723
Argentina	45.8	4.1	21,333	1,396
Australia	18	5.5	22,178	7,268
Brazil	28.8	6.2	39,528	5,899
New Zealand	59.0	8.8	13,235	2,329
China	3.4	6.5	32,543	51,653
India	11.7	4.2	14,412	7,840
Cameroon	28.3	-	1,011	-
Côte d'Ivoire	41.7	19.6	3,508	1,038
Nigeria	-	14.3	-	2,963 [2]
Kenya	45.6	-	1,503 [2]	-

[1] *Extra EU-25 trade.*
[2] *2005 number.*
Source: WTO, 2007.

2.6 Biodiversity

In the MNP study, biodiversity is expressed by 'the mean species abundance (MSA)', based on Alkemade *et al.*, 2006. The GLOBIO3 model uses quantitative relationships between environmental pressure factors and biodiversity, based on state-of-the-art knowledge from literature. By combining the results related to individual pressures, the overall change in biodiversity is calculated in terms of Mean Species Abundance of original species (MSA) and the extent of ecosystems. The model can be used to assess (i) biodiversity in the past, present and future in relation to the impacts of human pressures on species diversity and abundance; (ii) the relative importance of these pressures and (iii) likely effects of various policy options. The MSA is an indicator of the remaining mean species abundance of original species, relative to their abundance in primary vegetation. It can be interpreted as a measure of 'naturalness' or 'intactness'. The MSA value ranges from 100% in undisturbed, primary vegetation to 0% in completely destructed ecosystems, like a parking lot in a big city. The extent of ecosystems emerges from Land use change calculations. In the GLOBIO3 model, the MSA is calculated based on the following pressures: land use change, infrastructure impact, fragmentation level, nitrogen deposition and climate change.

Increasing consumption during the past 50 years has drastically changed ecosystems, due to expansion agricultural land. Loss of biodiversity occurs mainly because of conversion of forests and grassland into agricultural land. Since further expansion of agricultural lands is expected in the tropics, pressure on biodiversity will increase especially in the tropics. Globally about 35% biodiversity has been lost, mainly in Europe, India and China (MNP, 2007). One of the main outcomes of the MNP study is that it will not be possible to both produce enough food and feedstock, without substantial decrease of biodiversity.

3. Present situation and base projections in the European Union

3.1 The European Union

The Member States of the European Union are presented in Table 3.1. The EU-10 includes Member States that joined the European Union on May 1st 2004. EU-N2 refers to Member States that joined the European Union on January 1st 2007.

Table 3.1. Member States of the EU.

EU-15	Austria, Belgium, Germany, Denmark, Spain, Finland, France, United Kingdom, Greece, Ireland, Italy, Luxembourg, Netherlands, Portugal, Sweden
EU-10	Cyprus, Czech Republic, Estonia, Hungary, Latvia, Lithuania, Malta, Poland, Slovakia, Slovenia
EU-N2	Bulgaria, Romania

3.2 Population

Projections of European population developments for the coming decades have been based on demographic analyses that account for mortality, fertility and migration by sex and by age, and aging techniques for the population pyramid from year to year (EC, 2007f). Demographic developments always depend to some degree on variable factors that are difficult to forecast, such as net migration, which create a certain level of uncertainty. In particular, migration flows between countries and regions are highly uncertain.

Table 3.2. Population growth prospects for the European Union.

Year (at 1 January)	Population EU-15 (million)	Population EU-25 (million)	Population EU-27 (million)
2005	385.4	459.5	489
2015	394.7	467.3	495.3
2020	397.5	469.3	496.4
2040	394.6	463.0	486.9

Source: EC, 2007f.

Table 3.2 provides data on population development in the EU and shows that total population in the EU-27 amounted to nearly 489 million people in 2005 of which nearly 80% lived in the EU-15. Population growth is expected to rise marginally during the coming 1-2 decades followed by a decline after 2020, when annual population growth rate in Europe is expected to become slightly negative (-0.7%). The share of the EU-27 of the of world population, 7.5% in 2005, has been declining and is projected to decline further during the 21st century, primarily due to increasing population in developing countries (Nowicki *et al.*, 2006).

Table 3.3 shows that in 2003, nearly 54% of the population of the EU-25 lived in rural areas, which cover nearly 90% of the EU area. About 46% of the population lived in the most urban regions. Almost half of the population of the EU-25 lives on only 13% of the land area.

Table 3.3. EU-25 share of population and land area in three rurality groups, 2003.

Degree of rurality	% of population	% land area
Most rural regions	20	54
Intermediate rural regions	34	33
Most urban regions	46	13
Total	100	100

Source: Nowicki et al., 2006.

3.3 Production

Europe is one of the world's largest and most productive suppliers of food and fibre. The productivity of European agriculture is generally high, in particular in Western Europe and average cereal yields in the EU countries are more than 60% higher than the world average (Olesen, 2006).

Table 3.4 provides a balance for the main agricultural products for Europe in 2005. One can conclude that the EU is self sufficient and net exporter of total cereals, dairy products and meat (Table 3.4) as well for eggs, sugar and potatoes (EC, 2006a). It has to be noted that about two third (62%) of the cereal consumption was used as feed 32% was used for food and industrial consumption, 0.8% was used for bio energy, while the remaining 6% is used for other purposes (EC, 2007h). In the case of soybean (meal), nearly 98% of the consumption is imported. For vegetable oils and fats, the EU also depends on imports though to a smaller extent. The EU is also a net importer of fruit and vegetables (EC, 2006a), but these data are not presented in Table 3.4.

Table 3.4. Production, consumption and trade for main commodities of EU-25, 2005.

Product (mio tons)	Production	Consumption	Import	Export	Net trade	Percentage net trade of consumption (%)
Cereals[1]	253.2	246.4	10.5	21	10.6	4.3
Wheat[1]	123.4	117.0	7.0	13.6	6.6	5.6
Maize[1]	47.7	49.3	2.5	2.0	-0.5	1.0
Butter[2]	2.2	1.94	0.08	0.34	0.3	15.5
Cheese[2]	8.5	8.0	0.1	0.5	0.4	5
Meat[1]	41.0	39.8	1.3	2.5	1.2	3.1
Soybean[3]	1.08	44.1	44.3	1.2	-43.07	97.7
Vegetable oils and fats[4]	10.3	16.5	7.1	0.95	-6.2	37.3

Source: [1] *EC, 2007h.*
[2] *FAPRI, 2007.*
[3] *Ista Mielke, 2007. EU-27: Soybean and soybean meal expressed in soybean equivalents.*
[4] *Fediol, 2007.*

3.4 European Union, food self-sufficiency

To create insight in self-sufficiency ratios the production of food is related to the amounts consumed. As comparison of individual food items is too elaborate, conversion of diets into generic parameters that integrate the most important items is necessary.

The food security status of people is determined based on caloric intake. The United Nations World Food Program, for instance, has defined 2000 kcal/day as a minimum caloric intake per person. With lower intakes, people are assumed malnourished. However, actual consumption rates vary considerably between nations. The dietary need is also strongly related to body mass, health condition and physical activity level. Consumption per person per year for North American diets exceeds 3200 kcal p^{-1} d^{-1}, and is 2700 kcal p^{-1} d^{-1} for African and Asian diets (Gleick, 2000).

In order to relate food production to consumption the conversion to grain equivalents is used. This simplification is justified as Goudriaan and colleagues (2001) showed that cereal crops account for 60% of global carbon fixation in agriculture, followed by oil crops (including nuts) and sugar crops for 9% each. Combined with a productivity rate, i.e. carbon fixation per area unit per year, which is at 87% of the global average fixation rate, cereals are a good representation of global food production. For calculating global food production, the grain-equivalent approach, which converts non-cereal items into grain equivalents can be reliably pursued (e.g. WRR, 1995).

In this section, a comparison is made between the actual amounts of food items produced in the EU in 2005 to a demand based on an affluent diet. An affluent diet is considered to be the upper limit of food consumption and will mostly be found in rich societies (WRR, 1995). More information on this diet is provided in Annex I. Multiplication of the dietary demand per person with the European population gives the required consumption of food items of the diet. Self-sufficiency ratios for the EU have been calculated based on these variables and the actual production as compared to the 'diet consumption". Self-sufficiency for a particular commodity is attained at a ratio above 1, while the EU would not be self-sufficient at a ratio below 1. Relevant data and self-sufficiency ratios are presented in Table 3.5.

Table 3.5. Production to consumption ratios, EU-27, 2005.

Product	Production ('000 tons)	Diet consumption[1] ('000 tons)	Actual consumption ('000 tons)	Production/ consumption diet ratio	Production/ actual consumption
Cereals	278,350	48,012	246,400 [3]	5.80 [4]	1.13
Potato	62,270	47,120		1.32	-
Vegetable	66,000	17,849		3.70	-
Veg-oil		8,389		-	-
Sugar	20,300	15,528	17,000	1.31	1.19
Fruit	38,300	30,521		1.25	-
Milk	148,900	46,763		3.18	-
Cheese	8,641	6,604	8,184	1.31	1.06
Smp[2]	962	357	847	2.69	1.14
Butter	*2,195*	*2,677*	1,993	*0.82*	1.10
Eggs		6,425	6200	-	-
Meat	42,049	40,159	41,383	1.05	1.02

[1] Consumption based on an affluent diet.
[2] SMP (skimmed milk powder).
[3] Consumption for EU-25.
[4] In 2005, 62% of the cereals (approx. 150 mio tons) used for feed, 32% (approx. 80 mio tons) directly used for food and industrial consumption, 0.8% used for bio energy, while the remaining 6% was used for other purposes.
Source: EC, 2007h.

The difference between the production and consumption of cereals, results from the use of the major part of the cereals as feed rather than as food. If the total EU-27 population in 2005 would consume an affluent diet and this would be compared with the actual production of that year, the EU-27 would be self-sufficient in most commodities. The ratio of actual production and actual consumption shows that the EU-27 is self-sufficient, with a slight production surplus of most commodities only. Both approaches to estimate the European food situation confirm that food security is well guaranteed in the EU for selected commodities.

Furthermore, governments have the ability to influence food security on the short term. Small food shortages can be resolved by using intervention stocks. Intervention stocks are stocks held by national intervention agencies in the European Union because of intervention buying of commodities subject to market price support. Intervention stocks may be released onto the internal markets if internal prices exceed intervention prices; otherwise, they may be sold on the world market with the aid of export restitutions. The agricultural outlook of the European Commission (2007h) expects a decline in cereal harvest for the years 2006 and 2007 and an expansion in domestic use. A rapid decline is expected in public stocks for those years to recover afterwards. More detailed information about stocks can be found in Annex II.

3.5 Income allocated to food

An ever-decreasing share of the household income in the EU-15 is used for food, declining from 13.2% in 1995 to some 11.6% in 2005. However, the differences between European countries and between income groups are large. The poorest first quintile of people in Portugal spends almost 30% of their income to over 12% in the Netherlands, while the richest quintile uses less than 14% in Portugal and a mere 7% in Luxembourg (Figure 3.1). While Europeans on average are not likely to be affected by rising food prices, some groups, such as poor people in Southern Europe may experience the greatest impact.

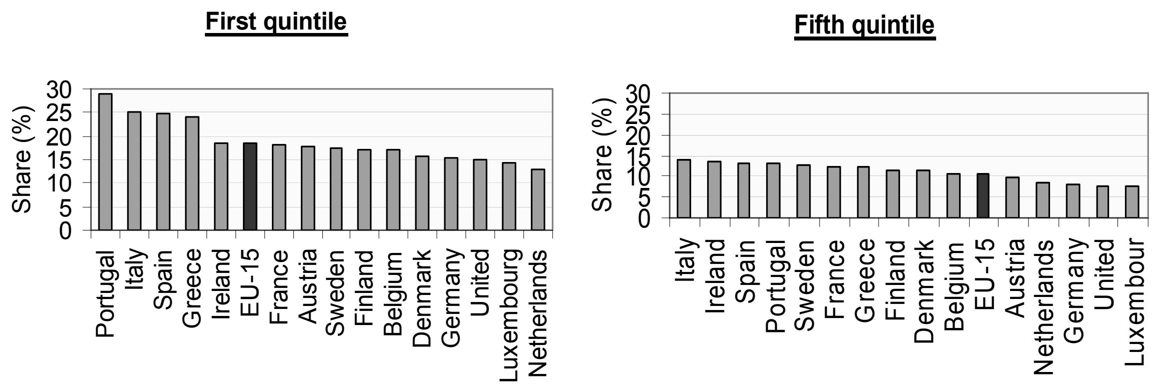


Figure 3.1. Share of income spend by the poorest and richest quintiles of European countries. Source: Mildon, 2007.

3.6 Extra EU-25 trade

Table 3.6 presents the most important trading partners, regarding countries that export to the EU-25. The table shows that imports from Brazil and Argentina account for almost 22% of total agricultural imports, which makes them the most important importers to the EU-25. Other important trading partners are NAFTA, ASEAN and ACP.

Table 3.6. Imports of agricultural products from various groups of countries to EU-25, 2005.

Group of countries	Main importers	Percentage of total imports	Products
Candidate EU countries	Turkey, Ukraine	6.8	Cereals
Mediterranean Area	Israel, Morocco	10.8	Vegetables, olive oil, potatoes
Arabian Gulf countries	-	0.4	
ASEAN	Philippines	14	Veg oils, sugar, preparations of fruit & vegetables, rice
NAFTA	USA, Canada, Mexico	12.4	Feed, rice, smp
MERCOSUR	Brazil, Argentina	21.9	Feed, beef, poultry, fruit
ACP	South Africa	14.2	Wine
Australia, New Zealand	-	6.1	Butter, sheep and goat, Cheese
Switzerland, Norway	-	4.5	Milk, cheese
India, China, Japan	-	6.2	Preparations of fruit & vegetables, rice

Source: EC, 2006a.

3.7 The agricultural sector

Looking at the EU-27, the average contribution made by agriculture to GDP was only around 2% in 2004. The economic importance of agriculture is much greater in the east and the south of the EU than in the west and the north. For example, the primary sector accounts for 17% of GDP in Romania, 12% in Bulgaria and only 0.6% in Luxembourg (EC, 2007c).

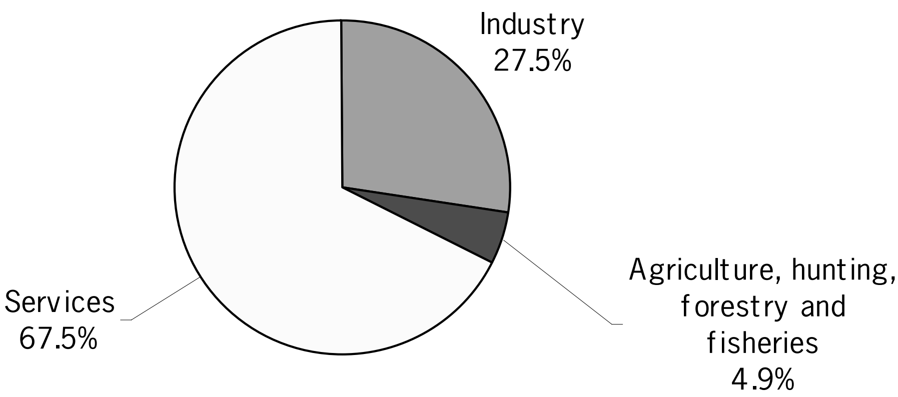


Figure 3.2. Share of economic activities in total employment in EU-25, 2005. Source: EC, 2007c.

In 2005, 4.9% of the total labour force in the EU-25 was employed in the agriculture, hunting, forestry and fisheries sector (Figure 3.2). This percentage differs between countries. For the EU-15, the percentage was only 3.7% and countries with a share of more than 10% are Greece, Latvia, Lithuania and Poland (EC, 2007c).

3.8 Land use in the EU-27

Total EU-27 territory covers 432 million hectares, of which rural areas, that comprise agricultural land and forest areas, cover nearly 90%. A total area of 184 million hectares (43%) is reported as utilised agricultural area (UAA) in 2005 (Table 3.7). The majority of the UAA (59%) is arable land, 34% and 7% are dedicated respectively to permanent grassland and permanent crops (orchards, vineyards, olive plantations). Forests and other wooded land cover approximately 160 million hectares (roughly 35% of the EU territory), of which 117 million hectares are available for wood supply (EC, 2007f). In 2005, the total set-aside land was reported to be 7 million hectares, of which 4 million hectares were obligatory set-aside.

Due to Europe's geography and climate, a very wide range of agricultural products is produced in the EU and a broad diversity in farming systems exists throughout the EU territory. Farmers in the EU cultivate a wide variety of crops: the main ones being cereals (wheat, barley, oats, rye, and maize), oilseeds (sunflower, rape), potatoes, sugar beet, olive oil and a large number of different fruits and vegetables. Farmers also raise cattle, sheep, goats, pigs and poultry.

Table 3.7. EU: area and agricultural area by land use (mio ha).

(mio ha)	EU-15	EU-25	EU-27
Total area	323.5	397.3	432.3
[1] Utilised agricultural area	130.5	164.1	183.6
Of which:			
[2] Arable land	72.6	97.1	109.4
[3] Permanent. grass-land	48.1	57.1	63.6
[4] Land under permanent crops	11.6	11.6	12.2

[1] *Utilised agricultural area (UAA): the total area used for crop production, which is exhaustively described as arable land including temporary grassing and fallow and green manure, permanent grassland, land under permanent crops, crops under glass and other utilized agricultural areas.*

[2] *Arable land: land worked regularly, generally under a system of crop rotation, which includes fallow land.*

[3] *Permanent grassland and meadow: land used permanently (for five years or more) to grow herbaceous forage crops, through cultivation or naturally and that is not included in the crop rotation on the holding; the land can be used for grazing or mowed for silage or hay.*

[4] *Permanent crops: crops not grown in rotation, other than permanent grassland, which occupy the soil for a long period and yield crops over several years.*

Source: EC, 2007f.

The structure of arable land for 2005 is shown in Figure 3.3. Over half of the arable land is cultivated under cereals, one of the most important crop groups. With a production quantity of over 287 million tonnes, the EU-27 accounted for 12.5% of the world production of all cereals including rice in 2005. France is the largest producer of cereals in the EU with about a quarter of the harvest. Wheat is the most widely grown cereal type in the EU accounting for nearly half of the production quantity in 2004. Over 60% of the domestic use of cereals in the EU-15 is animal feed and seed use. Vegetables and fruits, cover only 2% of the arable land, but are important crops in value terms. In particular, the climatic conditions in the south of Europe favour production of these food items.

The structure of arable land depends mainly on natural conditions, and there are major variations between Member States. Typical examples are the importance of permanent crops (vineyards, olive trees) in dry areas of the Mediterranean countries, or the major share of permanent pastures in mountain or rainy areas.

