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# Global agricultural market trends and their impacts on European Union agriculture

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**To G. Edward Schuh,**

**good friend and respected colleague.**

**May 4, 2008**

# Global agricultural market trends and their impacts on European Union agriculture*

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## Abstract

The economic, political and climatic conditions in which farmers around the world have to make their production and investment decisions are changing dramatically. This study analyses the driving forces of changes in agricultural world markets and their implications for European Union agriculture for the time period 2003/05 - 2013/15. The impacts on European Union agriculture are quantified using of a multi-market-model.

The mega-trend of declining world market prices has ended. Since the turn of the millennium world market prices for agricultural goods have been increasing. This trend can be expected to continue. Not only will prices have a tendency to increase, but also fluctuations of agricultural world market prices are likely to be higher in the future than they have been in the past.

The reason for the positive trend in agricultural world market prices is that global demand growth outstrips the growth in global supply, and this trend will continue in the foreseeable future. The global demand for food will continue to grow mainly for two reasons. One is the continued growth in world population; the other is the sustained growth in per capita incomes in developing and newly industrialised countries, with corresponding increase of per capita food consumption.

Global food supply will have difficulty keeping pace with the growth in demand. A key factor is that the globally available agricultural land is limited in scale. Consequently, to meet the needs of the rapidly growing world population the necessary production growth will have to a large extent be met by a rise in productivity on the land already being farmed today.

However, this will be difficult to accomplish as global agricultural productivity growth has been in decline since the Green Revolution of the 1960s and 1970s. Moreover, the rapid expansion of bio-energy production diverts agricultural land and other inputs away from food

* Research has been made possible in part by the European Crop Protection Association (ECPA).

production. In addition, increasing water scarcity is starting to act as a constraint to production growth, and climate change is also beginning to affect production.

The quantitative results of the analysis for key crops demonstrates that, both in the European Union and globally, agricultural demand will grow faster than supply during the time period 2003/05 - 2013/15. European Union demand for grains can be expected to increase by 10-20 percent and by more than 50 percent in oilseeds. However, European Union supply of wheat and other grains can only be expected to increase by less than 10 percent, corn by 15-20 percent, and oilseeds by more than 30 percent. As a consequence, the price of wheat can be expected to increase by more than 10 percent and the price of corn and oilseeds by more than 30 percent.

With regard to the trade balance, the net trade position of European Union agriculture can be expected to deteriorate. While there would be a reduction in net imports of corn, net imports of oilseeds are expected to increase by more than 70 percent. Moreover, it is foreseeable that for wheat the European Union will switch from being a net exporter to a net importer. The same is true for other grains.

Two additional aspects warrant further considerations. These are achieving world food security and combating global warming.

For the world's poor, increasing food prices may become a matter of survival. The results of the analysis confirm that the developing countries will not even come close to securing food supply for their rapidly growing population through domestic production, even under the best of all realistic scenarios. Consequently, the increasing food import needs of developing countries can only be met if the industrialised countries produce more and export more food.

However, growth in bio-energy production in the European Union will let the region revert back to a net importing position in wheat, and it will have to increase imports of oilseeds. This will reduce the European Union's ability to help in the fight against starvation in the world, unless there would be an increase in agricultural productivity beyond what is anticipated in this analysis.

Climate change is now widely accepted as a fact, and human activity is a contributing factor. While probably not being of major importance during the time period considered in this study, world agriculture will be affected by global warming in the long run. On balance, world food production will be negatively affected as a consequence of climate change.

Climate change and the associated additional increase in world food prices will amplify hunger and malnutrition in developing countries. Food production will decline predominantly in the countries which are already characterised by increasing food import needs. These countries are also those that are unable to make the necessary investment in agricultural research to adapt food production to the changing climate and to cope with increase in demand.

Higher food prices will also increase the incentives for deforestation in order to claim additional farm land. Deforestation however, is one of the most important causes of global warming.

In the global picture, the European Union will be less affected by climate change. It may even benefit. Europe will become a more secure production location in comparison to other world regions. Consequently, it has to take responsibility to significantly contribute to world food security and also to combat global warming by utilising its production potential.

To avoid negative repercussions and to fully capitalise on its production potential, it is imperative that the European Union employs strategies which increase overall agricultural productivity on the available agricultural land.

**Keywords:** World agriculture, food security, climate change, agriculture productivity growth

## Zusammenfassung

In diesem Beitrag werden die Bestimmungsfaktoren der Entwicklungen auf den Weltagrarmärkten untersucht und deren Auswirkungen auf die EU Landwirtschaft für den Zeitraum 2003/05 - 2013/15 quantifiziert. Dabei zeigt sich, dass die weltweite Nachfrage nach Agrargütern stärker steigt als das Angebot, so dass der Trend der Weltagrarpreise positiv ist. Die gegenwärtig (Mai 2008) sehr hohen Preise werden indes nicht von Dauer sein. Vielmehr ist mittelfristig mit einem eher moderaten Preisanstieg von etwa 15-30 % im Untersuchungszeitraum zu rechnen. Bei Weizen und anderem Getreide (außer Mais) wird die Europäische Union wieder zu einem Nettoimporteur.

Die zu erwartenden Entwicklungen auf den Weltagrarmärkten und die dadurch steigenden Preise für Nahrungsgüter werden zu einer ernsthaften Verschärfung der Welternährungslage führen. Da die Flächen, die weltweit für die Nahrungsgüterproduktion verfügbar sind, begrenzt sind, muss die Steigerung des Angebots, die notwendig ist, um die rasch wachsende Weltbevölkerung in hinreichendem Umfang mit Nahrungsgütern zu versorgen, weitgehend über eine Steigerung der Produktivität derjenigen Flächen erreicht werden, die bereits heute landwirtschaftlich genutzt werden.

Eine Steigerung der Produktivität in der Weltlandwirtschaft führt zu geringeren Nahrungsgüterpreisen. Sie verringert daher auch die Anreize auf dem Weg der Brandrodung zusätzliche landwirtschaftliche Nutzflächen zu erschließen. Gegenwärtig tragen diese Brandrodungen 18 % zum anthropogenen Klimawandel bei. Dies ist mehr als der Klimaeffekt der weltweiten Industrieproduktion. Damit ist das landwirtschaftliche Produktivitätswachstum nicht nur zentral im Kampf gegen den Hunger auf der Welt, sondern es leistet auch einen wichtigen Beitrag zur Verringerung des Klimawandels.

**Schlüsselwörter:** Weltlandwirtschaft, Sicherung der Welternährung, landwirtschaftliches Produktivitätswachstum

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## List of abbreviations

| | | |
|---|---|---|
| CAP | – | Common Agricultural Policy |
| CARD | – | Center for Agricultural and Rural Development |
| CIS | – | Commonwealth of Independent States |
| CRB | – | Commodity Research Bureau |
| EC | – | European Commission |
| ECPA | – | European Crop Protection Association |
| EU-27 | – | European Union (consisting of 27 Member States) |
| FAO | – | Food and Agriculture Organization of the United Nations |
| FAPRI | – | Food and Agricultural Policy Research Institute |
| GDP | – | Gross Domestic Product |
| IFPRI | – | International Food Policy Research Institute |
| IPCC | – | Intergovernmental Panel on Climate Change |
| LEAD | – | Livestock, Environment and Development Initiative |
| MMM | – | Multi-Market-Model |
| OECD | – | Organization for Economic Cooperation and Development |
| PRB | – | Population Reference Bureau |
| UN | – | United Nations |
| UNECE | – | United Nations Economic Commission for Europe |
| USDA | – | United States Department of Agriculture |
| WTO | – | World Trade Organization |

# 1. Problem setting and objectives

The economic, political and climatic conditions in which farmers around the world have to make their production and investment decisions are changing quite dramatically. On the one hand, world agricultural demand continues to grow rapidly. On the other hand, it is apparent that global agricultural supply is not keeping pace with the growth in demand.

Several global trends are directly and indirectly affecting agricultural markets globally and in the European Union. This study identifies and analyses the driving forces of changes in agricultural world markets for the time period 2003/05 - 2013/15 and their implications for European Union agriculture. It provides a quantitative analysis of these impacts looking into past, present and probably future developments.

In particular the following questions will be answered:

– Which are the key global trends significantly affecting European Union agriculture in the years ahead?
– How will these trends affect supply of and demand for agricultural goods globally and in the European Union?
– Which crops will be more affected by these trends than others?
– What are the quantitative impacts of these trends on European Union agriculture, including prices, production, yields, and acreage planted?

The remainder of this report is as follows:

– First, the conceptual approach for the analysis is presented in chapter 2.
– Then, the key trends in world agriculture will be identified and discussed in chapter 3.
– The model for the quantitative analysis and in particular its input data are presented in chapter 4.
– In chapter 5 model results, i.e. expected market developments, are discussed.
– Finally, the main findings of the study are summarised and conclusions are drawn in chapter 6.

# 2. Conceptual approach

In the following, the key trends affecting world and European Union agriculture are identified. Subsequently, a quantitative analysis of the impacts of these trends on European Union agriculture is provided.

## 2.1 Driving forces of world agriculture

Variables considered in the analysis include:

- world population growth,
- urbanisation and income growth and their implications for food consumption,
- climate change,
- availability of natural resources (in particular land and water),
- the trade-off between the use of resources for food production and bio-energy production,
- the role of ecologic/organic farming, and
- technology changes, in particular technological progress in plant breeding.

## 2.2 Quantitative analysis

Focus of the quantitative analysis will be on the following crop categories:

- wheat,
- corn,
- oilseeds (aggregate of soybean seed, rapeseed and sunflower seed) and
- other grains.

### General model characteristics and model specification

A partial equilibrium approach has been developed which is suitable for a quantitative analysis of the impacts of the changing economic environment on European Union agriculture. A detailed discussion of this model type which simultaneously analyses several markets, i.e. a so-called multi-market model (MMM), can be found in JECHLITSCHKA, KIRSCHKE and SCHWARZ (2007).

In the model, which will be discussed in greater detail in chapter 4, each market is characterised by a supply and demand function. Each market is linked with all other markets through a set of cross-price elasticities. The domestic European Union markets are linked with other regions of the world through international trade. In each of the equations the changing economic environment is captured by shift variables.

The generic MMM is specified for the purpose of this analysis. Focus is on the agricultural markets in the European Union mentioned above. Most of the crops included in the analysis may be used for a variety of purposes. The model will accommodate this as exhibited in figure 2.1. That means, for wheat, corn, and oilseeds respectively there will be separate markets for food, animal feed and bio-energy. For "other grains" there is only one market. In total, a number of ten markets will be analysed.

**Figure 2.1: Market coverage of the study**

| | Food | Feed | Bio-energy | Food+Feed+ Bio-energy |
|---|---|---|---|---|
| Wheat | | | | |
| Corn | | | | |
| Oilseeds | | | | |
| Other grains | | | | |

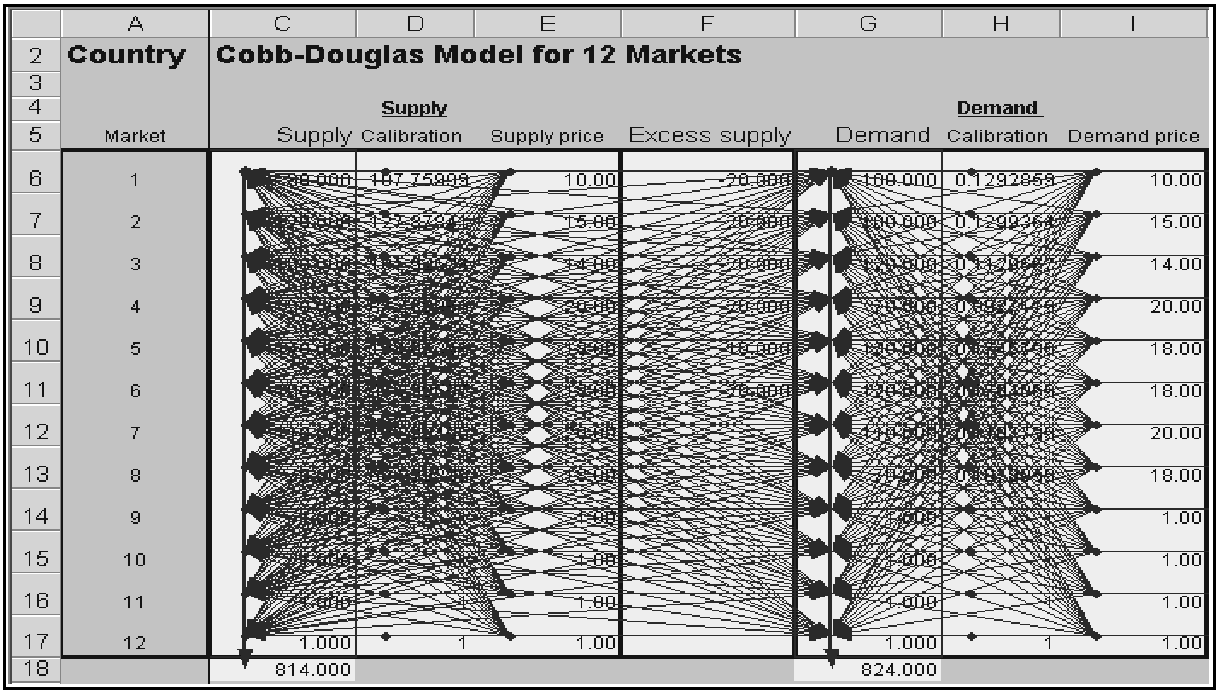
Source: Own figure.

The markets in the European Union will be linked through international trade with five other regions of the world. They are:

– Asia (with particular emphasis on China and India),
– Eastern Europe (with particular emphasis on Russia, the Ukraine and Kazakhstan),
– North America (with particular emphasis on United States and Canada),
– South America (with particular emphasis on Argentina and Brazil), and
– a region referred to as "Rest-of-the world" (to close the model).

Obviously the model is rather complex. In fact it will be characterised by a set of more than 50 equations which specify the markets in the European Union and elsewhere. The model's complexity is illustrated in figure 2.2.

**Figure 2.2: Complex interrelationships between markets in a multi-market-model**




Source: JECHLITSCHKA, KIRSCHKE and SCHWARZ (2007).

## 2.3 Input data and results

For the quantitative analysis a significant amount of data is required. They include such variables as supply and demand quantities, elasticities of supply and demand, cross-price elasticities for linking different markets, prices, and policies.

Data used in this analysis are from reliable sources only, such as the European Union, the Food and Agriculture Organization of the United Nations (FAO) and the World Trade Organization (WTO). In addition, data sources from the international agricultural economic modelling community are used. They include the Center for Agricultural and Rural Development (CARD), the Food and Agricultural Policy Research Institute (FAPRI), the International Food Policy Research Institute (IFPRI), the Organization for Economic Cooperation and Development (OECD), the United States Department of Agriculture (USDA) and other research organisations.

The reference period is defined by calculating the average value for each model variable for 2003-2005. This is done in order to account for random fluctuations caused by weather, plant and animal diseases, and other external shocks. The analysis will generate results for the year 2013-2015 (average).

### Scenarios and results provided

A variety of scenarios are analysed. They have been based on the results of the analysis of key trends. Sensitivity analyses will be performed to test for robustness of the model results, the principles of which are exhibited in figure 2.3.

**Figure 2.3: Principles of the sensitivity analyses in this study**

| | Minimum value for trend A | Likely value for trend A | Maximum value for trend A |
|---|---|---|---|
| Minimum value for trend B | *Output data in case of min/min* | *Output data in case of likely/min* | *Output data in case of max/min* |
| Likely value for trend B | *Output data in case of min/likely* | *Output data in case of likely/likely* | *Output data in case of max/likely* |
| Maximum value for trend B | *Output data in case of min/max* | *Output data in case of likely/max* | *Output data in case of max/max* |

Source: Own figure.

