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# The social, economic and environmental value of agricultural productivity in the European Union

## Impacts on markets and food security, rural income and employment, resource use, climate protection, and biodiversity

HFFA Working Paper 03/2013

# The social, economic and environmental value of agricultural productivity in the European Union

## Impacts on markets and food security, rural income and employment, resource use, climate protection, and biodiversity

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## Content



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## List of abbreviations

| | | |
|---|---|---|
| AWU | – | Annual Working Unit |
| BMELV | – | Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz |
| BMU | – | Bundesministerium für Umwelt |
| CBD | – | Convention on Biological Diversity |
| CIS | – | Commonwealth of Independent States |
| DG AGRI | – | Directorate General Agriculture and Rural Development |
| DG ENER | – | Directorate General Energy |
| EC | – | European Commission |
| ECPA | – | European Crop Protection Association |
| EU | – | European Union |
| FADN | – | Farm Accountancy Data Network |
| FAO | – | Food and Agriculture Organization |
| FAPRI | – | Food and Agricultural Policy Research Institute |
| FNL | – | Fördergemeinschaft Nachhaltige Landwirtschaft |
| FNVA | – | Farm Net Value Added |
| GBI-BIO | – | Global Environment Facility Benefits Index of Biodiversity |
| GDP | – | Gross Domestic Product |
| GHG | – | Greenhouse Gas |
| IFAD | – | International Fund for Agricultural Development |
| IFOAM | – | International Federation of Organic Agriculture Movements |
| IFPRI | – | International Food Policy Research Institute |
| ILUC | – | Indirect Land Use Changes |
| IPCC | – | Intergovernmental Panel on Climate Change |

| | | |
|---|---|---|
| JRC | – | Joint Research Center |
| KTBL | – | Kuratorium für Technik und Bauwesen in der Landwirtschaft |
| LEL | – | Landesanstalt für die Entwicklung der Landwirtschaft und des ländlichen Raums |
| LfL | – | (Bayerische) Landesanstalt für Landwirtschaft |
| MENA | – | Middle East and North African (countries) |
| NBI | – | National Biodiversity Index |
| OECD | – | Organization for Economic Cooperation and Development |
| OBT | – | OBservaçao da Terra |
| PEM | – | Partial Equilibrium Model |
| PRB | – | Population Reference Bureau |
| R&D | – | Research and Development |
| SITC | – | Standard International Trade Classification |
| UN | – | United Nations |
| UNEP | – | United Nations Environment Programme |
| USDA | – | United States Department of Agriculture |
| USDC | – | United States Department of Commerce |
| WFP | – | World Food Programme |

## Executive Summary

Manifold challenges affect global agriculture and rural development. Agriculture has to produce more raw materials to satisfy increasing and diversifying demands of the growing world population. It has to contribute to economic prosperity and social well-being in rural areas, and it has to preserve natural resources – such as land, water and biodiversity – by adopting efficient and sustainable production technologies.

A more productive and resource-efficient agriculture can mitigate the problems associated with the above mentioned challenges, because it enables humankind to have more of everything – more food, more feed, more non-food crops, more biodiversity and natural habitats – while at the same time reducing greenhouse gas emissions which result from an expansion of the world's agricultural acreage. This is the basic hypothesis of this study.

Its overarching objective is to provide evidence of the multiple benefits of productive agriculture relative to low input farming in the EU. The results of the study could help stimulate the public debate on the importance of productivity in EU agriculture for the social, economic and environmental objectives of European society.

Scientific methods are applied to achieve this objective. They include a partial equilibrium model, a multiplier analysis of income and employment, a tool to calculate indirect land use changes and $CO_2$ emissions, and an innovative approach to quantify biodiversity impacts.

The empirical analysis presented here includes a discussion of market and social welfare effects, an assessment of rural income and employment effects, a calculation of agricultural trade and virtual land trade effects, an evaluation of global greenhouse gas emission and biodiversity effects.

Almost 700 data sets from mainly peer-reviewed scientific literature were analysed to determine the yield impact of productive agriculture vs. low input farming in the EU. This is the broadest spectrum of available information on yield effects of productivity in EU agriculture which has ever been analysed. The identified yield differences per crop in EU member states are at the core of the analysis. The evidence suggests that, on average, yields are 31 per cent lower in low input farming than in productive agriculture in the EU.

The empirical analysis also demonstrates that productive agriculture in the EU results in an additional production of grains of almost 100 million tons annually. In oilseeds this number amounts to 10 million tons. In sugar beets, potatoes and pulses the additional production is in the range of 2 to 5 million tons. This acts to limit

international market price increases and facilitates building stocks which function as shock absorbers and help reduce price volatility.

In addition, productive agriculture in the EU is a key contributor to world food security. It provides carbohydrates for more than 400 million humans, protein for almost 350 million and vegetable oils for close to 300 million humans. Thus, it is indispensable for reaching the millennium goal on combating hunger and malnutrition.

In total, the social welfare gain generated by productive agriculture in the EU – measured at the agricultural commodity market level – amounts to EUR 16.2 billion. This implies that without it the EU's agricultural gross value added would decline by more than 12 per cent.

Increased production of higher productivity in EU agriculture generates additional income in the upstream and downstream sectors of the value chain. The sum of the agricultural GDP and the GDP generated in upstream and downstream industries amounts to more than EUR 26 billion.

In arable cropping, approximately 1.1 million farmers – measured as annual working units – benefit from productive agriculture in the EU. This type of agriculture generates an additional annual income relative to low input farming of at least EUR 14 000 per farmer. In Germany, a full conversion from productive agriculture to low input farming would lead to a decline in income of probably more than one third. The effect would be even more pronounced in low income countries such as Bulgaria.

Agricultural labour market effects of productive agriculture in the EU appear to be small, but this type of farming creates 267 000 additional jobs in upstream and downstream industries of the agricultural value chain of which almost 100 000 would be lost in the case of low input farming.

Productive agriculture in the EU generates large additional trade volumes. Without it, the EU would become a net importer in all major arable crops. Switching from productive agriculture to low input farming in the EU would act to increase EU net imports of virtual agricultural land by almost 38 million hectares. This represents an agricultural acreage which exceeds the entire territory of Germany. The total EU net import of virtual agricultural land would amount to 62.5 million hectares. This is equivalent to twice the territory of Poland.

In total, productive agriculture in the EU avoids about 6.8 billion tons of $CO_2$ emissions around the globe from the reduced expansion of the agricultural acreage. Since empirical evidence suggests that there are no major differences between both types of farming with regard to greenhouse gas emissions measured per unit of production, productive agriculture in the EU contributes much more to mitigate climate change than low input farming.

By avoiding the conversion of almost 38 million hectares of natural habitats into agricultural use in other world regions, productive agriculture in the EU preserves biodiversity. The biodiversity preserved is equivalent to 8.6 million hectares of Brazilian rainforest or 17.7 million hectares of Indonesian rainforest. This implies that, at the current pace, the loss of biodiversity from low input farming in the EU equals 16 years of deforestation in the Amazon region.

Low input farming averages 31 per cent lower yields than productive agriculture in the EU. This implies that each percentage point of agricultural productivity gained in EU:

- feeds more than 10 million humans per annum,
- increases the annual social welfare generated in European agriculture by approximately EUR 500 million,
- contributes EUR 500 to the annual income of an average EU arable farmer,
- reduces EU's net virtual land imports by about 1.2 million hectares,
- acts to save 220 million tons in $CO_2$ emissions, and
- preserves global biodiversity equivalent to fauna and flora of up to 600 000 hectares of rainforest.

In sum, the results in this study clearly demonstrate: Productivity matters!

# 1. Challenges for agriculture and rural development

Currently, manifold challenges affect global agriculture and rural development (FAO, 2009a). Agriculture has to produce more raw materials to satisfy increasing and diversifying demands of the growing world population. It has to contribute to economic prosperity and social well-being in predominantly rural areas, and it has to preserve natural resources – such as land, water and biodiversity – by adopting efficient and sustainable production technologies. These challenges will certainly change the prospects of European agriculture.

Traditionally, the market perspective has been in the focus of analysing such impacts. It has meanwhile been well accepted that the long-term trend of declining agricultural commodity prices has come to an end. Since the turn of the millennium prices have tended to go up. This may be expected to continue as global demand growth outpaces the growth in supply:

- FAO (2009a) estimates that world food needs will increase by at least 70 per cent until 2050 because of continued rapid population growth (e.g. Tilman et al., 2011; UN, 2013) and per capita consumption growth (e.g. World Bank, 2013b; Noleppa, 2013) in both developing and newly industrialising countries. Recent population projections suggest that by 2050 world agriculture may have to feed up to 10 billion humans (e.g. PRB, 2012; USDC, 2013). Bioenergy and industrial use of agricultural raw materials create additional food and feed demand (e.g. Laborde, 2011; Zeddies et al., 2012). Thus, global agricultural demand will increase between the turn of the millennium and the year 2050 by more than 100 per cent (Tilman et al., 2011; Ray et al., 2013).
- This rapidly growing demand will have to be met either by expanding the agricultural acreage or by increasing yields. As the land that is available globally for agricultural use is limited (see, e.g., Langeveld et al., 2013; Foley et al., 2011; Phalan et al., 2011), the production growth necessary to meet the growing food, feed, fuel and fibre needs of the world must come for the most part through productivity growth of the land being farmed already. FAO (2009a) expects that 90 per cent of future global agricultural production growth must be the result of higher yields. However, current yield trends are insufficient to double global crop production by 2050 (e.g. Ray et al., 2013).

From the perspective of society, market developments are obviously of interest. However, social, environmental and related issues matter as well. It may be expected, for example, that a continuing rise in prices of agricultural commodities and food obviously acts to aggravate the already alarming world food situation. Estimates suggest that presently close to 1 billion humans around the world are undernourished (FAO et al., 2012). Those are humans who have USD 1.25 or less per day in purchasing power and who have to spend 70 per cent or more of their income on food. Even moderate increases in the prices of agricultural commodities can, therefore, significantly aggravate world food security, increase hunger, and lead to political and social unrest. The world had to learn this lesson during the food crises in 2007 and 2008 and again in 2010 and 2011. During those periods there was increased incidence of political turmoil and violence in many countries, most of which being net food importers.

Achieving a rate of agricultural productivity growth sufficient to meet the world's needs in the decades to come will be quite a challenge as productivity growth has been declining since the Green Revolution. This is particularly true for the European Union (EU), where yields tend to stagnate or increase at rates of 1 per cent or less (Kirschke et al., 2011; Piesse and Thirtle, 2010; Spink et al., 2009), and this in times when, according to latest projections, a global yield increase of at least 2.4 per cent per annum is needed to meet accelerating agricultural demand (Ray et al., 2013).

A key reason for the declining productivity growth in world and EU agriculture has been the general neglect of agriculture and its contribution to tackle the challenges ahead in the public debate in recent decades as well as the neglect of agricultural research and development (R&D) which is directed at increasing productivity growth (e.g. Pardey et al., 2012; Rao et al., 2012). Other variables which act to slow down productivity growth include shortage of water and land suitable for farming, rising energy prices, global climate change, and growing competition for the scarce natural resources in world agriculture between the production of food crops, and non-food crops such as cotton, rubber, flowers and ornamentals, or bio-fuel crops. In addition, all attempts to increase productivity must be sustainable and preserve the world's environment (e.g. von Witzke, 2011).

Moreover, the lacking productivity growth in world agriculture leads to environmental damage. A continuing rapid expansion of the agricultural acreage around the globe is obvious, which, in turn, causes a loss of the world's natural habitats and biodiversity. This expansion of land is a major source of global greenhouse gas (GHG) emissions. In fact, it contributes more to global warming than global manufacturing or global transportation (Ecofys, 2012; Stern, 2007).

Modern, innovative and productive agriculture is a first-best approach and offers sustainable solutions to meet the multiple challenges agriculture faces today (e.g. Moldes, 2010; Royal Society, 2009):

- A more productive and resource-efficient agriculture can mitigate the problems associated with the above mentioned challenges, because it enables humankind to have more of everything – more food, more feed, more non-food crops, more biodiversity and natural habitats – while at the same time reducing GHG emissions which result from an expansion of the world's agricultural acreage (Noleppa and von Witzke, 2013).

- In addition, a sufficient and affordable global supply of food has the potential to contribute to political stability in developing and newly industrialising countries alike.
- And sustainably productive agriculture offers even more benefits such as securing competitiveness in an increasingly open international agricultural trade system. It also acts to raise the economic welfare of agriculture and related industries by securing income and employment particularly in rural areas (e.g. Hahn and Noleppa, 2013).

However, the general public in Europe is well fed and, by and large, not very well informed about the multitude of benefits generated by modern, productive and innovative agriculture. As a consequence, the public perception of modern agriculture often displays a remarkable indifference and even outright scepticism relative to modern farming practices (e.g., Gottwald, 2013).

This study aims at providing evidence of the multiple benefits of productivity in agriculture – based on reproducible findings and scientific facts. In particular, the results of the study should help better inform and facilitate an unbiased public debate on the importance of productivity in EU agriculture for specific social, economic and environmental objectives of the European society.

## 2. Research objectives and structure of the report

The overarching objective of this study is to demonstrate and quantify some of the key benefits of productivity in EU agriculture. In order to analyse respective effects it has to be clarified what is meant with productive agriculture in the EU throughout this study:

- This study focusses on land productivity, i.e. on the ratio of agricultural outputs (production of primary products) to land inputs. Sources of increasing agricultural productivity, in this sense, are various other inputs and innovation.
- Agricultural machinery allows for improved mechanisation, greatly improving land (and labour) productivity. This includes the use of modern tractors

and trucks, combine harvesters, aircraft and other vehicles, computers in conjunction with satellite images and global positioning system guidance for precision farming, etc.

- Improved crop varieties assure higher yields. These varieties can be developed through conventional breeding as well as biotechnology and genomics.
- Organic and/or mineral fertilizers provide primary plant nutrients (such as nitrogen, phosphorus and potassium) and secondary nutrients (such as sulphur, zinc, copper, manganese, calcium, magnesium and molybdenum) on deficient soil. In addition, liming raises the pH-value of acid soils and thus improves availability of soil nutrients for crops to grow.
- Modern plant protection products prevent crop losses nearly equally attributed to the three big 'enemies' of agricultural crops – weeds, insects and diseases. They can be effectively controlled and combated through the use of herbicides, insecticides and fungicides.

In the remainder of this study, the term 'productive agriculture' is used to characterise contemporary agriculture in which the aforementioned modern and science-based inputs and technologies are used. This will be contrasted with 'low input farming' typified by organic farming.

In this paper, emphasis is placed on revealing the effects of productive agriculture on international markets and social welfare in the EU, rural incomes and employment as well as the preservation of natural resources such as land and biodiversity, indirect land use changes (ILUC) and related GHG emissions.

The analysis documented in this research report encompasses several stages:

- As a starting point, the impact of productive agriculture in the EU on farmers, consumers, and on social welfare will be quantified. This analysis will use a standard partial equilibrium model (PEM). It constitutes the foundation for several methodological extensions of conventional economic analysis and will permit a much more complete assessment of the value of productive agriculture to society. Subsequently, the economic analysis will be expanded in a variety of ways.
- First, the economic spill-over effects of productive agriculture to upstream and downstream industries of the agricultural sector will be quantified. The idea behind this approach is that if one EUR and/or job is added/lost in EU agriculture, additional EUR and/or jobs are added/lost in other sectors of the economy – many of them located in rural areas. A straightforward multiplier

analysis will be used in this part of the analysis and quantify income and employment implications inside and outside of agriculture.

- Second, the analysis is extended to include productivity-induced environmental effects. In particular, the focus is on the impact of productivity growth on the (virtual) net import of agricultural land by the EU and related developments in ILUC, i.e. the conversion of natural habitats into arable land. The ILUC effect of productive agriculture will then be used to quantify the resulting $CO_2$ emissions.
- In addition, the impact of productive agriculture on global biodiversity will be calculated and its particular importance for ecosystem services will be highlighted. This has become possible, as there is now suitable data on how much biodiversity is endangered or lost by expanding the agricultural acreage in the regions around the globe.