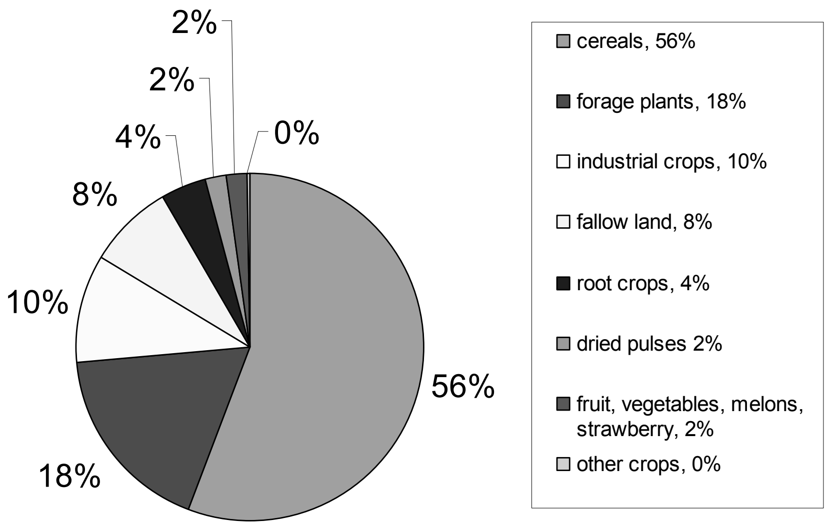


Figure 3.3. Structure of arable land, EU-27, 2005. Source: EC, 2007b.

3.9 Biodiversity

Europe has a low level of biodiversity, 50% as compared to the global figure of 70% (MNP, 2007). It has been estimated that 50% of all species in Europe depend on agricultural habitats. As, agriculture and forestry activities concern nearly two third of the European terrestrial area, changes in land use practice have widespread influence on biodiversity (EEA, 2006). Production of feedstock is mentioned as a threat to biodiversity, as set-aside lands may again be brought under production. These set-aside areas often, have a targeted biodiversity function. As any other intensively cultivated crop, bio-fuels create pressure on the aquatic environment through the leaching of nitrogen, phosphorus and pesticides, and result in increased ammonia emissions into the atmosphere as well. Increasing infrastructure and forestry will also have an impact on biodiversity.

Integration of environment into agriculture is very much about resolving conflicts between land use and the conservation of biodiversity. The EU has been adapting its policies to meet the challenge of the 2010 deadline for putting an end to loss of biodiversity (EEA, 2005b).

In 1993, the EC ratified the Convention on Biological Diversity (CBD). Specific measures haven been taken following this ratification. In 1998, it came forward with a European Community Strategy as a framework and four complementary Biodiversity Action Plans (BAP's), including a specific BAP for agriculture. The 6th Environmental Action Plan (2002-2012) gives implementation of the CBD with emphasis on (1) climate change, (2) nature and biodiversity (3) environment and health and quality of life, (4) natural resources and waste. Under the Natura 2000 network, 18% of Europe's land is designated as protected areas, which will contribute to securing the health and diversity of its ecosystems. However Europe's landscapes are undergoing widespread and potentially irreversible changes, which have impact on both species and ecosystem functioning.

Despite protection policies, many species remain threatened, including 42% of native mammals, 15% of birds, 45% of butterflies, 30% of amphibians, 45% of reptiles and 52% of fresh water fish (Nowicki *et al.*, 2006).

4. Future scenarios

4.1 Introduction to trade liberalization

In this chapter, the effects of trade liberalization on agricultural trade are studied. The focus is to analyse the shifts in trade patterns and to explore whether the EU will remain self-sufficient after a change in trade policy. From the many different models that estimate the effects of trade liberalization, four economic models have been selected and are compared. This Chapter is concluded with an analysis of a study conducted by Nowicki *et al.* (2006), 'Scenar 2020, a scenario study on agriculture and the rural world'. This study includes a biophysical model in the analysis where as the four trade models only include economic variables.

Introduction of the four models

This section compares four economic models that focus on the effect of trade liberalization. For most conclusions, the models agree on the effects. The issues on which the models disagree will be elaborated. The following four models were used:

- FAPRI model, calculating effects of the Doha round, referred to as FAPRI (FAPRI, 2002)
- a GTAP based model from ENAPRI, focusing on EU trade, referred to as ENAPRI (Yu and Jensen, 2005)
- a GTAP based model from FAO, focusing on world trade, referred to as FAO-GTAP (Conforti and Salvatici, 2004)
- IMPACT model by IFPRI, referred to as IMPACT (Rosegrant *et al.*, 2001).

Most models provide more than one trade liberalization scenario. Because all the models provide a full trade liberalization, here the comparison is made by looking into the full trade liberalization scenario. This scenario also represents the most drastic changes possible in regional food availability due to international trade.
The four models are economic models. This means that demand and supply are calculated in most of the cases by general equilibrium models. Projections of the models are based on assumptions regarding macro-economic conditions, international agricultural and trade policy and international market developments. The FAPRI and the ENAPRI models deal with total trade volumes of the EU, the IMPACT and the FAO-GTAP model do not look at total trade volumes, but at trade volumes per product. It has to be noted that only the ENAPRI model defines Europe as the EU-25, while the rest of the models focus on the EU-15. However, these differences will not influence the results significantly, as the role of Eastern European countries on the global positioning of European agricultural at the short and medium term will be small. Table 4.1 provides an overview of the different assumptions for the four models.

Table 4.1. Overview of main differences of the four models used in the analysis.

Model	Database	Focus year	Definition of Europe	Trade	Focus
FAPRI (2002)	FAPRI modelling system	2002 and 2011	EU-15	Volumes	Global trade for main exporters and importers
ENAPRI (2005)	GTAP	2013	EU-25	Cash flows	EU-25 trade
FAO-GTAP (2004)	GTAP	2013	EU-15	Cash flows	Global trade
IMPACT (2001)	IFPRI modelling system	2020	EU-15	Volumes	Global trade and developing countries

As the models date from 2005 and before, the effects of climate change and biofuels on future production and trade have not been taken into account in these projections. It is possible that biofuels will affect trade in the future.

4.2 Trade volumes for the European Union

The FAPRI model projects an increase in trade volume for the EU-15 due to trade liberalization. Figure 4.1 shows that the trade volume for most products in the chart will grow compared to the baseline level. Especially for wheat, an increase in exports is expected.

The reference baseline of the FAPRI model is the baseline established for the FAPRI 2002 World Agricultural Outlook (FAPRI, 2002). This baseline was prepared in January 2002. Therefore, the projection of 2002 in the graph is a projection for the end of the year. Figure 4.1 shows that the effect of trade liberalization for the year 2002 for wheat is a growth in wheat exports of 5%. For the year 2011, a growth in wheat exports of 29.9% is expected due to trade liberalization, compared to the baseline level of 2011. Remarkable numbers are those of beef exports. In the year 2002 the EU-15 is a small exporter of beef. Trade liberalization can cause a decline in exports of 80% in that year. For the year 2011, exports can decline with 156%, which will cause the EU-15 to become a small beef importer caused by trade liberalization. Price changes on the world market are the main cause of shifts in trade patterns. Section 4.3. on trade per commodity will elaborate on changing trade patterns and their causes.

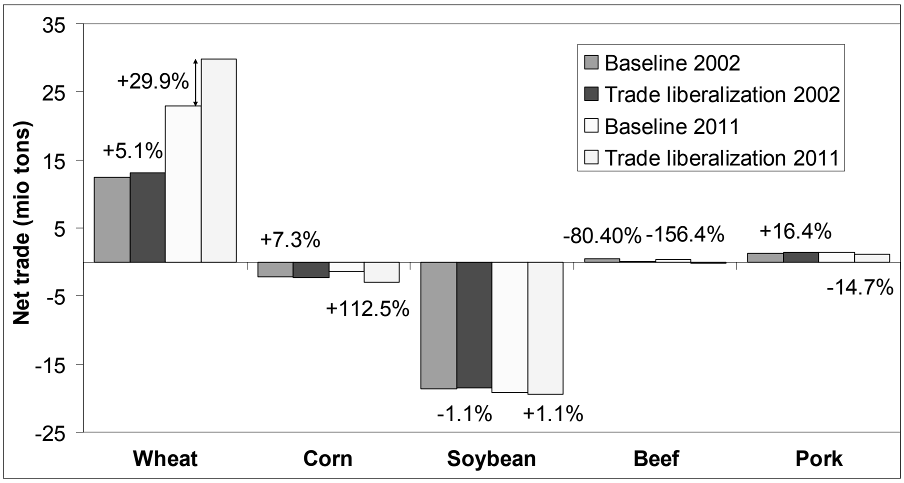


Figure 4.1. Net trade in volume and percentage change due to full trade liberalization, EU-15. Source: FAPRI, 2002.

The ENAPRI model divides trade volumes into intra-EU trade (EU-25) and extra-EU trade. In the trade liberalization scenario, Yu and Jensen (2005) expect that intra-EU trade flows will decrease and extra EU-trade flows will increase. This is mostly because lowering the EU's common external tariff will lead to more imports from outside the EU. These extra imports will divert some of the intra-EU trade to external trading partners. The new Member States would generally lose part of their exports shares in the internal EU market to external competitors, as will be especially the case for bovine meat and dairy products. They will not be able to compete against the low prices on the external market, will loose their role of large exporters to the internal EU-market and will eventually be crowded out.

Extra EU-trade is expected to increase, but the increase will not be symmetric. Imports into the EU would increase more than exports, on balance, the EU would either experience enlarged trade deficits or reduced trade surpluses in many agricultural and food products, most notably in bovine meats and dairy products. Figure 4.2 shows extra EU-25 trade in 2013. It compares the baseline level with the effect that trade liberalization has on net trade in that year.

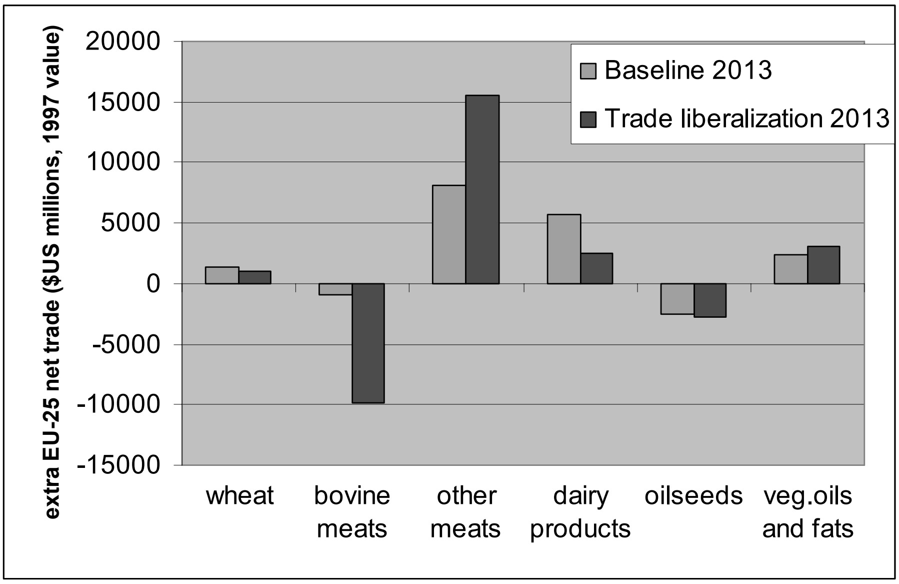


Figure 4.2. Effect of trade liberalization on extra EU-25 trade ($US millions, 1997 value). Source: Yu and Jensen, 2005.

ENAPRI provides trade flows in US dollars for different commodities. Figure 4.2 shows the effect of trade liberalization on extra EU-25 trade for selected commodities. As can be seen, imports will increase due to trade liberalization. In the case of wheat, bovine meats, dairy products and oilseeds, the increase in imports will be bigger than the increase in exports.

4.3 Global trade flows per product

In this section, changes in trade flows per product are discussed for all four models. The four models generally agree on future projections on most commodities. As the models consider different commodities in their analysis, the outcomes of the models are dealt with per commodity. The outcomes on which the models do not agree are specifically mentioned.

Cereals, excluding rice: (IMPACT and FAO-GTAP) Trade liberalization would improve the global trade position of Australia, Canada and Argentina. The US and the EU will experience a decrease in net exports. According to the FAO-GTAP model, the EU will be an importer of cereals in the year 2013. The IMPACT model disagrees with this fact and claims that although net exports will decline to some degree, Europe will remain a net exporter. Both models show that China, Japan and Korea will have increased imports of cereals due to trade liberalization.

Wheat: (FAPRI and ENAPRI analyses). The world price for wheat will go up with 4.8% in the liberalization scenario of FAPRI, therefore the EU will produce and export more wheat. ENAPRI agrees on this, imports will go up as well as exports.

Maize: Only the FAPRI model defines corn in the analysis. Due to trade liberalization, and despite lower numbers of animals to be fed and a higher world price, EU imports of maize will increase because of a much lower return for farmers. Current policies sustain EU maize prices at a greater premium compared to world prices than EU prices for other grains. The average annual increase in EU maize imports is 1.7 million tons under the full trade scenario.

Oilseeds: There will be increasing exports from Argentina, Brazil and Canada due to trade liberalization. Also increases in imports to China will occur. The trade balance for oilseeds for the EU will not change significantly.

Vegetable oils: The effects are somewhat similar to oilseeds although Indonesia and Malaysia appear as major exporters, given their prominent role of palm (kernel) oil production. There will be increases in imports to India and the Middle East. Once again, the position of Europe will not change significantly; Europe will remain a net importer.

Soybean: According to FAPRI, the soybean world price will increase in the first 5 years rapidly and decrease in later years. Soybean world production remains virtually unchanged but there will be shifts in production and processing

locations. Argentina and Brazil will expand their areas for soy. Natural importers with tariffs to protect domestic production, such as China, Japan and India will reduce their production and increasingly engage in crushing of seeds. ENAPRI supports the fact that prices of soybeans will fall significantly in countries such as India, China and Japan. The demand for soy in the EU will decrease first because of higher prices and will increase later on. IMPACT also claims that Europe will remain a net importer of soybeans.
Total meat: IMPACT does not make a distinction between beef and pork. It indicates that net exports of meat from Europe will decline, but Europe will remain a net exporter.
ENAPRI defines beef and 'other meats'. For 'other meats' exports will increase significantly. This differs from the FAPRI analyses that project Europe to loose market share on the pork market.
Beef: Big winners in the beef market caused by liberalization are exporters like the US, Argentina and Australia. According to FAPRI, the EU-15 loses significant market share, with a reversal of trade pattern from exporter to major importer (see Figure 4.1) starting in 2004 for the trade liberalization scheme. ENAPRI also indicates that the EU-25 will become a net importer for beef in 2013.
Pork: Exports of pork will increase in Brazil, Canada and the US. These countries gain market share in this sector. The EU will loose market share, according to FAPRI. Figure 4.1 shows that pork exports volume will increase with 16% in 2002 and will decrease with 15% in 2011 due to trade liberalization.

4.4 Gains and losses

ENAPRI does not focus on trading partners. It defines EU trade with the US and the rest of the world, and therefore, does not provide insight on the impact of changing world trade patterns on the EU. Looking at the total effect for Europe, ENAPRI projects that total economic welfare in the EU will improve due to trade liberalization, although some new member states will suffer terms-of-trade losses.

IMPACT looks at two aspects of gains from trade liberalization, total net benefits of trade liberalization and the value of agricultural production, both expressed in dollars. According to IMPACT, both developed and developing regions benefit, gaining $14.2 billion and $21.5 billion respectively. Although these gains are not significant in GDP, in many regions they are significant in relation to the total value of agricultural production. In proportion to their agricultural sectors, Japan and South Korea will experience the biggest value increase of their agricultural sector due to price changes. The biggest single gainer is Sub-Saharan Africa, at $4.4 billion, or 10 percent of the 2020 value of production of the commodities included in IMPACT. This is partly because African farmers would face less competition from subsidized exports from Europe and other developed countries under trade liberalization. However, a significant part is also due to the removal of taxes that many African governments impose on food production and consumption.

The FAO-GTAP model distinguishes two possible gains due to trade liberalization, allocative efficiency and terms of trade. Allocative efficiency is the efficiency gain with respect to resource allocation. In the model, effects on return to land and return to labour are calculated. Efficiency gains in resources can be accomplished by changing the agricultural production mix (e.g. by producing commodities that are biophysically and economically the most profitable), or by moving labour and capital inside or outside the primary sector. Terms of trade changes appear as a direct consequence of a more competitive international environment, in which comparative advantages in the different agricultural sectors play an increased role in shaping agricultural trade and prices. This being the case, losses in terms of trade may easily arise in countries with less diversified economies, where there are fewer possibilities of recovering international competitiveness in different production sectors, when the support to those activities which are now protected are reduced. In other words, this result tells that relatively poor economies may have less comparative advantages to resort to if protection is reduced in agriculture, as they have fewer activities other than their present agricultural sectors.

In general, import tariffs and exports subsidy reductions bring about an improvement in resource allocation in virtually all countries. However, changes in relative prices are a disadvantage for several economies, so that in the end they are worse off with than without trade liberalization. This is the case for the least developed countries in North and South Africa, and some Asian countries. On balance, most OECD countries are better off after trade

liberalization, especially countries like Australia and New Zealand. Furthermore, especially Argentina and Brazil will be better off after trade liberalization. This aspect of the FAO-GTAP model is a major difference with the IMPACT model, where the conclusion is that African countries will gain from trade liberalization. The difference is in the effect of terms of trade for Africa. IMPACT expects that Africa will have a better competitive position on the world market after trade liberalization while FAO-GTAP expects that this will not be the case.
The FAPRI model agrees with the FAO-GTAP model with respect to the gain of the OECD countries. FAPRI concludes that a significant expansion of production will occur in countries that are natural exporters, such as Brazil, Argentina and Australia. As FAPRI does not look at the effect of trade liberalization on the least developed countries, it cannot contribute to the discussion of the effect of liberalization on Africa.

4.5 Projections for the EU

Although the models may disagree on what happens to Africa, they all show the same pattern for the EU.

According to the FAO-GTAP model, the EU will loose due to terms of trade but will gain in allocative efficiency. On balance, the effect will not be significant so that the position of the EU will not change due to trade liberalization. ENAPRI concludes that the EU-25 will remain an exporter on balance, although exports will decline and imports will grow. Looking at the total effect, one can conclude that the EU-25 will remain self-sufficient for most commodities, even though the gap between production and demand will decrease and net exports will reduce, compared to the baseline level for 2013 where no trade liberalization has occurred. Comparable results are reported by FAPRI that Europe will loose market share in most commodities due to trade liberalization. These losses will not be significant enough to change position of the EU as a net exporter.

4.6 Scenar 2020

This section explores the future of European agricultural markets, as described in the study 'Scenar 2020, a scenario study on agriculture and the rural world' by Nowicki *et al.* (2006). Scenar 2020 has a reference scenario based on analyses of trends from 1990 to 2005 and these trends are projected forward to 2020. Under the assumption that agricultural, rural and environmental policies are able to inflect these trends, different policy scenarios are examined. Two counterfactual scenarios to the baseline scenario are defined: regionalization and liberalization.

Methodology of Scenar 2020

Scenar 2020 starts with the identification of drivers and corresponding trends on the global, national and regional level, and their likely projection into the future. Based on this data, a baseline scenario is established that projects the impact of these trends on developments in the rural and the agricultural economy. Two other scenarios were established to project the impact of different policy frameworks that differ in degree of support to the agricultural sector. The following section provides on overview of the assumptions divided into exogenous and policy related drivers for the three scenarios.

Assumptions on exogenous and endogenous drivers for the three scenarios.

The following assumptions are the same for each scenario:
Demographics: Major population trends as observed in the past.
Macro-economic growth: Moderate growth as seen in the past. Increasing trend for labour market liberalization.
Consumer preferences: More demand for value added and increasing absolute spending per capita: consumption of organic food as observed in the past.
Agri-technology: Continuous trends in cost saving technical progress; biotechnology; GMO.
World Markets: Trends in agric-markets as observed in OECD/FAPRI studies, adjusted for differences in macro-economic and population growth as well as for changes in consumer preferences and agri-technology.