The following results are provided for the European Union consisting of 27 Member States (EU-27) and the ten markets considered in this study:

- absolute and relative changes in demand (for food, feed, bio-energy),
- absolute and relative changes in supply (production quantities),
- absolute and relative changes in the crop acreages,
- absolute and relative changes in yields.

# 3. World agricultural markets: Theoretical framework and analysis

## 3.1 The end of the Agricultural Treadmill

The economic, political, climatic and technological environment world agriculture operates in is changing quite dramatically. The following is an analysis of these changes and an assessment of how these changes affect world and European Union agriculture.

**The Agricultural Treadmill: More food for more people at declining prices**

The Agricultural Treadmill (e.g. COCHRANE, 1958, 1979) is an economic process which characterised world agriculture between around 1870 and 2000. During this time period, world population was growing rapidly. In 1900 world population was at 1.5 billion. 100 years later the world was inhabited by four times as many humans (UN, 2007). In addition, per capita food consumption rose significantly during that time in today's rich countries. Both caused a dramatic increase in world food demand (e.g. ABEL, 1978; FAO, 2002).

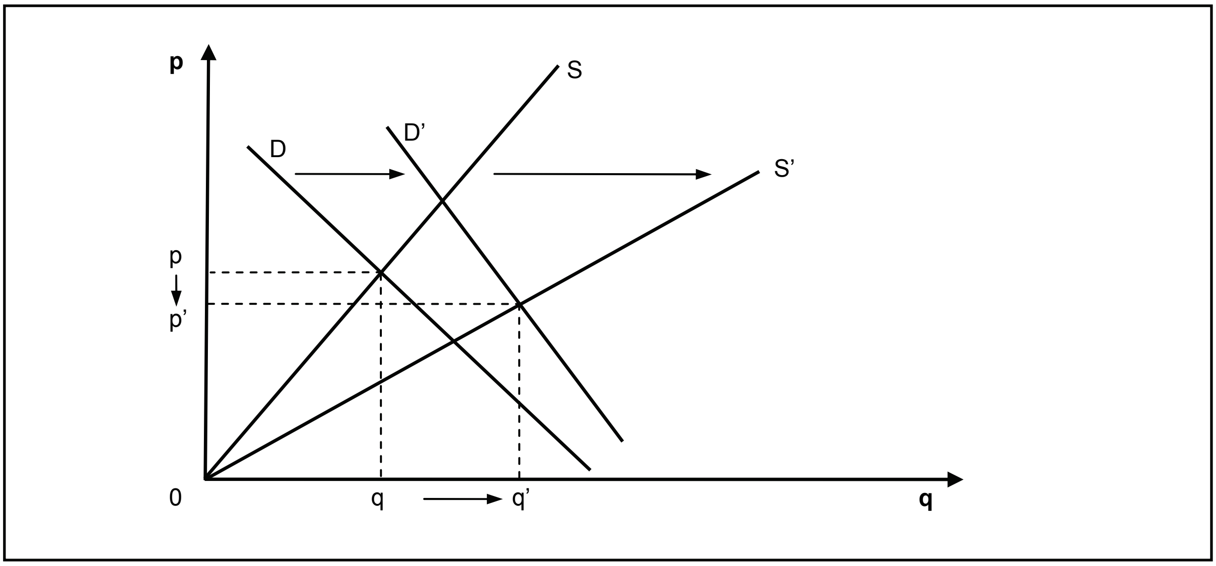
However, global food supply grew even more rapidly, mainly for two reasons. One was an expansion of the acreage for agricultural production (e.g. HAYAMI and RUTTAN, 1985), the other was productivity growth. The expansion of the agricultural acreage has declined in importance in the last 50 years. So, it is rather productivity growth which has been the main driving force of supply growth during that period of time. Productivity growth at times was so high that the 1960s and 1970s are referred to as the time of the Green Revolution (e.g. HAYAMI, 1997; HESSER, 2006).

As the growth in supply had outpaced the growth in demand, the trend in real prices of agricultural goods was negative. World agriculture has produced ever more food for ever more humans at ever declining prices. That is why agricultural economists refer to this phenomenon as the Agricultural Treadmill. World-wide, farmers have become more and more productive. Figuratively speaking, they have run ever faster. Economically, however, they have not gotten anywhere, as the income effect of productivity growth had been eroded time and again by declining prices.

The principle of the Agricultural Treadmill is illustrated in Figure 3.1. The horizontal axis depicts the quantity of food (q) while the vertical axis depicts the price (p). S represents the initial supply function, which has a positive slope, meaning an increase in price is followed by an increase in the quantity supplied. D denotes the initial demand function. It has a negative slope which implies that a price increase acts to reduce the quantity demanded. The equilibrium price is p. It is determined by the intersection of S and D.

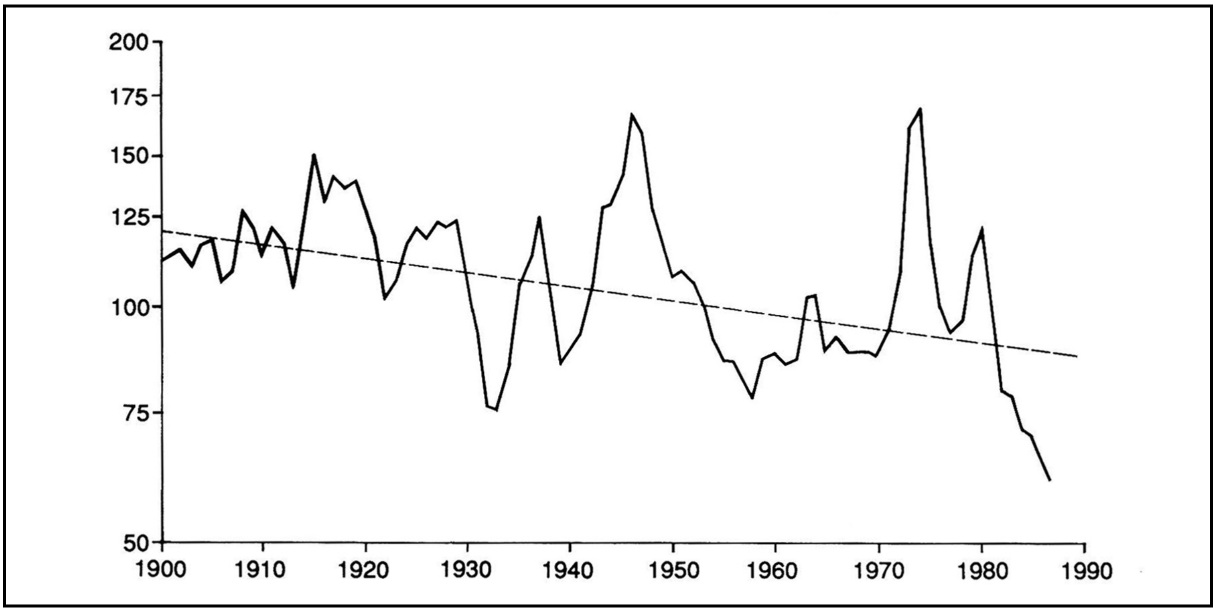
Population growth and growth in per capita food consumption both act to shift the demand curve to the right. D' is the new demand function. Productivity growth and expansion of the agricultural acreage both cause the supply function to shift to the right. S' represents the new supply function. As the rightward shift in the supply curve exceeds the shift in the demand function, the new equilibrium price is given by the intersection of S' and D' which is at the lower price p'.

**Figure 3.1: The global Agricultural Treadmill**




The actual evolution of the real world market prices over time is depicted in figure 3.2. The dotted straight line represents the linear trend in agricultural commodity prices between 1900 and 1990. As is evident, the trend has a negative slope. However, there have been significant fluctuations around the trend.

**Figure 3.2: Real international food prices, 1900-1990***




*Index of agricultural market prices, deflated (1977-1979 = 100).

Source: TYERS and ANDERSON (1992).

The economic consequences of the Agricultural Treadmill have been analysed in much detail and have been well documented for Europe (e.g. HANAU, 1958; PLATE et al., 1962; SCHMITT, 1972) and other parts of the world (e.g. COCHRANE 1958, 1979). Agricultural income growth lagged behind income growth in other industries. Agriculture was a shrinking industry, as labour moved out of agriculture and the share of agriculture in Gross Domestic Product (GDP) declined.

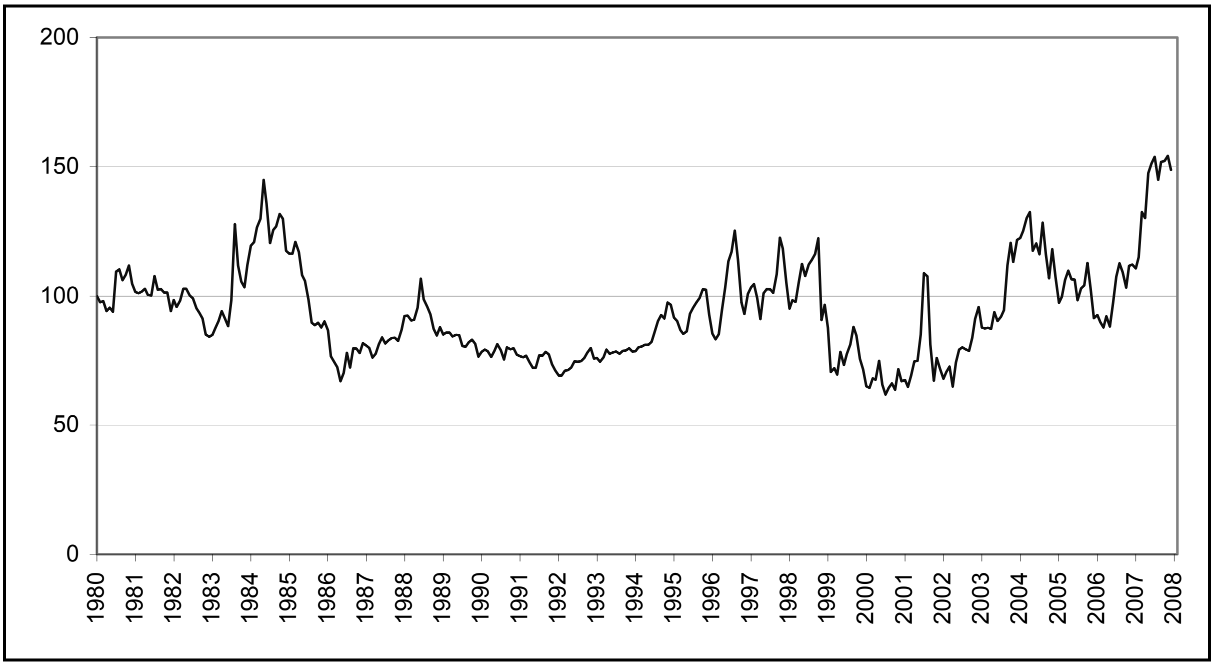
Virtually all industrialised countries have tried to counteract the economic effects of the Agricultural Treadmill by means of supporting agricultural producer prices above market levels. The painful experience with this type of policies was that they had a lot of negative side effects and, thus, were politically not sustainable.

Agricultural producer price support could not render dysfunctional the fundamental market forces of the Agricultural Treadmill (VON WITZKE and HAUSNER, 1997). Instead structural adjustment of agriculture was merely delayed by agricultural policies.

**The Agricultural Treadmill has come to an end as demand outpaces supply growth**

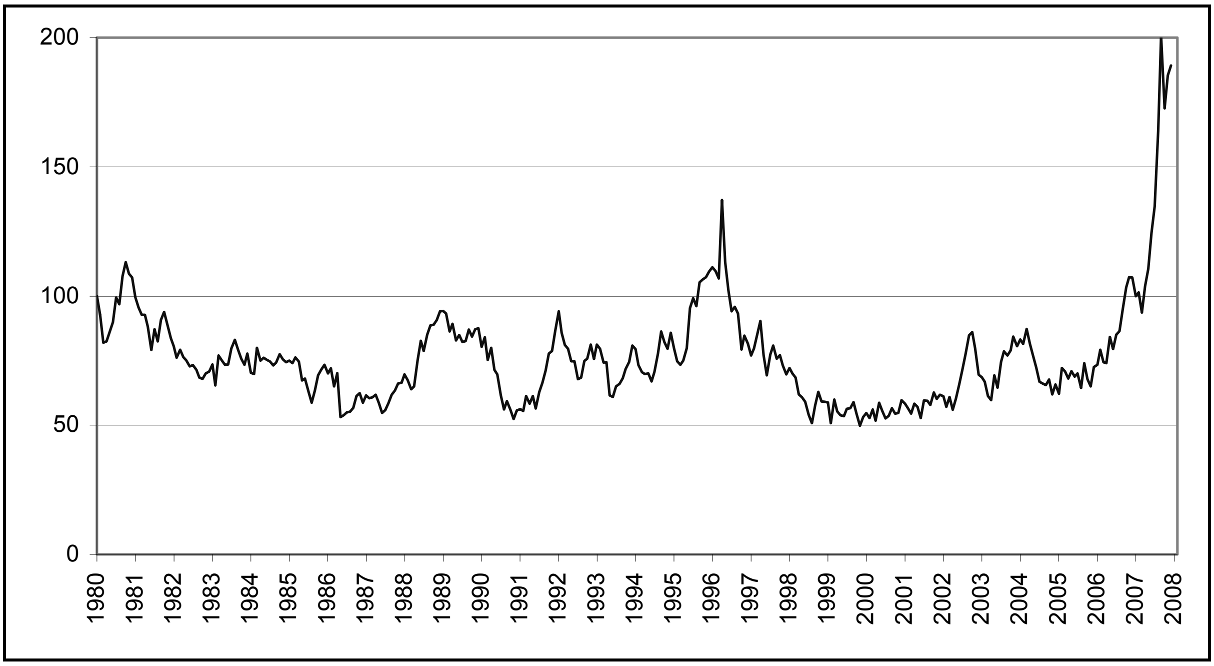
The Agricultural Treadmill has stopped. The turn of the millennium marks the end of the Agricultural Treadmill. Since the beginning of the new millennium the trend in agricultural prices has been positive (figures 3.3 and 3.4).