The basic hypothesis of this study is that productive agriculture in the EU offers the most favourable conditions for:

- increasing social welfare by generating additional income to farmers and by providing a greater quantity of less expensive food to meet the rapidly growing needs of the world;
- stabilising agricultural commodity markets and reducing price volatility;
- generating additional income in upstream and downstream industries related to the agricultural value chain;
- creating a significant number of jobs in particular in rural areas of the EU;
- preserving valuable natural habitats;
- reducing $CO_2$ emissions resulting from a reduction in the expansion of the global agricultural acreage; and
- protecting and enhancing biodiversity and ecosystem services around the globe.

In the remainder of this study the methodologies used are described first (chapter 3). Then, the results of the empirical analysis are presented (chapter 4). Those include the market and social welfare effects (chapter 4.1), rural income and employment effects (chapter 4.2), agricultural trade and virtual land trade effects (chapter 4.3), global GHG emission effects (chapter 4.4), and global biodiversity effects (chapter 4.5). The study ends with conclusions of the research (chapter 5).

# 3. Methodological foundation and data issues

## 3.1 Methods and major data sources

*Modelling market impacts*

The point of departure of the analysis is a PEM of world agriculture which permits to quantify the supply, demand and trade effects of productive agriculture in the EU. PEMs are frequently applied in agricultural economic analysis (e.g., OECD and FAO, 2013; Renwick et al., 2013; Schwarz et al., 2011; Vanuccini, 2009). The model used here has been described in much detail in Noleppa and Hahn (2013) as well as in Noleppa and von Witzke (2013). For the analysis in this paper a few model modifications have been made in order to fit the model to the research questions at hand:

- One of them is the regional focus. The EU-27 is modelled as one single region. EU production and consumption interact with all other regions of the world to determine the market equilibrium.
- Another modification is the inclusion of additional crops. More specifically, potatoes and pulses are now explicitly dealt with. Overall, approximately 80 million hectares of EU agricultural land, i.e. almost the entire arable land of the EU used to harvest crops other than fodder crops (DG AGRI, 2012), are included in the analysis.
- The calibration of the model is based on very recent statistical information provided by the European Commission (EC), Eurostat, the Food and Agriculture Organization (FAO), the Food and Agricultural Policy Research Institute (FAPRI), the Organization for Economic Co-operation and Development (OECD), and the United States Department of Agriculture (USDA). Main data sources have been DG AGRI (2012), Eurostat (2013), FAO (2013), FAPRI (2013), OECD and FAO (2013).

The PEM is calibrated for the years 2010-2012. A three-year average was used in order to minimise the risk that random shocks (such as weather extremes) and/or policy decisions (such as temporary export or import restriction in times of regional crises) affect the results of the analysis.

*Modelling economic impacts upstream and downstream in the value chain*

As mentioned earlier, the objective of the study is not only to analyse economic impacts of productive agriculture on the market level, but also to assess its benefits for the (rural) economy in the EU at large. Farm input suppliers as well as downstream industries depend on farmers' decisions. Changes of agricultural markets (such as changes in productivity) will immediately transfer to interlinked upstream and downstream sectors of an economy. Gross domestic product (GDP) effects (an indicator for income changes) and job effects (an indicator for employment changes) are of particular interest.

Multiplier analysis permits the assessment of such effects. Multipliers are parameters which reflect the transmission of a particular sector change into an economy-wide change and have often been applied in agricultural economic analysis (see, e.g., Breisinger et al., 2010; Schwarz, 2010). Focussing on multipliers established for rural areas of EU member states permits to analyse rural income and rural employment effects of productive agriculture in the EU.

In this study, the analysis makes use of an update of an earlier work on agricultural multipliers of the EU by Noleppa and Hahn (2013). The authors have analysed more than 20 mainly peer-reviewed academic articles determining agricultural multipliers with respect to GDP and jobs in the EU and single EU member states. In this analysis the multipliers depicted in figure 3.1 will be used.

**Figure 3.1: Range of and used agricultural multipliers of the European Union**

| | Identified range of multipliers (from ... to ...) | 'Average' multiplier used for own analysis |
|---|---|---|
| GDP multiplier | 1.50 – 1.90 | 1.70 |
| Job multiplier | 1.10 – 1.40 | 1.25 |

Source: Own figure based on Noleppa and Hahn (2013).

As can be seen, average multipliers, i.e. the average of the minimum and maximum value of the identified range of multipliers, serve as the base for further analysis. In essence, it is argued that, if EUR 1.00 in EU agriculture is created due to an increase in productivity, additional EUR 0.70 are created elsewhere in the rural economy of the EU; and that, if one job, here measured in annual working units (AWU), equal to approximately 1 800 working hours per annum, is created in EU agriculture, an additional quarter of a job is established upstream or downstream the value chains in rural areas of EU member states.

As a methodologically consistent input for the multiplier analysis, the producer surplus is endogenously calculated within the PEM, and the real agricultural labour force engaged in EU arable farming is taken into consideration. To determine the latter, EC (2012) data based on most recent information from the Farm Accountancy Data Network (FADN) of the EU are used.

*Modelling virtual land trade and ILUC impacts*

Sustainability of agricultural production systems can and should be assessed using economic, social and environmental indicators. The methodological aspects described so far will already lead to some important arguments pointing at the economic and partly at the social sustainability that productive agriculture in the EU might offer. In order to additionally analyse contributions towards environmental sustainability, other potential societal benefits will have to be analysed: resource protection (to be measured in terms of ILUC), climate protection (to be measured in terms of ILUC-related GHG emissions) and biodiversity protection (to be measured in terms of ILUC-related biodiversity parameters).

Virtual land trade and changes of virtual land trade will be analysed using the so-called ILUC tool. The specific methodology used here was initially developed by von Witzke and Noleppa (2010), and subsequently expanded (von Witzke et al., 2011). This methodology is now widely accepted in agricultural economic research (e.g. Kern et al., 2013; Destatis, 2013a; b). With the tool, it is possible to add to a region's own resource (land) base the amount of resources (land) which, on balance, is used outside its territory to meet regional demand.

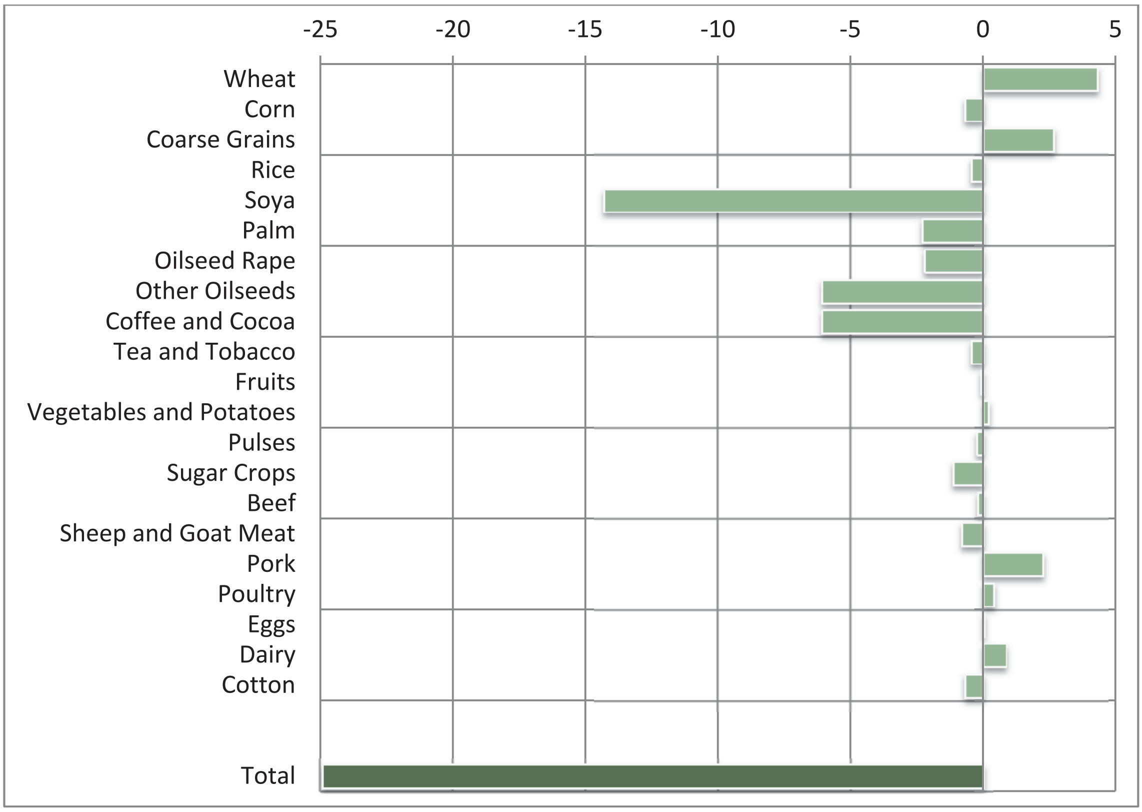
Most recently, the original methodology has been further expanded by Noleppa and Cartsburg (2013). The following improvements shall be noted:

- The calculations in von Witzke et al. (2011) are based on EU agricultural trade and international yield data for the years 2008-2010. Here, the calculations use trade and yield data for the years 2010-2012. Data is from Eurostat (2013). This means that comparably good harvests in the EU and also hectare yield improvements in other regions of the world, i.e. global agricultural productivity growth in most recent years, have been taken into account in the calculation approach.
- Data used in von Witzke et al. (2011) are based on 270 so-called Standard International Trade Classification (SITC) categories of crop and livestock products. These categories of tradable commodities were aggregated to 40 primary crops. Then the net trade flows were converted into the acreage used for their production. The analysis presented in this paper is expanded to include almost 300 SITC categories which can be aggregated to 45 primary crops and their acreage. This includes cocoa products, such as chocolate, and some additional fruits and vegetables.
- This expansion of the ILUC tool data base was possible because new information on technical conversion factors for transforming tradable commodities (by SITC categories) back to agricultural raw materials had become available.

> The ILUC tool is now based on conversion factors provided by FAO (2012) rather than FAO (2001) and USDA (1992). The new conversion factors point at efficiency improvements upstream and downstream the agricultural value chain over time. They include aspects such as higher oil yields in crushing, higher yielding plant varieties and more productive livestock.

The results of most recent calculations (Noleppa and Cartsburg, 2013) are, hence, based on more up to date and more precise information than previous calculations and suggest that the current (2010-2012) EU net trade in virtual agricultural land amounts to 25 million hectares. In von Witzke et al. (2011) some 28 million hectares were reported for the years 2008-2010. For the most part, the lower numbers for EU net imports of virtual agricultural land are caused by productivity growth in both, global agriculture as well as upstream and downstream sectors of the agricultural value chain. With respect to the EU trade of wheat and wheat products alone, this accounts for a decline of the virtual land trade balance of more than 2 million hectares. The results of these calculations are presented in figure 3.2.

**Figure 3.2: Net imports (–) and net exports (+) in virtual agricultural land of the European Union, 2010-2012 (in million hectares)**




Source: Own figure based on Noleppa and Cartsburg (2013).

A detailed discussion of the virtual net land trade calculations used here can be found in Noleppa and Cartsburg (2013) and in Annex 1 of this paper. They serve as the starting point for the analyses of ILUC effects of productive agriculture in the EU. Essentially the ILUC effects are calculated as the results of EU agricultural productivity changes, all other things being equal – including yields per hectare in the rest of the world. Therefore, the higher EU productivity growth, the lower is the net import and the higher is the net export of virtual agricultural land by the EU.

*Modelling GHG emission impacts*

Natural habitats which are not used for farming serve as a carbon sink. They sequester carbon and mostly do not release $CO_2$. Since the ILUC tool used here is based on changes in EU agricultural trade with single countries and world regions, the methodology allows for a regional differentiation of land conversion effects. Carbon release factors per converted hectare and by region are used for the calculations of $CO_2$ effects.

There are various sources for regional $CO_2$ release factors. Reported factors vary considerably due to the defined amount respectively ratio of potentially endangered above-ground and/or below-ground biomass of ecosystems (e.g. Noleppa and von Witzke, 2013c). Therefore, $CO_2$ emission factors per hectare of converted land established by Tyner et al. (2010) are used: These factors are lower compared to those published by, e.g., Searchinger et al. (2008), Heiderer et al. (2010) or most recently Laborde (2011) (see also DG Energy, 2010) and, hence, establish a lower bound to the calculation of potential climate benefits of productive agriculture in the EU.

Figure 3.3 displays the data used in this analysis (Tyner et al., 2010) as well as those proposed by Searchinger et al. (2008) and Searchinger and Heimlich (2008).

**Figure 3.3: Regional $CO_2$ emission factors per hectare of land converted for agricultural purposes (in t/ha)**

| Region | Data from Searchinger | Data from Tyner |
|---|---|---|
| Europe | 262 | 169 |
| North America | 384 | 146 |
| South America | 337 | 151 |
| Asia | 608 | 296 |
| Oceania | 232 | 113 |
| Rest of the World | 199 | 195 |

Source: Own figure based on Searchinger et al. (2008), Searchinger and Heimlich (2008) as well as Tyner et al. (2010).

*Modelling biodiversity impacts*

The preservation of biodiversity is essential for the maintenance of ecosystem services which both, nature and agriculture provide. Losses of global biodiversity caused by human activity have become of growing public concern. This includes agricultural activities and farming practices (e.g., Firbank et al, 2008). The announcement of the International Year of Biodiversity in 2010 led to manifold scientific efforts to measure biodiversity and its change (e.g., Alkemade et al., 2009; Butchert et al., 2007: Dev Pandey et al., 2006; Emerson et al, 2010). However, it turned out that measuring biodiversity and its changes is a challenging task.

Indeed, a variety of methods have been developed and a considerable number of biodiversity indicators have been published. All of them appear to have their pros and cons and the practice is still in its infancy as the scientific debate continues (e.g. Wright, 2011a). Hence, a generally accepted science-based indicator of mapping biodiversity and the loss thereof is not immediately in sight. In addition, attempts to link economic and biodiversity impact analysis have failed so far. Therefore, a rather pragmatic approach is applied here. Two indicators are used to cope with the inherent uncertainty in measuring biodiversity.

First, the Global Environment Facility Benefits Index of Biodiversity (GBI-BIO) is used (for an assessment of the indicator see, e.g., UNEP, 2009; Wright, 2011a). It is scientifically sound and plausible and can be combined with the economic and spatial approaches used here. In particular, the following characteristics led to its application in the analysis:

- The GBI-BIO captures the status quo of biodiversity as well as its changes.
- It allows not only for a pure accounting of species but also for mapping a regional distribution of species including potential threats across the ecosystems of the world. Biodiversity, thus, can be calculated at the single country and the world level. Therefore, it is consistent with the ILUC tool used in this study.
- Moreover, the indicator is already used fairly often and is beginning to be accepted as a pre-standard. It is consistent with the 2010 targets of the Convention on Biological Diversity (CBD) and widely used by individual research teams and international organisations (e.g. World Bank, 2013a).

In sum, the GEF-BIO, originally developed by Dev Pandey et al. (2006) is a field-tested composite index of relative biodiversity for single countries. It is based on the species represented in a country, their threat status, and the diversity of habitat types. Moreover, the index is easy to handle because it is normalised on the interval {0;100} (World Bank, 2013):

- Brazil is defined as the country with maximum biodiversity. Its natural habitats are rated as 100. The country's territory comprises many different ecosystems, such as the Amazon rainforest, the Atlantic forest and the Cerrado. They are considered to have the greatest diversity of flora and fauna in the world.
- On the other end of the scale is Nauru which is rated as 0. Nauru is a small island nation in the Pacific Ocean where only very few sea birds and insects live, while the flora is characterised by coconut palm trees which flourish on the only fertile area, a narrow coastal belt.
- All other countries are rated between these extremes.

Accordingly, a hectare in Brazil (in Nauru) that is not cultivated for agriculture or used by humans in other ways is valued at 100 (0) biodiversity index points; hectares in other countries of the world are rated in between. All hectares of a country can, then, be accumulated to get a country-specific value of preserved biodiversity. Accordingly, a value of 1 million biodiversity index points might be interpreted as an indicator of the still available richness in flora and fauna species of a country or region equivalent to what can be found in 10 000 hectares of tropical forest or the Cerrado in Brazil.