Table 4.2 presents the policy related assumptions that are different for the three scenarios.

Table 4.2. Assumptions on the policy related drivers.

Scenarios	CAP			*Biofuels*	*Enlargement*	*WTO and other international agreements*	*Environmental policies on agriculture*
	Market policies	*Direct payments*	*Rural development polices*				
Baseline	Balanced market i.e. keeping public stocks at 1 to 2% of domestic consumption	Financial discipline and 25% modulation	Taking into account the new financial perspectives	Continuation of EU Biofuels Strategy	EU-27	EU offer	Continuation of existing environmental legislation
Regionalization	Existing CAP	Financial discipline and 5% modulation	Significant increase in funding of rural development through all EAFRD axes	High policy support to produce biofuels	Baseline	No WTO agreement/ bilateral approach	Reinforcement of environmental legislation
Liberalization	No internal support policies	Removing direct agricultural payments	Rural development provisions decrease	No per hectare subsidies for biofuels	Baseline	Removing import tariffs	Partial withdrawal of environmental legislation

Source: Nowicki et al., 2006.

After formulating the drivers, the likely effects of assumptions on agricultural markets and the rural economy were simulated. In this part, general and partial equilibrium models were connected to quantitative data and regional/territorial models. The economic models that were used are LEITAP, ESIM and CAPRI of which LEITAP is a general economic model and ESIM and CAPRI are partial equilibrium models. The land-use simulation model that was used is CLUE-s. Indicators of the rural economy were generated at the global, national and at a sub-national territorial level (a combination of NUTS3/2 and HARM2 regions). A series of interdependent factors was analyzed in each area, in some cases requiring several iterations of simulation.

Scenar 2020 looks at the agricultural economy as a whole, unlike most trade-scenario models. Taking into account all kinds of structural changes in the agricultural markets, it provides a very complete concept of what the future might bring. The strong factor of this model is that it combines different economic models with land-use models, which gives it a comprehensive perspective. Scenar 2020 focuses on the EU-25 while the world economy is also taken into account.

Results of Scenar 2020

Conclusions of the Scenar 2020 study (*Nowicki et al., 2006*) describe changes in the agricultural sector due to different policies but it also describes changes that will occur, without any policy changes. For example, rural areas will undergo developments (e.g. changes in farm size and number of farms) and will change over time. Structural adjustments, like urbanization will be a driver for changes in land use. Furthermore, the agricultural areas in the EU-25 are very diverse and differences between the EU-10 countries and EU-15 countries are significant, with the share in agricultural employment in the EU-10 being 12% and in the EU-15 only 4%, for instance. Therefore, developments over time in these regions will have a different impact. The reduction in employment in the agricultural sector will be more significant in the EU-10 countries than in the EU-15.

According to Nowicki *et al.* (2006), population growth rate will no longer be the major driver of agricultural demand. Income growth, urbanization and dietary diversification not only lead to additional demand but also to changes in the composition of food consumption, with a fast growing share of animal products. All together, the growth rate in agricultural markets will slow down.

Another structural change that will occur in the long term with or without policy changes is the declining share of agriculture and industry in GDP in Europe. The agricultural sector will be of less importance for the economy; less people will work in this sector and the number of farm units will decrease.

Some key trends in the EU commodity markets are:

- Increasing segmentation and therefore, regional specialization within the EU, of the EU market will take place due to growing importance of transportation costs, which is enhanced by trade liberalization and enlargement of the EU.
- Production of cereals will increase but technical productivity will increase as well, therefore area requirements will diminish.
- The livestock market will undergo restructuring. Trade and consumption preferences will cause a decline in beef consumption and production. The cattle herd will shrink due to an increase in milk output productivity, which is also reflected in the reduction of fodder production, reinforced by liberalization.

Impact of different policies

Reduction of import tariffs and export subsidies has more impact on production than the reduction of domestic income support. On the other hand, reducing domestic income support has a larger impact on farm income than the reduction of border support. This supports the view that reducing income support is less production distorting than reducing border support (see Table 4.3).

The process of liberalization has a greater impact on agricultural income than agricultural production and land use, it pressures farms to decrease the amount of labour and increase the farm size. As described above, it depends on whether liberalization is defined as reduced income subsidies or the removing of border support. The most obvious effect of liberalization will be the augmentation of the rate of decline in the number of farms in the EU and, to a lesser extent the area of land under agriculture. Under liberalization, overall production will decrease, especially for beef and poultry. Some sub-sectors will increase, like cheese and pork. The regionalisation scenario shows an, occasionally strong, increase of production in all sub-sectors. An overview of the differences in impact on production and farms due to the removal of border support and the removal of farm income subsidies is given in Table 4.3.

Table 4.3. Effect of the removal of border support and income subsidies on production and number of farms in EU-25 under different world market price scenarios.

Border Support	Income subsidies	Price of world market relative to domestic market	Effect on production	Effect on number of farms	Explanation
Sustained	Sustained	Low	baseline	baseline	With border protection, world market prices do not influence domestic prices.
		High	baseline	baseline	With border protection, world market prices do not influence domestic prices.
Removed	**Removed**	**Low**	**- -**	**- -**	**Low price reduces production and reduces the number of farms.**
		High	+	-	A high price increases production for big farms, but without income subsidies, some small farms cannot survive.
Removed	Sustained	Low	-	+	Low prices only affect production of all farms, but do not affect the number of farms due to the remaining income support.
		High	++	++	High prices increase production while the number of farms doesn't change.
Sustained	Removed	Low	+/-	-	Because domestic markets determine production, world market prices do not influence production. Since the borders are closed, small farms will have to compete internally with big farms and without income subsidies some small farms cannot survive.
		High	+/-	-	Same effect as the previous one.

When looking at the most negative scenario for Europe's farmers, the removal of border support and income subsidies under a low world market price, Scenar predicts a certain degree of specialization in Europe. First, overall production will decrease slightly since prices negatively effect the motivation to produce products for most farmers. Second, small farms will not be able to survive because they do not receive income support and will not get high prices for their products. Mostly big farms will be able to survive under these conditions. Under this scenario, it is likely that there will be a shift of production to the areas that can best compete on the world market. Especially farms in Southern and Eastern Europe will not be able to compete under this scenario and their number will decrease. On the other hand, the Northern and Western parts of Europe will have an advantage. In these areas, soil and weather conditions are more favourable, infrastructure and institutional arrangements are more optimal so that economies of scale can be better exploited. ENAPRI supports this and claims that countries in Eastern Europe will not be able to compete and will loose their current trade position, where the EU-15 will successfully compete on the global market. Therefore, it can be concluded that the main part of agricultural production will be in the Northern and Western parts of Europe due to the removal of border support and income subsidies.

However, there are some drawbacks to this conclusion. First, these scenarios do not always take into account the developments, which have been set into motion in Eastern Europe. There are efficiency improvements to be gained in Eastern Europe that will benefit their position on the global market. Technological and scale improvements for example might bear their fruits on a larger time horizon, where Scenar does not look further than the year 2020. Second, the effects of bio-fuels on agricultural production bring some uncertainty. Production of feedstock for bio-energy might create opportunities (a new market) for farmers in Eastern Europe, which will prevent abandonment of agricultural areas. Last, the chances are slim that low value commodities will be transported to Eastern Europe, as transport costs will exceed the profits of such products. In this case, it is expected that Eastern Europe will remain a producer of bulk products like wheat.

5. Agricultural production potential and effects of climate change

This chapter describes first the biophysical model as designed by WRR (1995) in order to calculate the potential agricultural production of the EU-27. This production is compared to the present and projected consumption. The second section deals with the Global Agro-ecological Assessment for Agriculture in the 21st Century, of IIASA/ FAO (Fischer *et al.*, 2001). In this study, the biophysical limitations and production potential of major food and fibre crops are evaluated. The last section focuses on the impact of climate change on agricultural production with special emphasis on the EU.

5.1 WRR model

Introduction

The study 'Sustained risks: a lasting phenomenon' by the Netherlands Scientific Group for Government Policy (WRR, 1995) is an explorative study to determine the upper limits of global food production. According to this study, while there is an upper limit to food production, global agriculture is still far from it. Global food production potential was estimated to suffice for securing food availability for the world population in 2040.

The WRR study defines three different diets, the vegetarian diet, the moderate diet and the affluent diet, all of which are considered healthy but are different in protein and energy intake and, consequently, in the amount of plant biomass required (see for a more elaborate description section 3.4, Annex I and Luyten, 1995). To relate food demand to food production, diets have been converted into equivalents of amounts of grain. Grain equivalents refer to the amount of cereals needed as a raw material for the food consumed, plus the 'opportunity cost' to grow food that cannot be produced via grain.

Two alternative agricultural production systems are considered: a high external input (HEI) system and a low external input system (LEI). The HEI-system requires a high degree of mechanization and use of fertilizer and biocides. In the LEI -system, agriculture is practiced at a lower level of intensity without the use of agrochemicals. Both systems assume 'best technological means', implying that production systems make best use of production ecological principles to limit adverse environmental effects. The differences between the production systems were reflected in terms of trade-offs, e.g. related to land requirement, environmental load and total food production potential.

Results

The absolute maximum global food production is the production (from grassland and cropland) if potential yields can be attained everywhere and if all cropping land can be irrigated. This would be 84 and 31 billion ton Grain Equivalents for the HEI and LEI system respectively. However, since water availability is limited, the attainable maximum global food production is somewhat lower, 72 and 30 billion ton for HEI and LEI respectively. Global production in 1995 was 4 billion tons indicating therefore that the potential is 10 to 20 times higher.

There are differences among regions when it comes to production potential. South America for example has a huge potential for food and feed production, which results from a very large area of suitable soils, a favourable climate and abundant water. However, the potential includes production on soils that are currently covered with rain forests. On the other side, Northern, Southern and Western Africa have low potentials due to poor soils and lack of water resources, while potentials are high again for Central Africa with high rainfall and large areas of rain forests.

Some calculations are made for the production potential of the EU-27. First, actual consumption numbers and diet consumption for EU-27 are converted into grain equivalents. Actual consumption corresponds well with the diet consumption. However, there is a difference because cereals cause a double count. When converting to grain equivalents, feed is calculated in both cereals and meat, which is now counted double. The difference between actual consumption and diet consumption can be found in Section 3.4.

The changes in the amount of grain equivalents needed for the diet of the EU-27 population are due to changes in population growth (Figure 5.1). An (almost invisible in the Figure) increase in population growth and a decreases after the year 2020 (EC, 2007f), project an almost constant demand for food. For comparison, the projection of the IMPACT model of consumption for the year 2020 is also converted into grain equivalents. The potential grain equivalent production is given for the HEI and LEI system. Figure 5.1 shows the results of this conversion. It shows that the different consumption calculations will not exceed production potential under the HEI nor under the LEI production systems. This demonstrates a certain degree of self-sufficiency for the EU now and in the future. Hence, the EU has the potential to feed other countries.

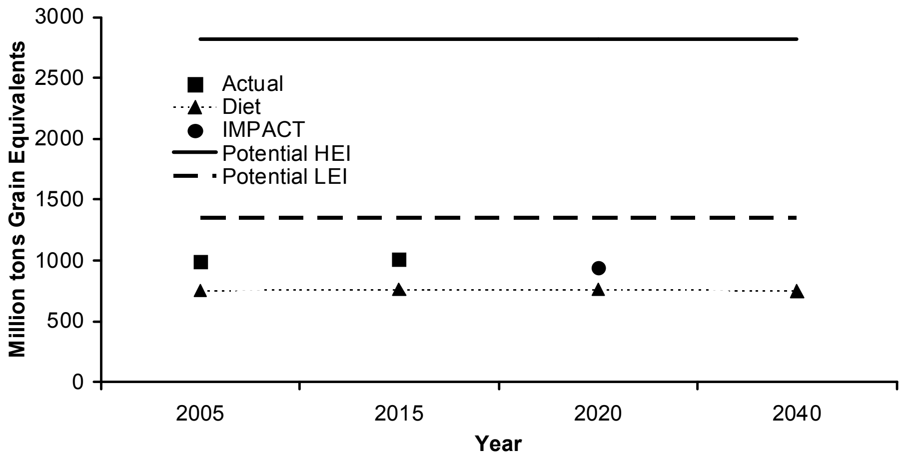


Figure 5.1. Consumption and production potential in grain equivalents EU-27 (See text for further explanation).

5.2 IIASA/FAO model

Introduction

The Food and Agriculture Organisation of the United Nations (FAO) in collaboration with the International Institute for Applied System Analysis (IIASA) has developed the Agro-ecological Zones (AEZ) methodology and a worldwide spatial land resource database. This database has enabled them to evaluate the biophysical limitations and production potential of major food and fibre crops under various levels of inputs and management conditions.
A scenario approach based on a range of assumptions related to changes in the future provides a wide range of outcomes. Assumptions are based on both ecological factors (e.g. climate change) and socio-economic factors (e.g. development of world population), thus providing a spatial and integrated ecological-economic planning approach to sustainable agricultural development. However, since farming technology and input assumptions are based on present-day knowledge, research and scientific developments in the future could alter projection outcomes. In this section, a summary of the key findings of this analysis is presented.

Climate, soil, and terrain limitations to crop production

More than three-quarters (10.5 billion ha of land) of the global land surface (totalling 13.4 billion ha of land), excluding Antarctica, is unsuitable for crop cultivation, suffering severe constraints of being too cold (13%), too dry (27%), or too steep (12%), or having poor soils (40%). In addition, multiple constraints occur in some locations.

Climate change is likely to have both positive and negative effects on extent and productivity of arable land resources. In some areas, prevailing constraints may be somewhat relieved by climate change, thus increasing the arable land resources. In other areas, however, currently cultivated land may become unsuitable for agricultural production.

Land with cultivation potential

Cultivable land in developing countries totals about 1.8 billion hectares (ha), of which some 20% is only moderately suitable for crop cultivation (Table 5.1). At present, over 900 million ha of this land is under cultivation. The corresponding figures for the developed countries are 765 million ha of cultivable land, 35% of which is only moderately suitable and 595 million ha under cultivation at present.

Over 80% of potentially cultivable land reserves are located in just two regions, South America and sub-Saharan Africa. In contrast, most of the cultivable land in Asia is already in use, and the population increase expected by 2050 will reduce per capita availability of cultivable land to below the critical level of 0.1 ha per person.

Table 5.1. Rain-fed cultivated land in 1994-1996 and rain fed cultivation potential for major food and fiber crops, mixed inputs (million ha).

Region	Total land	Cultivated land 1994-1006		Land with cultivation potential				Settlements and infra-structure
				VS+S		VS+S+MS		
		Rain-Fed	Irrigated	Total	In forest ecosystems	Total	In forest ecosystems	
Oceania	850	50	3					1
Asia	3,113	376	180	406	36	516	47	83
Africa	2,990	185	12	767	114	939	132	21
Europe & Russia	2,259	289	25	328	61	511	97	21
South & Central America	2,049	141	18	697	281	858	346	16
North America	2,138	203	22	266	96	384	135	9
Developing countries	8,171	702	208	1,872	433	2,313	527	124
Developed countries	5,228	543	53	669	168	1,012	247	33
World	13,400	1,245	260	2,541	601	3,325	774	156

Note: VS=very suitable; S=suitable; MS=moderately suitable.
Source: Fischer et al., 2001.

In Asia, Europe and Russia, the rain-fed land that is currently cultivated amounts to about 90% of the potential very suitable and suitable land. Hence, there is little room for agricultural extensification. In the case of North America, some 75% of the very suitable and suitable land is currently under cultivation. By contrast, Africa and Latin America are estimated to have some 1.1 billion ha of land in excess of currently cultivated land; of this, about 36% is in forest ecosystems. In these two regions, there is clearly scope for further expansion of agricultural land, even assuming that current forests are maintained.

Potential for expansion of cultivated land

The results of IIASA/FAO indicate that there is still a significant potential for expansion of cultivated land in Africa and South and Central America. In other regions, this potential is either very limited, as in Asia, or is unlikely to be used for agriculture in the future, as in Europe and Russia, North America and Oceania. In both the developed and developing worlds, some 1.4 billion ha constitute forest ecosystems, of which 12% and 30%, respectively, have good potential for crop cultivation. However, cultivation in these forest areas would result in adverse environmental consequences.

Yield and production potential

Intensification of agriculture will be the most likely means to meet food needs for a world population of some 9 billion people in 2050. The study asserts that enough food can be produced on currently cultivated land if sustainable management and adequate inputs are applied. However, this will require substantial improvements of socioeconomic conditions in many developing countries to enable access to inputs and technology. The yield attained in the long term, when accounting for fallow period requirements, are well below the estimated short-term maximum attainable yields. On average, long-term yields (for wheat, rice and maize) are 10%, 20% and 55% lower than maximum attainable yields at high, intermediate, and low levels of inputs respectively.

Climate change and food production

According to the results of IIASA/FAO, the projected climate change will result in mixed and geographically varying impacts on crop production. Developed countries substantially gain production potential, while many developing countries lose. In some 40 poor developing countries with a combined current population of 2 billion, including 450 million undernourished people, production losses due to climate change may drastically increase the number of undernourished, severely hindering progress against poverty and food insecurity. The impact of climate change will be elaborated in the next section of this report.

5.3 Climate change, global trends

Background

Climate is changing, influenced by increased atmospheric concentrations of the three main greenhouse gases (GHG), carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). Along with the combustion of fossil fuels, land use change is a primary source of anthropogenic GHG emissions. Without drastic changes in the current production and consumption patterns, the trend in global emissions of greenhouse gases will continue. By 2100 global surface temperature is projected to warm by 1.1 to 6.4 ^{0}C, and global sea level to rise by 18 to 59 cm in relation to the 1990 levels (IPCC, 2007). Table 5.2 presents the global average surface warming and sea level rise at the end of the 21st century for the different SRES scenarios.

Table 5.2. Projected global averaged surface warming and sea level rise at the end of the 21st century.

	Temperature change (^{0}C at 2090-2099 relative to 1980-1999) a, d		Sea level rise (m at 2090-2099 relative to 1980-1999)
Case	Best estimate	*Likely* range	Model-based range excluding future rapid dynamical changes in ice flow
Constant year 2000 concentrations b	0.6	0.3 - 0.9	Not available
B1 scenario	1.8	1.1 - 2.9	0.18 - 0.38
A1T scenario	2.4	1.4 - 3.8	0.20 - 0.45
B2 scenario	2.4	1.4 - 3.8	0.20 - 0.43
A1B scenario	2.8	1.7 - 4.4	0.21 - 0.48
A2 scenario	3.4	2.0 - 5.4	0.23 - 0.51
A1FI scenario	4.0	2.4 - 6.4	0.26 - 0.59

Notes:

a *Temperatures are best estimates and likely uncertainty ranges from a hierarchy of models of varying complexity as well as observational constraints.*

b *Year 2000 constant composition is derived from Atmosphere-Ocean General Circulation Models (AOGCMs) only.*

c *All scenarios above are six SRES marker scenarios. Approximate CO2-eq concentrations corresponding to the computed radiative forcing due to anthropogenic GHGs and aerosols in 2100 (see p. 823 of the WGI TAR) for the SRES B1, AIT, B2, A1B, A2 and A1FI illustrative marker scenarios are about 600, 700, 800, 850, 1250 and 1550 ppm, respectively.*

d *Temperature changes are expressed as the difference from the period 1980-1999. To express the change relative to the period 1850-1899 add 0.5 ^{0}C.*

Source: IPCC, 2007.