**Figure 3.3: Price index for grains and oilseeds, 1980-2008 (1980 = 100)**




Source: REUTERS and CRB (2008)

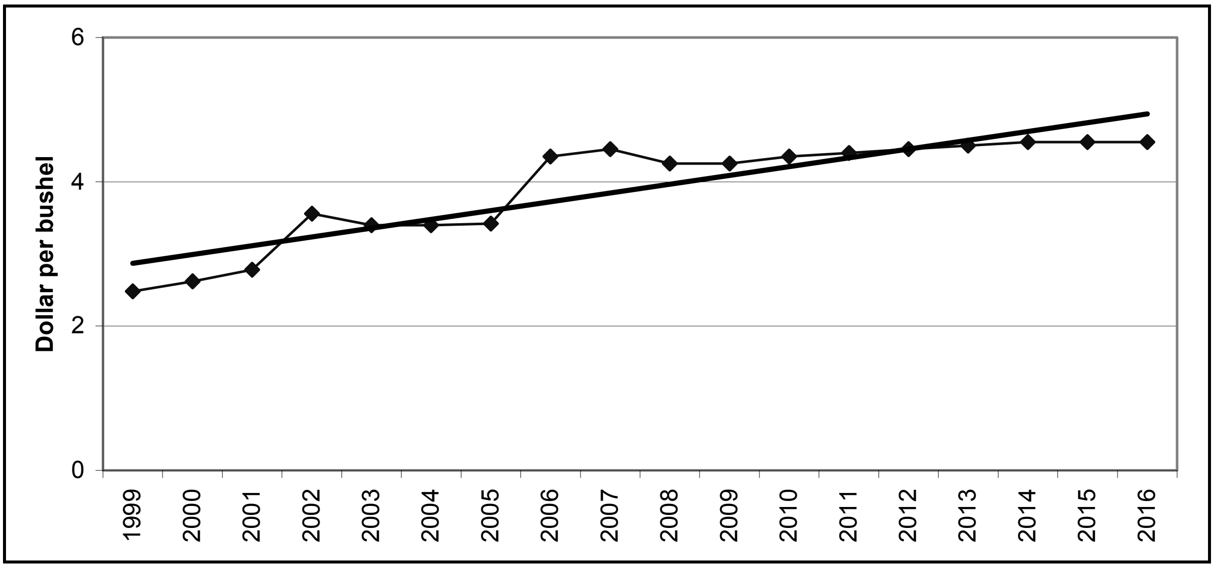
**Figure 3.4: Price index for wheat, 1980-2008 (1980 = 100)**




Source: REUTERS and CRB (2008)

Figure 3.5 exemplifies this for wheat. It shows the actual market price of wheat between 1999 and 2006 and the price of wheat projected by USDA (2007) to 2016. As is evident, the trend in the price of wheat is positive.

**Figure 3.5: Market price of wheat, 1999-2016**



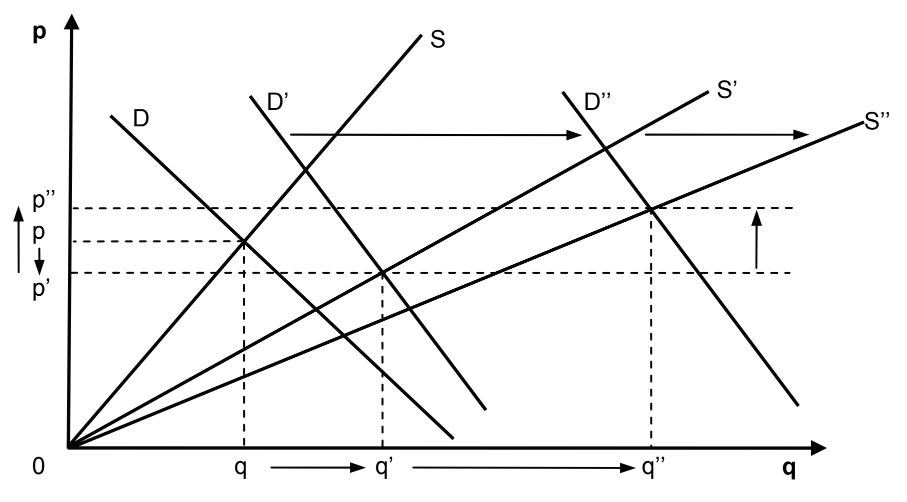

Source: USDA (2007) and own computations.

For an appropriate interpretation of figure 3.5, several comments need to be made:

– First, the order of magnitude of price changes in wheat may be considered representative for agricultural commodity prices in general.
– Second, the price will not be skyrocketing as it has sometimes been argued (e.g. HITZFELD, 2006) There will rather be a modest but sustained increase in the price over time.
– Third, as in the past there will be significant price fluctuations around the trend.
– Forth, the present (April 2008) market price of wheat is more than twice the trend price (REUTERS and CRB, 2008).
– This simply implies, fifth, that there will be times during which the market price will be below the trend price; i.e., the world market price is not likely to stay as high as it is now for an extended period of time.
– And finally, the price projections are based on rather conservative assumptions about the increase in the acreage planted to bio-energy crops.

The reason for the positive price trend is that global demand for food outpaces the global supply of food and that this will continue to be the case in the next few decades. This is graphically illustrated in figure 3.6. As can be seen, the growth in demand outstrips the growth in supply, i.e. the rightward shift from D’ to D’’ exceeds the shift from S’ to S’’. As a consequence, there is a price increase from P’ to P’’.

**Figure 3.6: The end of the global Agricultural Treadmill**




In the following, the forces behind these developments, i.e. the various global trends affecting world agricultural demand and supply will be discussed in more detail.

## 3.2 Global trends affecting world agricultural demand

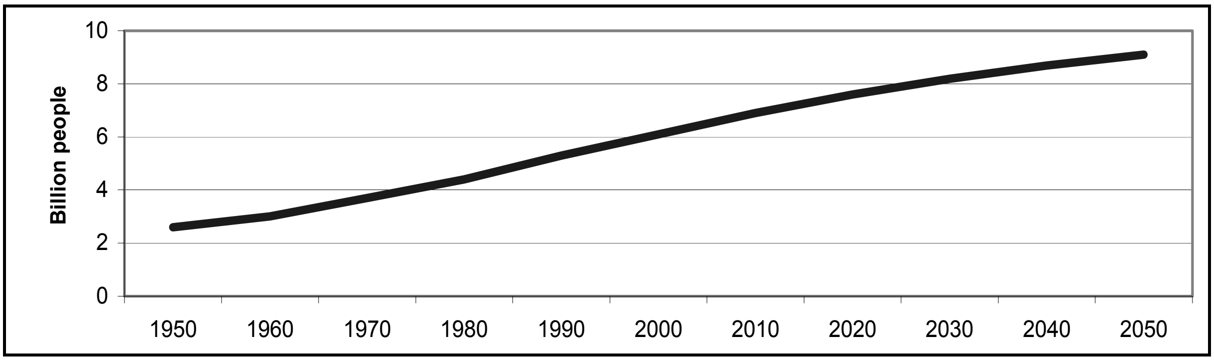
Several variables are significant drivers of growth in the global demand for agricultural goods. They are:

- continued rapid world population growth,
- sustained per capita income growth in developing countries, and
- swift increase in the demand for bio-energy.

**World population growth will be about 12 percent within a decade**

There is general consensus that world population will continue to grow at rapid rates (e.g. LEISINGER et al., 2002; UN, 2007). According to PRB (2007), world population was 6.6 billion in 2007, up from 6.1 billion in 2000. It is projected to rise to 9.3 billion by 2050, with a decline in annual growth rates in the decades ahead (figure 3.7).

**Figure 3.7: World population, 1950-2050**




Source: Own figure based on PRB (2007).

The UNITED STATES CENSUS BUREAU (2008) recently published population growth numbers which are in line with previous population projections. They are shown in figure 3.8. Therefore, it is reasonable to expect that in the next ten years world population will increase by about 12 percent.

**Figure 3.8: World population growth, 1950-2050**

| Year | Population (millions) | Average annual growth rate (percent) | (millions) |
|---|---|---|---|
| 1950 | 2 557 | 1.47 | 37.8 |
| 1975 | 4 084 | 1.72 | 71.0 |
| 2000 | 6 072 | 1.24 | 75.8 |
| 2025 | 7 959 | 0.85 | 68.1 |
| 2050 | 9 402 | 0.49 | 46.3 |

Source: UNITED STATES CENSUS BUREAU (2008).

Figure 3.9 provides some more detailed information on population growth by region. It is evident, that population growth will be most pronounced in developing nations. In the European Union and the Commonwealth of Independent States (CIS) population is stagnant or declining. The United States is the only developed country with a substantial increase in population. However, changes in United States immigration policy may alter this.

**Figure 3.9: Population increase in various world regions, 2007-2016**

| Region | Population increase (percent) | Population increase (millions) |
|---|---|---|
| Africa, All | 23 | 219 |
| Asia, All | 12 | 465 |
| - *China* | 7 | 88 |
| - *India* | 16 | 183 |
| Latin America | 11 | 66 |
| USA | 9 | 27 |
| European Union | 1 | 5 |
| CIS Republics | -0.2 | -1 |
| World | 12 | 791 |

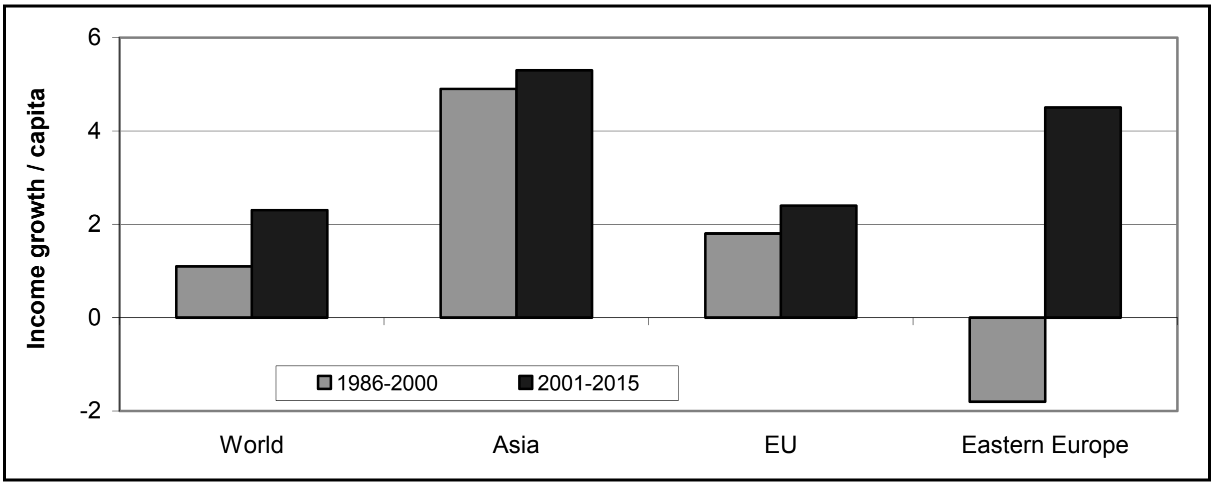
Source: Own figure based on FAPRI (2008a) and PRB (2007).

**Rising per capita incomes and urbanisation increase in developing countries**

Another main reason for continued rapid growth in world food demand is the success of policy reforms in many developing countries, including in the two largest countries in the world, namely India and China. These reforms have led to a sustained growth in per capita incomes.

And the process of economic growth can be expected to continue (USDA, 2007). Income growth is likely to double in the first fifteen years of this century as compared to the last fifteen years of the 20$^{th}$ century. This implies that global economic growth will be the strongest in decades (OECD and FAO, 2007). Economic growth will be particularly rapid in Asia as well as Eastern Europe (figure 3.10). In the European Union it will be around 2 percent per annum (NOWICKI et al., 2006).

**Figure 3.10: Recent and future income growth in the world and selected regions**

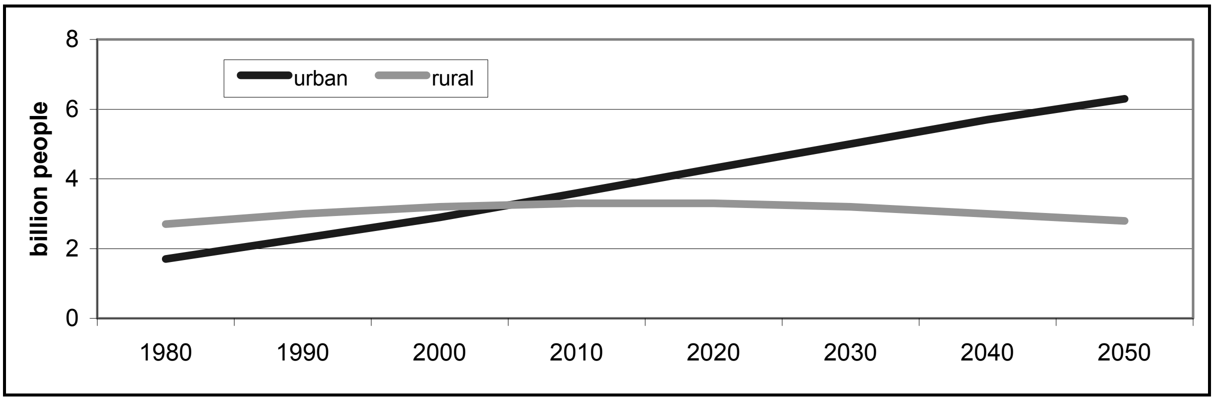



Source: Own figure based on WORLDBANK (2007).

In line with economic growth, the incidence of malnutrition will decline (FAO, 2002). However, the absolute number of malnourished people is still increasing.

Economic development is paralleled by urbanisation. SCHMIDHUBER and SHETTY (2005), expect the rate of urbanisation to accelerate and by 2030 virtually all population growth to be urban. Figure 3.11 clearly shows that by 2008, for the first time in human history, more people will live in urban than in rural areas. By 2050 two thirds of all humans can be expected to live in cities (e.g. COHEN, 2006).

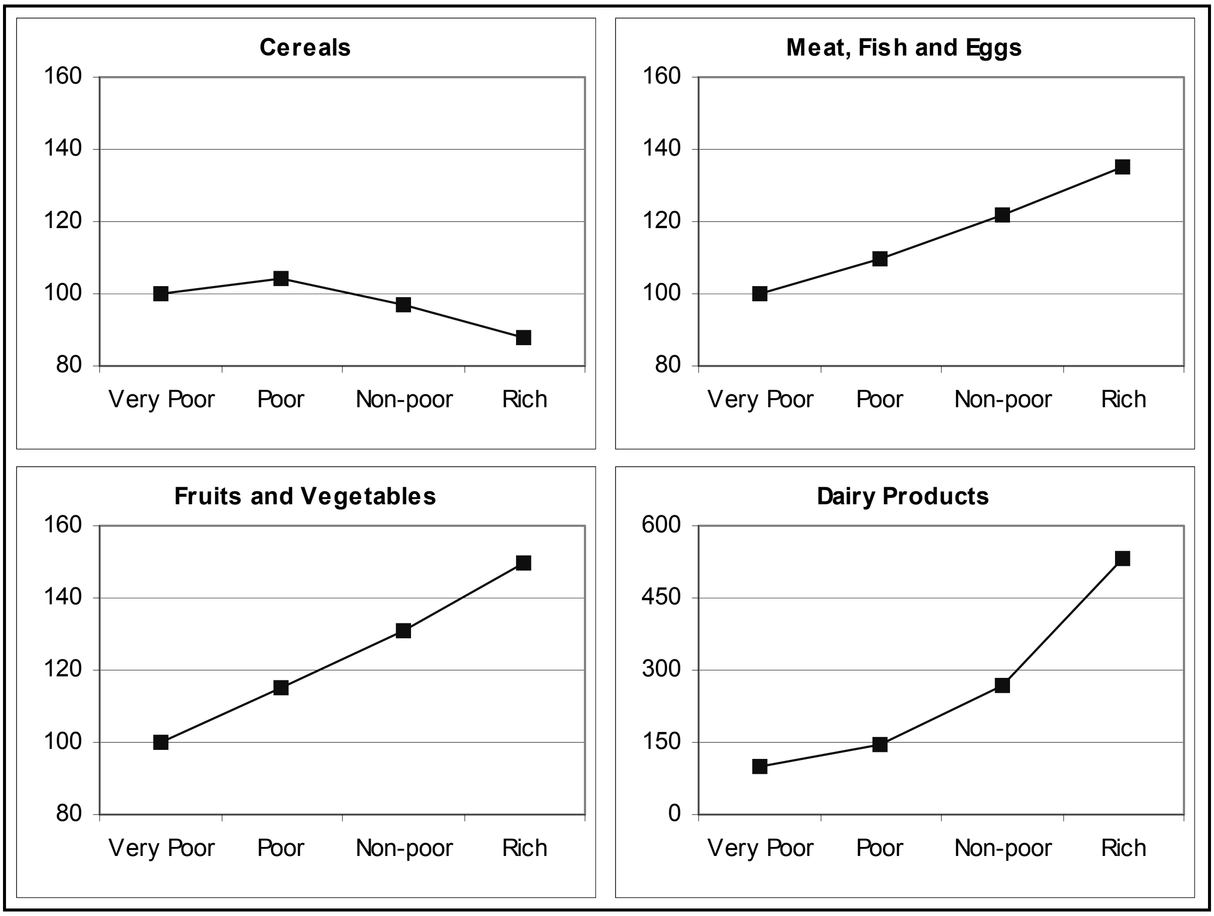
**Figure 3.11: World population in urban and rural areas, 1980-2050**




Source: Based on PINSTRUP-ANDERSON et al. (1999) and UN (2005).