Second, the National Biodiversity Index (NBI) is applied. This index has been developed by the CBD itself (CBD, 2001). It continues to be used in the Global Biodiversity Outlook Report (see latest available issue: CBD, 2010). The NBI is based on estimates of a country's richness and endemism in four terrestrial vertebrate classes and vascular plants. Vertebrates and plants have the same weight in the index. NBI values range between 1.00 (the maximum value of the NBI is assigned to Indonesia) and 0.00 (the minimum value of the NBI is allocated to Greenland). Countries with land area of less than 5.000 $km^2$, such as Nauru, are excluded.

This NBI can easily be transformed into values of zero to 100 by multiplying all country-specific values with 100. Thus, the NBI can easily be compared to the GEF-BIO.

Although status quo calculations with the GEF-BIO and NBI approach are not of particular interest for the analysis considered in this study, the reference values are listed below:

- According to the GEF-BIO, current global biodiversity is at 289 billion index points. In other words, global biodiversity is considered to be equal to the richness in species which, in principle, could be found on 2.89 billion hectares of Brazil's ecosystems. This is more than twice the arable land area currently cultivated in the world (FAO, 2013) or eight to nine times the acreage of the Brazilian Amazon forest (OBT, 2013).

- The NBI yields a present global biodiversity of 475 billion index points. This is equivalent to 4.75 billion hectares of species-rich ecosystems, as can be found in Indonesia. This almost equals the global acreage used for farming which is approximately 4.9 billion hectares (FAO, 2013).

Obviously, quantifying biodiversity is a challenging task, and work on this and related issues is at an early stage. Still, the use of the GEF-BIO and the NBI permits some valuable insights in the changes of biodiversity around the globe that result from productive agriculture in the EU.

ILUC (deforestation, grassland conversion etc.) caused by productivity changes in EU agriculture lead to changes in biodiversity. These changes can simply be analysed by multiplying the ILUC in a region (in hectare) with the GEF-BIO or the NBI of that region (in biodiversity index points per hectare). For instance, a loss of 10 000 biodiversity index points would indicate a loss of biodiversity equivalent to a loss of flora and fauna on 100 hectares of natural habitats in Brazil (using the GEF-BIO approach) or in Indonesia (using the NBI approach).

## 3.2 Data

The calculations of productivity effects in EU agriculture are based on a meta-analysis by the authors. Essentially yields of modern, productive agriculture to low input farming are compared. Many studies have been conducted comparing these two types of farming in the EU at large or in a single EU member state. In fact, almost all of the studies considered compared conventional with organic farming systems. The yield impact isolated from these studies is the nucleus for the present analysis.

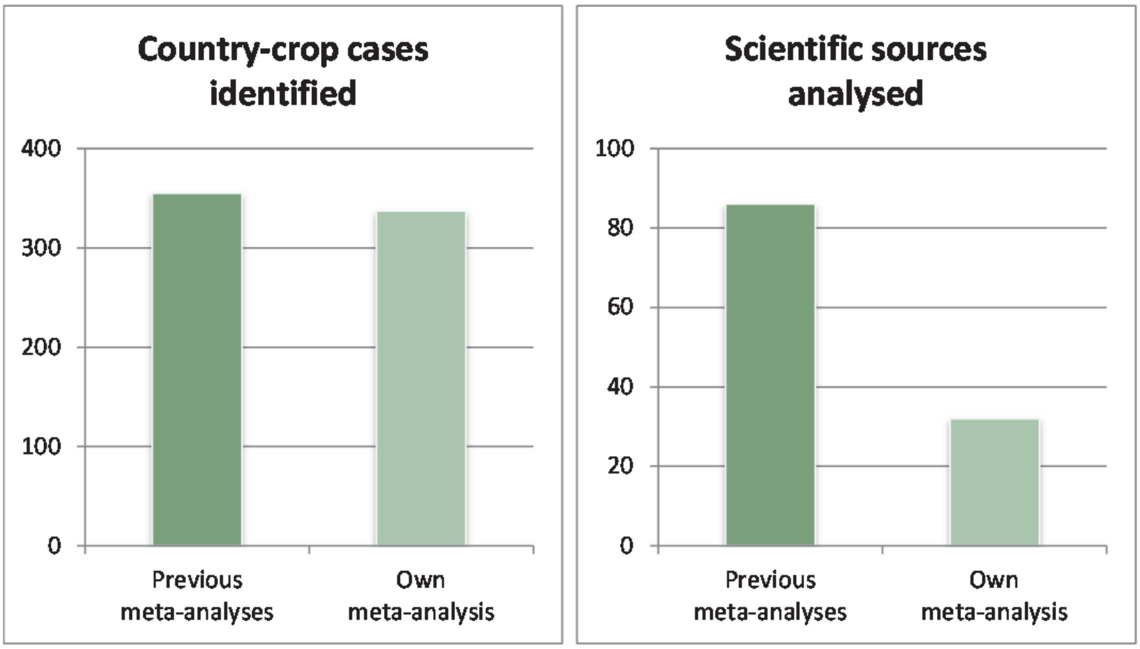
The following three peer-reviewed meta-analyses comparing productive and low input agriculture have been particularly helpful:

- The crop yield gap between organic and conventional agriculture for 362 country-crop cases in world agriculture was analysed by de Ponti et al. (2012). In particular, they considered the results of 132 EU-specific country-crop cases which had been published in 45 academic articles.

- Seufert et al. (2012) published results of a meta-analysis comparing roughly 200 country-crop cases. 145 of them relate to EU agriculture. They had been published in 19 research papers.
- Tuomisto et al. (2012) focus on differences of organic and conventional farming practices in Europe. They consider 78 EU-specific country-crop cases, which had been published in 22 scientific papers.

Although these three meta-analyses already provide a rather broad spectrum of research findings on yield impacts across the EU and for major crops in arable farming, data gaps still exist. Data availability with respect to Eastern European member states and some oilseed crops and pulses is particularly weak. To fill the gaps, more than 30 other, partly peer-reviewed, research papers have been analysed and 337 additional country-crop cases could be identified. The sources are provided with Annex 2. Against this background, figure 3.4 gives an overview on the data base used for the purpose of this study: to determine the yield impact of productive agriculture vs. low input farming in the EU.

**Figure 3.4: Data sets generated to define an initial yield impact for analysing benefits of productive agriculture in the European Union**




Source: Own figure and compilation based on de Ponti et al. (2012), Seufert et al. (2012), Tuomisto et al. (2012) and 32 other sources.

Altogether almost 700 country-crop cases have been filtered. Data from laboratory experiments and from study environments far away from practical agriculture have been excluded from the analysis to obtain a realistic picture about yields on field. This is the broadest spectrum of available information on yield effects of productivity in EU agriculture, which has ever been analysed.

Furthermore, data have been grouped per crop and EU region. Finally, the yield of low input farming has been calculated relative to productive agriculture. The results are exhibited in figure 3.5. As becomes obvious, EU yields in low input farming are considerably lower than in productive agriculture. The average, i.e. hectare-weighted, crop-specific yield depressions are within a range of –38 and –22 per cent. The yield impact is larger for major European crops such as wheat and oilseed rape and smaller for other cereals and oilseeds as well as sugar crops and pulses. For the EU as a whole and across all crops, the (again hectare-weighted) yield depression in low input farming is –31 per cent.

**Figure 3.5: Yield of low input farming relative to productive agriculture in the European Union (in per cent)**

| | Wheat | Corn | Other Cereals | Oilseed Rape | Other Oilseeds | Potatoes | Sugar Crops | Pulses |
|---|---|---|---|---|---|---|---|---|
| Mediterranean Member States | 71 | 81 | 74 | 82 | 82 | 76 | 59 | 68 |
| Atlantic Member States | 52 | 73 | 72 | 65 | 73 | 66 | 65 | 83 |
| Baltic Member States | 59 | 79 | 67 | 99 | 68 | 61 | 86 | 88 |
| Central European Member States | 65 | 82 | 68 | 60 | 74 | 69 | 74 | 77 |
| South Eastern Member States | 69 | 67 | 72 | 82 | 68 | 72 | 94 | 88 |
| **EU-27** | **62** | **73** | **71** | **67** | **73** | **69** | **75** | **78** |

Source: Own figure and calculations.

This specific outcome is crucial for the entire analysis of social benefits of productive agriculture in the EU and needs to be stress-tested, therefore:

- Seufert et al. (2012) conclude that overall yields in low input farming are 34 per cent below yields in productive agricultural systems.
- Advocates of organic farming systems arrive at similar results. According to Niggli et al. (2010), yields in low input farming systems such as organic farming in Central Europe average 65 per cent of conventional farming for wheat

(here: 65 per cent), 78 per cent for corn (here: 82 per cent), 70 per cent for other cereals (here: 68 per cent), 75 per cent for oilseeds (here: 74 per cent), 58 per cent for potatoes (here: 69 per cent), and 76 per cent for pulses (here: 77 per cent).

- Official statistics for Germany indicate even higher yield gaps of organic farming compared to those calculated here: This analysis is based on Germany-specific yield differences of –44 per cent in wheat, –33 per cent in other cereals, and –30 per cent in potatoes. Official data sources (BMELV, various years) suggest for Germany –55 per cent in wheat, –49 per cent in other cereals, and –45 per cent in potatoes. So does LEL and LfL (2013): –54 per cent in wheat and –43 per cent in potatoes.
- In addition, it should be noticed that most studies underestimate the yield gap. The results reported by de Ponti et al. (2012), Seufert et al. (2012) and Tuomisto et al. (2012) are usually based on one year only. This short time period neglects the typical rotation in low input farming which often includes occasional fallow or legumes and thus no cash crops.

In sum, the yield gaps used in this study are rather conservative and tend to underrate the yield gap between low input farming and productive agriculture in the EU. Therefore the benefits reported in the following represent a lower bound for the actual benefits.

# 4. Benefits of productive agriculture in the European Union

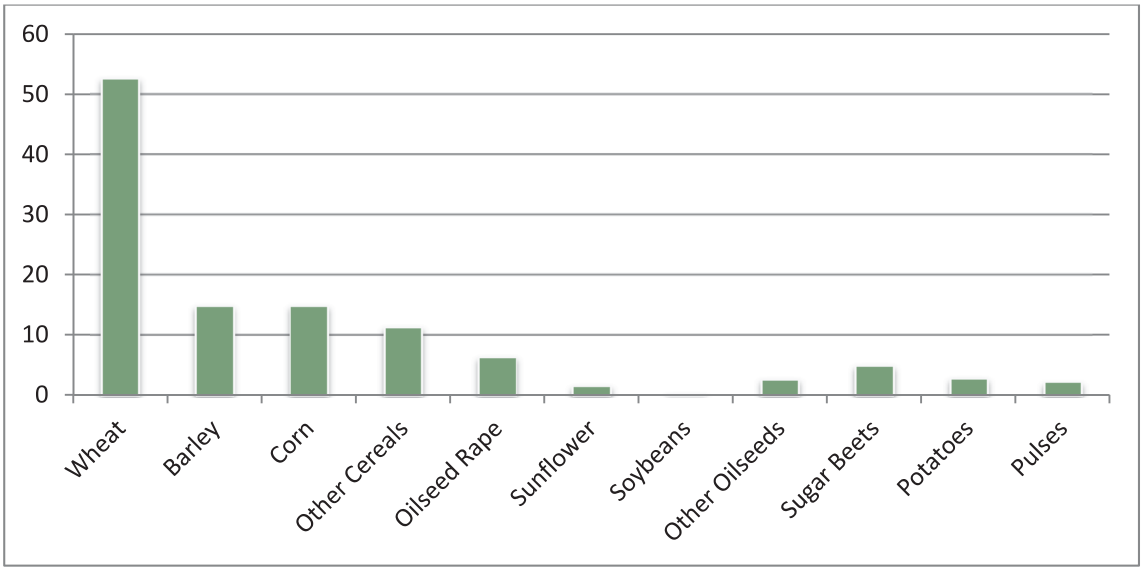
## 4.1 Effects on markets, global food security and European social welfare

In this section, the market and price effects of productive agriculture in the EU will be analysed first. Then, the implications for world food security will be discussed and the social welfare effects for the EU will be quantified.

In general, a more productive technology makes more efficient use of the scarce agricultural resources. Farmers can produce more commodities and have lower production cost. This benefit to farmers is referred to in economics as producer surplus. Consumers benefit as well, as they have more agricultural goods available at a lower price for them. This benefit to consumers is referred to as consumer surplus. Together consumer and producer surplus represent the benefit to the economy which is called social welfare.

The production effect of productive agriculture relative to low input farming in the EU is depicted in figure 4.1:

**Figure 4.1: Additional crop supply of productive agriculture in the European Union, average for the years 2010-2012 (in million t)**



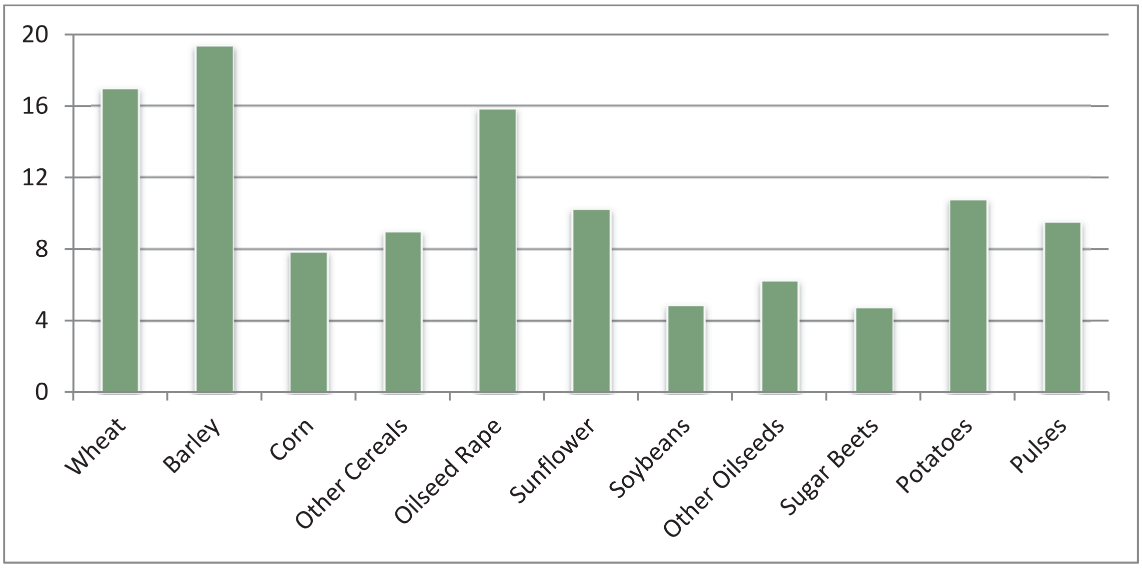

Source: Own figure and calculations.

For grains in total the production effect is almost 100 million tons. More than half of it is accounted for by wheat, which is not that surprising, as wheat is the most important single crop. Oilseeds in the aggregate contribute more than 10 million tons, while sugar beets, potatoes and pulses contribute between 2 and 5 million tons.

It is now generally accepted that the long-term trend of declining agricultural commodity prices has come to an end and that future prices of agricultural commodities and food will be much higher than in the past (e.g., FAPRI, 2013; Kirschke et al., 2011; OECD and FAO, 2013; von Witzke et al., 2009). This raises concerns about world food security (e.g. de Schutter, 2011). Obviously, productive agricultural practices have the potential to alleviate these concerns.

Figure 4.2 depicts the market price effect of productive agriculture relative to low input farming in the EU; i.e. the avoided price increases. As expected the numbers are highest in markets in which the EU is a large producer relative to total market size. This is the case in wheat, barley and oilseed rape, where the price effect exceeds 15 per cent. It is also interesting to note that there is a considerable price effect in soybeans although soybean production in the EU is not at all that important. The reason for this is simply a substitution effect. The price effect of oilseed production changes in the EU (being 10-15 per cent for major oilseed crops) spills over to soybeans.