The Intergovernmental Panel on Climate Change (IPCC) has developed scenarios to make projections for changes to the global climate to 2100. These projections are based on simulations with global climate models (GCM) for the IPCC emission scenarios SRES (Special Report on Emission Scenarios), which describe very different socio economic futures. Figure 5.2 shows how the SRES scenarios have been derived from four different categories: A1 world market, A2: provincial enterprise, B1: global sustainability, B2: local sustainability. These categories follow from two orthogonal dimensions, representing social values, ranging from consumerist to conservationist and level of governance, ranging from local to global.

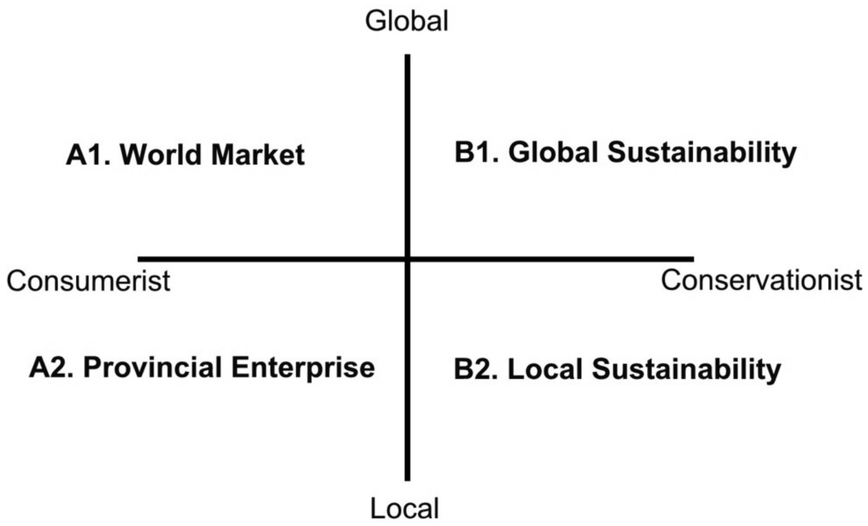


Figure 5.2. SRES scenarios as adapted by Olesen. Source: Olesen, 2006.

The characteristics of the storylines for the different scenarios are presented in Table 5.3 (IPCC, 2007).

Table 5.3. Four SRES storylines and their main characteristics.

World	A1 storyline	A2 storyline	B1 storyline	B2 storyline
	Market-oriented	Differentiated	Convergent	Local solutions
Economy	Fastest per capita growth	Regionally oriented: lowest per capita growth	Service and information based; lower growth than A1	Intermediate growth
Population	2050 peak, then decline	Continuously increasing	Same as A1	Continuously increasing at a lower rate than A2
Governance	Strong regional interactions; income convergence	Self-reliance with preservation of local identities	Global solutions to economic, social and environmental sustainability	Local and regional solutions to environmental protection and social equity
Technology	Three scenarios groups: A1F1: fossil intensive A1T: non-fossil energy sources A1B: balanced across all sources	Slowest and most fragmented development	Clean and resource-efficient	More rapid than A2; less rapid, more diverse than A1/B1

Source: IPCC, 2007.

Most of the recent global climate model (GCM) experiment results are based on coupled ocean-atmosphere models (AO-GCM). The main modelling uncertainties stem from the contrasting behaviour of different climate models in their simulation of global and regional climate change.

Mitigation of climate change

Global recognition of the significance of combating climate change, lead to the establishment of the United Nations Framework Convention on Climate Change (UNFCCC) to initiate actions for reducing GHG emissions and hence mitigating the effects of global climate change (EEA, 2005a).

The Kyoto Protocol under the UNFCCC commits industrialized signatory countries to reduce their future annual emissions to a level below that in 1990. The EU-15 has a common reduction target of 8%, to be attained in the period 2008-2012. The important significance of the climate change conference of the UNFCCC held in Bali, December 2007, is that 187 countries agreed to launch negotiations towards a crucial and strengthened international climate change deal. The decision includes a clear agenda for the key issues to be negotiated up to 2009. These are: 1) action for adapting to the negative consequences of climate change, such as droughts and floods, 2) ways to reduce greenhouse gas emissions, and 3) ways to widely deploy climate-friendly technologies and financing both adaptation and mitigation measures. Concluding negotiations in 2009 will ensure that the new deal can enter into force by 2013, following the expiry of the first phase of the Kyoto Protocol (UNFCCC press release, 2007).

Even if GHG emissions would stop as from today, the climate changes set into motion would continue for many decades to come and even centuries in case of the sea level. This is due to the historical built-up of the gases in the atmosphere and time lags in the response of climatic and oceanic systems to changes in the atmospheric concentration of the gases (EEA, 2005a). It is, therefore, important that, apart from mitigation, attention is placed on adaptive responses to avoid risks posed by climate change and to take advantage of the opportunities arising from global climate change.

Potential impact of climate change on agriculture

Agricultural systems will be affected by projected climate changes in the coming decades. This is because rising concentrations of carbon dioxide, increasing temperatures and changes in precipitation affect agricultural productivity, the quality and structure of the soil, and the abundance and distribution of pest and diseases. These and other factors, like the availability of resources and infrastructure, will interact in complex ways leading to geographical variations in the magnitude of impacts.

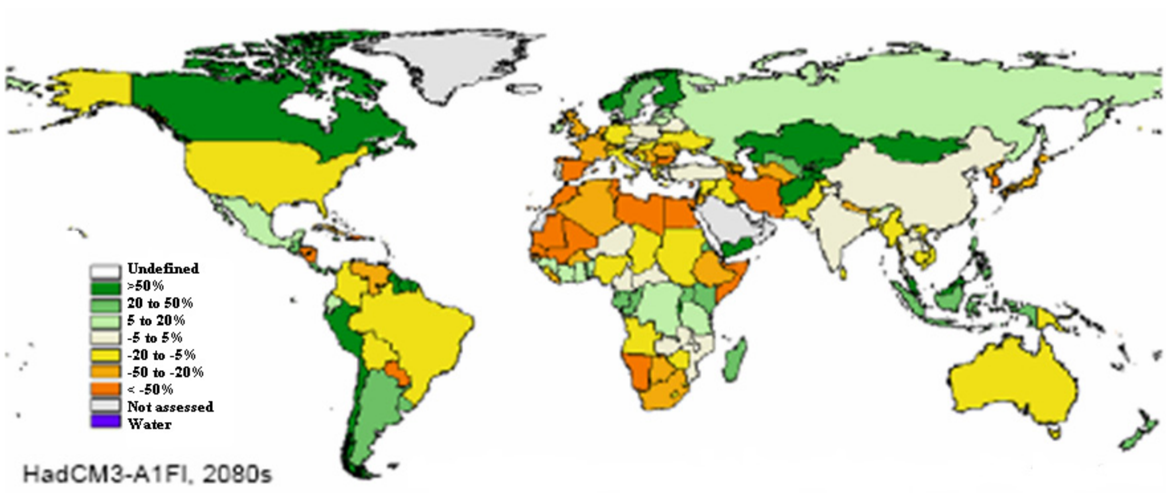


Figure 5.3. Country-level climate change impacts on rain-fed cereal production potential on currently cultivated land (HadCM3-A1FI, 2080s). Source: Fischer et al., 2002.

A general tendency is that the more adverse impacts on agricultural productivity are more likely to occur in tropical than in temperate areas (Figure 5.3). Developed countries will largely gain as cereal productivity is projected to be higher in Latin America, Canada, Northern Europe and parts of the former Soviet Union as compared with productivity without climate change (Bruinsma, 2003; Braun, 2007). However, in other regions, particularly Sub-Saharan Africa and Southern Europe, a widespread decline in the extent and productivity of cropland is expected.

In many parts of the developing world, food import dependency is projected to rise, as the increased risks of droughts and floods will result in crop yield losses. In more than 40 developing countries, mainly in Sub-Saharan Africa, cereal yields are expected to decline with mean losses of about 15% by 2080. Other estimates (Table 5.4) suggest that although the aggregate impact on cereal production between 1990 and 2080 might be small - a decrease in production of less than 1 percent - large reductions of up to 22 percent are likely in South Asia (Braun, 2007).

Table 5.4. Expected impacts of climate change on global cereal production.

	1990 - 2080 (% change)
World	-0.6 to - 0.9
Developed countries	2.7 to 9.0
Developing countries	-3.3 to -7.2
Southeast Asia	-2.5 to -7.8
South Asia	-18.2 to -22.1
Sub-Saharan Africa	-3.9 to -7.5
Latin America	5.2 to 12.5

Source: Braun, 2007 (adapted from Tubiello and Fischer, 2007).

Impacts on the production of cereals also differ by crop type. Projections show that area suitable for wheat production may almost disappear in Africa, because of rising temperatures. Nonetheless, global land use due to climate change is estimated to increase minimally by less than 1%. In many parts of the developing world, especially in Africa, expansions of arid lands of up to 8% may be expected by 2080.

Carbon fertilization could limit the severity of climate change effects. However, technological change is not expected to be able to compensate output losses so that climate change would depress the rate in yield increase to the extent that it would not keep up with growing food demand. Agricultural prices will thus, also be affected by climate variability and change. Temperature increases of more than 3 ^{0}C may cause agricultural prices to increase by up to 40% (Braun, 2007).

World agricultural GDP is projected to decrease by 16% by 2020 due to global warming. Again, the impact on developing countries will be much more severe than on developed countries. Agricultural output in developed countries is projected to decline by 20%, while it is projected to decline by 6% in industrial countries (Braun, 2007).

The above shows that climate change will affect food production very differently in different parts of the world. The effects of global climate change are likely to increase productivity of European agricultural systems, because increasing CO_2 concentration will directly increase resource use efficiencies of crops, and because warming will result in more favourable conditions for crop production in Northern Europe. However, this will require adaptation of current farming systems to new climatic conditions.

In the global context, Europe faces less negative effects than most other parts of the world. There may be an opportunity to increase Europe's share of world food production. Therefore, trade plays an important role in modifying the impacts on world food supply.

5.4 Effects of climate change in Europe

Projected trends in climate change

The studies on anthropogenic climate change performed in the last decade over Europe indicate consistent increases in projected temperature, with the greatest rise in temperature expected in Southern and North-eastern Europe. This will be accompanied by an increase in the frequency and intensity of heat waves, with greater risk of summer drought. Annual precipitation rates are expected to show a distinct spatial pattern, with increases and decreases in Northern and Southern Europe, respectively (Cooper and Arblaster, 2007). These changes in climate patterns are expected to greatly affect all components of the European agricultural ecosystems, e.g. crop suitability, yield and production, livestock, etc.

The results of global climate model (GCM) simulations based on the SRES scenarios indicate that annual surface temperatures over Europe warm at a rate of between 0.1 and 0.4 ^{0}C per decade (Alcamo *et al.,* 2007). The projected temperature increases are highest in Northern Europe during winter and highest in Southern Europe during summer. The warming is greatest over Eastern Europe during winter and over Western and Southern Europe in June-July-August. A very large increase in summer temperature is projected in the South-western parts of Europe (exceeds 6 ^{0}C in parts of France and the Iberian Peninsula) by the end of the 21st century under the A2 scenario. Generally, the mean precipitation increases in Northern Europe and decreases further south but the change in precipitation varies substantially from season to season and across regions. There is a projected increase in winter precipitation in Northern and Central Europe, whereas there is a substantial decrease in summer precipitation in Southern and Central Europe and to a lesser extent in Northern Europe. Variability in temperature and rainfall may increase considerably over large parts of Central Europe. Heat waves and droughts like the 2003 situation may become the norm in central and southern Europe by the end of the 21st century.

Impact on agriculture

Climate change may have positive impacts on agriculture also as increased CO_2 concentrations stimulate growth and water use efficiency. Table 5.5 presents projected impacts of climate change on arable, permanent crop and livestock systems. Particularly in Northern Europe, higher temperatures, coupled with increases in precipitation will serve to prolong growing periods, increase crop yields, decrease the risk of damage by freezing, allow cultivation of new crop species and expansion of suitable areas for crop cultivation farming. The projections for a range of SRES scenarios (Figure 5.4) show a 30 to 50% increase in suitable area for grain maize production in Europe by the end of the 21st century including Ireland, Scotland, Southern Sweden and Finland (Olesen, 2006).

Disadvantages may be an increase in the need for plant protection, the risk of nutrient leaching and depletion of soil organic matter. As climate change advances, however, its negative impacts, such as more frequent winter floods, are likely to outweigh the benefits (Cooper and Arblaster, 2007).

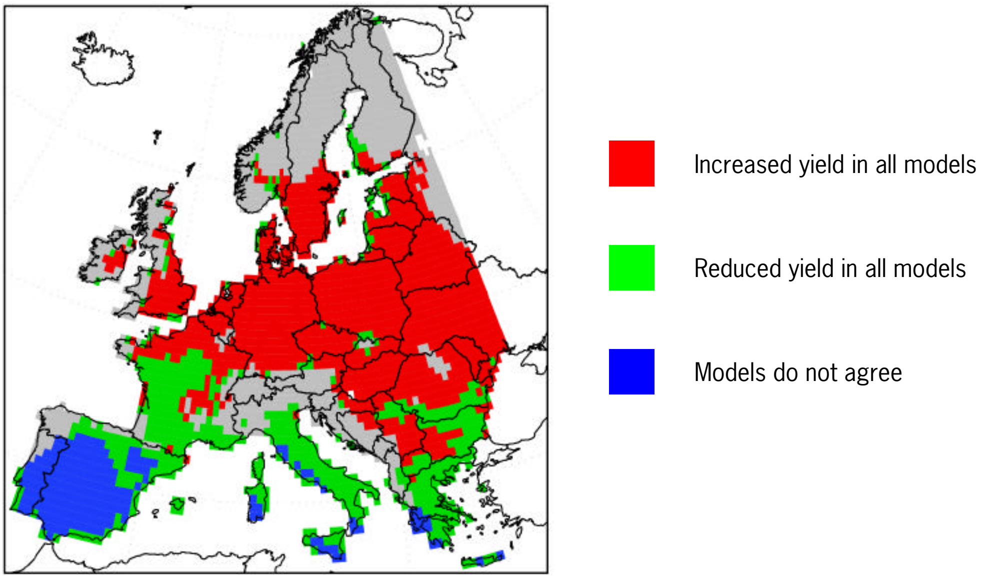


Figure 5.4. Changes in wheat yield, 2080 (amount of agreement between 9 regional models A2).
Source: Parry, 2005.

Farming systems in Southern Europe will be most vulnerable to climate change due to rising temperatures coupled with decreases in both summer and winter rainfall in areas already experiencing water scarcity (Giannakopoulos *et al.,* 2005; IPCC, 2007). The possible increase in water shortage and extreme weather events may cause lower harvestable yields, higher yield variability and a reduction in suitable areas for traditional crops.

Climate-related reductions in crop yields are expected around the Mediterranean, in the Southwest Balkans and in the South of European Russia. In Southern Europe decrease in yield is expected for spring-sown crops (maize, sun flower, soybeans), whilst on autumns sown crops (e.g. winter and spring wheat) the impact is more geographical variable: yield is expected to strongly decrease in the southern areas and to increase in the northern cooler areas (e.g. northern parts of Portugal and Spain). However, these results vary between SRES scenarios and climate models. Some crops that are currently mainly grown in Southern Europe, such as maize, sunflower and soy, will become more suitable further north or in higher altitude areas in the south (Olesen, 2006).

Olive is a typical Mediterranean species that is particular sensitive to low temperature and water shortage, thus both the northern and the southern geographical limits of cultivation are conditioned by the climate. The area suitable for olive production in Mediterranean basin may increase with climate warming.

Extreme weather events such as spells of high temperature, heavy storms, or droughts can severely disrupt crop production. Individual extreme events will not usually have lasting effects on the agricultural system. However, when frequency of such events increases, agriculture needs to respond, either in terms of adaption or in terms of abandonment.

These effects of climate change may reinforce the current trends of intensification of agriculture in Northern and Western Europe and extensification in the Mediterranean and South-eastern parts of Europe.

Table 5.5. Projected impacts of climate change on arable, permanent crop and livestock systems.

Sector	Specific Crop	Effect of Increased Temperature	Effect of Increased CO_2	Impact on Geographical Distribution
Cereals	Wheat	Temperature increase will shorten length of growing season, reducing yields (since determinate species.*)	Large yield increase due to C3 species outweighs negative temperature effect. Predict increase of 9-35 per cent of wheat yield across Europe by 2050 (Maracchi *et al.,* 2005).	Expansion of cereal cultivation northwards (Harrison *et al.,* 1995). Largest increases in yield expected in southern Europe, especially northern Spain, southern France, Italy and Greece (EEA, 2004). The drier conditions and increasing temperatures in the southern Mediterranean, such as southern Portugal and southern Spain, may lead to lower wheat yields and the need for new varieties and cultivation methods to maintain cereal production.
	Maize	Increased temperatures, particularly in the southern regions will decrease yield due to shorting growing season.	Small effect due to C4 species.	Increase in yield for northern areas, decreases in southern areas.
Seed Crops		Temperature increase will shorten growing periods of determinate species.		The cropping areas of cooler season seed crops, such as pea, faba bean and oil seed rape, may expand northwards into Fenno-Scandinavia leading to an increased productivity of seed crops but reductions in yield elsewhere (Maracchi *et al.,* 2005). Similarly, a northward expansion of warmer season seed crops such as soybean and sunflower is expected.
Vegetables		Increased temperature will reduce the duration of crop growth and hence yield in determinate species, such as onion. An extended growing season will increase the duration of growth of indeterminate species, such as sugar beet, if enough water is available.	Root and tuber crops likely to show large response due to underground capacity to store carbon and apoplastic mechanisms of phloem loading (Maracchi *et al.,* 2005).	For field grown vegetables, increasing temperatures may expand production northwards.

*) *Determinate plant species do not continue to grow indefinitely at the apex, but terminate in a flower. Their time to maturity depends on temperature and day length, and increased temperatures will shorten the length of the growing season, reducing yields.*

Table 5.5. (continued) Projected impacts of climate change on arable, permanent crop and livestock systems.

Sector	Specific Crop	Effect of Increased Temperature	Effect of Increased CO_2	Impact on Geographical Distribution
		For cool season vegetable crops like cauliflower, large temperature increases may decrease production in southern Europe during the summer.		
Perennial Crops	Grapevine	This woody perennial responds readily to high temperatures.	May strongly stimulate yields without causing negative repercussions on grape or wine quality.	Increased temperatures and CO_2 will expand the potential growing area northwards and eastwards. However, yield variability will increase, implying economic risk.
	Intermediate energy crops, e.g. *Miscanthus*	Favoured by conditions that extend the growing season and increase the light or water use efficiencies. For willow production in the UK, a temperature increase of 3^0C may increase yields up to 40% (Olesen and Bindi, 2002).	Increase water use efficiency.	
Livestock Systems	For livestock systems, climate change may have both positive and negative impacts. Increased temperatures and the likelihood of extreme weather events may increase the need for animal housing: prolonged dry weather may increase the need to supplement forage with bought-in feed, silage of forage, potentially increasing feed costs; changes in global feed markets may affect costs; increased variability in grazing regimes due to wetter soils in autumn/winter; increases in disease - e.g. spread of Bluetongue into Northern Europe (Purse *et al.,*2005). Climate change could herald a shift into feedlot systems where temperature can be controlled and water more easily used to generate energy - i.e. the collection of manure for use in biogas production (for example, Farming Futures, 2007). However this would have animal welfare implications as well as effecting biodiversity since it would reduce grazing and may impact adversely on HNV farming systems.			