Rising incomes and the apparent trend towards urbanisation, in developing countries and emerging economies alike, both tend to increase per capita food consumption and to change food preferences. More and more people will eat higher-quality food. This is exemplified for India in figure 3.12.

**Figure 3.12: Per capita consumption of food in India by expenditure class**




Source: Based on MITTAL (2006).

The potential increase in world food demand that can be realised through income growth and urbanisation in developing countries is huge (e.g. BROWN, 1995). According to FAO (2008b), overall food consumption in terms of kcal per person per day will increase by 8 percent between 2000 and 2015 in developing countries, by 4 percent in transition countries, and by only 1 percent in industrial countries.

**People eat more livestock products which implies a growing demand for animal feed**

Growth in the demand for food in developing countries will be more pronounced in dairy, meat, and processed foods than in the human consumption of grain. In fact, in some parts of the world human consumption of basic staple foods may even decline.

A growing consumption of animal products also implies a significant increase in the demand for feed grains and protein feed (VON BRAUN, 2007). According to FAPRI (2008a) per capita meat consumption between 2006 and 2015 will increase from 55 to 65 kg in China, and 3.2 to 3.6 kg in India. For the European Union and other industrialised countries only modest growth rates of meat consumption are expected.

Figure 3.13 presents the change in grain consumption between 1969 and 2025. As can be seen, global grain consumption can be expected to increase by more than 42 percent between 1997 and 2025. Most of it is the result of increasing grain consumption in developing countries (59 percent) while grain consumption in developed countries will go up by 15 percent during the same time period.

**Figure 3.13: World grain consumption 1969, 1997 and 2025**

| Region | 1969 (million tons) | 1997 (million tons) | 2025 (million tons) |
|---|---|---|---|
| Developed countries | 564 | 725 | 834 |
| Developing countries | 453 | 1 118 | 1 776 |
| World | 1 017 | 1 843 | 2 610 |

Source: RUNGE et al. (2003).

As shown in figure 3.14 global grain consumption will increase by 767 million tons between 1997 and 2025. As is also evident, nearly 60 percent of grain consumption growth will occur in Asia, while only one seventh of the total growth will be realised in developed countries.

**Figure 3.14: Change in grain consumption by region, 1997-2025**

| Region | Change (million tons) | (percent) |
|---|---|---|
| China | 192 | 25 |
| India | 92 | 12 |
| West Asia and North Africa | 77 | 10 |
| Other Asia | 107 | 14 |
| Sub-Sahara Africa | 100 | 13 |
| Latin America | 92 | 12 |
| Developed countries | 107 | 14 |
| World | 767 | 100 |

Source: Own calculations based on RUNGE et al. (2003)

Figure 3.15 details the growth in world demand by commodity. As is evident the growth in the consumption of oilseeds is larger than that of grains. These numbers are consistent with the assertion that food consumption will double in the first half of the 21$^{st}$ century (THOMPSON, 2007).

**Figure 3.15: Projected increase in world crop demand**

| Commodity | 2006 (million tons) | 2015 (million tons) | Increase (percent) |
|---|---|---|---|
| Wheat | 738 | 817 | 11 |
| Corn | 812 | 950 | 17 |
| Barley | 167 | 177 | 6 |
| Rice | 493 | 524 | 6 |
| Soybean | 279 | 334 | 20 |
| Rapeseed | 52 | 63 | 21 |
| Sunflowers | 31 | 37 | 19 |

Source: Own figure based on FAPRI (2008a).

### Exponential growth in bio-energy production is mainly policy driven

The numbers in figure 3.15 do not account for the rapidly growing demand for bio-energy made from agricultural raw materials. WESTCOTT (2007) observes an exponential growth in the United States in ethanol production during the first years of the new millennium. Likewise OECD and FAO (2007) identify a similar development not only in the United States but in the European Union, Canada, Brazil, and China as well. Also HERTEL (2007) expects a global bio-fuel boom which includes Brazil, China and other countries/regions. However, USDA (2008b) expects the growth in bio-energy production to slow down significantly by 2010.

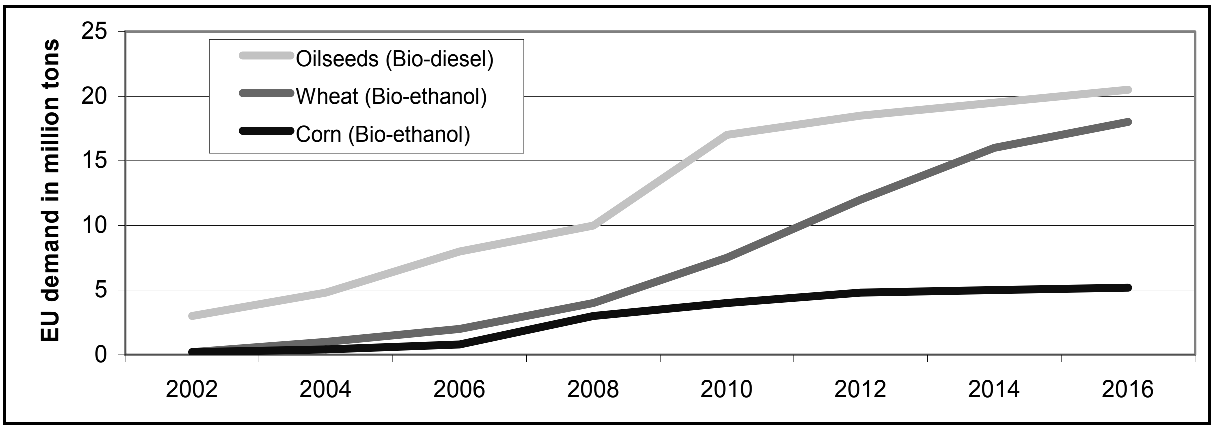
There are two driving forces behind the present bio-energy boom. One is the concern about the security of domestic fossil fuel supplies in oil importing nations. The other is the attempt to counteract global warming through the increased use of bio-energy.

The most important types of bio-energy are bio-ethanol and bio-diesel. Main producers of bio-ethanol are the United States (from corn) and Brazil (from sugar cane). In the European Union bio-diesel continues to be the main bio-energy source. In fact, the European Union accounts for 80-90 percent of the world's bio-diesel production (HERTEL, 2007; ROSEGRANT et al., 2006). However, it is expected that the European Union will become a major bio-ethanol producer as well (figure 3.16). The European Commission even argues that a bio-fuels bonanza has begun (EC, 2007a).

However, with the exception of bio-ethanol made of sugar cane in Brazil, bio-energy is hardly competitive at present prices and technologies. Hence, it is government market regulation, through subsidies and mandates, that is fuelling the rapid growth in bio-energy (VON LAMPE, 2007; HENNIGES, 2007).

The objective of the European Union is to use 5.75 percent bio-fuels in the transportation sector by 2010. By 2020 the target is for bio-fuels to account for 10 percent of total vehicular energy use (SCHUMACHER, 2007.

**Figure 3.16: Production of bio-energy crops to meet demand in the European Union, 2002-2016**

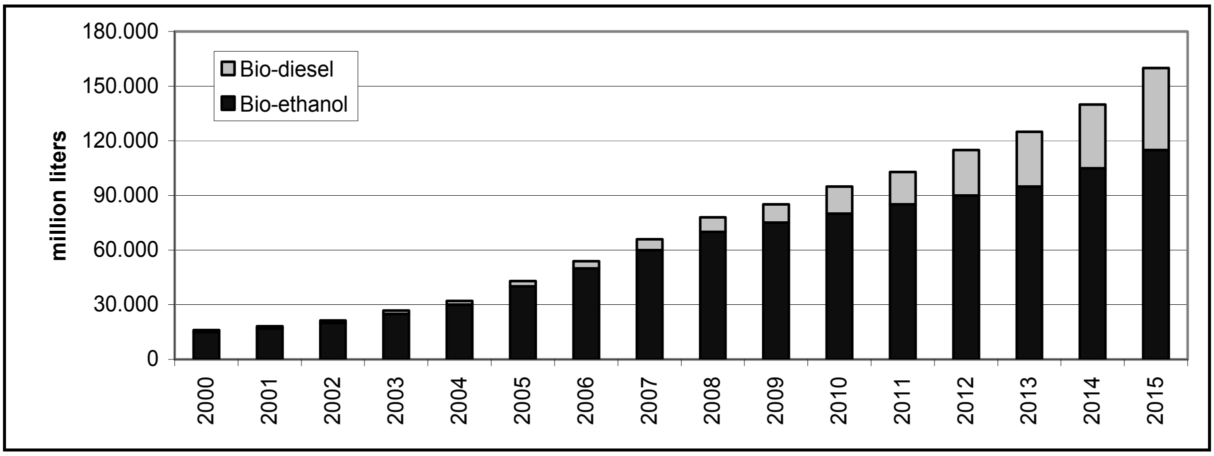



Source: Own figure based on OECD and FAO (2007).

The United States also have ambitious bio-energy objectives. The United States government has mandated the use of 7.5 million gallons of bio-ethanol by 2012. Other countries are mandating the use of bio-energy as well. They include such countries as Brazil, China, Indonesia, India and South Africa (COYLE, 2007).

The growth in bio-energy production is illustrated in figure 3.17. As can be seen, global bio-energy production in 2015 may be expected to more than double relative to 2007/08.

**Figure 3.17: Global bio-energy production, 2000-2015**




Source: Own figure based on COYLE (2007) as well as OECD and FAO (2007).

HERTEL (2007) projected that the European Union will have a particularly rapid demand growth for oilseeds, grains and sugar beets. However, recent policy changes have led to overcapacities in processing in Germany and other countries. In the United States, a strong ethanol expansion will give rise to corn production (TOKGOZ et al., 2007) while in Brazil and Argentina oilseed, coarse grain, and sugar production may be expected to increase significantly.

### Forecasts show a sustained strong increase in bio-energy demand

Over the next decade, rapid growth in bio-energy production is most likely to occur in the United States, the European Union, Brazil, Argentina, and Canada (USDA, 2007), i.e. in countries dominating bio-energy production already. These countries plus China account for 95 percent of today's global bio-energy production (COYLE, 2007). The following details these assertions:

– Projections by the EC (2008) as well as by OECD and FAO (2007) show that by 2013/14 around 20 million tons of oilseeds will be used for bio-energy in the European Union. This is four times what it was in 2004 and 200 percent of the use in 2007. The growth rates in grain production for bio-energy are even higher. Up to 20 million tons of wheat and coarse grains will be used in 2013/14, compared to less than 1 million tons in 2004 and 4.5 million tons in 2007.
– In the United States, ethanol made from corn will use 30 percent of the corn crop in 2016/17, up from 23 percent in 2007. Bio-diesel production will use 23 percent of the soybean acreage, up from 17 percent in the same period of time (COLLINS, 2007).
– A rapid growth in bio-energy production may be expected for Canada as well (e.g. OECD and FAO, 2007): Respective forecasts suggest ethanol production from corn to quadruple between 2005 and 2015.

Recently, the rapid expansion of bio-energy production has drawn some criticism (e.g. WISSENSCHAFTLICHER BEIRAT AGRARPOLITIK BEIM BUNDESMINISTERIUM FÜR ERNÄHRUNG, LANDWIRTSCHAFT UND VERBRAUCHERSCHUTZ, 2007), because of its negative impact on deforestation and, thus, on climate change as well as because of its negative impact on world food security. This criticism is well-founded. However, it is not likely to reduce the growth in bio-energy production by much as fossil energy prices are expected to continue to be high (KEMFERT, 2007) and concerns about the security of national energy supply appear to outweigh concerns about world food security and global warming.

### The role of second generation technologies

The rapid growth in bio-energy demand will tend to additionally increase world demand for agricultural goods, and will further boost world prices. This leads to two pivotal questions:

– Is agricultural supply capable to meet this additional demand now and in the future?
– When will second generation technologies be competitive?

To find an answer to the first question will be one of the objectives of the following more detailed analysis.

The second question is indeed important. However, it has become evident that second generation bio-energy will not be competitive during the time period covered in this study. Enzymatic processes in second generation technologies will continue to be too expensive. However, if technologies will become available which break up cellulose at competitive prices, one can expect this to change (LANEY, 2006). The EC (2007b) expects that second generation (biomass to liquid) technology will not be of significance before 2014 and that the share of second generation bio-fuels in total bio-fuels will not exceed 30 percent by 2020.

## 3.3 Global trends affecting world agricultural supply

Global supply of agricultural products will not keep pace with the growth in demand. The main reasons are:

– climate change,
– natural resource constraints (i.e. limited availability of water and agricultural land), and
– technology constraints.

In addition, it is sometimes argued that the expansion of organic farming also contributes to a decline in the growth of supply, as organic farming is rather land intensive.

**Climate change and agriculture**

Climate change is now widely recognised as a fact and human activity is contributing significantly to it through the emission of greenhouse gases such as carbon dioxide, methane or laughing gas. Climate change and agriculture are closely related for at least three reasons:

– One is the production of bio-energy, believed by many to be climate friendly.
– The other is the direct impact of climate change on world agriculture.
– And the third is the emission of greenhouse gases by agriculture.

The effects of global warming on agriculture have been analysed in much detail (e.g., AGGARWAL et al., 2006; BUTT et al., 2005; SCHRÖTER et al., 2005; THOMSON et al., 2005; and ZHAO et al., 2005). A meta analysis (see EASTERLING and AGGARWAL, 2007) of 70 publications on the effects of climate change on world agriculture arrived at the conclusion that, on balance, agricultural production will be positively affected, as long as the average temperature increase is in the range of one to three °C. In this range of global warming the increase in production in the very far northern and southern latitudes may exceed the decline in warmer regions. A temperature increase above three °C, however, tends to reduce global production (EASTERLING and AGGARWAL, 2007; see also PARRY, 2005).

Yield changes for a mean local temperature increase of three ºC in the mid to high latitudes are projected to be around +10 to +20 percent for wheat, -5 to +5 percent for maize and +5 to +10 percent for rice. In the lower latitudes the yield change is expected to be in the range -5 to -20 percent for wheat, -5 to -15 percent for maize and -1 to -15 percent for rice (EASTERLING and AGGARWAL, 2007). To put these numbers into perspective, in the next two decades a global warming of only 0.2 ºC per decade is projected (IPCC, 2007) while an increase in temperature of three ºC may be expected in 100 years.

**Overall climate change impact is still limited**

In essence, these results suggest that the effect of global warming on world agriculture is likely to be rather limited in the next few decades. This is in line with FAO (2002) which asserts that global warming will not reduce food production dramatically any time soon. Rather will climate change act to increase average yields in the range of 1 to 2 percent. TUBELLIO and FISCHER (2007) expect an even smaller effect of climate change on yields in world agriculture.