**Figure 4.2: Avoided price increases on world agricultural markets of productive agriculture in the European Union (in per cent)**




Source: Own figure and calculations.

A rather high market volume contributes to market stabilisation as well. Two aspects have to be distinguished:

- Significant production growth through productivity growth acts to reduce international agricultural commodity price spikes (von Witzke and Noleppa, 2011b). Two such price spikes – caused by a number of factors such as the price of oil and freight rates, world population growth and income growth, the devaluation of the US Dollar, export restrictions and to a lesser extent biofuel policies – have happened since the turn of the millennium and raised additional concern with respect to food security.

  The amplitude of price spikes can be calculated using a rather simple empirical method of analysing the effects of supply and demand determining variables on commodity price changes. This method is based on a decomposition analysis of iso-elastic short-term supply and demand functions; it is documented in Kirschke et al. (2011). Its application to this analysis leads to the following result, exemplified for the wheat market:

The price of wheat rose by more than 77 per cent between January 2007 and July 2008 (von Witzke and Noleppa, 2011b). Without additional production due to productive agriculture in the EU this price spike would have been even higher: The wheat price would probably have increased by at least 85 per cent. Hence, it can be concluded that a higher market volume due to productivity increases minimises short-term price changes following erratic market developments.

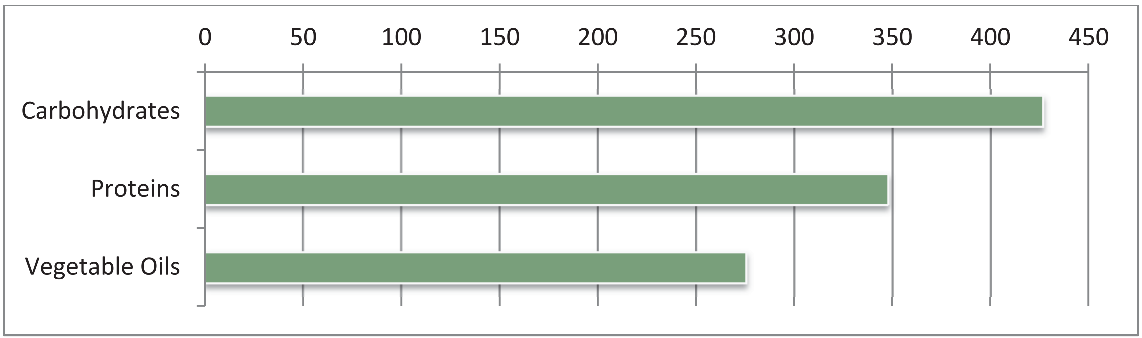
- Agricultural commodity prices indeed tend to be rather volatile for a number of reasons. First, production depends on weather phenomena as well as plant and animal diseases. Second, both supply and demand are inelastic with regard to the price – at least in the short-run. Third, supply reaction to changing prices may take up to one and more vegetation periods (Gilbert, 2010; Gilbert and Morgan, 2010; FAO, 2011; von Witzke and Noleppa, 2011b). In such an environment, a productive agriculture plays an important role in reducing the negative effects of price volatility on commodity markets. Keeping the production quantity high from season to season is crucial for increasing the market volume on agricultural commodity markets. The reason for this lies in the importance of stocks for agricultural commodities and the necessity to keep them high.

  Many commodities, including grains and oilseeds, can be stored for a year and often longer at moderate cost. As long as there is enough storage space available, the effects of short-term fluctuations in supply or demand on prices are cushioned through increasing or declining stocks (e.g. Abbott et al., 2009; Balcombe, 2009; FAO, 2009b; OECD, 2008; Wright, 2011b). These authors argue that high stock levels tend to decrease price volatility, while low stocks can increase price volatility, especially during supply or demand shocks.

  A growing demand for agricultural products coupled with stagnating or low productivity increases will put additional pressures on stocks (FAO, 2011). When following the path of low input farming it is likely that those pressures will be aggravated (Wright, 2010). A productive agriculture will increase the market volume that helps to build stocks which function as shock absorbers and help keep price volatility low (Wright, 2010; FAO, 2011).

A look at the nutrient content of the production increase caused by productive agriculture in the EU enables calculating the impact on world food security, all other things (food access conditions) being equal. According to FAO (2013), the average person on earth consumes 2828 kcal, 79 grams of vegetable proteins and 81 grams of vegetable oils per day. Given the crop-specific nutrient contents (obtained from FAO, 2013), the additional production caused by productive agriculture in the EU would provide enough carbohydrates for more than 400 million humans, enough vegetable proteins for almost 350 million people, and vegetable oils for close to 300 million humans, as figure 4.3 depicts.

**Figure 4.3: Additional potential global food supply for world population of productive agriculture in the European Union (in million humans)**




Source: Own figure and calculations.

Remember that the productivity difference between low input farming and productive agriculture in the EU is –31 per cent. Therefore, each percentage point of productivity forgone in EU agriculture would reduce the food availability for more than 10 million humans. It becomes obvious: In a world where still at least 870 million humans are malnourished (FAO et al., 2012), productive agriculture in the EU is a key contribution to world food security. These results lend strong support to Pingali's (2012) argument that crop yield growth is an effective mean to reduce undernourishment.

The social welfare effects (the sum of producer surpluses and consumer surpluses) of productive agriculture in the EU for the crops included in the analysis and in total are listed in figure 4.4 by market.

**Figure 4.4: Additional social welfare in the European Union of productive agriculture in the European Union (in billion EUR)**

| Crop | Wheat | Corn | Other Cereals | Sugar Beets | Potatoes |
|---|---|---|---|---|---|
| Social Welfare | 7.45 | 1.36 | 2.04 | 2.47 | 0.39 |

| Crop | Oilseed Rape | Sunflower | Other Oilseeds | Pulses | Total |
|---|---|---|---|---|---|
| Social Welfare | 1.15 | 0.25 | 0.64 | 0.31 | 16.19 |

Source: Own figure and calculations.

In total, the social welfare gain for the analysed crops as well as on other markets (not displayed in the figure) amounts to EUR 16.2 billion. Again, wheat has the largest effect. Almost half of the total social welfare gain is attributable to this crop. Other cereals contribute EUR 3.4 billion. Oilseed crops add a total of more than EUR 2 billion, and so does sugar.

From a national account point of view, the economic term social welfare can principally be compared to the gross value added. According to latest information, the gross value added in European agriculture totals approximately EUR 130 billion (BMELV, 2013). This implies that without productive agriculture in the EU this number would decline by more than 12 per cent.

A comparison of these results with those obtained by other authors yields the following insights:

- A similar analysis by von Witzke and Noleppa (2011a) for Germany resulted in a EUR 4 billion loss. Given the share of German agriculture in the EU farming sector this is by and large consistent with the result of this study.
- An analysis of Schmitz et al. (2011) for 2006 yields the result that a reduction in productivity which is about half of the magnitude used in this study results in a social welfare loss of up to EUR 6 billion. Remember that prices then were much lower and, thus, the welfare loss is lower.
- di Tullio et al. (2012) report that a 13 per cent yield decline in wheat in the EU would result in a welfare loss of EUR 4.6 billion.

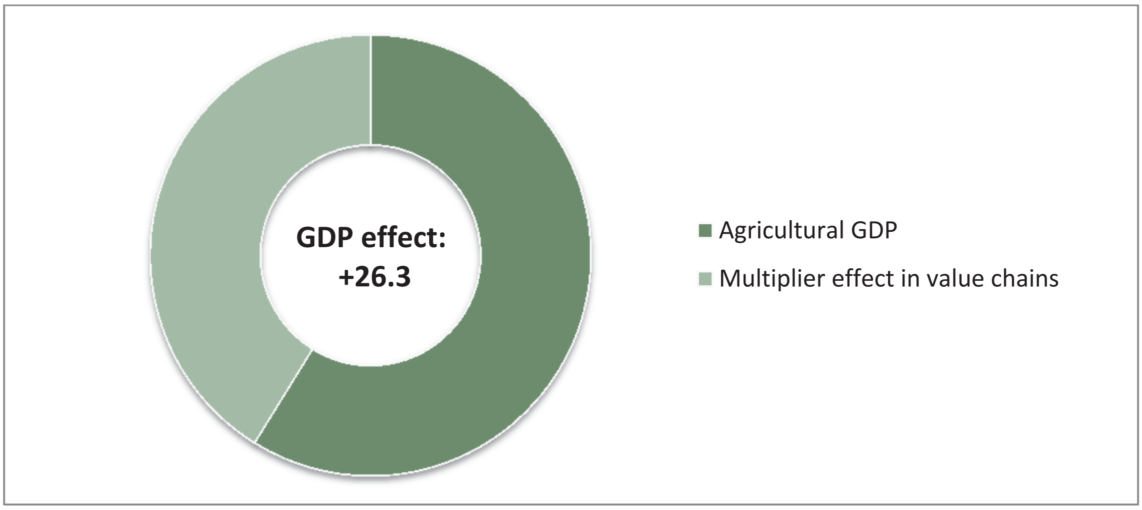
In sum, the results obtained so far are in the expected range. They are also consistent with results reported by others and imply that each percentage point of productivity forgone in EU agriculture would result in a social welfare loss of approximately EUR 500 million, almost equal to the gross value added of agriculture in Slovakia (BMELV, 2013).

## 4.2 Effects on rural income and employment

So far the analysis has been restricted to agricultural producers and consumers. However, agriculture is linked to the upstream industries on the input markets and to the downstream industries on the commodity and retail markets. Higher productivity leads to more production, all other things being equal. This in turn creates additional income and jobs in the economic sectors related to agriculture. In the following, these effects will be quantified. The analysis is based on a multiplier analysis which has been presented above and focusses on rural areas.

Starting point for the income analysis is the producer surplus generated by productive agriculture relative to low input farming. To be methodologically consistent, this surplus is considered an approximation of the agricultural GDP. The calculations are then based on the income, i.e. GDP multipliers presented in figure 3.1. Thus, figure 4.5 depicts the additional GDP generated by productive agriculture in the EU.

**Figure 4.5: GDP impact of productive agriculture in the European Union (in billion EUR)**




Source: Own figure and calculations.

It is the sum of the agricultural GDP and the GDP generated in upstream and downstream industries. It amounts to more than EUR 26 billion, a monetary value equivalent to the Latvian GDP (IMF, 2013). The additional producer surplus is EUR 15.5 billion while the additional GDP in upstream and downstream industries amounts to almost 11 billion EUR.

The income effect of productive agriculture in the EU should now be analysed for labour which is directly engaged in arable farming and in cultivating the crops under consideration, i.e. in crop-specific activities such as tillage, sowing and drilling, monitoring, applying fertilizers, irrigation, pest management, harvesting, transport of primary and secondary products from the field, and other area-related management efforts. To calculate the effect, primary information from the FADN based on DG AGRI (2012; 2013) is used. These data were double checked using KTBL (2012) information. Accordingly, productive agriculture in the EU affects approximately 1.1 million AWU. Dividing the already above mentioned producer surplus of around EUR 15.5 billion by these 1.1 million AWU yields the result that this type of agriculture generates an additional agricultural income relative to low input farming of almost 14 000 EUR/AWU.

This is quite remarkable, as the annual farm net value added (FNVA) – the comparable income indicator within the FADN – during the past three years had been 17 800 EUR/AWU (DG AGRI, 2013). This implies that without productive agriculture in EU the FNVA would have been approximately 3 800 EUR/AWU – even if present direct payments and other farm subsidies would continuously be transferred (see figure 4.6).

**Figure 4.6: Income induced by productive agriculture in the European Union and other income in arable farming in the European Union (farm net value added in EUR/AWU)**


Source: Own figure and calculations based in DG AGRI (2012; 2013).

In short, a one per cent higher (lower) productivity in EU agriculture acts to increase (reduce) agricultural income by about 500 EUR/AWU. However, regional differences are apparent:

- In Bulgaria, e.g., where the current FNVA is only around 11 500 EUR/AWU the absence of productive agriculture would certainly result in a negative FNVA.
- In Germany, to take another example, where the FNVA is fairly high at almost 42 000 EUR/AWU a full conversion from productive agriculture to low input farming would still lead to a decline in income of probably more than one third.

The income losses reported above establish a lower bound for the actual income losses, as low input farming tends to be more labour intensive (Cisilino and Madau, 2007; KTBL, 2010; 2012). Accounting for the labour intensity difference between low input farming and productive agriculture would increase farm employment by approximately 310 000 AWU. Instead of 1.1 million AWU (see above), 1.4 million

AWU would have to share the remaining income to be generated in arable farming if productive agriculture in the EU was discontinued. As a consequence, the component of other income as part of the FNVA (see figure 4.6) would decline from 3 800 to 3 100 EUR/AWU.

At first glance, the labour market effect of converting productive agriculture in the EU to low input farming practices appears to be small, but positive. As mentioned above, 310 000 AWU would be created as a result of more labour intensive low input farming. The corresponding decrease in production and buying-in of inputs, however, would cause some turbulence upstream and downstream the agricultural value chain. Using the job multipliers displayed in figure 3.1, productive agriculture in the EU currently creates 267 000 additional AWU in upstream and downstream industries of the agricultural value chain of which almost 100 000 would be lost.

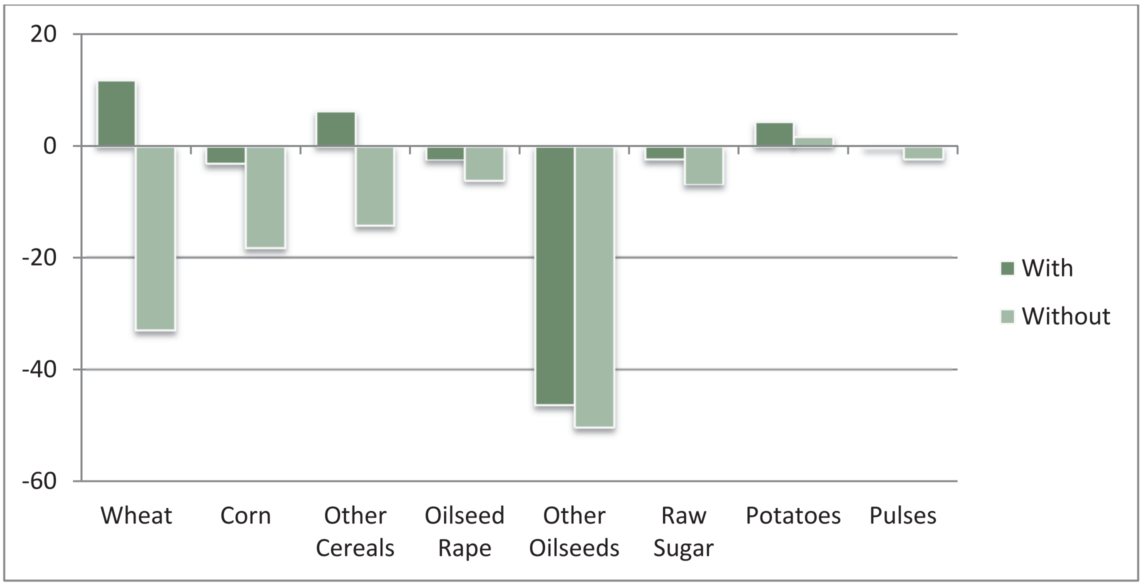
In addition, the average rural income effect would be rather low. According to Ecorys (2010), more than half of the population of the EU lives in predominantly or intermediate rural areas. These regions provide 53 per cent of total employment of the EU. The total work force is about 216 million (Eurostat, 2013), 114.5 million of them work in rural areas. The overall GDP impact in rural areas of productive agriculture in the EU is EUR 26.3 billion (see figure 4.5). This translates to a net income increase of just 230 EUR/AWU. Another aspect is that many people live in rural areas but work in cities and urban regions – an effect that dilutes the per capita income effect.

Arguing more realistically, it may be expected that a full conversion from productive agriculture to low input farming in the EU would not only jeopardise the income and jobs of more than one million AWU engaged in arable farming, but also all the additional work force related to farming in the EU, i.e. (most of) the AWU upstream and downstream the value chain as well as unpaid family labour on farm, which has not been taken into account here at all, but is currently subsidised through market income effects.