Source: Cooper and Arblaster, 2007.

Weeds, pests and diseases

The majority of pest and disease problems are closely linked with their host crops. This makes major changes in plant protection problems less likely. Climate warming will lead to earlier insect spring activity and proliferation of some pest species. A similar situation may be seen for plant diseases leading to an increased demand for pesticide control. Unlike pests and diseases, weeds are also directly influenced by increased atmospheric CO_2 concentrations, which will stimulate growth and water use efficiency. Changes in climatic suitability will lead to invasion of weed, pest and diseases adapted to warmer climatic conditions. The Colorado beetle, the European corn borer, the Mediterranean fruit fly and karnal bunt are examples of pests and diseases, which are expected to have a considerable northward expansion under climatic warming (Olesen, 2006).

Livestock

Climate and CO_2 effects influence livestock systems through both availability and price of feed and through direct effects on animal health, growth and reproduction. Climate change may have both positive and negative impacts. Increased temperatures and the likelihood of extreme weather events may increase the need for animal housing. Prolonged dry weather may increase the need to supplement forage with bought-in feed, silage or forage, potentially increasing feed costs. Changes in global feed markets may affect costs. Increased variability in grazing regimes may result from wetter soil in autumn/winter. Increase in diseases, e.g. spread of Blue Tongue into Northern Europe, could be expected.

Adaption to climate change

Adaptation strategies need to be introduced to reduce negative effects and exploit possible positive effects of climate change. Both short and long-term adjustments should be considered. Short-term adjustments include efforts to optimize production without major system changes. Examples are: changes in crop species, cultivar and sowing dates, and fertilizer and pesticide use. In particular, in Southern Europe short-term adaptations may include changes in crops species, changes in cultivars and sowing dates. In Northern Europe, new crops and varieties may be introduced only if improved varieties will be introduced to respond to specific characteristics of the growing season. The long-term adaption refers to major structural changes to overcome adversity caused by climate change. This involves changes in land allocation and farming systems, breeding of crop varieties, new land management techniques etc. Changes in farming systems may play a fundamental role in the adaption of European agriculture to climate change.

6. Bioenergy

6.1 Bioenergy defined

Biofuels are fuels of biological and renewable origin, such as fuel wood, charcoal, livestock, manure, biogas, biohydrogen, bioalcohol, agricultural waste and by-products, energy crops and others. The main sources of bioenergy are:
1. agricultural residues and wastes.
2. (purpose-grown) agricultural crops.
3. wild vegetation.

In their raw form, these sources are usually called biomass or energy feedstock.

Bioethanol (ethanol), mainly produced by fermentation of cereals, starch and sugar crops, is currently world's main biofuel. Biodiesel is produced from oilseeds crops and other raw materials, and until recently was produced almost solely in the EU, mainly from rapeseed. First generation biofuels, produced from edible plant parts, such as maize, potato, rapeseed, soybean and palm oil, can be used in low-percentage blends with conventional fuels in most vehicles and can be distributed through existing infrastructure.

Advanced conversion technologies are needed for a second generation of biofuels, produced from non-edible feedstock, comprising ligno cellulose. These technologies will use a wider range of biomass resources and are assumed to achieve significant reductions in GHG emissions and the costs of fuel production. For example, energy yields per hectare of cereals would increase by 30%-40% if the straw would be used in addition to the grains. Second generation technologies are presently still not available but are expected to be used in 10 to 15 years from now.

Table 6.1. Conversion factors.

	Density (kg/l)
Ethanol	0.79
Bio-diesel	0.88
1 t biodiesel = 0.86 toe	
1 t bioethanol = 0.64 toe	
1 toe (ton oil equivalent) = 41.868 GJ	

6.2 Energy consumption

Global energy consumption

Energy demand at the global level was 11,434 Mtoe in 2005. Oil is the dominant primary energy source accounting for 35% of world's total commercial primary energy consumption, followed by solids with 25% and natural gas with 21%. Biomass represented 10% of the total primary energy consumption, with the remainder supplied by nuclear, hydro and other renewable energy sources as presented in Figure 6.1 (EC, 2007e).

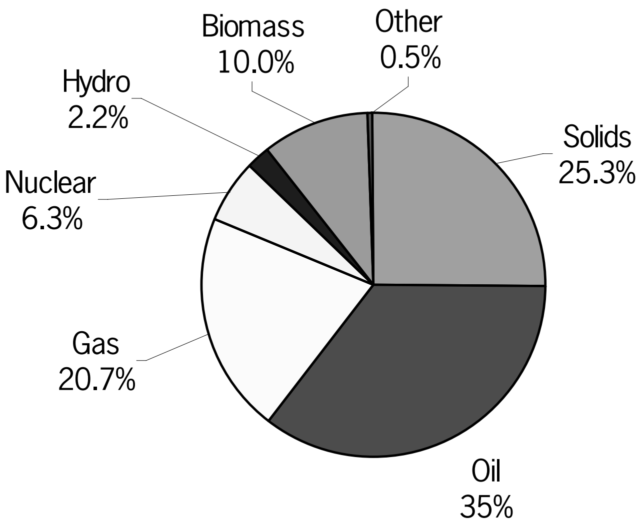


Figure 6.1. Gross Inland Consumption, world 2005. Source: EC, 2007e.

In 2006, Brazil and the USA together accounted for about 90% of the global ethanol production of around 40 billion litres. In Brazil and the USA, the feedstock is respectively sugarcane and maize. The EU accounted for about 4%, with as main feedstock starch crops including maize, wheat, rye and potatoes, and sugar beet. Of the global biodiesel production of 6.5 billion litres, 75% was produced in the EU, mainly in France and Germany. The main feedstocks for biodiesel are the oilseed crops: rape and sunflower (Licht, F.O. cited by World Bank, 2007).

Europe's energy consumption

The primary energy consumption for the EU-27 for 2005 was 1811.3 Mtoe. The import dependency on oil for the EU-27 was 82.2% in 2005. Energy derived from Renewable Energy Sources accounted for 120.6 Mtoe, 6.7% as shown in Figure 6.2 (EC, 2007e). About two third of the renewable energy produced in the EU-27 was from biomass (81.9 Mtoe). Detailed information on the energy consumption of the EU in 2005 and 2006 is presented in Annex III.

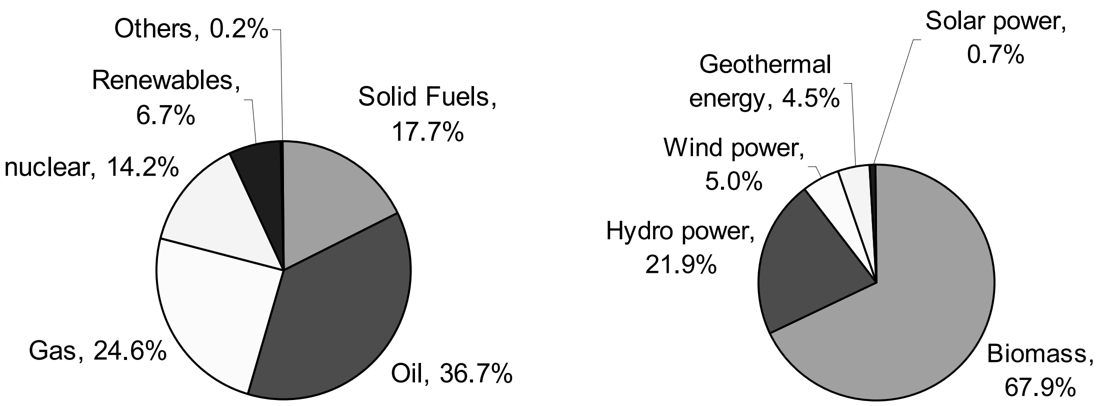


Figure 6.2. Energy consumption of EU-27 in 2005 and breakdown of Renewable Energy. Source: EC, 2007e.

In the EU, transport is responsible for an estimated 21% of all greenhouse gas (GHG) emissions that contribute to climate change. The transport sector accounts for about 30% of the final energy consumption (EC, 2007e). In 2006, biofuels represented 1.8% of EU petrol and diesel consumption vs. 1% in 2005 (EurObserv'ER, 2007).

Europe's energy policy

Concerns about global warming, rising world fuel prices and growing demand for energy, are the key factors driving the increasing interests in renewable energy sources and in biofuels in particular. Additionally, the use of biofuels will make the EU less dependant on fossil oil imports and offer an alternative for farmers.

Through the Biomass Action Plan (EC, 2005) the EU plans to double the share of renewable energy in its primary energy consumption to 12% by 2010. In order to reach this target, the energy derived from biomass will have to increase from 69 Mtoe in 2002 to 149 Mtoe in 2010 (Table 6.2). This includes a share of biofuel of 5.75% of total transport fuel.

The new energy policy for Europe (EC, 2007d) includes:

- A binding 20% target for the overall share of renewable energy in 2020
- A binding 10% target for the share of biofuels in petrol and diesel in each member state in 2020, to be accompanied by the introduction of a sustainability scheme for biofuels.

Conditions for the target for 2020 are that the feedstock has to be produced in a sustainable way and second-generation technology will have to be available. Table 6.2 presents the share of renewable energy consumption for 2002 and the targets for 2010 and 2020 for the EU-25. The comparison of the current trend of energy based on biomass with the Biomass Action Plan scenario is shown in Figure 6.4.

Table 6.2. Renewable energy consumption for EU-25.

In Mtoe resp. (% primary energy consumption)	2002	2010	2020
Renewable energy sources	97 (5.8)	210 (12)	325-340 (20)
of which bioenergy	69 (4.1)	149 (8.3)	210-230 (13) [1]
electricity	20	55	90
heat	48	75	90-95
transport	1	19	31-43

[1] *Includes 25Mtoe import. Source: MNP, 2007.*

The 5.75% target for the contribution of biofuels to total fuel consumption by 2010 will probably not be met. Only Germany and Sweden met the intermediate target of 2% for the contribution of biofuels by 2005. As markets and technologies have too little time to react, an incorporation of 6.9% could be expected by 2020 (EC, 2007g).

The EU Common Agriculture Policy (CAP) has an important influence on farming in the EU even though wider economic, social and technological trends have also significant impact. Several measures that support the production of energy crops are part of the current CAP policy framework.

- Up to the marketing season 2006/2007, most EU arable farmers had an obligation to set-aside 10% of their arable land. These fields can be planted with oilseeds or other energy crops as long as the produce is contracted solely for the production of biodiesel or other industrial products and not sold to either food or feed markets.
- The production of energy crops is eligible for a premium of 45 Euro per hectare (restricted to a maximum guaranteed area of 1.5 million ha). In 2005 an estimated 0.5 million ha received the energy crop payment.
- It is expected that CAP policy will continue to stimulate feedstock production in future.

6.3 Land potential for energy crops in the EU

A study of the European Environmental Agency (EEA, 2006) concluded that the EU has enough area to produce the required feedstock to meet the 2010 and 2020 targets in a sustainable way. Figure 6.3 and Table 6.3 present the bioenergy potential of the three main components of biomass, which are agricultural production, forestry and biowaste. To meet the 2020 target of 210-230 Mtoe, 70-90 Mtoe has to be contributed by agricultural production. It is assumed that CAP has reformed and second generation technology is available.

In the short term, the largest potential for bioenergy comes from the waste sector with around 100 Mtoe. This remains more or less constant over the time horizon. The main biowaste streams contributing to this system are solid agricultural residues (e.g. straw), wet manures, wood processing residues, the biodegradable part of municipal waste and black liquor from the pulp and paper industry. At country level, Germany and France have by far the largest potential for bioenergy from waste.

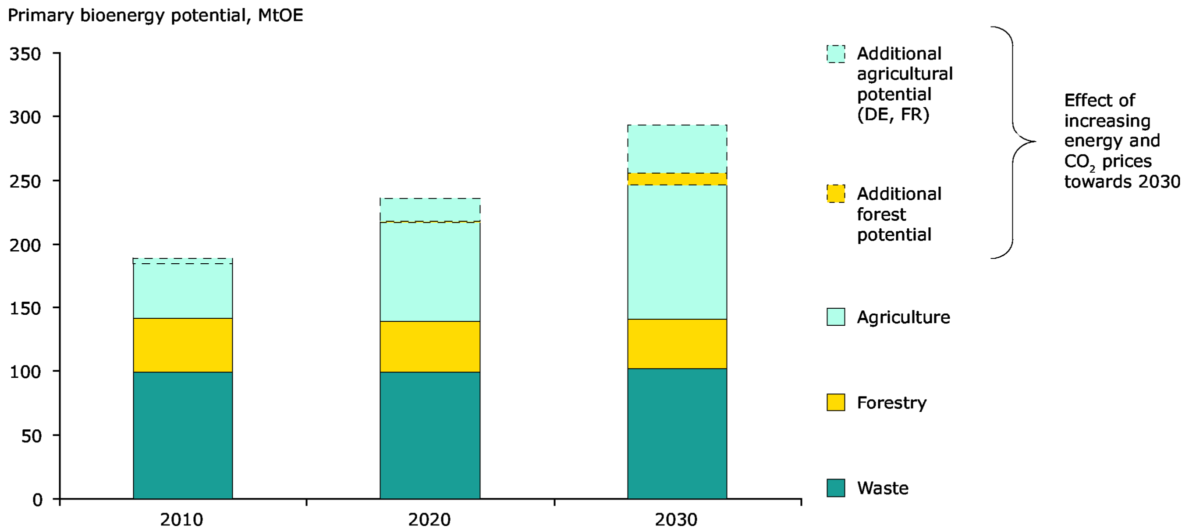


Figure 6.3. Environmentally-compatible primary bioenergy potential in Mtoe for the EU-25. Source: EEA, 2006.

The environmentally compatible bioenergy potential from forestry is estimated to be almost constant at around 40 Mtoe. An additionally potential of more than 16 Mtoe is released from competing industries (mostly at the expense of pulp and paper production) by 2030. In the long-term, bioenergy crops from agriculture provide the largest potential. This development will be driven by additional productivity increases; further liberalization of agricultural markets; and the introduction of high yield bioenergy crops. The environmentally compatible bioenergy potential from agriculture can reach up to 142 Mtoe by 2030, compared to 47 Mtoe in 2010 (Table 6.3).

Figure 6.4 presents the actual energy production derived from biomass for 2005 and 2006, the expected bioenergy for 2010 and the target as set by the Biomass Action Plan, which is 149 Mtoe in 2010. Solid biomass comprises wood (wood, wood waste & pellets), organic material, waste, and black liquor. According to EurObserv'ER (2007) it is expected that in 2010, 102.3 Mtoe will be locally produced in the EU, which is below the target of 149 Mtoe and the potential of 188.5 Mtoe as calculated by EEA. The data provided by EEA and EurObserv'ER, relate to biomass produced locally in the EU. The Biomass Action Plan leaves room for import as long as environmental issues are taken into consideration.

Table 6.3. The environmentally compatible bioenergy potential (in Mtoe) by sector in 2010, 2020 and 2030, for EU-25, actual production for 2005, and expected production for 2010.

Year	Bioenergy (Mtoe)			
	Agriculture	Forestry	Waste	Total
2005 (actual)[1]	3.0	69.1		72.1
2010 (trend)[1]	12.6	89.7		102.3
2010 (target)	19	130		149
2010 (potential)	46.8	42.5	99.3	188.5
2020 (potential)	95.8	39.2	99.8	234.7
2030 (potential)	142.4	39.0	102.1	283.4

Source: EEA, 2006. [1] EurObserv'ER, 2007.

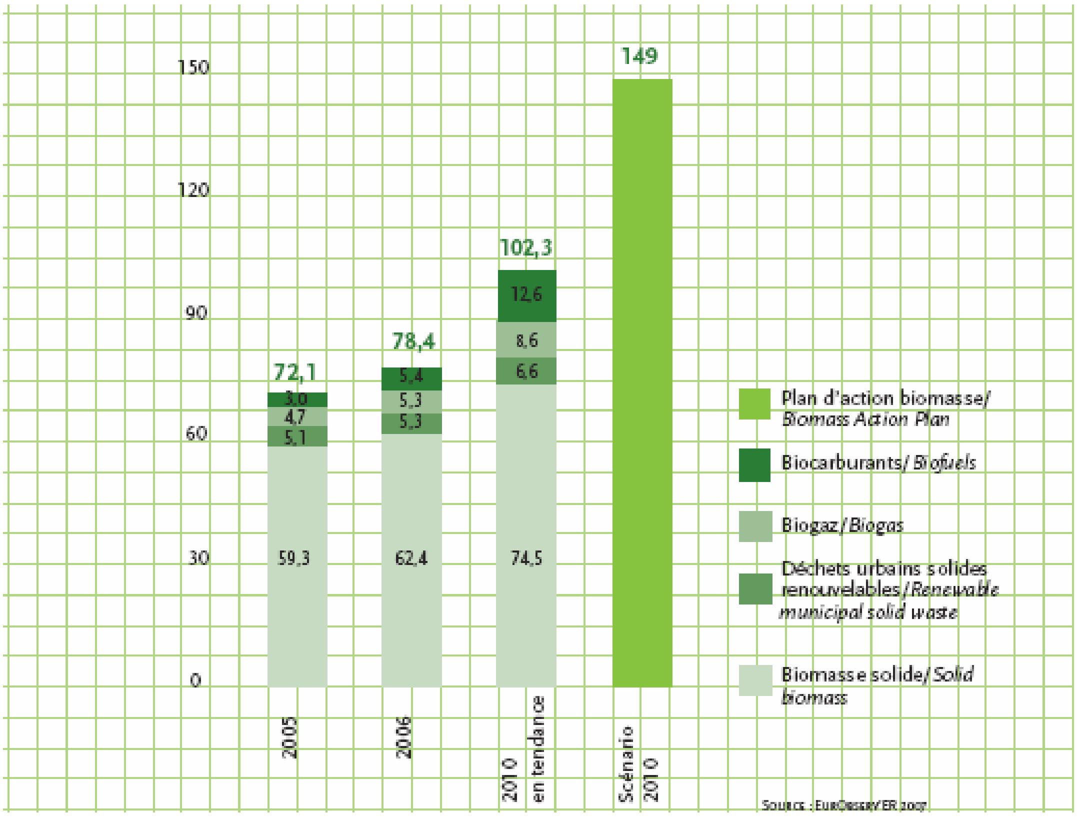


Figure 6.4. Comparison of the current trend with the Biomass Action Plan scenario (in Mtoe). Source: EurObserv'ER, 2007.

Figure 6.5 presents the available arable land, which can be used for dedicated bioenergy production. The production area increases from 13 million ha in 2010 to 16 million ha in 2020 to reach 19.3 million ha in 2030 (for EU-25 without Cyprus, Luxembourg and Malta). Additional land will also be released in the grassland and olive grove categories, rising from 1.7 million ha in 2010 to 5.9 million ha in 2030. Most of the available land is due to release of land from food and fodder production because of the CAP reform, set aside areas and increase in crop productivity. However, out of the available arable area of 19.3 million ha in 2030, around 5 million ha are due to assumed competition between energy and food production in areas used to produce export commodities in Germany and France.