While average yields may not change by much in the next few decades, it has become clear that weather extremes are likely to increase in both frequency and intensity (PARRY, 2005). Of course, this will have temporary and significant effects on the availability of food on a global scale (e.g. STERN, 2007) and thus contributes to more pronounced price fluctuations than in the past.

The impact of climate change on European Union agriculture is analogous. Average yields are not likely to change much in the next few decades, but the increased frequency and intensity of extreme weather are likely to result in more pronounced yield fluctuations than in the past (ALCAMO et al., 2007). An analysis by PARRY (2005) suggests that the annual temperatures will increase by 0.1 to 0.4 ºC per decade in Europe. Hot summers will double in frequency by 2020, and they will become drier in Southern Europe. In Northern Europe winters are expected to become wetter, as the intensity of rainfall will increase.

**Mitigating agricultural greenhouse gas emissions**

World agriculture is not only a victim of climate change. It is also a major emitter of greenhouse gases. In fact, world agriculture accounts for almost one third of the anthropogenic climate effect (e.g. STERN, 2007; LEAD, 2007). This is the result of two dimensions of agriculture:

– One is farming on the acreage presently in use. It accounts for about 14 percent of the anthropogenic climate effect. This is as much as global transportation or global manufacturing contribute to global warming.
– The other is deforestation for the purpose of claiming additional agricultural land. This accounts for another 18 percent of the man made climate effect.

European Union agriculture also contributes significantly to global warming although deforestation is of minor importance there. For instance, German agriculture employs about 2.5 percent of the labour force. It contributes 1.3 percent to GDP but it accounts for about 11 percent of Germany's contribution to global warming (VON WITZKE and NOLEPPA, 2007).

Given the significant contribution of world agriculture to global warming, it has to be expected that agriculture will be included in climate policy strategies. Such policies are likely to use a two pronged approach:

– One would be to limit deforestation. This implies that production on the land that is already being farmed has to be increased. And this, in turn, implies a growing intensity of land use.
– The other would be a mitigation of agricultural greenhouse gas emissions on the land presently being farmed (e.g. HOLM-MÜLLER and PEREZ, 2007).

**Main supply drivers in the past were expansion of land and yield increases**

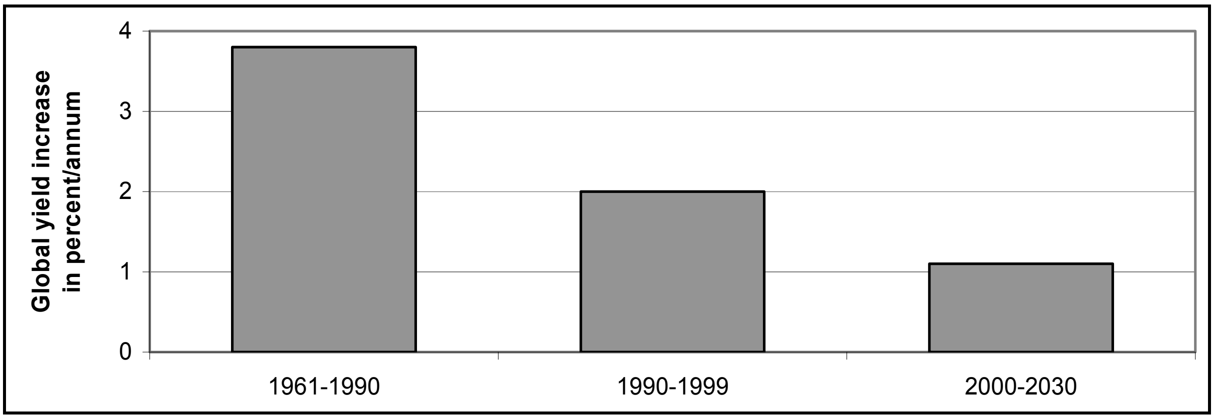
On a global scale land available for farming is limited. The best and most productive land is already being farmed. In many parts of the world there are no major land reserves left, or where land reserves such as the tropical rain forests exist, they should not be used for farming for environmental reasons. At the same time, as discussed above, deforestation is a major cause of global warming. Consequently, the increase in production necessary to feed the growing world population must come, above all, from increasing productivity of the land presently being farmed (e.g. RUNGE et al., 2003, FAPRI, 2008a; FAO, 2008a, b; OECD, 2008; USDA, 2008b).

In the second half of the 20th century, productivity growth, rather than expansion of the acreage, accounted for most of the production growth in world agriculture. In fact, between 1961 and 1999, almost 80 percent of global agricultural production growth was the result of increasing land productivity (BRUINSMA, 2003). In the decades to come the importance of productivity growth will even increase further (VON WITZKE, 2007, 2008).

**Declining yield growth in the future**

Without more intense land use and more productive technologies it will be difficult to meet the growing demand for food. In fact, since the time of the Green Revolution in the 60s and 70s of the past century annual productivity growth in world agriculture has declined from around 4 percent in the 1961-1990 period to about 2 percent in the last decade of the 20th century. This is often expected to continue (figure 3.18) in the absence of a major breakthrough in technology (RUTTAN and VON WITZKE, 1988; FAO, 2008a, b).

**Figure 3.18: Global yield increases, 1961-2030**




Source: Adapted from FAO (2008a, b).

The projected increases in wheat yields are illustrated in figure 3.19. As is evident, the annual growth rates in yields are below 1 percent except for Brazil and India. In the European Union wheat yields are higher than in any of the other regions. However the expected annual growth in yields is around 0.5 percent only.

**Figure 3.19: Regional differences in projected wheat yields**

| Region / Country | 2004-2006 (tons/ha) | 2015 (tons/ha) | Increase (percent) |
|---|---|---|---|
| Ukraine | 2.82 | 3.01 | 7 |
| Russia | 1.88 | 2.01 | 7 |
| Brazil | 1.83 | 2.11 | 15 |
| China | 4.32 | 4.43 | 2 |
| India | 2.68 | 3.07 | 15 |
| USA | 2.77 | 3.00 | 8 |
| European Union | 5.55 | 5.81 | 5 |

Source: Adopted from FAPRI (2008a).

The numbers in figure 3.19 are not based on an explicit technology assessment. Rather they are based on past growth rates in yields. They assume conventional breeding programs and imply unchanged crop management practices. Major breakthroughs in plant breeding and other technologies, which would lead to a rapid increase in productivity, are not in the pipeline. Yet another Green Revolution can hardly be expected anytime soon (FAO, 2002).

**Land is available but the acreage is limited**

The traditional presumption has been that there is plenty of land for a significant and sustained expansion of agricultural land. A few years ago FAO suggested that there would be about 2.9 billion hectares of as yet unused land which is “very suitable” or “suitable” for crop production (BRUINSMA, 2003). Others have suggested that the cultivated area in the world could be expanded by 60 percent (FISCHER and HEILIG, 1998). However, these assessments are far from reality.

Recent analyses have arrived at the conclusion that the acreage that can be mobilised for crop production is rather limited. One assessment suggests that the 2000 crop acreage may be expected to increase by about 80 million hectares by 2020 (VON WITZKE, 2008). Figure 3.20 lists the expected changes in acreage by region. The results are in line with other recent projections of the global expansion of agricultural land (see also figure 3.21 as well as HOFREITHER, 2005; IFPRI, 2005). Even FAO has recently corrected its earlier and overly optimistic expectation of the potential for expansion of crop land (FAO, 2008b).

**Figure 3.20: Change in agricultural acreage for selected countries/regions, 2000-2020**

| Region / Country | Change in acreage (million ha) |
|---|---|
| European Union | 4 |
| Russian Federation and Ukraine | 13 |
| USA | 15 |
| Canada | 2 |
| Latin America | 45 |
| Sub-Sahara Africa | 6 |
| Asia and Australia | -4 |

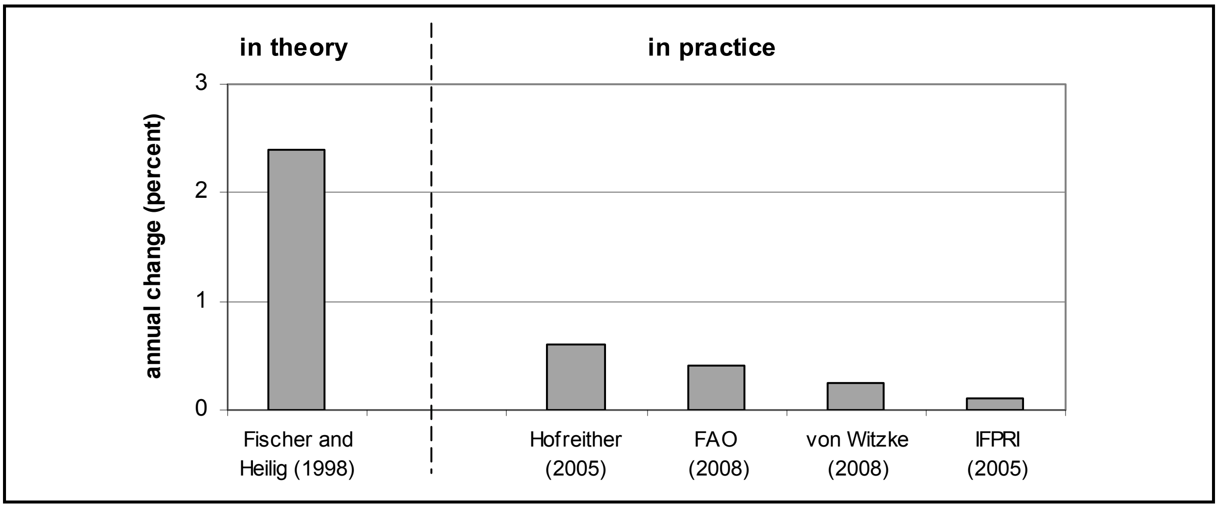
Source: VON WITZKE (2008).

One has to keep in mind that the acreage that will be added in the years ahead is typically less productive than the land already being farmed. Moreover, it is important to keep in mind that it takes some time to take land that was previously unused into crop production, because of necessary complimentary private and/or public investment in farm machinery, storage, processing and transportation facilities. In many parts of the world, political instabilities also reduce the expansion of the acreage. Moreover, climate change may already affect the availability of crop land in some regions of the world today.

The numbers listed in figure 3.20 warrant some further discussion:

– In the European Union and the United States significant areas were idled under land set-aside programs (e.g. EC, 2008). To a large extent the set-asides can be expected to be reverted back to crop land.
– At the same time there is some loss in farm land in these countries through urbanisation and infrastructure development. CIAIAN (2007) as well as HENZE and ZEDDIES (2007) arrive at the conclusion that usable agricultural land in the European Union will decrease by almost 3 percent within a decade.
– In the Russian Federation and the Ukraine a lot of farm land was abandoned after the collapse of the Soviet Union. A significant portion of this land will be used for farming again under a regime of more favourable market prices.
– Canada is likely to benefit from climate change and will be able to expand its cropping area. However, a lot of these soils are very shallow and not very productive.
– Latin America clearly has the largest cropland reserves that can be mobilized until 2020. Most of these are in Brazil and Argentina.
– Sub-Sahara Africa also has a significant cropland potential that could be taken into production. However, economic and political instabilities act as significant constraints in this regard.
– Asia and Australia are likely to lose cropland because of climate change.

**Figure 3.21: Expected changes in global land availability, 2000-2015**




Source: Own figure based on FISCHER and HEILIG (1998), HOFREITHER (2005), FAO (2008b), VON WITZKE (2008), and IFPRI (2005).

## Water scarcity will increase and may change yields slightly

The other significant natural resource constraint for an increased agricultural production is water. Agriculture is by far the most important user of fresh water, accounting for 70 percent of global water withdrawals (UN, 2006). An increase in agricultural production has always been associated with growing water use for farming. Water, however, is becoming ever scarcer and thus more expensive, which tends to slow down production growth. In 1995, 25 percent of the world area was characterised by severe water stress (ALCAMO et al. 2000). Water withdrawals in industrialised countries are expected to decline. But this will be more than offset by developing nations' water withdrawals.

Grain yields in developed countries are likely to be unaffected by growing water shortages, as they can be compensated by changes in cropping practices and water management. However, in developing countries water shortages will lead to depressed grain yields. Keeping all other factors unchanged, water shortages will reduce grain yields in these countries by 10 percent over a 30 year period (ROSEGRANT et al., 2002). Regions most severely affected by water shortages are the Middle East, Western and Southern Africa as well as South and East Asia.

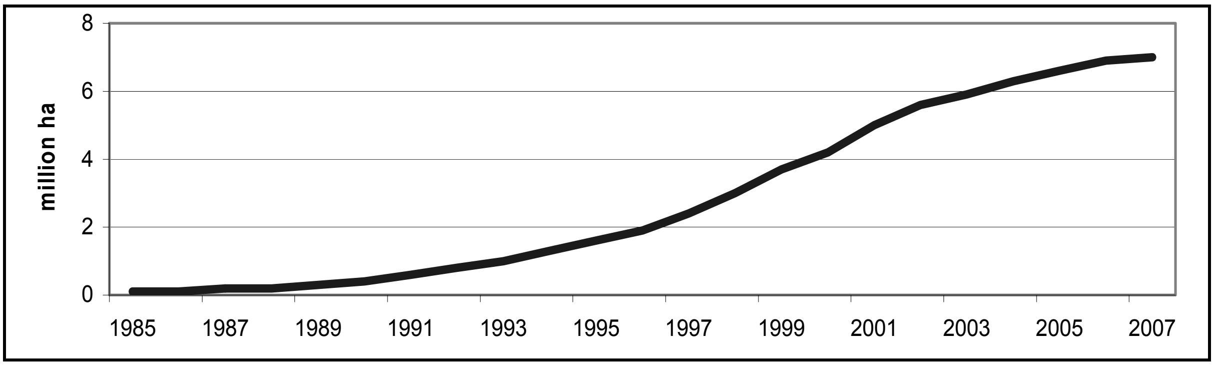
## Organic food remains a niche market

In the public debate, organic farming is sometimes considered to be the bonanza for European Union farmers. However, organic farming is land intensive, and agricultural land is a significant constraint to the growth in production necessary to meet the needs of the growing world population.

On a global scale, almost 31 million hectares are farmed organically. This is 0.7 percent of total agricultural land (WILLER and YUSSEFI, 2007). In the European Union, organic farming is of more importance. In 2007, about 7 million hectares have been or are in the process of being converted into organic farm land. This is 4 percent of the total utilised agricultural land in the European Union (LAMPKIN, 2008).

While it is sometimes argued that organic food is becoming ever more popular, the reality is different. As can be seen in figure 3.22, the growth in the expansion of the acreage farmed organically has declined since the turn of the millennium.

**Figure 3.22: Agricultural land used for organic farming in the EU, 1985-2007**




Source: Own figure based on ORGANIC CENTRE WALES (2008).

The reform process in the Common Agricultural Policy (CAP) of the European Union has resulted in more liberal markets. Farmers, now, produce for the market rather than for the European Union intervention agencies.

European Union agriculture has long stopped producing homogenous commodities. Rather it has become "boutique agriculture". Farmers produce a wide range of goods which are characterised by differing production cost and sold for differing prices in the market place. Domestic consumers and those from abroad choose those qualities that best meet their individual preferences and income. It is likely that sustained higher market prices for agricultural products will act to slow down the growth in the demand for organic food. Moreover, the price of organic food relative to that of other food has declined in recent years, making organic food less profitable to produce.

## 3.4 Main drivers of agricultural world market prices

As discussed above, the global supply of food will not keep pace with the growth in demand. Subsequently, the trend in food prices for the next ten years and beyond will be positive. However, price fluctuations around this trend are likely to increase.