## 4.3 Effects on agricultural trade and the net virtual land trade of the European Union

Changing market conditions also affect trade volumes. The resulting changes in trade volumes of productive agriculture vs. low input farming in the EU are depicted in figure 4.7. Notice that the traded processed and semi-processed products have been converted back to the commodity level (see above and Noleppa and Cartsburg, 2013).

**Figure 4.7: Agricultural trade volumes with and without productive agriculture in the European Union (in million t)**




Source: Own figure and calculations based on Noleppa and Cartsburg (2013).

As can be seen, productive agriculture in the EU generates large additional trade volumes:

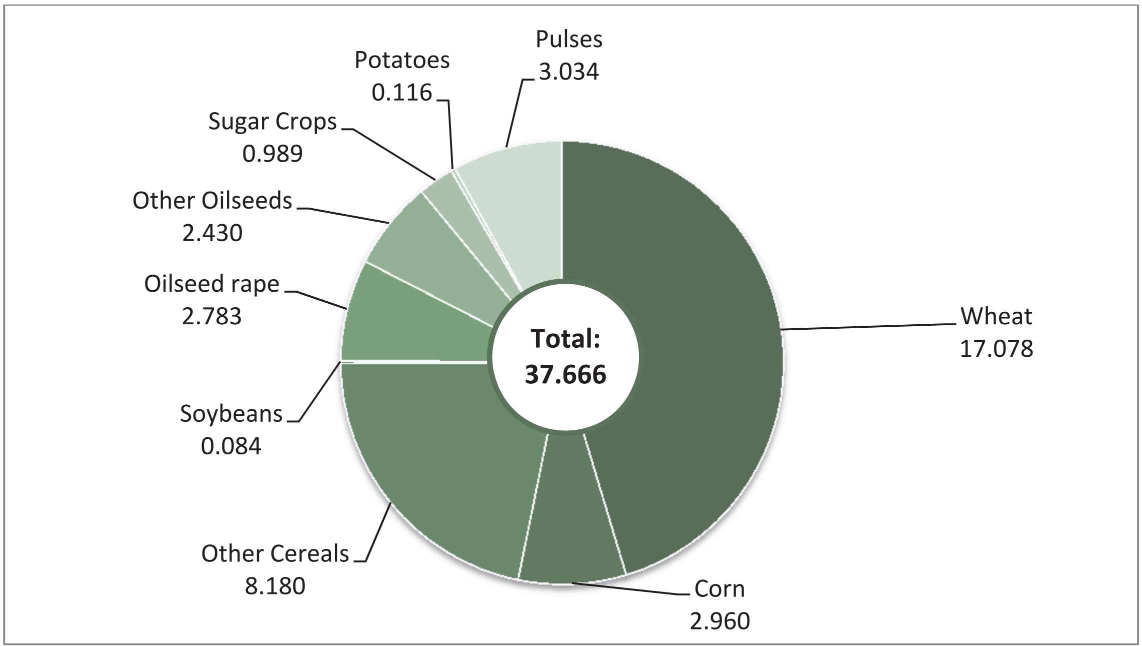
- Wheat and wheat products are currently, on balance, exported (almost 12 million tons). Converting to low input farming in the EU would cause a decline in trade volumes of almost 45 million tons. The EU would become a net importer. On balance, 33 million tons of wheat would be imported.
- In corn, the EU already is in a net importing position. Imports would increase from 3 to more than 18 million tons.
- For the other cereals, the EU would become a net importer. Instead of net exporting more than 6 million tons, the EU would end up importing more than 14 million tons of other cereals such as barley, rye, and oats.
- In oilseed rape, the EU is presently a net importer. Net imports would increase by 150 per cent to more than 6 million tons with low input farming.
- The large net imports in other oilseeds would also increase by roughly 4 million tons leading to a net import volume of more than 50 million tons if productive agriculture was discontinued.

- In raw sugar, net imports would increase as well. Without productive agriculture in the EU, net imports would be three times as high as they are now resulting in a net import of almost 7 million tons.
- Only in potatoes, the EU would remain a net exporter. However, the net trade volume would shrink by 60 per cent to less than 2 million tons.
- In pulses, imports, on balance, would also increase.

In sum, the EU agricultural trade deficit, when broken down to the commodity level, would worsen considerably. This would increase the carbohydrate, protein and oil deficit which is rather high already (see Noleppa, 2013).

The reductions in exports and the increases in imports of low input farming relative to productive agriculture would also change the balance of EU net imports of virtual agricultural land. This is depicted in figure 4.8.

**Figure 4.8: Avoided net virtual land trade of productive agriculture in the European Union, by primary crops (in million ha)**




Source: Own figure and calculations.

On balance, about 25 million hectares of virtual agricultural land were imported by the EU in 2010-2012 (see figure 3.2). Switching from productive agriculture to low input farming in the EU would increase EU net imports of virtual agricultural land by 37.7 million hectares. This would be an increase of 150 per cent and represents an agricultural acreage which exceeds the entire territory of a country of the size of Germany. The bulk of the growth in net land imports is caused by wheat and other grains followed by pulses. The total net import of virtual agricultural land would, thus, amount to 62.5 million hectares. This is equivalent to twice the territory of Poland.

The results also imply that one per cent of agricultural productivity growth reduces EU net imports of virtual agricultural land by about 1.2 million hectares. This is equivalent to the territory of Cyprus or the German Federal State of Mecklenburg-Western Pomerania.

The regional distribution of the additional imports of virtual agricultural land is listed in figure 4.9. More than 10 million hectares would come from the Commonwealth of Independent States (CIS), while almost 7 million and 5.4 million hectares would be located in North and South America respectively. Africa would contribute 4.5 million hectares, while Middle East and North African (MENA) countries would account for 4.9 million and Oceania for 1.9 million hectares.

**Figure 4.9: Regional distribution of avoided net virtual land imports of productive agriculture in the European Union (in million ha)**

| North America | Asia | Africa | CIS |
|---|---|---|---|
| 6.935 | 2.203 | 4.467 | 10.360 |

| South America | MENA Countries | Oceania | Europe |
|---|---|---|---|
| 5.399 | 4.901 | 1.891 | 1.511 |

Source: Own figure and calculations.

## 4.4 Effects on the global GHG balance

Estimates suggest that the global agricultural acreage will be expanded by 45 million hectares between 2010 and 2020 (Marelli et al., 2011; Laborde, 2011) even if productivity growth continues as in the past. As could be shown in the previous section, without productive agriculture in the EU the acreage expansion would almost be twice as high.

As has been demonstrated, in the CIS this would mean that 10 million hectares have to be won by re-cultivating land that had been abandoned after the collapse of the Soviet Union and/or by converting prairie into farm land; the MENA region would have to expand its own agricultural acreage and/or virtual land use in other regions by almost 5 million hectares; the Americas would have to expand the agricultural acreage by about 12 million hectares. All this land is presently a store of carbon – both above and below ground. A lot of this carbon would be released into the atmosphere in the form of $CO_2$ if the land was used for farming. The amount of $CO_2$ emitted per newly cultivated hectare in the regions of the world has been exhibited in figure 3.3 above.

Multiplying these numbers by the expansion of the acreage in these regions yields the $CO_2$ emissions avoided by productive agriculture in the EU. This is listed in figure 4.10.

**Figure 4.10: Additional global $CO_2$ emissions in the absence of productive agriculture in the European Union (in million t)**

| North America | Asia | Africa | Europe and CIS |
|---|---|---|---|
| 1 012 | 652 | 871 | 2 275 |

| South America | MENA Countries | Oceania | Total |
|---|---|---|---|
| 815 | 956 | 216 | 6 798 |

Source: Own figure and calculations.

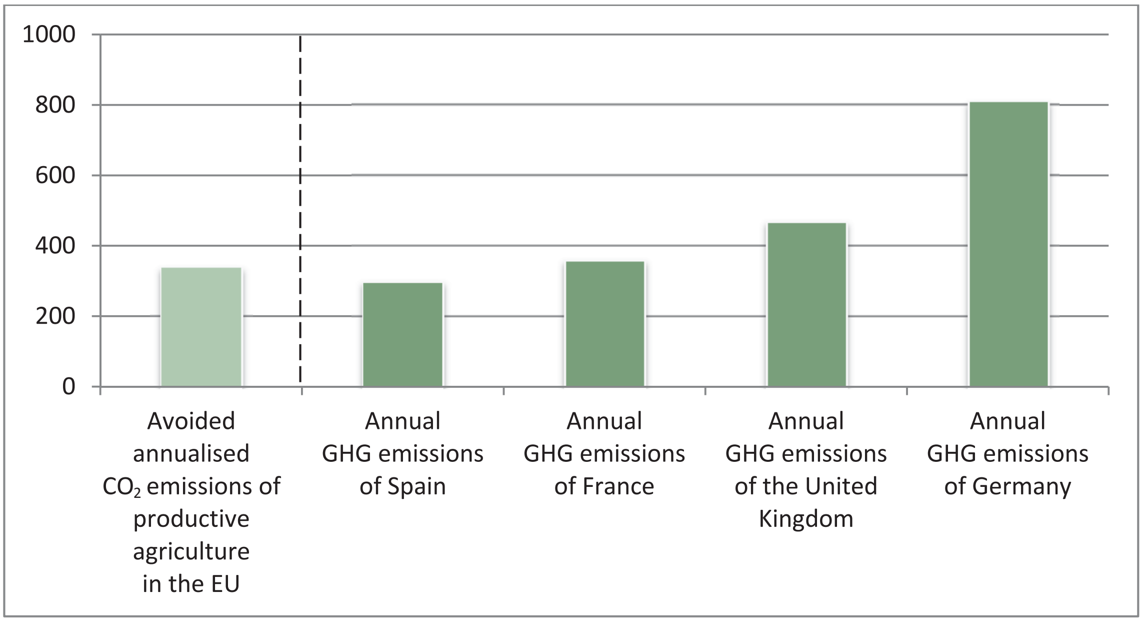
In total, productive agriculture in the EU avoids about 6.8 billion tons of $CO_2$ emissions around the globe. Putting this number into perspective is challenging since the $CO_2$ savings reported here have to be considered a one-time-only effect, whereas available sector and national emissions are annual releases. For an easier comparison, emissions from ILUC are usually annualised by dividing the total emissions by 20 (e.g. Laborde, 2011; Noleppa, 2012). The avoided 'annualised' $CO_2$ emissions of productive agriculture in the EU would, thus, amount to approximately 340 million tons.

Figure 4.11 puts this into perspective and displays both, the avoided 'annualised' $CO_2$ emissions of productive agriculture in the EU and total annual GHG emissions of selected European countries. As can be seen, the avoided 'annualised' $CO_2$ emissions of productive agriculture in the EU exceed the total GHG emissions of Spain and are almost equal to those of France. They are only slightly lower than the annual GHG emissions of the United Kingdom and almost half as large as those of Germany.

It is interesting to note also, that the EU-27, according to latest available figures, emits 3.79 billion tons of $CO_2$ equivalents (JRC, 2011). In other words: This GHG emission inventory would increase by almost 10 per cent if additional 'annualised'

$CO_2$ emissions via ILUC in the absence of productive agriculture in the EU were to be taken into account.

**Figure 4.11: Avoided 'annualised' $CO_2$-emissions of productive agriculture in the European Union and total annual greenhouse gas emissions of various countries (in million t $CO_2$ equivalents)**




Source: Own figure and calculations based on JRC (2011).

Another argument points to the extraordinarily high $CO_2$ emissions, which are avoided by productive agriculture in the EU. According to most recent information of the Intergovernmental Panel on Climate Change (IPCC), the annual global $CO_2$ emissions of farming on the presently used land through tilling, seeding, fertilizing, harvesting, and other on-farm activities are in the range of 5.1 to 6.1 million tons (Smith et al., 2007). Other authors have come up with different estimates, however. Their numbers are in the range of 5.4 to 12.7 million tons of $CO_2$ equivalent (Eugster and Buchmann, 2011; Tubiello et al., 2013; Vermeulen et al., 2012). By and large, the total $CO_2$ savings of productive agriculture in the EU (over an assumed time period of 20 years) are, hence, equal to annual GHG emissions of global farming.

The numbers on GHG emissions calculated in this research paper also imply that low input farming would significantly hamper EU member states attempts to reduce GHG emissions, because a per cent increase in EU agricultural productivity acts to save 220 million tons in $CO_2$ emissions. This is equivalent to the initial and rather ambitious emission reduction target of Germany formulated in the country's climate and energy programme (BMU, 2007).

So far this analysis has focused on ILUC-induced, i.e. indirect GHG emissions avoided due to productive agriculture in the EU. One might also expect that the direct GHG emissions differ between productive agriculture and low input farming in the EU. However, the empirical evidence suggests that there are no major differences in this regard between both types of farming if only direct GHG emissions are measured per unit of production (see, e.g., Bos et al., 2007; Hillier et al., 2009; Hülsbergen and Rahmann, 2012; Klimekova and Lehocka, 2007; Mondelaers et al., 2009; Venkat, 2011; von Witzke and Noleppa, 2012; Williams et al., 2006).

In addition, a re-allocation of agricultural production from the EU to other world regions probably leads to additional direct GHG emissions (e.g. Isermeyer et al., 2010; von Witzke and Noleppa, 2012). Hence, on balance, productive agriculture in the EU contributes much more to mitigate climate change than low input farming (see also Lybbert and Sumner, 2011; Valin et al., 2013).

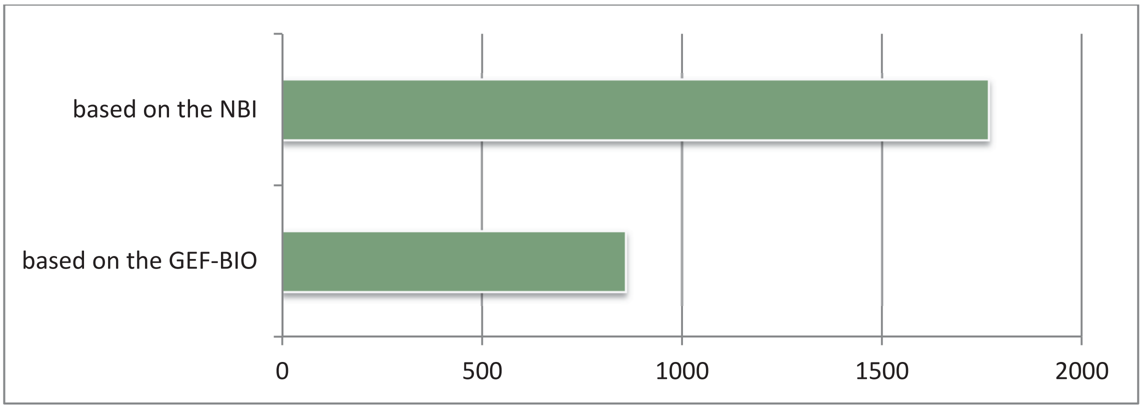
## 4.5 Effects on global biodiversity

Traditional analyses of agricultural productivity effects usually cover the social welfare effects of changes in commodity markets. Some also consider effects on upstream and downstream industries and/or indirect land use changes and GHG emissions. So far no analysis has attempted to quantify the loss of biodiversity due to agricultural productivity changes. This study is the first to do so.

Remembering that productive agriculture in the EU avoids the conversion of around 37.7 million hectares of natural habitats into agricultural use in other world regions. Two methods for capturing the biodiversity effects (see chapter 3.1) are employed: One is the NBI and the other one is the GEF-BIO approach. The results of the analysis are depicted in figure 4.12.

Based on the GEF-BIO, about 860 million biodiversity index points would be lost by converting productive agriculture in the EU back to low input farming. This is equivalent to the biodiversity found in 8.6 million hectares of Brazilian rainforest. The current cutting rate in the Brazilian Amazon Forest is at 0.54 million hectares annually (OBT, 2013). This implies that the loss of biodiversity from low input farming in the EU equals 16 years of deforestation in the Amazon region at current pace.

**Figure 4.12: Globally preserved biodiversity of productive agriculture in the European Union (in million biodiversity index points)**




Source: Own figure and calculations based on CBD (2010) and World Bank (2013a).