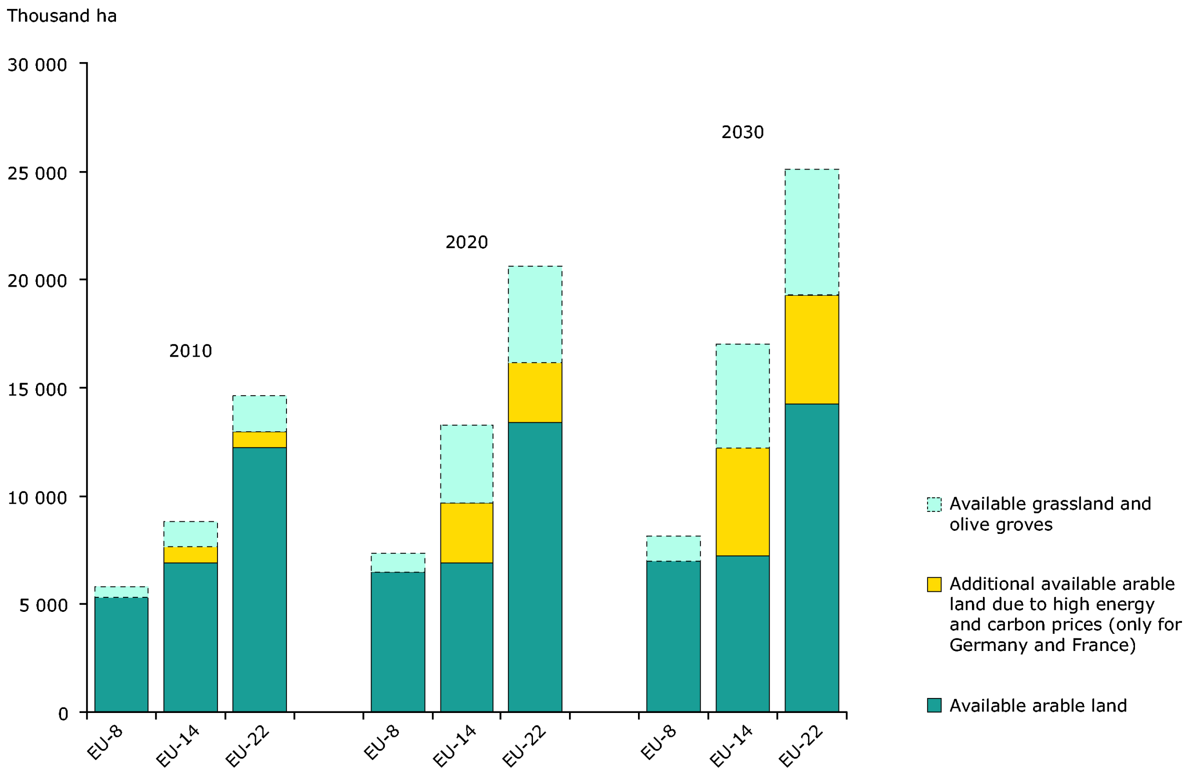


Figure 6.5. Land available for biomass production for energy, EU-25. Source: EEA, 2006.

The MNP study compares the result of the EEA study with those of EUruralis (WUR/MNP, 2007) (Table 6.4). If CAP reforms are materialized, the available area in 2020 is for both the EEA and the WUR/MNP study in the same range of approx. 16 million ha. The EEA study expects these production areas to be evenly distributed over the EU, whereas the WUR/MNP study expects concentration of production areas in Western Europe. If 2nd generation technology is available 90 Mtoe can be produced, otherwise 70Mtoe. In case the CAP is not reformed, as in the Continental Markets scenario (=SRES A2 scenario), only 4.75 million ha will be dedicated to energy crops in 2020, which will produce approx. 30 Mtoe.

Table 6.4. Available arable land for feedstock production in EU-25 in 2020 for different scenarios.

Author	Area (mio ha)	Feedstock production (Mtoe)	Scenario
EEA (2006)	16,170	90	- 2nd generation technology available - CAP reformed (trade liberal) - prod. areas distributed over EU-25
EEA (2006)	16,170	70	- 1st generation technology - CAP reformed (trade liberal) - prod. areas distributed over EU-25
WUR/MNP (2007)	15,813	-	- Global economy (Cap reformed) - prod. concentrated in Western Europe
WUR/MNP (2007)	4,752	30	- 'Continental Markets': no CAP reform

Source: EEA, 2006 and MNP, 2007.

Other studies that focus on the EU biofuel targets for 2010 and 2020, have also calculated the required amount of feedstock and area for cultivation. Some of the main characteristics are presented in Table 6.5. The Scenar 2020 study (Nowicki *et al., 2006),* bases itself on an analysis of European food and input markets, predicting future developments in demand as well as production technology. According to this study, 12.02 million hectares would be required to meet the target of 5.75% for 2010. For 2020, Scenar projects a 7.4% share of biofuels, (which is lower than the set target of 10%) which would require a production area of 14.4 million hectares. However, it is not expected that these amounts will be actually produced in the EU. The EU-25 would therefore have to import 40% of its requirements: 6.3 million tons and 8.40 million tons of biofuels resp. in 2010 and 2020. According to the Scenar 2020 study, the production of biofuel crops (and the imports of biofuels) contributes to only 3.6% of total fuel consumption in 2020 in case the Biofuels Directive is not implemented.

In the Annex to the Biofuels Progress Report (EC, 2007a), area of arable land was calculated in order to meet the demand in 2020, given a range of assumptions about the biofuel share of total road fuel demand. In case of 7% share of biofuels, the domestic production would require 7.6 million hectares for feedstock production (rape, cereals and sugar beet). In case of 14% share of biofuels, a production of 43.1 Mtoe of biofuel (37% second generation) is required. With a 22% share of import, 33.4 Mtoe has to be produced locally. This would require 18.3 million hectares (rape, cereals, sugar beet and farmed wood), of which 7.5 million hectares would be arable land formerly used in the production of food, 7 million hectares would be formerly set aside land, 4 million hectares would be land that otherwise would have been converted from arable land into other uses.

This modelling work suggests that for each additional 1 million hectares needed in the EU to produce raw material for biofuels, land use will change as follows:
370,000 ha of arable land will be re-oriented from exports to domestic production;
400,000 ha will be taken out of set-aside;
220,000 ha that would otherwise have fallen into other uses will remain in arable use.

Table 6.5. Scenarios for biofuel use and required area of arable land for EU-25 in 2010 and 2020.

Author	Time horizon	Share biofuel (%)	Biofuel required	Import (%)	Local production (%)	Area Local production (mio ha)	Area Local production if extrapolated to 100% domestically produced (mio ha)
Nowicki *et al.*	2010	5.75	15 mio t (19 Mtoe)	42	58	7.0	12.0
Nowicki *et al.*	2020	7.4	21 mio t (27 Mtoe)	40	60	8.6	14.4
Nowicki *et al.*	2020	3.6					
EC	2020	7	23.1 Mtoe	27	73	7.6	10.4
EC	2020	14	43.1 Mtoe	22	78	18.3	23.5

Source: Nowicki et al., 2006; EC, 2007a.

A study by Langeveld *et al.* (in press) estimated that the EU feedstock demand from agricultural origin in 2020 will range between 67 to 105 Mt per year, depending on feedstock choice, % share of biofuel and availability of second generation technology. In line with EEA, they conclude that the feedstock can be covered by existing production sources (yield increase, area expansion and improved conversion). According to their calculations, the required area ranges between 11 to 30 million hectares.

Several studies have been conducted in order to calculate the potential of biomass production in the EU, or have more specifically focussed on the ability to meet the biofuel target. It is difficult to compare the outcome of these studies, as there are many assumptions, such as share of biofuel, availability of second generation technology, choice of crops and their productivity. Based on studies by the EEA (2006) and WUR/MNP (2007) it can be assumed that approx. 16 million hectares arable land is available for feedstock production. Additional land available from grassland and olive groves increases the area to 20 million ha in 2020. In this scenario, CAP reforms have been put in place.

The studies differ in energy production per hectare. In the Scenar and EC studies energy production per ha ranges from 1.6 to 2.2 toe per ha. According to own calculations, energy yields for the EEA study are approx. 4.3 toe/ha, which is comparable with production based on sugarcane in Brazil. It requires further studies to calculate the amount of energy, which can be produced by agricultural production.

Even if the EU would be capable of producing enough feedstock, the 10% target might not be produced locally. As markets and technologies have too little time to react, an incorporation of 6.9% could be expected by 2020 (EC, 2007g). Even in case of a 7% share biofuels the Scenar and EC study expect that biofuels will have to be imported.

6.4 Bioenergy and climate change

The main aim of biofuels is to decrease the concentration of atmospheric CO_2. Biofuels positively affect net carbon emissions as an alternative to fossil fuels. However, bioenergy uses fossil fuels for growing, transporting and processing the feedstock and for refining and distributing of the biofuel. Therefore, emission reductions must be assessed considering the full life cycle. This life cycle includes production (choice of feedstock, agricultural practices, land use change etc.), refining and conversion processes and end-use practices. It has to be considered that electricity and heat from biomass can generate greater savings than transport fuels. Key factors to ensure GHG emission reduction from bioenergy are:

- No conversion of high carbon containing land for feedstock production, as land conversion from high carbon content land will eliminate GHG reduction potentials.
- Use of agricultural practices that increase carbon sequestration below and above ground, minimize fertilizer use, and increase energy efficiency of mechanized operations.
- Energy efficiency in refining and conversion, utilizing biomass residues for process heat where possible.
- Efficiency in end use applications- electricity, heat and transport (GBEP, 2007).

6.5 Biodiversity

Changes in land use in the EU will have their impact on biodiversity. However, within EU mandate the impact can be restricted due to EU-policy. It will be very difficult to monitor the impact of increased demand for feedstock out of EU territory. The EU can however impose sustainability criteria for feedstock that is imported for the production of biofuels or for the biofuels themselves, as is currently under development in the Netherlands (Cramer, 2007) and other European countries.

The communication 'An EU Strategy for Biofuels' (EC, 2006b) stated that:
'it is essential to guarantee that feedstock for biofuels is produced in a sustainable manner, both in the EU and in third countries, particularly with regard to the protection of biodiversity, water pollution, soil degradation and the protection of habitats and species.'

Demand for bioenergy in the EU will most likely lead to less food produced in EU, and an increasing demand for biofuel imports. This means that elsewhere agricultural land has to expand. Most likely this will be in Brazil, Central Africa and Indonesia. These regions are also 'hotspots' for biodiversity (MNP. 2007).

6.6 Food security

Agricultural production serves food, feed, industrial and renewable energy use. Any change in competiveness of any of these four main outlets leads to competition for arable land. Bioenergy uses resources such as land, water (nutrients) and labour and therefore competes with food production. If land use is converted from food production into feedstock production, this will imply that food has to be produced elsewhere in order to meet the food demand. Most likely, this will require more land due to lower productivity in regions out of the EU. Most likely the production areas will be in Brazil, Central Africa and Indonesia (MNP, 2007), jeopardizing the food security of poor regions.

It has to be noted that the diverse biofuel co-products can serve as a valuable protein supplement for livestock feeding. Due to a higher demand for vegetable oil for biodiesel production, more protein meals are produced. An excess supply may lead to a decline in protein meal prices (Baize, 2006).

The additional issue that food becomes more expensive due to increasing demand for food, feed and bioenergy, will be discussed in the following section.

6.7 Trade-off

About 854 million people in this world suffer from hunger, and although the proportion of undernourished has declined over recent years, absolute figures have remained constant. Growth in bioenergy has repercussions on food security through two predominant channels.

1. Price effects in international markets.
2. Local factors related to specific production methods and of bioenergy and the local context.

Increase in price of food

World cereal and energy prices are becoming increasingly linked. Since 2000, the prices of wheat and petroleum have tripled, while the prices of corn and rice have almost doubled. The impact of cereal price increases on food-insecure and poor households is quite dramatic. Faced with higher prices, the poor switch to foods that have lower nutritional value and lack important micronutrients (Braun, 2007).

Feedstock represents the principal share of total biofuel production costs. For ethanol and biodiesel, feedstock accounts for 50-70 resp. 70-80% of overall cost. Food-price projections have not yet been able to fully take into account the impact of biofuels expansion. The increase in crop prices resulting from expanded biofuel production is also accompanied by a net decrease in the availability of and access to food, with calorie consumption estimated to decrease across all regions compared to baseline levels. Food calorie consumption decreases the most in Sub-Saharan Africa (Braun, 2007).

For developing countries, biofuels create either an opportunity or negative impact due to higher food prices and claims on natural resources.

Table 6.6. Impact of rising biofuel production on food security.

Impact of rising biofuel production on food security	
Availability (The world's ability to produce sufficient food)	**Stability** (People's continuous access to sufficient food - also in situations of crisis)
(-) land, water and other resources are diverted away from food production, depending upon developments in improved and new technologies (including second generation fuels) which reduce competition between food and fuel (+) new demand for agricultural products leads to higher returns to farming and increased production (+) biofuel growth may lead to increased rural energy services increasing agricultural productivity	(+) floor prices for staple food products ensure minimum return to all producers (including poor producers) (+) biofuels may offer new rural employment opportunities, and reduced insecurity compared to subsistence farming (-) increased volatility of prices between floor and ceiling prices increases risk to poorest consumers
Access (The ability of households to access food - they can find it in their area, and they can afford it)	**Utilisation** (People's ability to absorb nutrients from food - linked to clean water, health and energy access)
(+) new demand for agricultural products leads to higher farm incomes and greater ability to purchase food (-) higher food prices reduce affordability and negatively affect poor buyers (-) displacement of local food production by new biofuel developments may reduce local access to food	(+) increased access to energy offers improved opportunities for food preparation and preservation (-) competition for water may reduce water access by the poorest for drinking and hygiene (+) rural regeneration related to biofuel growth may improve service provision in rural areas, including healthcare

(-) Negative impacts.
(+) Positive impacts.
Source: GBEP, 2007.

Food security, as defined by FAO (FAO, 2002) is a situation which exists when 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. This definition comprises four key dimensions of food supplies: **availability**, **stability**, **access** and **utilization**.

Availability of sufficient food: i.e. the overall ability of the agricultural system to meet food demand. Food availability is the net effect of changes in production, net trade and stocks. Availability of stocks do not matter in the long run though they can be crucial in short-run food supplies.

Stability relates to individuals who are at high risk of temporarily of permanently losing their access to the resources needed to consume adequate food.

Access covers access by individuals to adequate resources (entitlements) to acquire appropriate foods for a nutritious diet. (key element: purchasing power of consumer and the evolution of real incomes and food prices.)

Utilization encompasses all food safety and quality aspects of nutrition.

7. Shocks

7.1 Disaster Outlook

Introduction

The OFDA/CRED International Emergency Disasters Database (EM-DAT) provides data and statistics on natural disaster occurrence and their impact.

CRED defines a disaster as a 'situation or event, which overwhelms local capacity, necessitating a request to national or international level for external assistance (definition considered in EM-DAT); an unforeseen and often sudden event that causes great damage, destruction and human suffering'. For a disaster to be entered into the database at least one of the following criteria must be fulfilled:

- 10 or more people reported killed
- 100 people reported affected
- Declaration of a state of emergency
- Call for international assistance.

The number of people killed includes 'persons confirmed as dead and persons missing and presumed dead'; people affected are those 'requiring immediate assistance during a period of emergency, i.e. requiring basic survival needs such as food, water, shelter, sanitation and immediate medical assistance (definition considered in EM-DAT)'. In the tables, people reported injured or homeless were aggregated with those reported affected to produce a 'total number of people affected'.

The economic impact of a disaster usually consists of direct, e.g. damage to infrastructure, crops, housing, and indirect, e.g. loss of revenues, unemployment, market destabilization, consequences on the local economy. In the data provided by EM-DAT the registered figure corresponds to the damage value at the moment of the event and only to the direct damage. Economic damage is given in 2003 US$.

EMDAT distinguishes natural and technical disasters divided into 15 main categories, covering more than 50 sub-categories.

Natural disasters are split up in three specific groups:

- *Hydro-meteorological disasters:* including floods and wave surges, storms, droughts and related disasters (extreme temperatures and forest/scrub fires), and landslides & avalanches;
- *Geophysical disasters:* divided into earthquakes & tsunamis and volcanic eruptions;
- *Biological disasters:* covering epidemics and insect infestations.

As for famines, which are neither natural nor technological disasters, but the result of long term processes, they have not been considered in this analysis.

According to the data available at EM-DAT, natural disasters have increased over the past years (Figure 7.1). This is probably due to increasing population. Areas are more densely populated which causes severe events sooner to be defined as a disaster. In addition, measurement error has probably occurred. In 1900, the technology to measure all earthquakes was absent, let alone did people register all natural disasters.

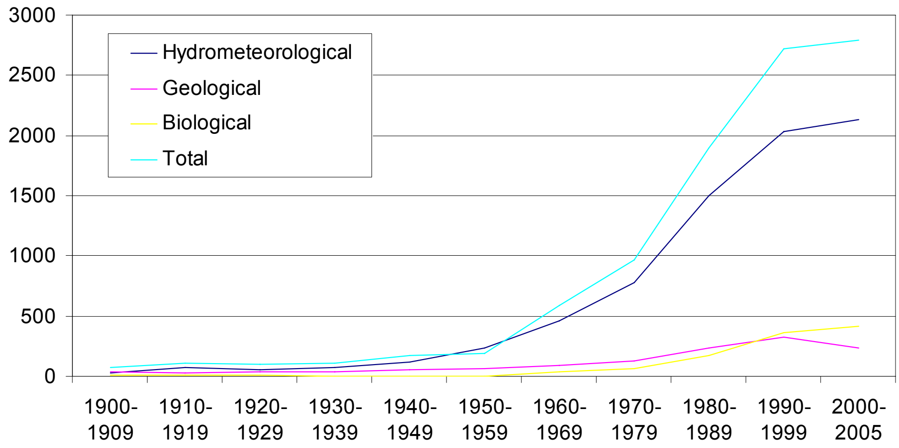


Figure 7.1. Occurrence of natural disasters (1900-2005). Source: ISDR, 2007.

Regional distribution of disasters

Table 7.1 provides the number of disasters that have occurred over the period 1991 to 2005. Asia has the highest amount of disasters, likely due to the high population density, of which hydro-meteorological disasters are the most numerous. Floods and windstorm are disasters that occur the most.

Table 7.1. Regional distribution of natural disasters by origin (1991 - 2005).

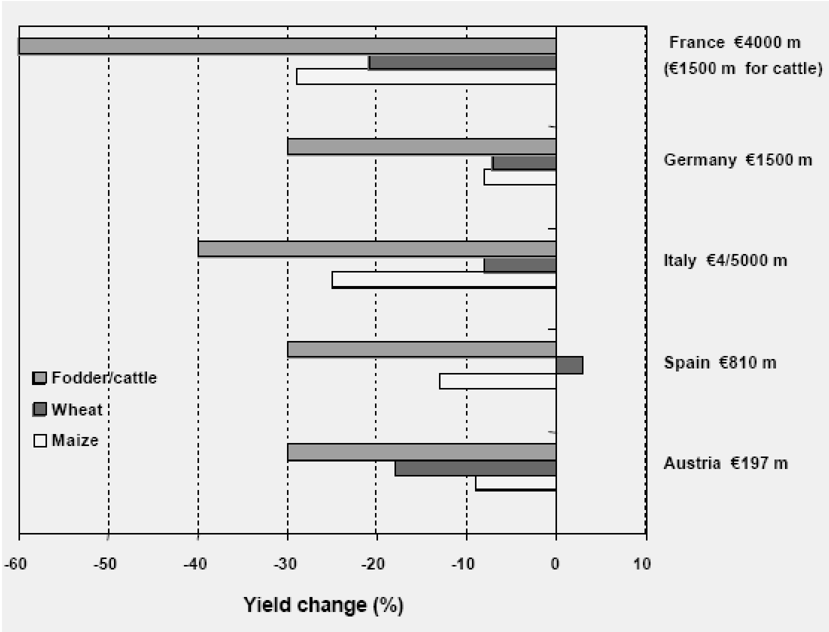
Type of disaster	Hydro-meteorological	Geological	Biological
Africa	607	31	393
Americas	1072	114	76
Asia	1532	298	199
Europe	581	44	42
Oceania	184	24	13
Total	3976	511	723

Source: EM-DAT.