The global demand for food will continue to grow at rapid rates for mainly two reasons:

- One is the continued swift growth in population – mainly in developing and newly industrialising countries.
- The other is a sustained per-capita income growth in these countries with a corresponding increase of per-capita food consumption.

The global food supply growth will be limited as land available for agricultural production is limited in scale. The best and most productive land is already being farmed today. In many parts of the world, there are no major land reserves which could be used for farming; or where there are such land reserves existing, they often should not be claimed as farm land for environmental reasons.

Consequently, the necessary growth in production to meet the needs of the rapidly growing world population will have to come predominately from productivity gains on the land already being farmed. However, this will be difficult to accomplish, as the annual growth rates in productivity are in decline since the Green Revolution of the 20th century.

Moreover, the growth in bio-energy production diverts agricultural land and other production factors away from food production and influences market developments.

Additional constraints to production growth are climate change and increasing scarcity of water. Both may not be of major importance in the decade ahead, neither on a global scale nor in the European Union, but they may have significant implications for some regions of the world.

# 4. Model and data

## 4.1 Model

The subsequent chapters provide a more detailed quantitative analysis of how the changing economic environment affects European Union agriculture. A partial equilibrium model has been used for this quantitative analysis.

Partial equilibrium models are widely used in the analysis of agricultural markets. They are particularly suitable for the simulation of alternative scenarios (SADOULET and DE JANVRY, 1995; SAUNDERS et al. 2002). The comparative advantage of the multi-market, multi-region partial equilibrium model used in this analysis is that it can quantify in a rather detailed way changes in supply, demand and prices as well as in trade flows between regions (FRANCOIS and REINERT, 1997).

The multi-market-model used is based upon the principles of the Static World Policy Simulation Modelling Framework (RONINGEN et al., 1991) developed by JECHLITSCHKA, KIRSCHKE and SCHWARZ (2007). The model is static and assumes that domestically produced and foreign goods are perfect substitutes in consumption. International trade is the difference between domestic supply and demand in each region.

The model is assumed to be in equilibrium in the initial state. After a simulation of an exogenous shock (such as population growth and yield changes), the model generates a new equilibrium by finding a new set of prices which equalize supply and demand. The elasticities used in the model are based on RONINGEN et al. (1991) and the FAPRI elasticity database (FAPRI, 2008b).

The model employs isoelastic Cobb-Douglas supply and demand functions (for more details see CHIANG, 1984). Cobb-Douglas supply and demand functions are widely used in partial equilibrium models in agricultural policy analysis. An example is LEDEBUR (2001) who applies Cobb-Douglas functions for the analysis of agricultural trade liberalization between the European Union and the Mercado Comum do Sul countries.

Each market in each region is characterised by one supply and one demand function. Commodity interdependencies are introduced through the use of cross price elasticities of supply and demand.

**The supply side**

In the model, the quantity supplied of a good depends on its own price, prices of competing goods, and a calibration factor. Hence, the supply function (1) is as follows:

$$(1)\quad qs_{l,g}(p_{l,g}) = a_{l,g} * ps_{l,g} \wedge \eta_{lg} * \prod_{m=1}^{w} ps_{m,g} \wedge \eta_{lmg}$$

where:

| | |
|---|---|
| l | = commodity l |
| m, …, w | = competing goods (cross commodities) |
| g | = model region g |
| $qs_{l,g}$ | = supply quantity of commodity l in region g |
| $a_{l,g}$ | = constant parameter (calibration factor) |
| $ps_{l,g}$ | = supply price for commodity l in region g |
| $\eta_{lg}$ | = own price elasticity of commodity l in region g |
| $\prod_{m=1}^{w} ps_{m,g}$ | = cross prices for commodities m, …, w in region g |
| $\eta_{lmg}$ | = cross price elasticity for commodities m, …, w in region g |

The term $a_{l,g}$ is a calibration parameter which, in the initial state, is chosen to match the quantity supplied in the reference scenario. Variations in this parameter are used to account for changes in the determinants of supply other than market prices.

### The demand side

The quantity demanded of a commodity depends on its own price, prices of consumption substitutes, a calibration parameter and demand elasticities. Thus, the demand function (2) can be written as follows:

$$(2)\quad qd_{l,g}(pd_{l,g}) \;=\; b_{l,g} * pd_{l,g} \wedge \eta_{lg} * \prod_{m=1}^{w} pd_{m,g} \wedge \eta_{lmg}$$

where:

$qd_{l,g}$ = demand quantity of commodity l in region g

$b_{l,g}$ = constant parameter (calibration factor)

$pd_{l,g}$ = demand price for commodity l in region g

$\eta_{lg}$ = own price elasticity of commodity l in region g

$\prod_{m=1}^{w} pd_{m,g}$ = cross prices for commodities m, …, w in region g

$\eta_{lmg}$ = cross price elasticity for commodities m, …, w in region g

The term $b_{l,g}$ is a calibration parameter analogous to the calibration parameter in the supply equation.

### Closure of the model

The model is closed by the assumption of market equilibrium. This means, trade flows are such that world supply equals world demand and that total global exports equal total global imports.

An important part of the model development is the implementation of shift factors of supply and demand representing the impacts of market forces. The study follows a commonly used approach to integrate multiplicative shift factors in supply and demand functions (e.g., KAZLAUSKIENE and MEYERS, 1993, 2003; MILLER et al., 1988).

### Implementation of shift factors

The implementation of a multiplicative shift factor allows for a percentage change of the supply and demand quantities depending on the specific impacts to be analysed with the model. Supply shift factors are implemented in the supply function while demand shift factors are implemented in food, feed and energy demand functions of the different commodities in each of the model regions.

To exemplify the implementation of the multiplicative shift factors in the model, the case of a supply shift factor is presented in more detail below. The implementation of the shift factor modifies the supply function (1) as follows:

(3) $qs_{l,g}(p_{l,g}) = a_{l,g} * ps_{l,g} \wedge \eta_{lg} * \prod_{m=1}^{w} ps_{m,g} \wedge \eta_{lmg} * e_{l,g}$

where:

$e_{l,g}$ = supply shift factor.

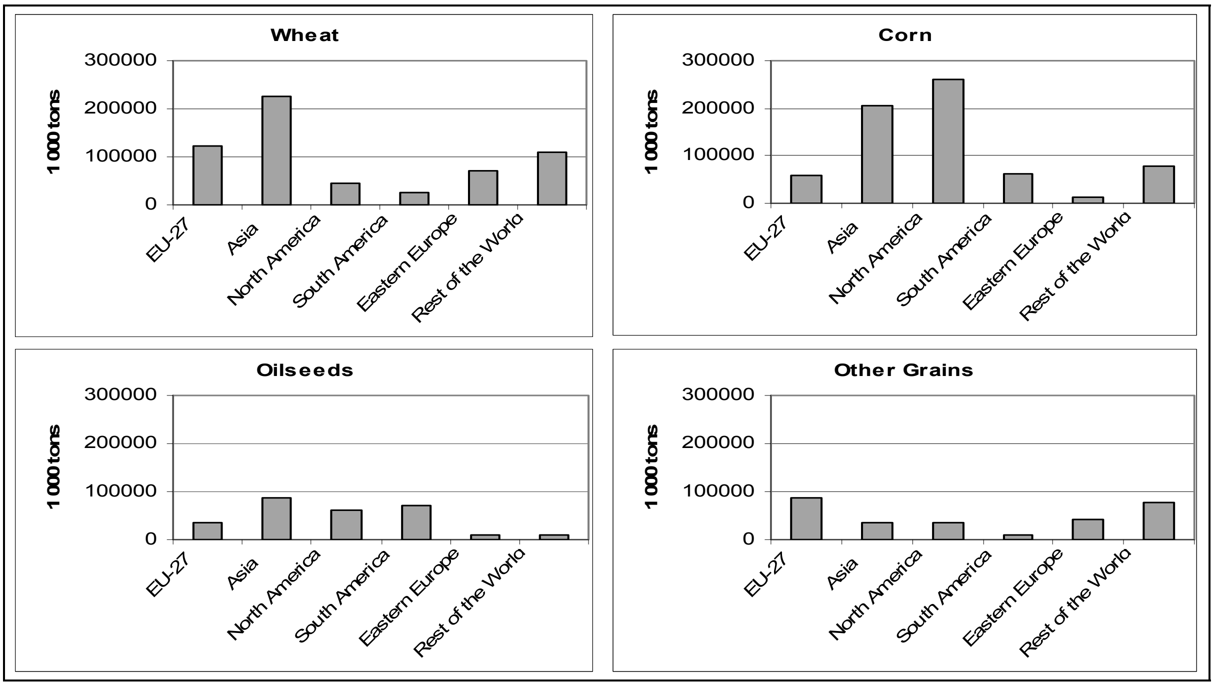
## 4.2 Data

As discussed in chapter 3, the following variables are of relevance for the purpose of the analysis. On the demand side they are population growth, changing food preferences due to per capita income growth, and bio-energy. On the supply side they include productivity growth and the availability of crop land.

A significant part of the data base used in this analysis is from USDA's PSD database (USDA, 2008a). As a large number of publications are based on this database, it may be considered to be a very reliable data source. Additional data were obtained from other sources quoted in chapter 3. In particular, projections of well-known institutions with a strong academic background were used, thus adding additional reliability to the data and related information.

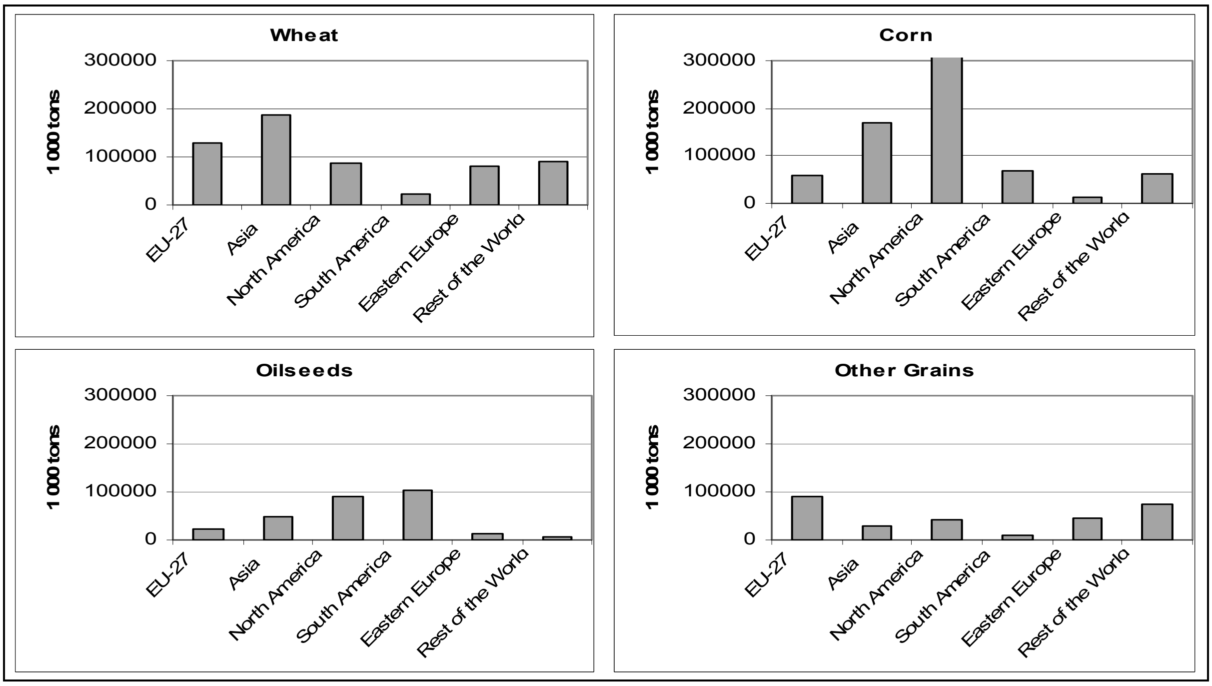
The analysis begins with characterising the status quo in 2003/05 which serves as the reference scenario. Subsequently, the shifts of supply and demand curves were determined in order to capture the driving forces of agricultural markets and to quantify alternative scenarios for 2013/15. The reference scenarios for the base period 2003/05 are exhibited in Figures 4.1 and 4.2 for the demand and the supply side respectively. More detailed information can be found in Annex A1 and Annex A2.

**Figure 4.1: Demand situation for defined markets in selected world regions, 2003/05**




Source: Own figure based on USDA (2008).

**Figure 4.2: Supply situation for defined markets in selected world regions, 2003/05**




Source: Own figure based on USDA (2008).

The number of hectares planted in the European Union to wheat, corn and oilseeds each for food feed and bio-energy has been determined by assuming that yields are identical for each crop regardless of its use as food, feed or bio-energy and that domestic bio-energy demand in the European Union is met entirely by domestic supply; i.e., no wheat, corn, and oilseeds are imported to be converted into bio-energy in the European Union. In addition, the structure of imports and exports has been taken into consideration. Figure 4.3 displays the results of these calculations. It becomes obvious that wheat and corn production/acreage for bio-energy is still fairly small in 2003/05. However, bio-energy already accounted for almost a quarter of oilseed production/acreage at that time.

The shifts of the supply and demand function which are the result of market changes (see also chapter 3) are exhibited in Annex A3 and Annex A4.

**Figure 4.3: Area harvested in the European Union necessary to meet food, feed and bio-energy demand, 2003/05**

| Crop area … | … to meet food demand | | … to meet feed demand | | … to meet bio-energy demand | |
|---|---|---|---|---|---|---|
| | (1000 ha) | (percent) | (1000 ha) | (percent) | (1000 ha) | (percent) |
| Wheat | 13 743 | 54.1 | 11 522 | 45.4 | 117 | 0.5 |
| Corn | 1 994 | 21.3 | 7 306 | 78.2 | 48 | 0.5 |
| Oilseeds | 1 623 | 18.6 | 4 974 | 57.0 | 2 135 | 24.4 |

Source: Own calculations.

# 5. Analysis of European Union markets to 2013/15

Altogether, changes in demand and supply of four key crops (wheat, corn, oilseeds, other grains) are analysed for all regions listed in chapter 2. In this chapter the results of the empirical analysis for the EU-27 will be presented. In addition, some inferences from the model results will be drawn.

In the following, percentage changes will be displayed. The changes in demand, supply and trade in absolute numbers are provided in Annex A5.

## 5.1 Changes in demand and supply

Figure 5.1 displays the changes in European Union demand for the crops included in the analysis. It becomes evident that the demand can be expected to increase significantly on all markets. The increase in demand is particularly large for oilseeds. This is mainly the result of a continuing expansion of the acreage planted with bio-energy crops to meet an increasing domestic bio-energy demand.

**Figure 5.1: Changes in total demand (EU-27) between 2003/05 and 2013/15**

| Key crop | Change (in percent) |
|---|---|
| Wheat | 21 |
| Corn | 13 |
| Oilseeds | 51 |
| Other grains (residuum crop) | 11 |

Source: Own calculations.

**Demand increases, in particular demand in bio-energy and in oilseeds**

Figure 5.2 disaggregates the change in demand by its use as food, feed, and bio-energy. While the food and feed demand for all crops does not increase by large there is considerable growth in the demand for bio-energy. This reflects both the fairly low demand in the reference period and the considerable growth in demand during the time period analysed here.