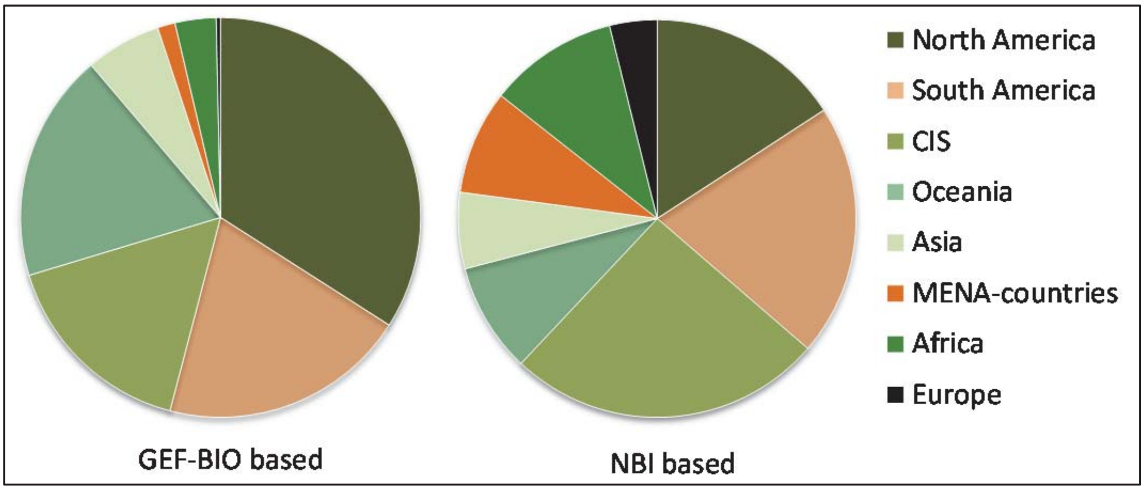
The NBI suggests an even larger loss in biodiversity. It would decline by 1.77 billion index points. Latest available figures for Indonesia, the country for which the NBI gets 100 index points per hectare, indicate a loss of almost 30 million hectares of rainforest from 1990 to 2005 (Leigh, 2011). Low input farming in the EU would have reduced the biodiversity by even 50 per cent more (biodiversity on an additional 17.7 million hectares).

In sum it becomes apparent that productive agriculture in the EU does not only help to preserve natural habitats but also avoids huge losses in biodiversity. Each per cent of additional agricultural productivity in the EU protects global biodiversity that can principally be located on 'species-richest' areas accounting for:

- almost 300 000 hectares (using the GEF-BIO approach); this is more than the territory of Luxembourg, and
- almost 600 000 hectares (using the NBI approach), twice the territory of Luxembourg.

Figure 4.13, finally, depicts the regional distribution of biodiversity preserved by productive agriculture in the EU. As can be seen, most of the biodiversity losses avoided would be located in four regions of the world, namely North America, South America, the CIS, and Oceania. This is the result of both, avoided acreage expansion and biodiversity on that land.

**Figure 4.13: Regional distribution of potential biodiversity losses of converting productive agriculture to low input farming in the European Union**




Source: Own figure and calculations.

So far, the analysis has focused on effects on biodiversity of productive agriculture in the EU at the global level. However, biodiversity inside the EU matters as well, including its link to and value for ecosystem services.

Ecosystems provide a wide range of services to humankind. According to the Millennium Ecosystem Assessment Board (2005) and Power (2010), ecosystem services generate food and water, regulate climate and diseases, support nutrient cycles and crop pollination, and add cultural, i.e. spiritual and recreational benefits.

Biodiversity is an essential part of ecosystems and, hence, the services it provides. Feeding a rapidly growing world population with low input farming practices would leave less room for a green infrastructure. In contrast, productive agriculture helps maintain and even create valuable ecosystems and their services (e.g. Swift et al., 2004; Swinton et al., 2007). In particular, it acts to increase the number of options for land sharing (supporting species with a rather broad global scale) and land sparing measures (helping species with a comparably small global range to establish and survive) (e.g. Benayas and Bullock, 2012; Martin, 2012).

Productive agriculture in the EU already led to a rather broad diversity of habitats close to and within farmed land such as field margins and mosaics, edge habitats, ditches, hedge row plantations, ponds, perches and nest boxes, stone mounds and huts, longitudinal landscape features, buffer strips, etc. (e.g. Benayas and Bullock, 2012; Christen and Dalgaard, 2013) and permits to establish protected areas. The benefits are obvious:

- All of these habitats can be considered biodiversity hotspots and support connectivity of biodiversity. Specific elements of biodiversity are created or restored and particular services of biodiversity, such as pollination, are assured (again, Benayas and Bullock, 2012; Christen and Dalgaard, 2013).
- They are also a proper way to purify water and air as well as to regulate water flows and the micro climate.
- Currently, Europe faces a decline in biodiversity. The habitats suitably managed in parallel to productive agriculture in the EU certainly contribute to minimise this decline and will be able, in the long run, to provide a suitable solution for reversing this negative trend.
- Finally, these habitats, rich in biodiversity, preserve specific ecosystem services the rural economy depends on. Recreation activities and the tourism market would be heavily endangered without current agro-biodiversity and biodiversity in the other ecosystems.

To conclude, an argument of Gabriel et al. (2013) shall be raised: Low input farming does not do better than productive agriculture in providing biodiversity. Instead, productive agriculture in the EU allows for a meaningful habitat management and has, therefore, the potential not only to provide high yields, but to improve biodiversity and related ecosystem services (Gabriel et al., 2013).

## 5. Concluding remarks

This study demonstrates that productive agriculture in the EU acts to (a) increase social welfare by generating additional income to farmers and by providing a greater quantity of less expensive food for to meet the rapidly growing needs of the world, (b) stabilise agricultural commodity markets and reduce price volatility, (c) generate additional income in upstream and downstream industries related to the agricultural value chain, (d) create jobs in particular in rural areas of the EU, (e) preserve valuable natural habitats, (f) reduce $CO_2$ emissions resulting from a reduction in the expansion of the global agricultural acreage, and to (f) protect and enhance biodiversity and ecosystem services around the globe.

As has been shown in this paper, productive agriculture in the EU contributes to at least ten social, economic and environmental values:

1. Increasing yields

   The use of sustainable and efficient production technologies in EU agriculture increases yields per unit of arable land. On average and across all major arable crops harvested in EU member states, yields would be 31 per cent lower in low input farming compared to productive agriculture in the EU (figure 3.5).

2. Improving market conditions

   Higher yields per unit of arable land increase the supply of primary agricultural products on international markets. For example, an additional 100 million tons of cereals and 10 million tons of oilseeds can be produced with productive agriculture in the EU. This acts to stabilise markets and to reduce price volatility (figures 4.1 and 4.2).

3. Increasing potential world food supply

   Productive agriculture in the EU is indispensable for reaching the millennium goal on combating hunger and malnutrition and improves the world food security situation. Given current global per capita rates of nutrient consumption, this assures additional availability of carbohydrates, proteins and vegetable oils to feed 300 million humans and more (figure 4.3).

4. Generating economic prosperity and increasing social welfare

   Productive agriculture in the EU generates additional economic prosperity by increasing the GDP. The entire agricultural value chain, from the input supplier to the final consumer, gains. In total, productive agriculture in the EU generates an additional social welfare gain of almost EUR 16 billion in the agricultural sector alone and it adds more than EUR 26 billion to the EU's GDP (figures 4.4 and 4.5).

5. Creating additional farm income and securing agricultural jobs

   Productive agriculture in the EU also acts to secure employment and to increase the income of farmers and agricultural employees. On average, approximately 14 000 EUR/AWU, i.e. more than three quarters of the income of an arable farmer in the EU are technology-induced (figure 4.6).

6. Maintaining rural livelihood

   Disparities between rural and urban regions are reduced. Although the net employment effect of converting to low input farming is very small in rural areas, income losses would be so severe that economic sustainability of much more than one million people and thus rural livelihood in many European regions might be jeopardised.

7. Improving the agricultural trade balance

   Productive agriculture in the EU not only brings about positive economic and social effects, but it also generates substantial environmental effects. It helps save scarce land resources around the globe by generating higher yields per unit of area. This improves the EU agricultural trade balance. Without productive agriculture, the EU would become a net importer in all major arable crops (figure 4.7).

8. Minimising net virtual land imports

   In addition, it minimises the net virtual land imports of the EU, which currently amount to 25 million hectares. In the absence of productive agriculture in the EU the global agricultural acreage would have to be expanded by almost 38 million hectares (figure 4.8 and figure 4.9).

9. Reducing $CO_2$ emissions

   This acts to preserve natural habitats and to reduce GHG emissions resulting from an expansion of the acreage. Indeed, productive agriculture in the EU not only emits fewer GHG, it also secures that less $CO_2$ is emitted as it helps to avoid negative land use change. In total, productive agriculture in the EU avoids about 6.8 billion tons of indirect $CO_2$ emissions around the globe (figures 4.10 and 4.11).

10. Preserving biodiversity and maintaining ecosystem services

   Finally, productive agriculture in the EU generates a large positive biodiversity effect. Without it, additional biodiversity, which is equivalent to 8.6 million hectares of Brazilian rainforest or 17.7 million hectares of Indonesian rainforest, would be lost (figures 4.12 and 4.13).

As has been demonstrated, low input farming averages 31 per cent lower yields than productive agriculture in the EU. This implies, in essence, that each percentage point of agricultural productivity gained in EU:

- allows to feed more than 10 million humans per annum,
- increases the annual social welfare generated in European agriculture by approximately EUR 500 million,
- contributes EUR 500 to the annual income of an average EU arable farmer,

- reduces EU's net virtual land imports by about 1.2 million hectares,
- acts to save 220 million tons in $CO_2$ emissions, and
- preserves global biodiversity equivalent to fauna and flora of up to 600 000 hectares of rainforest.

The objective of this study was to provide science-based evidence of the multiple social, economic and environmental benefits of productive agriculture in the EU. This is the first analysis of this kind. The results lend support to the basic hypothesis of this study – that productivity matters – and are expected to provide important information that will facilitate an objective public debate on the productivity issue.

## Reference list

Abbott, P.C.; Hurt, C.; Tyner, W.E. (2009): What's driving food prices?: March 2009 update. Oak Brook, IL: Farm Foundation.

Alkemade, R.; van Oorschot, M.; Miles, L. (2009): GLOBIO3: A framework to investigate options for reducing global terrestrial biodiversity loss. In: Ecosystems 12, p. 374-390.

Balcombe, K. (2009): The nature and determinants of volatility in agricultural Prices: An empirical study from 1962-2008. MPRA Paper No. 24819. Munich: University Munich.

Benayas, J.M.R.; Bullock, J.M. (2012): Restoration of biodiversity and ecosystem services on agricultural land. In: Ecosystems 15, p. 883-899.

BMELV (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) (2013): Sektorale Gesamtrechnung: Tabellen für die EU: Erzeugung, Vorleistungen und Wertschöpfung des Wirtschaftsbereiches Landwirtschaft. Berlin: BMELV.

BMELV (Bundesministerium für Ernährung, Landwirtschaft und Verbraucherschutz) (various years): Buchführung der Testbetriebe: Haupterwerbsbetriebe des ökologischen Landbaus nach Betriebsformen im Vergleich zu konventionell wirtschaftenden Betrieben. Bonn: BMELV.

BMU (Bundesministerium für Umwelt) (2007): Costs and benefits of the German government's energy and climate package. Berlin: BMU.

Bos, J.; de Haan, J.; Sukkel, W.; Schils, R. (2007): Comparing energy use and greenhouse gas emissions in organic and conventional farming systems in the Netherlands. Paper presented at the 3rd QLIF Congress, March 20-22, Frankfurt. Wageningen: Wageningen University and Research Center.

Breisinger, C.; Thomas, M.; Thurlow. J. (2010): Food security in practice: Social accounting matrices and multiplier analysis: An Introduction with Exercises. Washington, DC: IFPRI.

Butchart, S.H.M.; Resit Akçakaya, H.; Chanson, J. (2007). Improvements to the Red List Index. In: PLoS ONE 2, p. e140.

CBD (Convention on Biological Diversity) (2010): Global Biodiversity Outlook 3. Montreal: CBD.

CBD (Convention on Biological Diversity) (2001): Global Biodiversity Outlook 1. Montreal: CBD.

Christen, B.; Dalgaard, T. (2013): Buffers for biomass production in temperate European agriculture: A review and synthesis on function, ecosystem services and implementation. In: Biomass and Bioenergy 55, p. 53-67.

Cisilino, F.; Madau, F.A. (2007): Organic and conventional farming: A comparison analysis through the Italian FADN. Rome: INEA.

Dev Pandey, K.; Buys, P.; Chomitz, K.; Wheeler, D. (2006): New tools for priority setting at the global environment facility. World Bank Development Research Group Working Paper. Washington, DC: World Bank.

de Schutter, O. (2011): Mandate of the Special Rapporteur on the Right to Food: The Common Agricultural Policy towards 2020: The role of the European Union in supporting the realization of the right to food. New York: United Nations.

de Ponti, T.; Rijk, B.; von Ittersum, M.K. (2012): The crop yield gap between organic and conventional agriculture. In: Agricultural Systems 108, p. 1-9.

Destatis (2013a): Ernährungsproduktion zunehmend auf Flächen im Ausland. In: Agra-Europe 54, 02.September 2013, p. Dok1-Dok20.

Destatis (2013b): Flächenbelegung von Ernährungsgütern 2010. Wiesbaden. Destatis.

DG AGRI (Directorate-General for Agriculture and Rural Development) (2013): EU cereal farms report 2012 based on FADN data. Brussels: DG AGRI.

DG AGRI (Directorate-General for Agriculture and Rural Development) (2012): Agriculture in the European Union: Statistical and economic information 2011. Brussels: DG AGRI.

DG ENER (Directorate General Energy) (2010): The impact of land use change on greenhouse gas emissions from biofuels and bioliquids:Literature review. Brussels: European Commission.

di Tullio, E.; Camanzi, L.; Fontolan, F.; Volpato, C.; Zucconi, S. (2012): The assessment of the economic importance of azole in European agriculture: Wheat case study. Bologna: Nomisma.

Ecofys (2012): World GHG emissions flow chart 2010. London. Ecofys.

Ecorys (2012): Study on employment, growth and innovation in rural areas (SEGIRA). Final report. Rotterdam: Ecorys Nederland.

Emerson, J.; Esty, D.C.; Levy, M.A.; Kim, C.H.; Mara, V.; de Sherbinin, A.; Srebotnjak. T. (2010): The 2010 environmental performance index. New Haven, CT: Yale Center for Environmental Law and Policy.

Eugster, W.; Buchmann, N. (2011): Greenhouse gas emissions from agricultural soils: A global perspective. Zurich: ETH.

Eurostat (2013): Statistics - agriculture. Luxembourg: Euostat.

FAO (Food and Agriculture Organization) WFP (World Food Programme), IFAD (International Fund for Agricultural Development) (2012): The state of food insecurity in the world: Economic growth is necessary but not sufficient to accelerate reduction of hunger and malnutrition. Rome: FAO.

FAO (Food and Agriculture Organization) (2013): FAOSTAT – database. Rome: FAO.

FAO (Food and Agriculture Organization) (2012): Technical conversion factors for agricultural commodities. Rome: FAO.

FAO (Food and Agriculture Organization) (ed.) (2011): Price volatility in food and agricultural markets: Policy responses. Rome: FAO.

FAO (Food and Agriculture Organization) (2009a): High level expert forum: How to feed the world in 2050. Rome: FAO.

FAO (Food and Agriculture Organization) (2009b): The state of agricultural commodity markets: High food prices and the food crises – experiences and lessons learned. Rome: FAO.

FAO (Food and Agriculture Organization) (2001): Inter-temporal changes of conversion factors, extraction rates, and productivity of crops and livestock and related measures: 1963-1967 to 1993-1997. Rome: FAO.

FAPRI (Food and Agriculture Policy Research Institute) (2013): FAPRI 2012 U.S. and world agricultural outlook database. Ames: IA: FAPRI.