7.2 EU Heat wave 2003

A severe heat wave over large parts of Europe started in June 2003 and continued through July until mid-August, raising summer temperatures by 3 to 5 ^{0}C from Northern Spain to the Czech Republic and from Germany to Italy. Extreme maximum temperatures from 35 to 40 ^{0}C were repeatedly recorded in July and tot a larger extent in August. This heat wave has been found to be statistically an extremely unlikely event under current climate. It is however considered to be consistent with an increase in mean temperature and temperature variability. As such, the 2003 heat wave resembles simulations by regional climate models of summer temperatures in the latter part of the 21st century under the A2 scenario (Olesen, 2006).

The heat wave was associated with annual precipitation deficits up to 300 mm, and this drought was a major contributor to losses in agricultural production. This reduced agricultural production and increased production cost resulted in an estimated damage of 13 billion euro's (Olesen, 2006). The main sectors hit by the extreme weather conditions were green fodder supply, the arable sector, the livestock sector and the forestry sector.



- Winter crops affected by harsh winter and late spring frost
- Heat wave from early June till mid August
- Crops enter 10 to 20 days earlier in ripening and maturity stage
- Increase in crop water consumption
- Soil water reservoirs depleted

Figure 7.2. Summer heat wave 2003: effects on EU agriculture.
Source: Olesen and Bindi, no year; COPA-COGECA, 2003.

Winter crops suffered form the effects of a harsh winter and late spring frost. The heat wave started as early as June and caused crops to develop in advance by 10 to 20 days, anticipating ripening and maturity stages. The higher temperatures increased crop's water consumption, which in combination with the dry spell resulted in acute depletion of the soil water reservoirs available to the crops. Both the quantity and the quality of the harvest decreased particularly in Central and southern European areas. EU-15 cereal production in 2003 reached 186 million tons: a reduction of 24 million tons (11.4%) compared to 210 million tons in 2002. The low harvest was topped up by more than 6 million tons imports (under the mandatory quotas) and more than 10 million tons from carry over stocks (COPA-COGECA, 2003). Also rapeseed yield, decreased and, was 6.6% lower than the average at about 2.9 t/ha instead of 3.1 and sunflower yield dropped by some 25%.

The hot and dry conditions led to forest fires, which destroyed 647 thousand ha of forest mainly in Portugal, Spain, France and Italy (COPA-COGECA, 2003). Many major rivers were at record low levels, resulting in disruption of irrigation.

7.3 Fires in Greece

In the summer of 2007, blazes spread across central Greece, affecting olive oil production farms. In total, 244 thousand hectares of land originally used for olive production, was affected. The following table shows the extent of the damage, and the required measures to recover the olive trees from the fires.

Table 7.2. Effect of fires in Greece on olive oil production.

Case	Percentage of affected area	Degree of fire damage	Required measures	Productivity
A Light damage	16.1%	Only green leaves	Light pruning (only small branches + leaves)	Still productive in the following year
B Medium damage	20.3%	< 25% slightly burn of branches and trunk	Heavy pruning (prune branches)	Productive in 2-3 years
C Serious damage	63.6%	> 25% burned	Replant or graft	Productive in 8-10 years

Source: Zervas and Eleutheroxorinos, 2007.

Total damage to the olive oil production in Greece was estimated at 123 million Euros. This is the amount of money used for the replanting of olive trees and for recovering of other damage caused by the fires. The total amount of olive trees in Greece is approximately 120 million trees. This accounts for 16% of the international olive market. The trees, which were lost in the fire account for a loss of 2% of the total market (Zervas and Eleutheroxorinos, 2007).

7.4 Plant diseases

There is an increasing number of notifications by European Member countries of findings of harmful organisms in imports. Fytosanitaire signalering 2006 (Plantenziektenkundige Dienst, 2007) reports that the number of notifications increased from 1210 in 2004, to 1534 in 2005 up to 1827 in 2006. Highest notifications are reported by The Netherlands, France and the UK, respectively. France scores by far the highest notifications of 2.3 per million kg of imported product, and Netherlands assumes a 8th place with 0.4 notification per million kg. Important quarantine-organisms found in Dutch imports are Bemisia tabaci (Israelian cutflowers and basilicum, Zimbabwe mostly), Guignardia citricarpa (Brazil citrus) and Thrips palmi. Top 3 countries from which imports were disqualified include Brazil, Thailand and Israel for vegetables; and Israel, Zimbabwe, Kenya for flowers.

Roques and Auger-Rozenberg (2006) reported a total of 8889 interceptions of non-indigenous pests were reported for 29 European countries for the period 1995-2004, among which insects were largely dominant (75.9%) followed by nematodes (11.7%). Pests came predominantly from Asia (38.2%) but intra-European exchanges contributed roughly the same proportion of pests (33.2%). The predominant commodities on which pests arrived were cut flowers (22.3%), plants for planting and potted plants (19.1%) and vegetables (18.7%) but bonsais (8.6%) appeared to contribute more than wood/bark (3.7%) and wood derivates (2.3%).

7.5 Stem rust

Stem or black rust, caused by *Puccinia graminis tritici,* historically caused severe losses to wheat production worldwide. Over three decades the disease has been controlled by use of genetic resistance.

In 2005, the highly virulent stem rust *Puccinia graminis tritici* (race TTKS Ug99) was detected in the Eastern African Highlands, posing a risk to Uganda, Kenya and Ethiopia. Its likely further migration path would be North Africa, through the Arabian Peninsula and then to the Middle East and Asia. Most wheat cultivars, currently grown in its likely migration path, are highly susceptible to this race. Due to favourable environmental conditions, coupled with the extensive coverage of susceptible wheat varieties, an area of 50 million ha is at risk i.e. 25% of the world's wheat area (Singh *et al.*, 2006).

7.6 Locusts in Africa

Within a very short period, from June to December 2004, a very wide geographical area in the Western Region of Africa was invaded by large and very dense desert locust populations.

The 2003-05 upsurge started in the Sahel region, while in the past swarms originating from the Central Region breeding areas, around the Red Sea coasts and in the interior of the Sudan and Saudi Arabia, have usually preceded desert locust population explosions in West and Northwest Africa. The regional impact of the locusts' disaster was very significant as households had to decrease food consumption: food quantity and number of daily meals were significantly reduced. However, on a global level, the impact of the desert locusts' disaster was not significant (Brader*et al.*, 2006). Table 7.3 shows the regional impact of the desert locust on three countries that were affected.

Table 7.3. Impact of desert locusts on Burkina Faso, Mali and Mauritania.

Country	Effect on cereal production	Effect on leguminous crop production	Effect on cattle and fodder
Burkina Faso	80% loss	85-90% loss	One third of pastures lost
Mali	90% loss	85-90% loss	One third of pastures lost
Mauritania	90-100%	85-90% loss	85% loss of fodder production

Source: Brader et al., 2006.

7.7 Chernobyl nuclear catastrophe

The accident at the Chernobyl nuclear power plant in 1986 was the most severe in the history of the nuclear power industry, causing a huge release of radio nuclides over large areas of Belarus, Ukraine and the Russian Federation.

The agricultural sector was the area of the economy worst hit by the effects of the accident. A total of 784 thousand hectares of agricultural land was removed from service in the three countries, and timber production was halted for a total of 694 thousand hectares of forest. Restrictions on agricultural production crippled the market for foodstuffs and other products from the affected areas. 'Clean food' production has remained possible in many areas thanks to remediation efforts, but this has entailed higher costs in the form of fertilizers, additives and special cultivation processes (Chernobyl Forum, 2003-2005).

However, it is crucial to note that the region also faced great economic turmoil in the 1990s owing to factors completely unrelated to radiation. The disruption of trade accompanying the collapse of the Soviet Union, the introduction of market mechanisms, prolonged recessionary trends, and Russia's rouble crisis of 1998 all combined to undercut living standards, heighten unemployment and deepen poverty. Agricultural regions, whether contaminated by radio nuclides or not, were particularly vulnerable to these threats, although Chernobyl-affected regions proved particularly susceptible to the drastic changes of the 1990s.

Coping with the impact of the disaster has placed a huge burden on national budgets. In Ukraine, 5-7 percent of government spending each year is still devoted to Chernobyl-related benefits and programs. In Belarus, government spending on Chernobyl amounted to 22.3 percent of the national budget in 1991, declining gradually to 6.1 percent in 2002. Total spending by Belarus on Chernobyl between 1991 and 2003 was more than US $ 13 billion (Chernobyl Forum, 2003-2005).

7.8 Global governance of food security

In case of threats of food shortages, the options open to a country to increase the availability of food depend on the causes of the shortage. Shortage, by definition, implies that supply is less than demand. In a closed economy, shortages result in higher prices; if prices are controlled it results in rationing of food. The early studies by Amartya Sen made clear that high prices, when combined with speculation, may lead to parts of the population being deprived from food, even where it was de facto available, if they do not have the means (*entitlements*) to buy food. Price controls may reduce speculation, and thereby favour a fairer distribution of the limited quantities, but it requires effective governance intervention. The limited local quantities can be augmented with the help of food aid from the outside world.

In a more open economy, prices are linked to the world market. If a global shortage occurs, world market prices go up. This would normally spill over into the country, and possibly harm the poorer groups in the society. Government options now include the possibility to limit the spill-over from the world market by raising export taxes or reducing any import taxes. Both lead to domestic prices that are lower than world market prices, while leaving the market 'free'. The recent actions taken by countries such as China, Russia and Vietnam are examples of increasing export taxes in the face of recent price surges of food in the world market. Pakistan, India and Japan are reported to have increased their levels of stocks in order to be able to cope with any shortages that may occur domestically. This behaviour, like that of speculators, contributes to increasing world market prices.

Internationally, countries have taken joint initiatives to respond to possible food shortage. The FAO has a division GIEWS (Global Information and Early Warning System) that is geared toward early detection of possible shortages in order to enable timely responses. Detected shortages trigger possible international action by the World Food Program. Availability of food aid, or of the means to buy this food is assured (to some extent) by the commitments made by the signatories to the Food Aid Convention. They have obliged themselves to avail substantial amounts of food when called for. To help prevent (as far as possible) food aid from distorting the food market, the International Grains Council monitors grain shipments. They do this on the authority of the International Grains Convention, and follow the market on a weekly or even daily basis; as of 2006, they also include trade in rice and oil seeds.

Early warning systems are not all functioning properly. A recent report (Tefft *et al.*, 2006), makes clear that before and during famines in Niger (2005) and Ethiopia (2000), the warning and response mechanisms failed. Enhanced national commitment, and more expertise and communication (technology) is proposed to improve this situation. The Food Aid Convention is under extension, for one more year until 1 August 2009. Its efficacy is considered small in view of the large amounts of food aid provided outside the FAC and the small amounts of food aid that are duly registered. In addition, the WTO based negotiations are including food aid among other forms of subsidizing grain exports and a call is made to retarget food aid so as to be less distortionary, more targeted (WEMOS, 2005) and less geared to help the producers (Barrett and Maxwel*.* 2005).

Thus, while some aid mechanisms are in place to be put into action in case of calamities, the overall international framework is still very much in discussion. In particular, the WTO negotiations on liberalization of trade in agricultural products includes a contested issue of leaving room for countries to maintain barriers to trade if this helps secure food provision domestically. Similarly, food donors should leave ample room for local authorities to foster reliable food production, as recently argued by Keyzer and Wesenbeeck (2007).

8. Conclusions

In this section, some concluding remarks are made of the main findings from this review study and suggestions as to how the impact of calamities on the food security situation of the EU can be analysed in more depth. Also, negative consequences due to the transfer of adverse externalities to third countries resulting from Europe's attempt to resolve a potential food insecurity situation should be explicitly considered in future analyses. A basic scenario and possible calamities are described for future analyses.

8.1 Current situation

Current food security of the EU

The current degree of self-sufficiency in the EU-27 is high and is likely to remain high in the near future. For the most basic food items 95-100 to over 100% of European consumption is produced on its own territory. Extra-EU trade volumes generally do not exceed 10% of the production volumes, with net trade volumes below 5%. Of all cereals produced about a quarter is consumed directly, and the remainder is destined to animal feed, which suggest some flexibility in overall food availability by modifying diets. Primarily processed foods and dairy products are exported. Europe imports about a quarter of its fruits and less than 10% of its vegetables, with total per capita supply doubling amounts strictly needed for an affluent diet. Soybean is a basic commodity to feed chicken and pigs, and for oil production that is almost fully imported from Latin American countries. Europe is heavily dependent on imported vegetable oils and fats, amounting to 40% of its consumption.

Income allocated to food

An ever-decreasing share of the household income in Europe-15 is used for food declining from 13.2% in 1995 to some 11.6% in 2005, though the differences between European countries and between income groups are large. The poorest first quintile of people in Portugal spend almost 30% of their income to over 12% in the Netherlands, while the richest quintile uses less than 14% in Portugal and a mere 7% in Luxembourg. While Europeans on average are not likely to be affected by rising food prices, some groups, such as poor people in Southern Europe seem most vulnerable and may experience the greatest impact of food shortages.

Actual acreage

Actual agricultural area of the EU-27 reaches 184 million hectares on a total land mass of 432 hectares. A much larger acreage of 332 million hectares is potentially suitable for agriculture, which suggests room for expansion whenever needed, further raising the potential production volumes that could be realized, however at the expense of natural lands and forest. The current acreage is actually expected to decline during the coming decades because of increasing productivity at rates varying from 0.5-1.5% per year. As the gap between current yield levels and potential levels is still substantial, same amounts of food can potentially be produced on much less land.

8.2 Future analyses

Modelling approaches

Production estimates explore possible options that are not necessarily time-bound. Some biophysical analyses that specifically look for instance into the impact of climate change on crop yield are time related (long term 20-100 years), but should be considered as explorations rather than predictions. Predictive analyses are generally based on economic principles and attempt to predict developments for the near future (short term 10-20 years). These models generally take past trends as a basis and assess future developments by imposing (econometric) empirical relationships of the past trends. Some model analyses try to comprehensively account for various possible future changes, such as climate change, demand for food, feed and for fuel, and trade liberalization. The approach in this case, in general, is to perform calculations of different thematic models sequentially in an attempt to account for the various aspects. Often, sophisticated interactions are lost and crude assumptions are introduced to account for certain aspects and processes, such as for the impact of climate change on yield in production-trade models. Fully integrating various (complex) models generally turn out to be too complex or tedious. Also the errors and uncertainties accumulate to the extent that the final quantitative accuracy of the analysis is reduced. Due to these limitations, it may be questioned whether comprehensive analyses that attempts to integrate a too large number of factors, provide better quantitative insight than stepwise and logical qualitative analyses based on partial quantitative studies.

Biophysical production potential

To be able to compare production (estimates) to consumption without having to calculate the production of all individual food items, diets have been converted into grain-equivalent. The production potential of Europe exceeds the demand of food by more than a factor 2 to 4 depending on the production system applied. These levels are attained however when all suitable lands and available water is allocated to food production. The study does not suggest taking additional natural lands and forest into cultivation, but does reflect the available 'ground for choices'.

Climate change

The overall global impact of climate change on the productivity of crops will be modest as positive and negative impacts will be in balance, but regional differences are expected to be large. Globally, a widespread decline in productivity is expected in particular in Sub-Saharan Africa and Southern Europe, while improvements will occur in current temperate climates like Northern Europe, Canada, Latin America and the former Soviet Union. These findings suggest a further global diversion in productivity between developed and developing countries and within Europe between Northern and Southern countries. Agricultural production systems can be expected to gradually adapt to these changing conditions to mitigate climate impact.

It should be noted that the consequences of climate change include large uncertainties. In particular, a change in the thermohaline currents in the oceans is a possibility which can not be excluded, leading to a strong cooling of western Europe. This could completely call for a reorientation of future scenarios for the long term, while developments for the coming two to three decades are not likely to be affected much.

Bio-fuels

The European obligatory target of 10% for bio-fuels for the transport sector in 2020, amounting to 31-43 MTOE, will put a potential claim on 10-20 million hectares, depending on the crops used. Economic analyses indicate that approximately 7% only can be realized when taking market and technology development into account, of which half will be supplied from its own territories and the other half will be imported.

In addition, Europe has set a target for 20% of its total energy to be derived from renewable sources, including solar and wind energy, amounting to 325-340 MtOE. Biomass should account for two thirds of this target in the form of electricity, heat and bio-fuels, representing respectively 90, 90-95 and the 31-43 MTOE. Half of this total amount is estimated to be derived from waste flows, though it remains unclear whether the large contribution from waste is adequately estimated and can be attained, as it compares to an equivalent of over 80 million hectares of rapeseed. The remainder will be collected from forest areas and agriculture. Reports differ enormously with regard to the acreages needed for producing these amounts of energy. The study of the EEA suggests 90 MToe in the form of electricity, heat and bio-fuels to be derived from 16 million hectares. Other studies estimate almost 9 million hectares to produce only 19 Mtoe in the form of transport fuel. The high energy levels of the EEA imply land productivity levels that would exceed potential production level in Europe, like over 25 tons total dry matter per hectare for producing electricity or heat and over 6 tons vegetable oils per hectare, etc. It remains unclear what the acreage of 'energy production forest' would be to meet the targets. Converted to agricultural acreages, a total amount of 180 MTOE would put a claim on a total acreage ranging from almost 50 to over 160 million hectares. These figures and values should be looked at in more detail in future analyses.

Economic predictions

Trade models are rather consistent in projecting declining acreages in the EU for food production with continued net trade balances. Though estimated trade volumes do differ significantly between models they suggest a reducing difference between production and consumption. A most extreme global liberalization scenario whereby both border and farm support are eliminated shows for 2020 that agricultural productivity and farm size will increase, total production of some commodities will be reduced, as will the agricultural area. The agricultural pattern within the EU will show a concentration of production in North-western Europe due to its competitive ability with other global regions and with other European countries. East European countries will hardly be able to participate in this competing scenario because of low degree of technology use, fragmented and small farming systems, poor infrastructure and the like, and South European countries will lag behind because of climate change. Note that the competitiveness of Eastern European countries might improve at the longer term. Under the regionalization scenarios with border control and farm support, a more dispersed production pattern is expected. Current analysis that includes Eurasia, show that cereal production under trade liberalization will concentrate in North-western Europe and in Eurasian countries, like Ukraine, while Eastern European countries will make a small contribution only (Hermans and Verhagen, 2008). It should be mentioned that the models analyse rather extreme changes to occur under full liberalization due to the inherent characteristics in modelling approach, so that production might be less concentrated than expected.