**Figure 5.2: Changes in food, feed and bio-energy demand (EU-27) between 2003/05 and 2013/15**

| Key crop | Change (in percent) | | |
|---|---|---|---|
| | Food demand | Feed demand | Bio-energy demand |
| Wheat | 6 | 8 | 2539 |
| Corn | 11 | 4 | 1567 |
| Oilseeds | 5 | 1 | 333 |

Source: Own calculations.

### Supply increase lags behind growth in demand

The changes in European Union supply are shown in Figure 5.3. As is evident, the growth in supply lags behind the growth in demand. Corn is the exception in this regard, as supply growth exceeds the growth in demand. The growth in the oilseed supply is considerably larger than supply growth in other crops. The growth in corn and oilseed supply reflects substitution in production. Corn and oilseed acreages are expanded at the expense of other crops (wheat, other grains). This is reflected by figure 5.4.

**Figure 5.3: Changes in total supply (EU-27) between 2003/05 and 2013/15**

| Key crop | Change (in percent) |
|---|---|
| Wheat | 7 |
| Corn | 18 |
| Oilseeds | 32 |
| Other grains (residuum crop) | 5 |

Source: Own calculations.

**Figure 5.4: Changes in the area harvested (EU-27) between 2003/05 and 2013/15 (yield increase potential = 100 percent)**

| Key crop | Change (in percent) |
|---|---|
| Wheat | -2 |
| Corn | 10 |
| Oilseeds | 10 |
| Other grains (residuum crop) | -2 |

Source: Own calculations.

### Substitution between crops and the importance of set-aside

These numbers reflect two developments. One is the overall 2 percent increase in the acreage planted to the crops included in this analysis. The other is a decline in total agricultural acreage of 3 percent.

As discussed earlier, the overall effects of climate change on European Union agriculture may be expected to be minor during the time period considered here. However, there is considerable uncertainty with regard to two aspects of climate change that warrant further discussion. These are the increase in frequency and intensity of weather extremes, and the higher likelihood of milder winters which tend to increase the survival of plant pathogens. Both would result in lower yields, all other factors remained unchanged.

Figure 5.5 takes this into account by assuming that the expected yield growth is not fully realised, but cut in half. If the European Union wishes to keep production growth at the levels presented in figure 5.3, the acreage planted with wheat, corn, oilseeds and other grains would need to be expanded significantly. The numbers in figure 5.5 imply an increase in acreage of almost 7 percent or about 4.5 million hectares. This exceeds the acreage presently enrolled in set-aside programs (approximately 4 million hectares; see EC, 2008) by half a million hectares.

**Figure 5.5: Changes in the area harvested (EU-27) between 2003/05 and 2013/15 (yield increase potential = 50 percent)**

| Key crop | Change (in percent) |
|---|---|
| Wheat | 3 |
| Corn | 14 |
| Oilseeds | 20 |
| Other grains (residuum crop) | 2 |

Source: Own calculations.

**Figure 5.6: Acreage planted for the supply of food, feed and bio-energy crops (EU-27), 2003/05 and 2013/15**

| Key crop | Time period | Acreage planted for (in percent) | | |
|---|---|---|---|---|
| | | Food | Feed | Bio-energy |
| Wheat | 2003/05 | 54 | 45 | 1 |
| | 2013/15 | 46 | 43 | 11 |
| Corn | 2003/05 | 21 | 78 | 1 |
| | 2013/15 | 20 | 73 | 7 |
| Oilseeds | 2003/05 | 19 | 57 | 24 |
| | 2013/15 | 5 | 15 | 80 |

Source: Own calculations.

The changes in the supply of food, feed and bio-energy crops can be seen in figure 5.6. As is evident, the relative importance of domestic production of wheat and corn for food will decline to some extent, while for oilseeds it will approximately be reduced by three fourths. A very similar pattern can be found for feed crops.

By symmetry the relative importance of supply for bio-energy use will increase. About four fifth of the oilseed production is for bio-energy in 2013/15. The high percentage of oilseeds production for bio-energy in the model results is in line with other projections of future acreage requirements (e.g. BAMIERE et al., 2007). About half of the supply of bio-energy crops projected for 2013/15 has already been realised in 2007/08.

## 5.2 Changes in prices and international trade

The implications of the demand and supply changes in the European Union in the context of international trade flows are displayed in figure 5.7.

### Changing net trade position

Consistent with the findings for demand and supply changes, the net trade position will deteriorate for wheat, oilseeds and other grains while it will improve slightly for corn. In oilseeds, net imports increase; and the European Union will switch from a net exporting to a net importing position for grains (sum of wheat, corn, and other grains).

**Figure 5.7: Net trade position (EU-27), 2003/05 and 2013/15**

| Key crop | 2003/05 | 2013/15 |
|---|---|---|
| Wheat | 7 993 k tons | - 7 824 k tons |
| Corn | - 1 643 k tons | 958 k tons |
| Oilseeds | - 14 083 k tons | - 25 229 k tons |
| Other grains (residuum crop) | 1 534 k tons | - 3 622 k tons |

Source: Own calculations.

A central reason for the changes in the net trade position is the significant growth in domestic demand for bio-energy production. As land and other inputs are diverted from domestic food or feed to bio-energy production, there is an increased need for imports to balance domestic European Union supply and demand.

If the European Union wishes to maintain its present level of self-sufficiency in food and feed crops for food security reasons, agricultural land productivity will have to increase. As agricultural land reserves are limited, yields would have to be increased even further.

The yield increases necessary to maintain the net-trade position in the reference period are listed in figure 5.8.

**Figure 5.8: Yield increases needed to maintain EU-27 net trade position of 2003/05 in 2013/15**

| Key crop | Increase (in percent) |
|---|---|
| Wheat | 19 |
| Oilseeds | 84 |
| Other grains (residuum crop) | 11 |

Source: Own calculations.

In wheat the yield would have to be increased by 1.8 percent annually compared to the reference period; in other grains it would have to increase by almost 1.1 percent per annum. In oilseeds the yield increase would have to be an extraordinary 6.3 percent annually.

### Increasing world market prices

The changes in world market prices are shown in figure 5.9. As can be seen, the price increase during the time period analysed here is in the range of 30 percent for corn and oilseeds while the price of wheat and other grains goes up by more than 10 percent. The results of this analysis are in line with other empirical investigations of future changes in world market prices (e.g. FAPRI (2008a), USDA (2008a, b), see also figure 3.5). The differences in price increases between wheat and other grains on the one hand, and corn and oilseeds on the other hand again reflect the rapid growth in bio-energy production based on these two crops.

**Figure 5.9: Change in world market prices between 2003/05 and 2013/15**

| Key crop | Change (in percent) |
|---|---|
| Wheat | 14 |
| Corn | 30 |
| Oilseeds | 32 |
| Other grains (residuum crop) | 13 |

Source: Own calculations.

### Sensitivity tests: Scenarios for variations in food and bio-energy demand

There is some uncertainty with regard to two determinants of agricultural world markets. They include bio-energy policies around the globe and economic growth in developing countries. To account for this uncertainty a set of sensitivity analyses has been performed by altering the global changes in food demand and bio-energy demand. The results of these sensitivity analyses are shown for oilseeds in figures 5.10 - 5.12 for European Union demand and supply as well as world market prices.

**Figure 5.10: Variations in oilseeds demand (EU-27) between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 37 % | 37 % | 37 % |
| | 100 % | 50 % | 51 % | 51 % |
| | 130 % | 64 % | 64 % | 64 % |

Source: Own calculations.

**Figure 5.11: Variations in oilseeds supply (EU-27) between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 28 % | 28 % | 29 % |
| | 100 % | 31 % | 32 % | 32 % |
| | 130 % | 34 % | 35 % | 35 % |

Source: Own calculations.

**Figure 5.12: Variations in world market prices of oilseeds between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 25 % | 26 % | 29 % |
| | 100 % | 30 % | 32 % | 32 % |
| | 130 % | 34 % | 38 % | 40 % |

Source: Own calculations.

Results of sensitivity analyses for other crops are comprised in Annexes A6 and A7.

As can be seen in figures 5.10 – 5.12 as well as in the Annexes A6 and A7, a variation in world food demand growth has some to no effect on European Union demand and supply. However, world market prices are affected by changes in world food demand. As expected, a growing global food demand acts to increase the world market price. A variation of global demand for bio-energy has significant effects on European Union demand and supply as well as world market prices. In all, the results of the analyses are fairly robust with regard to alternative demand growth scenarios.

# 6. Summary and conclusions

In this study the driving forces of changes in agricultural world market prices and their implications for European Union agriculture have been analysed for the time period 2003/05 - 2013/15. The mega-trend of declining world market prices, which is sometimes referred to as the Agricultural Treadmill, has ended. Since the turn of the millennium, world market prices for agricultural goods have been increasing. This trend can be expected to continue for at least the time period analysed here. Not only will prices have a tendency to increase, but also fluctuations of agricultural world market prices are likely to be higher in the future than they have been in the past.

The reason for the positive trend in agricultural world market prices is that global demand growth outstrips the growth in global supply, and this trend will continue in the foreseeable future. Global demand for food will continue to grow at a fairly rapid pace mainly for two reasons. One is the continued growth in world population; the other is the sustained growth in per capita incomes in developing and newly industrialising countries, with a corresponding increase of per capita food consumption.

Global food supply will not keep pace with the growth in demand. A key factor is that the globally available agricultural land is limited in scale. The most productive land is already being farmed. In many parts of the world there are no major land reserves left that could be converted to expand the agricultural acreage. Where land reserves exist, they often should not be used for farming because of environmental reasons. Consequently, to meet the needs of the rapidly growing world population, the necessary production growth will have to come to a very large extent from a growth in productivity of the land already being farmed today.

However, this will be difficult to accomplish, as global agricultural productivity growth has been in decline since the Green Revolution of the 1960s and 1970s. Moreover, the rapid expansion of bio-energy production diverts agricultural land and other inputs away from food production.

In addition, increasing water scarcity is starting to act as a constraint to production growth in some parts of the world. Climate change is also beginning to affect production. Nevertheless, during the time period covered by this study, both impacts are not yet likely to be of major importance on a global scale.

Next to this, organic food production, which requires more land acreage than conventional farming, has increased in the past decade in the European Union and elsewhere. However, in the European Union the growth rates in the production of organic food have declined. Sustained high prices for food in general will likely contribute to a further slow-down of production growth in this market segment.

The results of the analysis suggest that both in the European Union and globally agricultural demand will grow faster than supply during the time period 2003/05 - 2013/15. European

Union demand for grains can be expected to increase by 10-20 percent and by more than 50 percent in oilseeds. The key driver on the demand side is bio-energy. However, European Union supply of wheat and other grains can be expected to increase by less than 10 percent, corn by 15-20 percent, and oilseeds by more than 30 percent. The supply reaction of European Union agriculture mainly reflects the changes in demand for bio-energy as well as increasing yields. As a consequence, the price of wheat can be expected to increase by more than 10 percent and the price of corn and oilseeds by more than 30 percent.

The net trade position of European Union agriculture can be expected to change significantly during the time period analysed. While there would be a reduction in net imports of corn, net imports of oilseeds are expected to increase by more than 70 percent. It is foreseeable that for wheat the European Union will switch from being a net exporter to being a net importer. The same is true for other grains.

European Union agricultural demand and supply are driven to a large extent by bio-energy. However, bio-energy is not competitive and has to be subsidised. The analysis is based on the assumption that present policies continue unchanged, both in the European Union and elsewhere. In case of significant changes in bio-energy policies around the world the results of the analysis would need to be adjusted.

Two additional aspects warrant further considerations:

– implications for world food security and
– the fight against global warming.

Increasing prices of food and other agricultural commodities, such as bio-energy crops, and a growing volume of global consumption are certainly good news for net food sellers around the globe. This holds for individual producers as well as for countries. Their welfare is growing because they can sell more quantity at a higher price.

For net food buyers, however, the situation is a different story. Net food buyers are worse off, because they will have to pay more for their food. Consumers in the rich countries should be able to cope with increasing food prices, as in most of the industrialised countries the proportion of income spent on food is around 10 percent.

However, for net food buyers living in developing countries in absolute poverty increasing food prices represent a major threat to their livelihoods. There are about 850 million humans who live in absolute poverty today and who have the purchasing power equivalent to 1 USD per person and day or less. They have to spend almost all their income on food in order to survive. For the world’s poor, increasing food prices, therefore, may become a matter of survival.

The United Nations continue to pursue the objective of cutting in half the number of people who were malnourished in 1995 by 2015. It has become clear, however, that this objective is far from being achieved. To the contrary, the number of malnourished people is going up by about 4 million annually (UN, 2006).

In the 1960s, developing nations were net exporters of food. Now they are net importers. It can be expected that the food import gap with quintuple between 2000 and 2030 (BRUINSMA, 2003). The developing countries will not even come close to securing food supply for their rapidly growing population through domestic production even under the best of all realistic scenarios. The results of the analysis confirm this. Therefore, increasing food import needs of developing countries can only be met if the industrialised countries produce more and export more food.

Today, developing countries are on balance net importers of food and developed countries are net exporters. This is contrary to the traditional paradigm of international agricultural trade. According to the traditional paradigm, developing countries on balance should be net food exporters and developed countries net food importers based on the presumption that the production of food requires a lot of unskilled and cheep labour. Clearly a typical characteristic of developing countries is their relative abundant and thus cheap supply of labour.

The traditional paradigm of international agricultural trade, however, has been proven false, both on theoretical grounds and by empirical evidence. Developed countries have significantly reduced their agricultural protectionism in the last 15 years. Also many of the developing countries have reduced their (direct or indirect) taxation of domestic farm production. If developing countries actually had a comparative price and cost advantage when it comes to international trade with developed countries, net food imports by developing countries should have decreased.

Furthermore, developing countries are characterised by a rapid population growth. This also serves to reduce the price of labour relative to those of other production factors and should have contributed to a reduction of net food imports of developing countries.

However, the opposite has happened. The key reason for this is that the very nature of food production has changed significantly. Agriculture has become a technologically advanced industry. Indeed, the production of agricultural commodities and processed food is a modern business using “high tech” – especially when it comes to the production of high quality food demanded in developed countries.

The production of high quality food requires sophisticated quality management systems, which are both capital intensive and human capital intensive. Both capital and human capital are relatively abundant production factors in developed countries and, consequently, they are relatively inexpensive there. Both are in relatively short supply in developing countries and, therefore, they are relatively expensive, which results in a comparative disadvantage in agricultural production of developing countries

Further empirical support for the new paradigm of international agricultural trade can be obtained by analysing developing countries, who have managed to become exporters on some markets. Often this is linked to foreign direct investment by companies from developed countries. They provide those factors that producers in developing countries do not have in sufficient supply – capital and knowledge to produce high quality food and access markets.

Therefore, industrialised countries have a comparative advantage to produce and export more food. However, the growth in bio-energy production in the European Union will revert it back to a net importing position in wheat and will increase imports of oilseeds. This will reduce the European Union's ability to help fight starvation in the world unless there would be an increase in agricultural productivity beyond what can reasonably be expected.

Climate change is now widely accepted as a fact and human activity is a contributing factor. While probably not being of major importance during the time period considered in this study, eventually world agriculture will be affected by climate change and will need to adapt to it in the long run; and it may also be subject to mitigation policies aiming at a reduction of agricultural greenhouse gases (VON WITZKE and NOLEPPA, 2007; HOLM-MÜLLER and PEREZ, 2007).

Global warming has a large number of impacts on world agriculture. Additional carbon dioxide acts as a plant fertilizer. In the very northern and southern as well as in many moderate latitudes the vegetation period will be extended and the atmosphere will contain more water. In other latitudes, the climate will become less favourable for agricultural production. In many parts of the world weather extremes can be expected to increase in frequency and magnitude. As a consequence, agricultural production in regions with temperate climate may increase while the opposite is likely to occur in sub-tropical and tropical areas of the world. On balance, world food production will be negatively affected as a consequence of climate change in the long run (e.g. STERN, 2007).