Firbank, L.G.; Petit, S.; Smart, S.; Blain, A.; Fuller, R.J. (2008): Assessing the impacts of agricultural intensification on biodiversity: A British perspective. In: Philosophical Transactions of the Royal Society B 363, p. 777-787.

Foley, J.A.; Ramankutty, N.; Brauman, K.A.; Cassidy, E.S.; Gerber, J.S. (2011): Solutions for a cultivated planet. In: Nature 478, p. 337-342.

Gabriel, D.; Sait, S.M.; Kunin, W.E.; Benton, T.G. (2013): Food production vs. biodiversity: Comparing organic and conventional agriculture. In: Journal of Applied Ecology 50, p. 355-364.

Gilbert, C.L. (2010): How to understand high food prices. In: Journal of Agricultural Economics 62, p.398-425.

Gilbert, C.L.; Morgan, C.W. (2010): Food price volatility. In: Philosophical Transactions of the Royal Society B 365, p. 3023–3034.

Gottwald, F.T. (2013): Die moderne Landwirtschaft wird die Welt nicht retten! In: topagrar-online 25.01.2013.

Hiederer, R.; Ramos, F.; Capitani, C.; Koeble, R.; Blujdea, V.; Gomez, O.; Mulligan, D.; Marelli, L. (2010): Biofuels: A new methodology to estimate GHG emissions from global land use change: A methodology involving spatial allocation of agricultural land demand and estimation of $CO_2$ and $N_2O$ emissions. Luxembourg: Publications Office of the European Union.

Hillier, J.; Hawes, C.; Squire, G.; Hilton, A.; Wale, S.; Smith, P. (2009): The carbon footprint of food crop production. In: International Journal of Agricultural Sustainability 7, p. 107-118.

IMF (International Monetary Fund): (2013): World economic outlook database. Washington, DC: IMF.

JRC (Joint Research Center): $CO_2$ time series 1990-2011 per region/country. Brussels: JRC.

Hülsbergen, K.J.; Rahmann, G. (2012): Klimaschutz: Ökologische und konventionelle Betriebe sind auf Augenhöhe. In: Wissenschaft erleben 2012/1, p. 12-13.

Kern, M.; Noleppa, S.; Schwarz, G. (2012): Impacts of chemical crop protection applications on related $CO_2$ emissions and $CO_2$ assimilation of crops. In: Pest Management Science 68, p.1458-1466.

Kirschke, D.; Häger, A.; Noleppa, S. (2011): Rediscovering productivity in European agriculture: theoretical background, trends, global perspectives, and policy options. HFFA Working Paper 01/2011. Berlin: HFFA.

Klimekova, M.; Lehocka, Z. (2007): Comparison of organic and conventional farming systems in terms of energy efficiency. Vortrag auf der 9. Wissenschaftstagung Ökologischer Landbau.

KTBL (Kuratorium für Technik und Bauwesen in der Landwirtschaft) (2012): Betriebsplanung Landwirtschaft 2012/13. Darmstadt: KTBL.

Laborde, D. (2011): Assessing the land use change consequences of European biofuel policies. Final Report October 2011. Washington, DC: IFPRI.

Langeveld, J.W.A.; Dixon, J.; van Keulen, H.; Quist-Wessel, P.M.F. (2013): Analysing the effect of biofuel expansion on land use in major producing countries: Evidence of increasing multiple cropping. Biomass Research Report 1301. Wageningen: Biomass Research.

Leigh, M. (2011): Indonesian rainforest statistics: A timeline of statistics relating to the degradation of Indonesian rainforests. In: Internet [http://prezi.com/bi4r3t6rpxbv/indonesian-rainforest-statistics/; last access: October, 18th, 2013].

LEL (Landesanstalt für die Entwicklung der Landwirtschaft und des ländlichen Raums); LfL (Bayerische Landesanstalt für Landwirtschaft) (2013): Agrarmärkte 2013: Unterlagen für Unterricht und Beratung in Baden-Württemberg. Schwäbisch-Gmünd: LEL.

Lybbert, T.; Sumner, D. (2011): Agricultural technologies for climate change mitigation and adaptation in developing countries: Policy options for innovation and technology diffusion. Geneva: ICTSD.

Marelli, L.; Ramos, F.; Hiederer, R.; Koeble, R. (2011): Estimate of GHG emissions from global land use change scenarios. Luxembourg: Publications Office of the European Union.

Martin, P. (2012): Land sharing vs. land sparing – meeting agricultural and biodiversity goals. In: Internet [http://ecologyforacrowdedplanet.wordpress.com /2012/ 09/23/land-sharing-vs-land-sparing-meeting-agricultural-and-biodiversity-goals/; last access: October, 18th, 2013].

Millennium Ecosystem Assessment Board (2005): Ecosystems and human well-being. Chicago, IL: Island Press.

Moldes, W.C. (2010): Modern agriculture and its benefits: Trends, implications and outlook. Washington, DC: Global Harvest Initiative.

Mondelaers, K.; Aertens, J.; van Huylenbroeck, G. (2009): A meta-analysis of the differences in environmental impacts between organic and conventional farming. In: British Food Journal 111, p. 1098-1119.

Niggli, U.; Slabe, A.; Schmid, O.; Halberg, N.; Schlüter, M. (2010): Forschungsvision 2025 für die ökologische Land- und Lebensmittelwirtschaft: Bio-Wissen für die Zukunft. Brüssel: IFOAM.

Noleppa, S.; Cartsburg, M. (2013): The virtual agricultural land trade of the European Union: A revised methodology and an update for 2012 trade data. agripol research paper 04-2013. Berlin: agripol GbR.

Noleppa, S.; Hahn, T. (2013): The value of Neonicotinoid seed treatment in the European Union: A socio-economic, technological and environmental review. HFFA Working Paper 01/2013. Berlin: HFFA.

Noleppa, S.; von Witzke, H. (2013a): Die gesellschaftliche Bedeutung der Pflanzenzüchtung in Deutschland: Einfluss auf soziale Wohlfahrt, Ernährungssicherung, Klima- und Ressourcenschutz. HFFA Working Paper 01/2013. Berlin: HFFA.

Noleppa, S.; von Witzke, H. (2013b): Societal benefits of plant protection in Germany. Frankfurt am Main: IVA.

Noleppa, S.; von Witzke H. (2013c): Biokraftstoffe in der Europäischen Union und indirekte Landnutzungsänderungen: Eine Bestandsaufnahme aktueller wissenschaftlicher Studien und politischer Vorschläge. agripol research paper 2013-03. Berlin: agripol GbR.

Noleppa, S. (2013): Agricultural self-sufficiency in the European Union: Statistical evidence. Berlin: agripol GbR.

Noleppa, S. (2013): Biogaserzeugung und die „Tank vs. Teller"-Debatte: Situationsbeschreibung und modellbasierte Analyse. agripol research paper 2013-01. Berlin: agripol GbR.

Noleppa, S. (2012): Klimawandel auf dem Teller: Ernährung – Nahrungsmittelverluste – Klimawirkung. Berlin: WWF Deutschland.

OBT (Observaçao da Terra) (2013): Monitoramento da Floresta Amazonica Brasileira por Satelite. São José dos Campos: OBT.

OECD (Organization for Economic Cooperation and Development); FAO (Food and Agriculture Organization) (2013): OECD – FAO Agricultural Outlook 2013-2022. Paris: OECD.

OECD (Organization for Economic Cooperation and Development) (2008): Rising agricultural prices: Causes, consequences and responses. Policy Brief August 2008. Paris: OECD.

Pardey, P.G.; Alston, J.M.; Chan-Kang, C, (2012): Agricultural production, productivity and R&D over the past half century: An emerging new world order. Staff Papers 133745, Minneapolis, MN: University of Minnesota.

Phalan, B.; Balmford, A.; Green, R.E.; Scharlemann, J.P.W. (2011): Minimizing the harm to biodiversity of producing more food globally. In: Food Policy 36, p. S62-S71.

Piesse, J.; Thirtle, C. (2010): Agricultural productivity in the United Kingdom. In: Alston, J.M.; Babcock, B.A.; Pardey, P.G (eds.): The shifting patterns of agricultural production and productivity worldwide. Ames, IA: The Midwest Agribusiness Trade Research and Information Center, Iowa State University: 149-192.

Pingali, P.L. (2012): Green revolution: Impacts, limits, and the path ahead. In PNAS 109, p. 12302-12308.

Power, A.G. (2010): Ecosystem services and agriculture: Tradeoffs and synergies. In: Philosophical Transactions of the Royal Society B 365, p. 2959-2971

PRB (Population Reference Bureau) (2012): 2012 World population data sheet. Washington, DC: PRB.

Rao, X.; Hurley, T.M.; Pardey, P.G. (2012): Recalibrating the reported rates of return to food and agricultural R&D. Staff Papers 135018. Minneapolis, MN: University of Minnesota.

Ray, D.K.; Mueller, N.D.; West, P.C.; Foley, J.A. (2013): Yield trends are insufficient to double global crop production by 2050. In: PLOS one 8 (6): e66428.

Renwick, A.; Jansson, T.; Verburg, P.; Revoredo-Giha, C.; Britz, W.; Gocht, A.; McCracken, D. (2013): Policy reform and agricultural land abandonment in the EU. In: Land Use Policy, 30, 446-457.

Royal Society (2009): Reaping the benefits: science and the sustainable intensification of global agriculture. London: The Royal Society.

Schmitz, P.; Matthews, A.; Keudel, N.; Schröder, S.; Hesse, J.W. (2011): Restricted availability of azole-based fungicides: impacts on EU farmers and crop agriculture. Giessen: Institute for Agribusiness.

Schwarz, G.; von Witzke, H.; Noleppa, S. (2011): Impacts of future energy price and biofuel production scenarios on international crop prices and trade. In: Schmitz, A.; Wilson, N. (eds.): Economics of Alternative Energy Sources and Globalization. pp. 76-90, Oak Park, FL: Bentham Science Publishers.

Schwarz, G. (2010): Contributions of LFA agriculture to the Scottish economy: A SAM based analysis of intersectoral linkages. In: Management Theory and Studies for Rural Business and Infrastructure Development 22. Research Paper #3. Braunschweig: vTI.

Searchinger, T.; Heimlich, R. (2008): Estimating greenhouse gas emissions from soy-based US biodiesel when factoring in emissions from land use change. In: Outlaw, J.L.; Ernstes, D.P. (eds.): The lifecycle carbon footprint of biofuels. p. 35-35. Miami Beach, FL: Farm Foundation.

Searchinger, T.; Heimlich, R.; Houghton, A.; Dong, F.; Elobeid, A.; Fabiosa, J.; Togkoz, S.; Hayes, D.; Yu, T.-H. (2008): Use of U.S. croplands for biofuels increases greenhouse gases through emissions from land-use change. Princeton, NJ: Princeton University.

Seufert, V.; Ramankutty, N.; Foley, J.A. (2012): Comparing the yields of organic and conventional agriculture. In: Nature 485, p. 229-232.

Smith, P.; Martino, D.; Cai, Z.; Gwary, D.; Janzen, H.; Kumar, P.; McCarl, B.; Ogle, S.; O'Mara, F.; Rice, C.; Scholes, B.; Sirotenko, O. (2007): Agriculture. In: Metz, B.; Davidson, O.R.; Bosch, P.R.; Dave, R.; Meyer L.A. (eds.): Climate change 2007: Mitigation. Contribution of Working Group III to the Fourth Assessment Report of the Intergovernmental Panel on Climate Change Cambridge: Cambridge University.

Spink, J.; Street, P.; Sylvester-Bradley, R.; Berry, P. (2009): The potential to increase productivity of wheat and oilseed rape in the UK. Report to the Government Chief Scientific Adviser. Hereford: ADAS.

Stern, N. (2007): The economics of climate change: The Stern review. Cambridge: Cambridge University Press.

Swift, M.J.; Izac, A.M.N.; van Noordwijk. M: (2004): Biodiversity and ecosystem services in agricultural landscapes: Are we asking the right questions? In: Agriculture, Ecosystems and Environment 104, p.113-134.

Swinton, S.M.; Lupi, F.; Robertson, G.P.; Hamilton, S.K. (2007): Ecosystem services and agriculture: Cultivating agricultural ecosystems for diverse benefits. In: Ecological Economics 64, p. 245-252.

Tilman, D.; Balzer, C.; Hill, J.; Befort, B.L. (2011): Global food demand and the sustainable intensification of agriculture. In: PNAS USA 108, p. 20260-20264.

Tubiello, F.N.; Salvatore, M.; Rossi, S.; Ferrara, A.; Fitton, N.; Smith, P. (2013): The FAOSTAT database of greenhouse gas emissions from agriculture. In: Environmental Research Letters 8, doi:10.1088/1748-9326/8/1/015009.

Tuomisto, H.L.; Hodge, I.D.; Riordan, P.; Macdonald, D.W. (2012): Does organic farming reduce environmental impacts? – A meta-analysis of European research. In: Journal of Environmental Management 112, p. 309-320.

Tyner, W.E.; Taheripour, F.; Zhuang, Q.; Birur, D.; Baldos, U. (2010): Land use changes and consequent $CO_2$ emissions due to US corn ethanol production: a comprehensive analysis. West Lafayette, IN: Purdue University.

UN (United Nations) (2013): World population prospects: The 2012 revision. New York: UN.

UNEP (United Nations Environment Programme) (2009): Science Panel review of the GEF Benefits Index (GBI) for biodiversity. Nairobi: UNEP.

USDA (United States Department of Agriculture) (1992): Weights, measures, and conversion factors for agricultural commodities and their products. Washington DC: USDA.

USDC (United States Department of Commerce) (2013): World Population: Total midyear population for the World: 1950-2050. Washington, DC: USDC.

Valin, H.; Havlik, P.; Mosnier, A.; Herrero, M.; Schmid, E.; Obersteiner, M. (2013): Agricultural productivity and greenhouse gas emissions: Trade-offs or synergies between mitigation and food security? Environmental Research Letter 8, p. 035019.

Vannuccini, S. (2009): The OECD-FAO AGLINK-COSIMO projection system. Rome: FAO.

Venkat, K. (2011): Comparison of twelve organic and conventional farming systems: a life-cycle greenhouse gas emissions perspective. Portland, OR: Clean Metrics Corp.

Vermeulen, S.J.; Campbell, B.M.; Ingram, J.S.I. (2012): Climate change and food systems. In: Environment and Resources 37, p. 195-222.

von Witzke, H.; Noleppa, S.; Schwarz, G. (2011): The European Union's virtual 'land grab' of agricultural trade in 2010: The conflicting impacts of productivity and animal protein production. Research Report. Berlin: agripol GbR.

von Witzke, H.; Noleppa, S. (2012): Klimaeffekte des Pflanzenschutzes in Deutschland: Darstellung von vorläufigen Ergebnissen zum Modul „Klimaeffekte" des Projektes zum gesamtgesellschaftlichen Nutzen des Pflanzenschutzes in Deutschland. Berlin: Humboldt-Universität zu Berlin.

von Witzke, H.; Noleppa, S. (2011a): Der gesamtgesellschaftliche Nutzen von Pflanzenschutz in Deutschland. Darstellung des Projektansatzes und von Ergebnissen zu Modul 1: Ermittlung von Markteffekten und gesamtwirtschaftlicher Bedeutung. Berlin: Humboldt-Universität zu Berlin.

von Witzke, H.; Noleppa, S. (2011b): The economics of Rumpelstiltskin: Why speculation is not a prime cause of high and volatile international agricultural commodity prices: An economic analysis of the 2007-08 price spike. Berlin: HFFA.

von Witzke, H.; Noleppa, S. (2010): EU agricultural production and trade: Can more efficiency prevent increasing 'land-grabbing' outside of Europe? Research Report. Piacenca: OPERA.

von Witzke, H.; Noleppa, S.; Schwarz, G. (2009): Global agricultural market trends revisited: The roles of energy prices and biofuel production. Working Paper 98/2009. Berlin: Humboldt University Berlin.

von Witzke, H. (2010): Bananas from Bavaria. Augsburg: Ölbaum.