The trade models are not consistent however with regard to the impact of liberalization on different global regions, particularly Africa. Differences result from different assumption such as the competitive power of developing nations. The IMPACT model for instance, expects Africa to have a better competitive position on the world market after trade liberalization than the FAO-GTAP models. Whereas Africa would benefit from trade liberalization according to IMPACT, this would not be the case according to the FAO model.

Recent developments in current analyses

The unprecedented developments of the past year and even months due to the obligatory blending targets for bio-fuels have made many analyses almost obsolete. The recent dramatic increases in food prices, the changes in global stocks, and the speed of increase in demand of bio-fuels are often not taken into account in these analyses. Farmers, for instance, will respond differently in a liberalized scenario to high or low world market prices. Higher margins at higher prices would favour larger farmers who benefit from economies of scale.

8.3 Calamities

The increasing frequency of extreme climatic conditions due to climate change, such as hot and dry spells and of flooding, is likely to have a larger impact on acute food availability than the overall long term changes and variability. While much research has been done on the long term overall effect, little is known about the impact of this increased frequency, especially when a number of consecutive years with extreme weather events would occur.

There is a high dependency of Europe on imported vegetable oils or basic commodities for oil production. Most of these oils are an essential component in the food processing industry in combination with cereals. A combined reduction in the availability of both oils and grains could limit the supply of several food items simultaneously. Oil import might be reduced because of problems in the supply chain, losses due to disease pressures in producing countries or ICT, while grain supply could be curtailed due to extreme weather events. The extent to which these calamities will affect food availability remains to be analysed.

The intensity of plant and animal diseases will increase with increasing concentration of production due to the exposure of a larger number of individuals. At the same time, increasing insights as to how to deal with intensive pressure and introduced diseases, control measures and optimal institutional arrangements allow timely response to limit excessive effects.

The impact of the Chernobyl nuclear catastrophe on overall food availability in Europe has hardly been noticed. Similarly, extensive fire in Greece affected only 5% of the oil production that was compensated by a higher production in Spain. Single events of short duration, seems therefore not to drastically affect food availability.

Geopolitics and war might have a more pronounced effect under global liberalization than under regionalization. Whether the vulnerability of Europe-27 will increase because of the concentration of agricultural production in North-Western Europe (and Eurasia) remains to be assessed. Risks might be lower under regionalization scenarios, as virtually all EU-27 countries would continue to engage in production.

Food stocks

Cereal stocks were adequate to absorb the reduced cereal production of 24 million tons cereals in the EU-15 in 2003 due to extreme climatic event together with increased imports. Current stocks of the EU-27 reach some 50-70 million tons and are expected to remain stable in the near future, though models do differ in their estimates.

Impact on global food development

The increasing demand for food from Asian countries, the relocation of food crops to biofuels and the low production in some important food exporting countries has caused a hike in food price that has not been experienced before. World market prices are rather volatile as only a few percent of global food production is traded, and many price reactions are worsened by speculations. Price hikes have occurred for single commodities in the past due to a combination of factors affecting availability, such as for rice. The current surge in price of several food commodities is likely caused by the relocation of several commodities simultaneously, affecting prices of other crops because of substitution. Several newly developing countries have responded to these price hikes by restricting exports and raising stocks because of fear from social unrest that results from increasing food prices.

A suddenly increased demand by the EU in case of a calamity might have an impact on food prices for some individual commodities only, such as soybean, and to a small degree cereals in case of several years of consecutive shortages. The impact through international price changes and availability of these and other food items to the poorest countries and regions that still rely heavily on agriculture, whose population spend a large portion of their income to food and that depend much on food aid, is likely to be modest. Still any adverse impact resulting from an European reaction should be prevented or compensated, which will likely be most relevant for Sub-Saharan African countries.

Because Europe will face less negative effects due to climate change than most other parts of the world, including Sub-Saharan Africa, it might assume an important role in supplying more risk prone areas with food through food aids to absorb shocks and which may be combined with higher European stocks required to buffer calamities. However, structural aid to increase overall food production and self-sufficiency in Africa is a more stable approach. Such structural aid may be a necessary impulse also because model finding are contradictory in terms of the opportunities for Sub-Saharan Africa to benefit from trade liberalization and overall increase of food prices.

8.4 Risk assessment

Overall, the European population is not likely to experience fierce shortages in food availability in the near future. Within Europe, however, under continued global liberalization an increasing proportion of food production may concentrate in North-western countries, while southern nations will experience an overall decline in production and might be exposed to increasing risks due to more frequent extreme climatic events. The importance of agricultural production in Eastern European countries is even expected to decline at the medium term because of their poor competitiveness. Liberalization will divert intra-European trade to extra-European trade because of the lowering of the EU common external tariffs. Intra European trade may have to be better coordinated under these conditions and stock volumes may have to be raised as a means to mitigate adverse effects of calamities.

A sequential occurrence of calamities, such as dry and hot spells and floods together with disruptions in the oil chains under a globalizing scenario with concentrated production areas, might reduce the availability of food within the EU to levels that have not been experienced over the past decades. The occurrence of such a sequence of calamities is not unthinkable. Bio-energy was discarded as a feasible option some 30 year ago, while it is heavily stimulated today. The coincidental occurrence of a number of developments over the past years, as elaborated in the Chapter 1, has lead to this dramatic change.

The largest vulnerable groups that might be at risk under the combined occurrence of global changes could be the poorer people in South European countries. South European countries may be more prone to climate calamities, be less competitive in an international market and poor people currently spend up to 25-30% of their income to food. Vulnerability of some groups in some East European countries might be high also, and needs to be looked into in more detail.

8.5 Suggested analyses

To analyse the likely impact of the occurrence of a sequence of calamities, the globalization scenario is taken as a baseline development. The basic parameters of global liberalization with a world market and fast per capita economic growth of the SRES-scenarios will be taken as a basis. World population will peak in 2050 and then decline, where no adjustments are required to the projected population of the EU that reaches somewhat less than 500 million. The food consumption rate can be assumed to remain stable at current levels, equivalent to some 4 kg grain equivalents per person per day. The agricultural productivity will increase at a rate of maximally 1% per year, leading to an overall decrease in total required acreage under agriculture. A climate scenario with a high impact on shifts in agricultural systems should be selected.

A number of factors ought to be considered in the analysis to assess food risk to the European community.

a. A quantitative analysis of the sequential occurrence of calamities over time, such as two to three consecutive hot and dry years, assuming a concentrated production of food in the North-western part of Europe.
b. The impact of the increased intensity of plant and animal epidemic due the increased concentration of production.
c. The insufficient availability of a combination of food items, both regionally produced such as grains and imported such as vegetable oils.
d. The effect of the different impacts of calamities between European countries, primarily north-south, on the intra-European food situation.
e. The demand for biofuels according to the obligatory targets of the EU, assuming a certain (high) fraction of the renewable biomass to be derived from agriculture and from forest areas.

It is recommended to distinguish the causes of calamities from the calamities themselves because this analysis looks into the impact of calamities, irrespective of how they have been caused. Moreover, a distinction might be needed between mitigation and adaptation measures, because measures to prevent calamities from occurring and measures needed to reduce the impact of calamities may differ. Events b and c can happen because of natural causes, for instance, but can also be caused by human actions, such as bioterrorism. It can then be argued that the severity of such an extreme event can be very high because of a combination of such intended and unintended causes, in order to analyse apparent unlikely events.

Analysing the impact of calamities for the European food situation can best be pursued by combining quantitative production simulations with the occurrence of calamities on agricultural production within Europe and descriptive qualitative analyses of past extreme events and logical lines of thought for institutional processes in the food chain.

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Appendix I.
WRR Diet

Diets that are composed of food items for a balanced intake to comply with caloric, protein, fat and vitamin needs can be converted in grain equivalents, which facilitate analyses of production and consumption of food. Conversion factors have been used to converse each food product in fresh weight to grain in dry weight. Grain equivalents refer to the amount of cereal needed as raw material for the products plus the opportunity costs to grow the food that cannot be produced via 'grain'. (e.g. fruit).

Global cereal production in 2005 (FAO, 2007) is 2,239 Million tons which represents total food production of 3732 Million tons. The global arable acreage derived from cereals can be estimated by correction for 60% (the proportion of food produced) and 87% (the relative carbon fixation rate relative to the global average) which reaches 685.6 (current area for cereals) /0.6/0.87 = 1313 Million hectares. This estimated acreage is close to the current arable land of 1402 Million hectare. For the 6.47 billion people on earth in 2005, a total amount of 1580 g cereals is available per day, equivalent to 577 kg y^{-1}.

In a study by the WRR (1995), three diets are distinguished to indicate the range in food needs, i.e. a vegetarian diet, a moderate diet and an affluent diet (Table I.1). Based on definitions of Bakker (1985), the vegetarian diet and moderate diet are representative for a moderate but satisfactory diet. The affluent diet is considered the upper limit of food consumption. This diet can be mostly found in rich societies such as Western Europe and the US. Trends show that developing countries have had an increase in meat consumption over the years, therefore they are moving slowly towards moderate and affluent diet standards.

Table I.1. Average daily per caput consumption, energy intake and grain equivalents.

	Consumption (kg d^{-1})	Energy intake (kJ d^{-1})	GE (kg d^{-1})
Vegetarian Diet	1.5	10049	1.3
Moderate Diet	1.6	10046	2.4
Affluent Diet	1.5	11540	4.2

Source: WRR, 1995.

The total weight of food consumed is similar for all diets with comparable amounts of energy intake, except for the affluent diet. Major differences do occur in terms of grain equivalents for the various diets due to their compositions. The amount of grain equivalent needed for the affluent diet is almost twice as the amount required for the moderate diet and almost four times the amount for the vegetarian diet.

The minimum caloric intake of 2000 kcal/day which is equivalent to 8368 kJ/day is adequately met in all these diets and is in line with actual levels of consumption (e.g. Gleich 2003). Current global average consumption of 1.6 kg grain equivalents d^{-1} slightly exceeds a vegetarian diet. As current food intake in wealthier nations is not likely to decrease, while the intake in developing nations will increase towards more protein rich diets, global average intake in grain equivalents is likely to increase in the near future. Wealthier nations are however not likely to consume ever larger amounts.

Table I.2. Composition of affluent, moderate and vegetarian diet.

Affluent Diet	Consumption ($g\ d^{-1}$)	Energy intake ($kJ\ d^{-1}$)	Conversion Factor (kg GE/kg prod)	GE ($g\ d^{-1}$)
Cereals	269	2327	0.7188	
Potato	264	932	0.4	106
Vegetables	100	100	1.0	100
Veg-oil	47	1481	3.0	141
Sugar	87	1462	3.0	261
Fruit	171	383	2.0	342
Milk	262	707	1.5	393
Cheese	37	535	14.0	518
Pwdrmilk[1]	2	40	12.5	25
Pwdrmilk[2]	2	29	17.0	34
Butter	15	473	0.0	0
Eggs	36	228	5.3	191
Beef	64	750	11.1	710
Pork	105	1636	6.3	662
Poultry	46	328	9.5	437
Mutton	10	129	9.8	98
Total	**1517**	**11540**	**2.77**	**4206**

Vegetarian Diet			Moderate Diet		
Food item	Consumption ($g\ d^{-1}$)	GE ($g\ d^{-1}$)	Food item	Consumption ($g\ d^{-1}$)	GE ($g\ d^{-1}$)
Cereals	558	390	Cereals	491	344
Potato	477	191	Potato	420	168
Legumes	55	22	Legumes	9	4
Fruit	57	114	Fruit	50	100
Vegetables	114	114	Vegetables	100	100
Sugar	28	84	Sugar	24	72
Veg-oil	46	138	Veg-oil	40	120
Milk	122	135	Milk	408	612
Cheese	8	112	Cheese	20	280
Pwdrmilk[2]	2	34	Pwdrmilk[2]	15	255
Butter	8	0	Butter	10	0
Eggs	4	5	Eggs	16	85
Total	1457	1339	Beef	14	155
			Pork	8	50
			Poultry	1	10
			Total	1626	2355

[1] *Fat powder milk.*

[2] *Lean powder milk.*

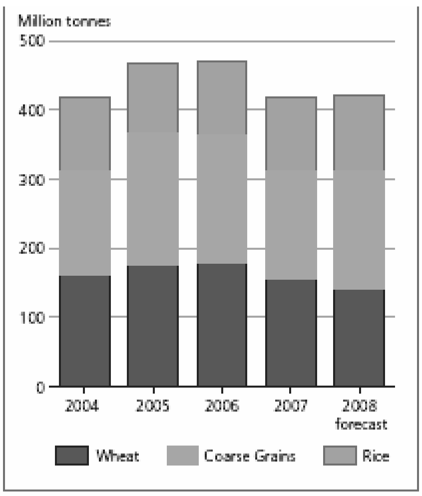
Appendix II.
Stocks

Global cereal and wheat stocks

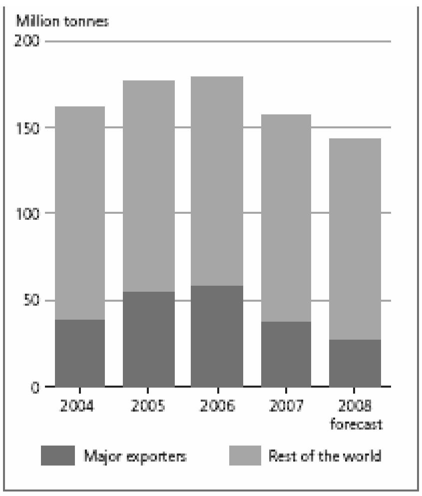
On a global scale, stocks are expected to decline in 2008. The FAO agricultural outlook of November 2007 mentions 2008 wheat stocks to be the lowest since 1982. Wheat stocks of major exporters by the closing of the crop seasons in 2008 are forecasted to exceed 42 million tones, 17 million tones or 10% below the already low opening levels. Total wheat stocks will be approximately 150 million tons at the end of 2008. At this level, world wheat stocks-to-use ratio is forecast to reach 22.5 percent; again below the reduced level in 2006/07 and the lowest since the early 1980s. The strong reduction of wheat reserves reflects the continuation of strong demand and insufficient increase in world production. The reduction in stocks is expected to be biggest in the major exporting countries, which are also the leading stock holders.

The drop in stocks is expected to prove most significant in the case of Australia, which is suffering from a prolonged drought for the second consecutive year. Reduced inventories are also forecast for Argentina, Canada and the European Union. In spite of a sharp rebound in its production, stocks in the United States would still fall significantly in order to sustain increased export this season. As a result, ending stocks in the United States are forecast at roughly 8 million tonnes, the smallest in more than three decades and 2 million tonnes below the previous low registered in the mid-1990s.

Among other countries, inventories are anticipated to increase in only a few cases, notably in India, sustained by a rise in this year's production and large imports before the start of the season, and in China, following a 2.5 percent expansion in domestic production from the previous season (FAO, 2007).



World cereal stocks



Major exporters wheat stocks

Figure II.1. Global cereal and wheat stocks. Source: FAO, 2007.

European stocks for cereals and wheat

Table II.1. Stocks for total cereals and total wheat, EU-27.

	2004	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014
Total cereals (mio tons)											
Beginning stocks	44.4	74.7	69.7	53.2	46.8	49.5	53.4	56.6	59.1	61.3	60.9
Ending stocks	74.7	69.7	53.2	46.8	49.5	53.4	56.6	59.1	61.3	60.9	59.7
Intervention stocks	17.4	14.6	2.2	0.7	4.2	4.7	7.2	9.2	10.3	11.2	10.9
Total wheat (mio tons)											
Beginning stocks	15.1	29.0	28.8	23.5	21.8	23.8	27.1	29.7	30.8	33.0	32.7
Ending stocks	29.0	28.8	23.5	21.8	23.8	27.1	29.7	30.8	33.0	32.7	31.9
Intervention stocks	10.9	5.8	0.0	0.1	2.8	4.1	5.5	6.6	6.8	6.5	5.8

[1] *Stocks apply to the EU-25 for the years 2004, 2005 and 2006, and to the EU-27 from 2007 onwards. Source: EC, 2007h.*

The agricultural outlook of the European Commission expects a decline in cereal harvest for the years 2006 and 2007 and an expansion in domestic use. Table II.1 shows a rapid decline in public stocks for those years to recover afterwards. Intervention stocks are stocks held by national intervention agencies in the European Union as a result of intervention buying of commodities subject to market price support. Intervention stocks may be released onto the internal markets if internal prices exceed intervention prices; otherwise, they may be sold on the world market with the aid of export restitutions.

Table II.2. Wheat stocks, EU-27.

	2004[1]	2005[1]	2006[1]	2007	2008	2009	2010	2011	2012	2013	2014
Total wheat (mio tons)											
Beginning stocks	10.6	25.2	21.0	14.7	14.0	14.2	14.3	14.4	14.5	14.6	14.8
Ending stocks	25.2	21.0	13.6	14.0	14.2	14.3	14.4	14.5	14.6	14.8	14.9

[1] *Values apply to the EU-25. Source: FAPRI, 2007.*

For the year 2004-2006 that have passed already, the values in wheat stock between Eurostat and FAPRI are showing comparable trends of a drastic increase from 2004 to 2005 and 2006. The differences in absolute values may be attributed to the countries included or to a difference in definition of total wheat. The FAPRI projections of beginning and ending wheat stocks are however much lower than the projections of the European Commission. The EU projects the stocks to decline after 2006 but to recover after 2008 moving up to over 30 mio tons in 2014. FAPRI does projects a heavy decline in wheat stocks until the year 2008 to 14 mio tons that, however, will remain virtually unchanged until 2014. The two analyses seem to pursue different approaches, methodologies, variables and variable values in their projections. The discrepancies suggest that future estimates might be rather subjective, but that a certain level of stocks is likely to remain available in the near future.

Projections of the both the European Commission and FAPRI are based on assumptions regarding macro-economic conditions, international agricultural and trade policy and international market developments. Since biofuels are an upcoming commodity in the international market, the projections include the effect of these biofuels. The effect of climate change on future production, consumption and stocks has not been taken into account in these projections.

Appendix III.
EU, energy consumption

The Gross Inland Consumption (GIC) is the quantity of energy consumed within the borders of a country (or EU). It is calculated using the following formula:
Primary production + recovered products + imports + stock changes - exports - bunkers
Bunkers: quantities supplied to sea-going ships

Table III.1. Gross Inland Consumption for EU in 2005 (Mtoe).

	EU 27		EU 25	
All fuels	1,811.3	100.0%	1,752.3	100.0%
Solid fuels	320.0	17.7%	304.3	17.4%
Oil	665.5	36.7%	650.5	37.1%
Natural gas	444.8	24.6%	428.1	24.4%
nuclear	257.4	14.2%	251.1	14.3%
Renewables	120.6	6.7%	114.4	6.5%
Other	3.1	0.2%	3.9	0.2%

Other: electrical energy and industrial waste.

Table III.2. Gross Inland Consumption for EU in 2005, renawables in ktoe.

	EU-27		EU-25	
Renewables	120,565	100.0%	114,437	100.0%
Biomass	81,900	67.9%	77,998	68.2%
Hydro	26,394	21.9%	24,283	21.2%
Wind	6,060	5.0%	6,060	5.3%
Solar	816	0.7%	816	0.7%
Geothermal	5,395	4.5%	5,280	4.6%

Source: EC, 2007e.

Table III.3. Import dependency 2005, in %.

	EU-27	EU-25
All fuels	53.3	52.9
Solid fuels	39.6	39.9
Oil	82.2	82.7
Gas	57.7	58.4

Source: EC, 2007e.