Future Crops for Food, Feed, Fibre and Fuel

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Review of the current situation for land use in the EU-27

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List of abbreviations

CAP	Common Agricultural Policy
EU	European Union
EU-27	following countries are included:
	AT, BE, BG, CZ, CY, DE, DK, EE, ES, FI, FR, GR, HU, IE, IT, LU, LT, LV, ML, NL, PL, PT, RO, SE, SI, SK, UK
EU-15	following countries are included:
	AT, BE, DE, DK, ES, FI, FR, GR, IE, IT, LU, NL, PT, SE, UK
EU-12	following countries are included:
	BG, CZ, CY, EE, HU, LT, LV, ML, PL, RO, SI, SK
EU-10	following countries are included:
	CZ, CY, EE, HU, LT, LV, ML, PL, SI, SK
Mha	million ha
Mt	million tonnes
NUTS	Nomenclature of Units for Territorial Statistics

Executive summary

Agriculture land covers on average 40% of total land in the EU-27 amounting at almost 175 Mha (data for 2006). Only Scandinavian countries and high mountain regions, which are characterized by adverse growing conditions for crops, show higher proportion of forests than agricultural land.

The agricultural area is predominantly used for arable crop. This is reflected in the fact that the arable land covers on average 61% of agricultural land in the EU-27, amounting to 107 Mha. Areas with very high contribution of arable land are very widespread across Europe, including: whole of Denmark, Bulgaria, south-east UK, plains of France, western part of Poland, eastern Germany, whole Hungary, etc. **Permanent grassland and meadows** cover on average 31% of agricultural land. In traditional livestock breeding areas they are dominant land use, i.e. whole of Ireland, western UK, west of France, part of Belgium and the Netherlands. Permanent grasslands are very important in less-favorable areas, mountainous areas and foothills, when only stock-rising activities are possible. **Permanent crops** have little share with average of 8% of agricultural land in the EU-27. Only in southern countries olives and vineyards have considerable contribution to the land use (Greece, Cyprus, etc.).

Cereals are the most important crops. Cereals total covered some 59.6 Mha in 2006, which equal to 56% of arable land in the EU-27. Wheat covered 29% of arable land on average, then comes barley and maize. Apart from cereals other important crop categories are oilseeds (17% of arable land) and sugar beet (12%). Oilseeds are dominated with rapeseed.

In the **most productive regions** mainly cereals are produced. Most of the EU-27 cereal production is concentrated in northern France, eastern England, north-western Germany, western Poland and Hungary. Commonly wheat is exchanged in the crop rotation with rapeseed and sugar beet, thus these regions are also main production areas for rapeseed and sugar beet.

There are large differences in land productivity across Europe. The highest wheat yields are found in northern France and north-western Germany and reached 8-9 t/ha on average in 2006. In southern and central-eastern Europe the yields amounted to 2-4 t/ha on average. However, the development is such that the variation in productivity is decreasing.

The superior function of agriculture is to supply food for the population. The EU is self-sufficient in food to a great extend, exporting large quantities of agricultural produce outside the EU. The citizens have affluent diet with broad variety of food items. Changes in the demand for food come from the shifts in diet rather than from growth of the EU population.

The **EU agricultural sector is affected by the global market situation**. The imbalance between supply and demand for cereals world wide resulted with very high producer price in 2007 and the beginning of 2008. This gave immediate response in the increased cereal cultivation area in 2008 in whole of the EU-27.

In the EU **farmers are obligated to set-aside part of their land**. The obligatory set-aside rate is established on a yearly basis and basically amounts to 10%. In 2006 the obligatory set-aside area amounted to some 8 Mha, and this includes only EU-15 member states. Apart

from that some 3 Mha belonged to a voluntary set-aside. From 2011 the set-aside obligation would also apply for the EU-10 member states, which would add 1 Mha, and Bulgaria and Romania would bring additional 0.5 Mha from 2014. Set-aside land can be used for non-food crops, i.e. energy crops or crops to produce biobased materials.

So, far **a significant part of the set-aside land was used for energy crops**. In 2006 oilseeds (mainly rapeseed) for biodiesel covered some 800,000 ha out of the 4 Mha of obligatory set aside. Apart from set-aside land energy crops are grown under the aid for energy crops as well as without any specific regime. In total the energy crop acreage in the EU-25 was estimated at 2.5 Mha in 2005. Most of the production (90%) is concentrated in Germany, France and the UK.

The increase in energy crop areas is determined by the **demand for biofuels**, which is stimulated by the biofuel policy. So far, most of the energy crops are oil, starch or sugar crops used for transportation biofuels. Perennial ligno-cellulosic crops are mainly used for heat and power production, however the total acreage is less than 100,000 ha in the whole EU. The Climate and Energy Package approved in December 2008 is expected to boost the energy crop sector. **Perennial crops shall have an increasing importance**. The area of energy crops is foreseen to expand significantly in a short term mainly on the set-aside land.