This is of relevance for at least three reasons:

- The associated additional increase in world food prices will amplify hunger and malnutrition in developing countries.
- Food production will decline predominantly in the countries which are already characterised by increasing food import needs.
- And these are also the countries which are unable to make the necessary investments in agricultural research, so their farmers face even more obstacles to adapt to the changing climate and to cope with increase in agricultural demand.

In the global picture, the European Union will be less affected by climate change than other parts of the world. It may even benefit in years with only few or no weather extremes in the region. Europe will become a more secure production location in comparison to other world regions. Consequently, it has to take responsibility to significantly contribute to both world food security and also to combat global warming by using its production potential (UNECE, 2007). However, to fully capitalise on its production potential it is imperative that the European Union employs strategies which increase overall agricultural productivity.

As discussed, increasing food prices do result in growing malnutrition and starvation affecting particularly humans living in absolute poverty in developing countries. A lot of them reside in rural areas. At the same time, rising food prices increase the incentives for deforestation in an attempt to claim additional farm land. Already today deforestation contributes almost one fifth to the total of man made climate change. This contributes more to global warming than the global manufacturing industry or the global transportation sector (e.g. STERN, 2007).

The growing production of bio-energy will increase competition for land and other agricultural production factors. To the extent that agricultural land is used for bio-energy production the growth in food production is slowed down. As a consequence, the increase in food prices is even more pronounced, which would increase starvation and malnutrition (and, hence, deforestation) even further. Again, the way out of this dilemma is an increase in agricultural productivity in both food and bio-energy production.

In today's global economy international mobility has grown significantly. This includes rich and poor countries alike. A significant and sustained increase in international food prices and the attendant problems of growing malnutrition will tend to increase legal and illegal immigration from poor and food deficient countries to rich countries where food is perceived to be relatively more abundant. Of course, this will create problems for both countries experiencing emigration as well as those with immigration.

To conclude: The rapidly growing demand for food and bio-energy can be met through an expansion of the acreage used for agricultural production, through growth in the productivity of the land already being farmed, or a combination of both. As the expansion of the acreage is limited, the production growth needs to come mainly through productivity growth of the land already being farmed. Productivity growth, however, is the result of investment in research and development, an increase in the intensity of production and a reduction of losses of potential yields. It is estimated that about 50 percent of potential yields are presently lost to weeds, pests and diseases, of which almost half could have been avoided through appropriate measures (OERKE, 2005). Increased productivity, therefore, enables the world to meet food, feed and bio-energy production requirements and, thus, safeguards land for other purposes such as nature protection, and by reducing deforestation it makes a significant contribution to combat global warming.

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# Annexes

## Annex A1: Total demand, food, feed, and bio-energy demand for key crops in various world regions, 2003/05

**Figure A1.1: Model data for wheat (in 1 000 tons)**

| Region | Demand, total | Food demand | Feed demand | Bio-energy demand |
|---|---|---|---|---|
| EU-27 | 121 947 | 63 133 | 58 213 | 600 |
| Asia | 224 833 | 215 957 | 8 227 | 650 |
| North America | 45 808 | 36 422 | 8 836 | 550 |
| South America | 27 102 | 26 182 | 920 | n. a. |
| Eastern Europe | 71 597 | 50 968 | 20 630 | n. a. |
| Rest of the World | 110 021 | 102 549 | 7 472 | n. a. |

**Figure A1.2: Model data for corn (in 1 000 tons)**

| Region | Demand, total | Food demand | Feed demand | Bio-energy demand |
|---|---|---|---|---|
| EU-27 | 60 155 | 12 833 | 47 021 | 300 |
| Asia | 205 800 | 57 656 | 146 144 | 2 000 |
| North America | 260 973 | 51 656 | 173 800 | 35 400 |
| South America | 63 540 | 14 133 | 49 406 | n. a. |
| Eastern Europe | 11 915 | 1 638 | 10 277 | n. a. |
| Rest of the World | 76 815 | 38 511 | 38 304 | n. a. |

**Figure A1.3: Model data for oilseeds (in 1 000 tons)**

| Region | Demand, total | Food demand | Feed demand | Bio-energy demand |
|---|---|---|---|---|
| EU-27 | 35 351 | 7 416 | 22 735 | 5 200 |
| Asia | 86 592 | 35 318 | 51 274 | n. a. |
| North America | 62 304 | 10 980 | 47 665 | 3 660 |
| South America | 69 626 | 5 419 | 64 206 | 3 660 |
| Eastern Europe | 10 517 | 2 557 | 7 960 | n. a. |
| Rest of the World | 9 108 | 5 211 | 3 897 | n. a. |

**Figure A1.4: Model data for other grains (in 1 000 tons)**

| Region | Demand, total | Feed demand | Other demand |
|---|---|---|---|
| EU-27 | 88 301 | 64 827 | 23 474 |
| Asia | 36 181 | 7 655 | 28 526 |
| North America | 36 921 | 28 108 | 8 813 |
| South America | 9 015 | 6 210 | 2 805 |
| Eastern Europe | 41 827 | 26 827 | 15 000 |
| Rest of the World | 78 509 | 32 071 | 46 438 |

Source: Own calculations based on USDA (2008), COLLINS (2007), EC (2008), OECD and FAO (2007).

## Annex A2: Total supply, yields and area harvested for key crops in various world regions, 2003/05

**Figure A2.1: Model data for wheat**

| Region | Production (1 000 tons) | Yields (tons/ha) | Area harvested (1 000 ha) |
|---|---|---|---|
| EU-27 | 129 940 | 5.12 | 25 382 |
| Asia | 187 475 | 3.11 | 60 307 |
| North America | 87 188 | 2.82 | 30 886 |
| South America | 23 746 | 2.56 | 9 279 |
| Eastern Europe | 79 788 | 1.77 | 45 106 |
| Rest of the World | 91 902 | 2.08 | 44 150 |

**Figure A2.2: Model data for corn**

| Region | Production (1 000 tons) | Yields (tons/ha) | Area harvested (1 000 ha) |
|---|---|---|---|
| EU-27 | 58 512 | 6.26 | 9 347 |
| Asia | 169 496 | 3.89 | 43 560 |
| North America | 309 879 | 8.13 | 38 103 |
| South America | 67 811 | 3.47 | 19 527 |
| Eastern Europe | 13 431 | 3.59 | 3 740 |
| Rest of the World | 60 337 | 2.01 | 29 944 |

**Figure A2.3: Model data for oilseeds**

| Region | Production (1 000 tons) | Yields (tons/ha) | Area harvested (1 000 ha) |
|---|---|---|---|
| EU-27 | 21 268 | 2.44 | 8 732 |
| Asia | 48 545 | 1.27 | 38 098 |
| North America | 91 502 | 2.48 | 36 918 |
| South America | 101 744 | 2.40 | 42 458 |
| Eastern Europe | 11 499 | 1.09 | 10 556 |
| Rest of the World | 5 227 | 1.36 | 3 856 |

**Figure A2.4: Model data for other grains**

| Region | Production (1 000 tons) | Yields (tons/ha) | Area harvested (1 000 ha) |
|---|---|---|---|
| EU-27 | 89835 | 3.81 | 23587 |
| Asia | 30503 | 1.16 | 26271 |
| North America | 41164 | 3.20 | 12872 |
| South America | 8982 | 2.46 | 3644 |
| Eastern Europe | 44488 | 1.68 | 26492 |
| Rest of the World | 75254 | 1.15 | 65252 |

Source: Own calculations based on USDA (2008).

## Annex A3: Global trends and their impact on demand until 2013/15 for key crops in various world regions

**Figure A3.1: Impact of population growth on food and feed demand (in percent, same for all key crops)**

| Region | Growth |
|---|---|
| EU-27 | 4.29 |
| Asia | 11.73 |
| North America | 8.90 |
| South America | 12.17 |
| Eastern Europe | -0.36 |
| Rest of the World | 20.95 |

Source: Own calculations based on UNITED STATES CENSUS BUREAU (2008), EC (2008).

**Figure A3.2: Impact of changing food preferences on food demand (in percent)**

| Region | Wheat | Corn | Oilseeds | Other grains |
|---|---|---|---|---|
| EU-27 | 2.16 | 15.05 | 8.54 | 15.05 |
| Asia | -2.60 | -10.14 | 33.63 | -10.14 |
| North America | -2.26 | 0.77 | 3.44 | 0.77 |
| South America | 0.76 | -0.15 | 16.07 | -0.15 |
| Eastern Europe | 1.08 | 7.28 | 29.31 | 7.28 |
| Rest of the World | -3.64 | 4.00 | 30.81 | 4.00 |

Source: Own calculations based on USDA (2008), FAPRI (2008a), OECD and FAO (2007).
Note: Same percentage changes had to be used for corn and other grains.

**Figure A3.3: Impact of changing food preferences on feed demand (in percent)**

| Region | Wheat | Corn | Oilseeds | Other grains |
|---|---|---|---|---|
| EU-27 | 4.33 | 3.90 | 4.40 | 4.82 |
| Asia | 10.65 | 16.00 | 15.81 | 17.82 |
| North America | 15.77 | -1.18 | -0.50 | -1.36 |
| South America | 12.98 | 29.90 | 29.47 | 28.48 |
| Eastern Europe | 9.06 | 10.62 | 6.69 | 3.35 |
| Rest of the World | 15.63 | 13.85 | 11.83 | 8.52 |

Source: Own calculations based on USDA (2008), FAPRI (2008a), OECD and FAO (2007).

**Figure A3.4: Impact of bio-energy market developments on bio-energy demand (in additional 1 000 tons)**

| Region | Bio-energy demand | | |
|---|---|---|---|
| | Wheat | Corn | Oilseeds |
| EU-27 | 15 833 | 5 000 | 22 500 |
| Asia | 1 200 | 8 000 | 10 000 |
| North America | 1 533 | 111 300 | 5 600 |
| South America | 1 000 | n. a. | 8 500 |
| Eastern Europe | n. a. | n. a. | 200 |
| Rest of the World | n. a. | n. a. | 1 300 |

Source: Own calculations based on OECD and FAO (2007), Collins (2007), EC (2008), and Schumacher (2007).

## Annex A4: Global trends and their impact on supply until 2013/15 for key crops in various world regions

**Figure A4.1: Impact of technology developments on yields (in percent)**

| Region | Wheat | Corn | Oilseeds | Other grains |
|---|---|---|---|---|
| EU-27 | 8.60 | 7.27 | 19.48 | 6.78 |
| Asia | 6.63 | 10.22 | 10.07 | 11.46 |
| North America | 2.64 | 8.89 | 7.42 | 9.29 |
| South America | 3.61 | 11.62 | 9.89 | 4.81 |
| Eastern Europe | 11.32 | 8.03 | 17.13 | 6.78 |
| Rest of the World | 10.02 | 3.04 | 16.92 | 9.93 |

Source: Own figure based on USDA (2008), OECD and FAO (2008) and FAPRI (2008a).

**Figure A4.2: Changes in area availability (in percent)**

| Region | Area changes |
|---|---|
| EU-27 | -3.00 |
| Asia | -0.50 |
| North America | 3.50 |
| South America | 5.00 |
| Eastern Europe | 3.00 |
| Rest of the World | 2.00 |

Source: Own figure based on FAO (2002) and von Witzke (2008).

## Annex A5: Changes of EU-27 demand, supply and trade between 2003/05 and 2013/15

**Figure A5.1: Total demand (EU-27) in 2003/05 and 2013/15 (in 1 000 tons)**

| Region | 2003/05 | 2013/15 | Change |
|---|---|---|---|
| Wheat | 121 947 | 146 992 | 25 045 |
| Corn | 60 155 | 68 023 | 7 869 |
| Oilseeds | 35 351 | 53 240 | 17 889 |
| Other grains (residuum crop) | 88 301 | 98 295 | 9 994 |

Source: Own calculations.

**Figure A5.2: Food demand (EU-27) in 2003/05 and 2013/15 (in 1 000 tons)**

| Region | 2003/05 | 2013/15 | Change |
|---|---|---|---|
| Wheat | 63 133 | 66 760 | 3 627 |
| Corn | 12 833 | 14 185 | 1 351 |
| Oilseeds | 7 416 | 7 763 | 347 |

Source: Own calculations.

**Figure A5.3: Feed demand (EU-27) in 2003/05 and 2013/15 (in 1 000 tons)**

| Region | 2003/05 | 2013/15 | Change |
|---|---|---|---|
| Wheat | 58 213 | 62 878 | 4 665 |
| Corn | 47 021 | 48 839 | 1 817 |
| Oilseeds | 22 735 | 22 925 | 190 |

Source: Own calculations.

**Figure A5.4: Bio-energy demand (EU-27) in 2003/05 and 2013/15 (in 1 000 tons)**

| Region | 2003/05 | 2013/15 | Change |
|---|---|---|---|
| Wheat | 600 | 15 833 | 15 233 |
| Corn | 300 | 5 000 | 4 700 |
| Oilseeds | 5 200 | 22 500 | 17 300 |

Source: Own calculations.

**Figure A5.5: Total supply (EU-27) in 2003/05 and 2013/15 (in 1 000 tons)**

| Region | 2003/05 | 2013/15 | Change |
|---|---|---|---|
| Wheat | 129 940 | 139 167 | 9 227 |
| Corn | 58 512 | 68 981 | 10 470 |
| Oilseeds | 21 268 | 28 011 | 6 743 |
| Other grains (residuum crop) | 89 835 | 94 673 | 4 839 |

Source: Own calculations.

## Annex A6: Sensitivity analyses for wheat

**Figure A6.1: Variations in wheat demand (EU-27) between 2003/05 and 2013/15**

| | | Variations on global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 16 % | 17 % | 17 % |
| | 100 % | 20 % | 21 % | 21 % |
| | 130 % | 24 % | 24 % | 25 % |

Source: Own calculations.

**Figure A6.2: Variations in wheat supply (EU-27) between 2003/05 and 2013/15**

| | | Variations on global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 7 % | 7 % | 7 % |
| | 100 % | 7 % | 7 % | 7 % |
| | 130 % | 7 % | 7 % | 7 % |

Source: Own calculations.

**Figure A6.3: Variations in world market prices of corn between 2003/05 and 2013/15**

| | | Variations on global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 11 % | 11 % | 11 % |
| | 100 % | 13 % | 14 % | 14 % |
| | 130 % | 16 % | 16 % | 16 % |

Source: Own calculations.

## Annex A7: Sensitivity analyses for corn

**Figure A7.1: Variations in corn demand (EU-27) between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 11 % | 12 % | 12 % |
| | 100 % | 13 % | 13 % | 14 % |
| | 130 % | 13 % | 14 % | 15 % |

Source: Own calculations.

**Figure A7.2: Variations in corn supply (EU-27) between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 14 % | 15 % | 15 % |
| | 100 % | 17 % | 18 % | 18 % |
| | 130 % | 20 % | 21 % | 21 % |

Source: Own calculations.

**Figure A7.3: Variations in world market prices of corn between 2003/05 and 2013/15**

| | | Variations in global food demand | | |
|---|---|---|---|---|
| | | 90 % | 100 % | 110 % |
| Variations in global bio-energy demand | 70 % | 22 % | 23 % | 25 % |
| | 100 % | 28 % | 30 % | 31 % |
| | 130 % | 35 % | 36 % | 37 % |

Source: Own calculations.

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