Williams, A.G.; Audsley, E.; Sandars, D.L. (2006): Determining the environmental burdens and resource use in the production of agricultural and horticultural commodities. Main report. Defra Research Project IS0205. Bedford: Cranfield University.

Wright, B.E. (2011a): Measuring and mapping indices of biodiversity conservation effectiveness. Worcester, MA: Clark University.

Wright, B.D. (2011b): The economics of grain price volatility. In: Applied Economic Perspectives and Policy 33, p.32-58.

Wright, B.D. (2010): Recent agricultural price volatility and the role of grain stocks. Washington, DC: International Food and Agricultural Trade Policy Council.

World Bank (2013a): Data: GEF benefits index for biodiversity. Washington, DC: World Bank.

World Bank (2013b): World data bank: World development indicators: Washington, DC: World Bank.

Zeddies, J.; Bahrs, E.; Schönleber, N.; Gamer, W. (2012): Globale Analyse und Abschätzung des Biomasse-Flächennutzungspotentials. Hohenheim: Universität Hohenheim.

# Annex

## Annex 1: EU trade in virtual agricultural land by region and commodity (in million ha)

| | Wheat | Corn | Coarse Grains | Rice | Soya | Palm | Oilseed Rape | Other Oilseeds | Coffee and Cocoa | Tea and To-bacco | Fruits | Vegetables and Potatoes | Pulses | Sugar Crops | Beef | Sheep and Goat Meat | Pork | Poultry | Eggs | Dairy | Cotton | Total |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| North America | 0.713 | 0.055 | -0.183 | 0.010 | 1.638 | 0.034 | 0.281 | 0.247 | 0.032 | 0.032 | -0.210 | -0.019 | 0.156 | 0.140 | 0.098 | 0.001 | -0.061 | -0.004 | 0.002 | -0.050 | 0.090 | 3.001 |
| USA | 0.320 | 0.037 | -0.143 | 0.011 | 1.163 | 0.000 | 0.052 | 0.068 | -0.410 | 0.030 | -0.187 | -0.010 | 0.048 | 0.018 | 0.100 | 0.000 | -0.047 | -0.001 | 0.002 | -0.013 | 0.090 | 1.127 |
| Canada | 0.532 | 0.018 | 0.014 | -0.001 | 0.473 | 0.000 | 0.230 | 0.153 | -0.075 | -0.004 | -0.095 | -0.002 | 0.100 | -0.001 | 0.004 | 0.001 | -0.004 | -0.001 | 0.000 | -0.002 | 0.000 | 1.341 |
| South America | 0.037 | 0.347 | -0.138 | 0.076 | 12.757 | 0.037 | 0.023 | 0.811 | 1.382 | 0.171 | 0.477 | -0.002 | 0.054 | 0.167 | 1.317 | 0.053 | 0.004 | 0.380 | 0.000 | -0.010 | 0.070 | 18.013 |
| Brazil | 0.029 | 0.251 | -0.104 | 0.014 | 5.916 | 0.000 | 0.000 | 0.047 | 0.695 | 0.147 | 0.139 | -0.010 | 0.000 | 0.138 | 0.660 | 0.000 | 0.000 | 0.350 | 0.000 | -0.001 | 0.050 | 8.321 |
| Argentina | 0.006 | 0.064 | 0.058 | 0.010 | 5.515 | 0.009 | 0.013 | 0.752 | -0.006 | 0.021 | 0.066 | 0.002 | 0.049 | 0.000 | 0.332 | 0.017 | -0.001 | 0.013 | 0.000 | 0.000 | 0.010 | 6.933 |
| Asia | -0.499 | -0.107 | -0.429 | 0.415 | 0.259 | 1.985 | -0.038 | 1.495 | 0.695 | 0.134 | -0.154 | -0.021 | 0.007 | 0.234 | -0.091 | -0.024 | -1.276 | 0.024 | -0.007 | -0.237 | 0.240 | 2.609 |
| China | -0.001 | -0.003 | -0.066 | 0.000 | 0.046 | 0.000 | -0.011 | 0.057 | 0.011 | 0.067 | -0.057 | 0.008 | 0.013 | 0.000 | -0.011 | 0.000 | -0.370 | 0.007 | 0.000 | -0.044 | 0.010 | -0.339 |
| India | 0.001 | 0.000 | 0.010 | 0.126 | 0.220 | 0.000 | -0.006 | 0.419 | 0.178 | 0.074 | 0.004 | 0.002 | -0.007 | 0.115 | 0.000 | 0.000 | 0.000 | -0.001 | 0.000 | -0.007 | 0.230 | 1.358 |
| Japan | -0.002 | -0.021 | -0.146 | 0.000 | 0.000 | 0.000 | -0.003 | -0.006 | -0.060 | -0.057 | -0.086 | -0.009 | 0.000 | 0.000 | -0.001 | 0.000 | -0.211 | -0.003 | -0.002 | -0.011 | 0.000 | -0.618 |
| North Africa/ Middle East | -3.770 | -0.221 | -1.108 | -0.010 | -0.532 | 0.000 | 0.104 | -0.092 | -0.200 | -0.091 | 0.001 | -0.033 | -0.034 | 0.092 | -0.218 | -0.040 | -0.006 | -0.194 | -0.009 | -0.328 | -0.090 | -6.780 |
| Africa | -1.463 | -0.044 | -0.307 | -0.002 | -0.705 | 0.289 | -0.015 | 0.141 | 4.841 | 0.262 | 0.079 | -0.034 | 0.007 | 0.214 | -0.110 | -0.011 | -0.131 | -0.340 | -0.011 | -0.151 | 0.360 | 2.868 |
| GUS | 0.930 | 0.603 | -0.066 | 0.000 | 0.875 | -0.034 | 1.089 | 3.865 | -0.393 | -0.052 | -0.310 | -0.063 | 0.050 | 0.222 | -0.414 | -0.001 | -0.649 | -0.202 | -0.010 | -0.079 | 0.100 | 5.459 |
| Russia | 0.349 | 0.073 | -0.068 | 0.000 | 0.445 | -0.034 | 0.300 | 1.327 | -0.220 | -0.030 | -0.335 | -0.051 | 0.028 | 0.089 | -0.362 | 0.000 | -0.459 | -0.112 | -0.008 | -0.066 | 0.010 | 0.874 |
| Developed Pacifics | 0.126 | -0.002 | -0.014 | -0.001 | 0.000 | 0.000 | 1.048 | -0.007 | -0.070 | -0.003 | 0.207 | -0.005 | 0.005 | 0.039 | 0.159 | 0.858 | -0.055 | 0.000 | 0.000 | 0.012 | 0.000 | 2.294 |
| Rest of Europe | -0.393 | 0.043 | -0.407 | -0.044 | -0.017 | -0.010 | -0.293 | -0.461 | -0.255 | -0.003 | -0.003 | -0.018 | 0.002 | 0.021 | -0.531 | -0.013 | -0.090 | -0.071 | -0.018 | -0.017 | -0.080 | -2.659 |
| Switzerland | -0.101 | -0.029 | -0.130 | -0.009 | -0.063 | 0.000 | -0.035 | -0.058 | 0.003 | -0.017 | -0.125 | -0.006 | -0.002 | 0.000 | -0.026 | -0.005 | 0.017 | -0.019 | -0.017 | 0.016 | 0.000 | -0.606 |
| Norway | -0.110 | -0.019 | -0.093 | -0.003 | 0.107 | 0.000 | -0.205 | -0.031 | -0.064 | -0.005 | -0.067 | -0.006 | -0.010 | -0.002 | -0.020 | -0.002 | -0.001 | -0.001 | 0.000 | -0.002 | 0.000 | -0.533 |
| Turkey | -0.086 | -0.049 | -0.095 | -0.023 | -0.133 | 0.000 | -0.046 | -0.267 | -0.072 | 0.023 | 0.128 | 0.005 | 0.015 | 0.000 | -0.300 | -0.019 | -0.001 | -0.001 | 0.000 | -0.002 | -0.070 | -0.994 |
| Rest of the World | -0.007 | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | 0.000 | 0.073 | 0.060 | 0.000 | -0.002 | 0.000 | 0.000 | 0.000 | -0.002 | 0.000 | -0.003 | 0.000 | 0.000 | -0.001 | 0.000 | 0.115 |
| Total | -4.326 | 0.673 | -2.654 | 0.443 | 14.275 | 2.301 | 2.198 | 6.072 | 6.093 | 0.449 | 0.085 | -0.195 | 0.248 | 1.129 | 0.208 | 0.822 | -2.267 | -0.408 | -0.053 | -0.863 | 0.690 | 24.921 |

Source: Own figure and calculations.

## Annex 2: Additional references used for analysing benefits of productive agriculture in the European Union

Argiles, J.A.; Brown, N.D. (2008): A comparison of the economic and environmental performances of conventional and organic farming: Evidence from financial statements. Barcelona: University of Barcelona.

Arncken, C.M.; Mäder, P.; Mayer, J.; Weibel, F.P. (2012): Sensory, yield and quality differences between organically and conventionally grown winter wheat. In: Journal of Science in Food and Agriculture 92, p. 2819-25.

Badgley, C.; Moghtader, J.; Quintero, E.; Zakem, E.; Chappell, J.; Avilés-Vázquez, K.; Samulon, A.; Perfecto, I. (2006): Organic agriculture and the global food supply. In: Renewable Agriculture and Food Systems 22, p. 86-108.

Bertilsson, G.; Kirchmann, H.; Bergström, L. (2008): Energy analysis of organic and conventional agricultural systems. In. Kirchmann, H.; Bergström, L. (eds.): Organic crop production – ambitions and limitations. pp. 173-188, Dordrecht: Springer.

Bruulsema, T.; Dibb, D.W.; Reetz Jr., H.F.; Fixen, P.E. (2003): Productivity of organic cropping systems. In: Better Crops 87, p.16-18.

Dalgaard, T.; Halberg, N.; Porter, J.R. (2001): A model for fossil energy use in Danish agriculture used to compare organic and conventional farming. In: Agriculture, Ecosystems and Environment 87. pp. 51-65.

Deike, S.; Pallutt, B.; Christen, O. (2010) : Untersuchungen zur Energieeffizienz im integrierten und ökologischen Landbau am Beispiel eines Langzeitversuches auf einem lehmigen Sandboden. In: Journal für Kulturpflanzen 62, S. 259-263.

Delmotte, S.; Tittonell, P.; Mouret, J.C.; Hammond, R.; Lopez-Ridaura, S. (2011): On farm assessment of rice yield variability and productivity gaps between organic and conventional cropping systems under Mediterranean climate. In: European Journal of Agronomy 35, p. 223-236.

Denison, R.F.; Bryant, D.C.; Kearney, T.E. (2004): Crop yields over the first nine years of LTRAS, a long-term comparison of field crop systems in a Mediterranean climate. In: Field Crops Research 86, p. 267-277.

Fagnano, M.; Fiorentino, N.; D'Egidio, M.G.; Quaranta, F.; Ritieni, A.; Ferracane, R.; Raimondi; G. (2012): Durum wheat in conventional and organic farming: Yield amount and pasta quality in Southern Italy. In: The Scientific World Journal 2012, Article ID 973058.

FAO (Food and Agriculture Organization) (2012): Agriculture and environmental stability of the food supply. Rome: FAO.

FNL (Fördergemeinschaft Nachhaltige Landwirtschaft) (2010): Energieeffizienter Pflanzenbau: Fragen und Antworten. Berlin: FNL.

Gutsche, V. (2011): Managementstrategien des Pflanzenschutzes im Pflanzenbau im Fokus von Umweltverträglichkeit und Effizienz. Quedlinburg: JKI.

Guzman, G.I.; Alonso, A.M. (2008): A comparison of energy use in conventional and organic olive oil production in Spain. In: Agricultural Systems 98, p. 167-176.

Hülsbergen, K.J.; Schmid, H. (2013): Energie- und Treibhausgasbilanzierung in ökologischen und konventionellen Betriebssystemen. Präsentation auf der Wissenschaftlichen Tagung „Klimawirkungen und Nachhaltigkeit ökologischer und konventioneller Pilotbetriebe in Deutschland“, Braunschweig, 27. Februar 2013. Braunschweig: vTI.

IFOAM (International Federation of Organic Agriculture Movements) (2010): Organic food and farming: A system approach to meet the sustainability challenge. Brussels: IFOAM.

Ingver, A.; Tamm, I; Tamm, Ü. (2008): Effect of organic and conventional production on yield and the quality of spring Cereals. In: Latvian Journal of Agronomy 11, p. 61-66.

Lansink, A.O.; Pietola, K.; Bäckman, S. (2002): Efficiency and productivity of conventional and organic farms in Finland 1994–1997. In: European Review of Agricultural Economics 29, p. 51-65.

Leifert, C. (2012): Better soil management is essential for future food security, opportunities and barriers. Presentation for the Soil Association's National Soil Symposium, 15th and 16th November 2012, Coventry. Newcastle: Newcastle University.

Mazzoncini, M.; Belloni, P.; Risaliti, R.; Antichi, D. (2007): Organic vs. conventional winter wheat quality and organoleptic bread test. Pisa: Universita di Pisa.

Moerschner, J.; Gerowitt, B. (1998): Energiebilanzen von Raps bei unterschiedlichen Anbauintensitäten. In: Landtechnik 6/98, S. 384-385.

Moreno, M.M.; Lacasta, C.; Meco, R.; Moreno, C. (2011): Rainfed crop energy balance of different farming systems and crop rotation in a semi-arid environment: Results of a long-term trial. In: Soil and Tillage Research 114. pp. 18-27.

Moudry Jr., J.; Konvalina, P.; Moudry, J., Kopta, D.; Sramek, J. (2010): Efficiency of production on arable land in organic and conventional farming. Ceske Budejovice: University of South Bohemia.

Munzing, K. (2010): Qualitätsvergleich ökologisch und konventionell erzeugten Getreides. Detmold: Max Rübner Institut.

Nemes, N. (2009): Comparative analysis of organic and non-organic farming systems: A critical assessment of farm profitability. Rome: FAO.

Niggli, U.; Slabe, A.; Schmid, O.; Halberg, N.; Schlüter, M. (2010): Forschungsvision 2025 für die ökologische Land- und Lebensmittelwirtschaft: Bio-Wissen für die Zukunft. Brüssel: IFOAM.

Pacini, C.; Wossink, A.; Giesen, G.; Vazzana, C.; Huirne, R. (2003): Evaluation of sustainability of organic, integrated and conventional farming systems: A farm and field-scale analysis. In: Agriculture, Ecosystems and Environment 95, p. 273-288.

Quirin, M.; Emmerling, C.; Schröder, D. (2004): Ökologische Bewertung unterschiedlicher Energiekenngrößen am Beispiel konventionell, integriert und biologisch bewirtschafteter Acker- und Grünlandschläge. In: Pflanzenbauwissenschaften 8. S. 91-98.

Rahmann, G.; Aulrich, K.; Barth, K.; Böhm, H.; Koopmann, R.; Oppermann, R.; Paulsen, H.M.; Weißmann, F. (2008): Klimarelevanz des ökologischen Landbaus – Stand des Wissens. In: vTI Agriculture and Forestry Research 58, S. 71-89.

Rahmann, G. (2012): Produktionsweise nicht entscheidend für Klimawirkung. In: FoRep Spezial – Ökologischer Landbau 2012, S.14-15.

Schmid, H.; Braun, M.; Hülsbergen, K.J. (2012): Klimawirksamkeit und Nachhaltigkeit von bayerischen landwirtschaftlichen Betrieben. München: TUM.

Sipiläinen, T.; Marklund, P.O.; Huhtala, A. (2008): Efficiency in agricultural production of biodiversity: Organic vs. conventional practices. Helsinki: Agrifood Research Finland.

Trewawas, A. (2004): A critical assessment of organic farming-and-food assertions with particular respect to the UK and the potential environmental benefits of no-till agriculture. In: Crop Protection 23, p. 757-781.

Tuomisto, H.L.; Hodge, L.D.; Riordan, P.; Macdonald, D.W. (2012a): Comparing energy balances, greenhouse gas balances and biodiversity impacts of contrasting farming systems. In: Agricultural Systems 108, p. 42-49.

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