Non-food crops used for biobased materials have a long tradition in Europe. Most commonly these are materials such as natural fibers and substances, such as starch and oils. However, biomass is also broken into blocks i.e. lactic acid, ethanol, furans in order to build new product. The size of the biobased market is considerable: 780 out of some 4,000 products included in the Eurostat-Nace database are partly or fully based on biomass or can be potentially build from biomass.

The climate change impact on the land use in the EU is not well understood so far. The projections shows that the climate change and increasing CO_2 concentration will increase crop yields compared to the baseline in north Europe while decreasing yields in southern Europe, especially in Spain, Portugal and south Italy and secondary in France and north Italy.

The main findings of the study are the driving forces for land use in Europe. Land use is shaped in relation to climatic and soil conditions. It is affected by traditional land use patterns, the farming structure and overall economic conditions in the agricultural sector. The most important driving forces for land use change in the EU are currently the demand and supply for certain crops and the rules of the Common Agricultural Policy.

Decoupling payments from production under the CAP came out to free the farmers decisions what to produce. Thereby the land use corresponds to the market situation for specific crops. The set-aside obligation proved to be a very effective to promote non-food crops production. Ingeneration in specific crop market, such as putting production quotas and/or setting an intervention market price, has a very strong and direct effect on crop areas. The specific policy targets such as biofuel targets proved to have an important impact on land use. The situation on global agricultural market has an visible effect on the allocation of crop areas in the EU, one example is the increase in the demand for cereals in the world.

1. Introduction

This deliverable is a part of the 4F CROPS project founded by the European Commission in order to survey and analyze all parameters that will play important role in successful development of non-food cropping systems in the EU-27. Crops supplying raw material for food, feed, fiber and fuel markets are in focus. The project includes following objectives:

- Review of the agricultural land uses in EU-27 and the prediction in short (2020) and longer terms (2030), so as to identify possibilities for non-food cropping systems .
- Mapping of cropping possibilities like choice of crops, rotation cycles, yielding potential, raw material characteristics.
- Comparative cost analysis of the food and non-food crops with consideration and evaluation of the most critical socio-economic parameters.
- Evaluation of the most important environmental criteria by means of an Environmental Impact Assessment (EIA) and a Life Cycle Analysis (LCA).
- Record of the existing policies and the driving forces in the future crops.
- Development of scenarios for promising non-food cropping alongside food cropping systems, by defining systems' boundaries and evaluating the priorities and trends.

Both food and non-food cropping systems compete for the same available land resources. This deliverable, which has been prepared under the work package 1 titled "Land use in the EU-27", shows the current situation in land use in the European Union. Current agricultural land use is analyzed as a reference for building scenarios for further development of non-food systems. Land use is defined as the area of different crop types.

At the beginning an environmental stratification of Europe is presented to show differentiated growing conditions for crop in Europe (chapter 2). An insight is made into the mechanisms that shaped the structure of agricultural land use in the past (chapter 3). Current land use analysis is performed on regional level (NUTS-2) based on international agricultural statistics from Eurostat with data available for 2006 (chapter 4). An attention was given to the changes in crops areas in 2008, which were coursed by record cereals prices and tight market situation in cereal sector in 2007. DG Agriculture mid-term projections on crops areas are presented over the period 2004-2014. In order to understand better the developments in land use structure in the EU some of the most important land used drivers were discussed (chapter 5).

The deliverable was elaborated by Institute for Fuels and Renewable Energy from Poland, however input was also given from Wageningen UR-BBP from the Netherlands (chapter 5.3) and from University of Bologna from Italy (chapter 5.5).

2. Environmental stratification of Europe

Environmental conditions in Europe are differentiated across the continent with regard to various climates. This creates various land use patterns and crop growing conditions. For the needs of the 4F CROPS project the consortium decided (Bologna 2008) to use an environmental stratification of Europe elaborated by Metzger at al. (2005). These are 13 environmental zones, each of them representing different growing conditions for crops.

Metzger et al. (2005) selected twenty relevant environmental variables based on the experience from previous studies. The environmental stratification was elaborated consisting of 84 strata, which were gathered into 13 environmental zones, see Figure 1. The resolution of stratification amounts to 1 km^2.

Table 1 presents the average values of minimal and maximal temperature and precipitation in each zone. There are significant differences in the European regions. Mediterranean South is characterized with the highest temperatures and the lowest precipitation. The most favorable conditions for growing crops are in the Atlantic North, Atlantic Central and Lusitanian zones.

Table 1. Average variables for environmental zones (Metzger 2008- personnal communication)

Climate	Average minimal temperature [^{0}C]	Average maximal temperature [^{0}C]	Precipitation [mm]
Continental	4.10	12.92	61.93
Pannonian	6.06	15.60	47.48
Atlantic Central	6.15	13.75	74.35
Atlantic North	4.28	10.71	112.96
Lusitanian	8.02	17.06	93.21
Mediterranean North	8.57	18.45	63.33
Mediterranean South	11.51	22.00	43.57

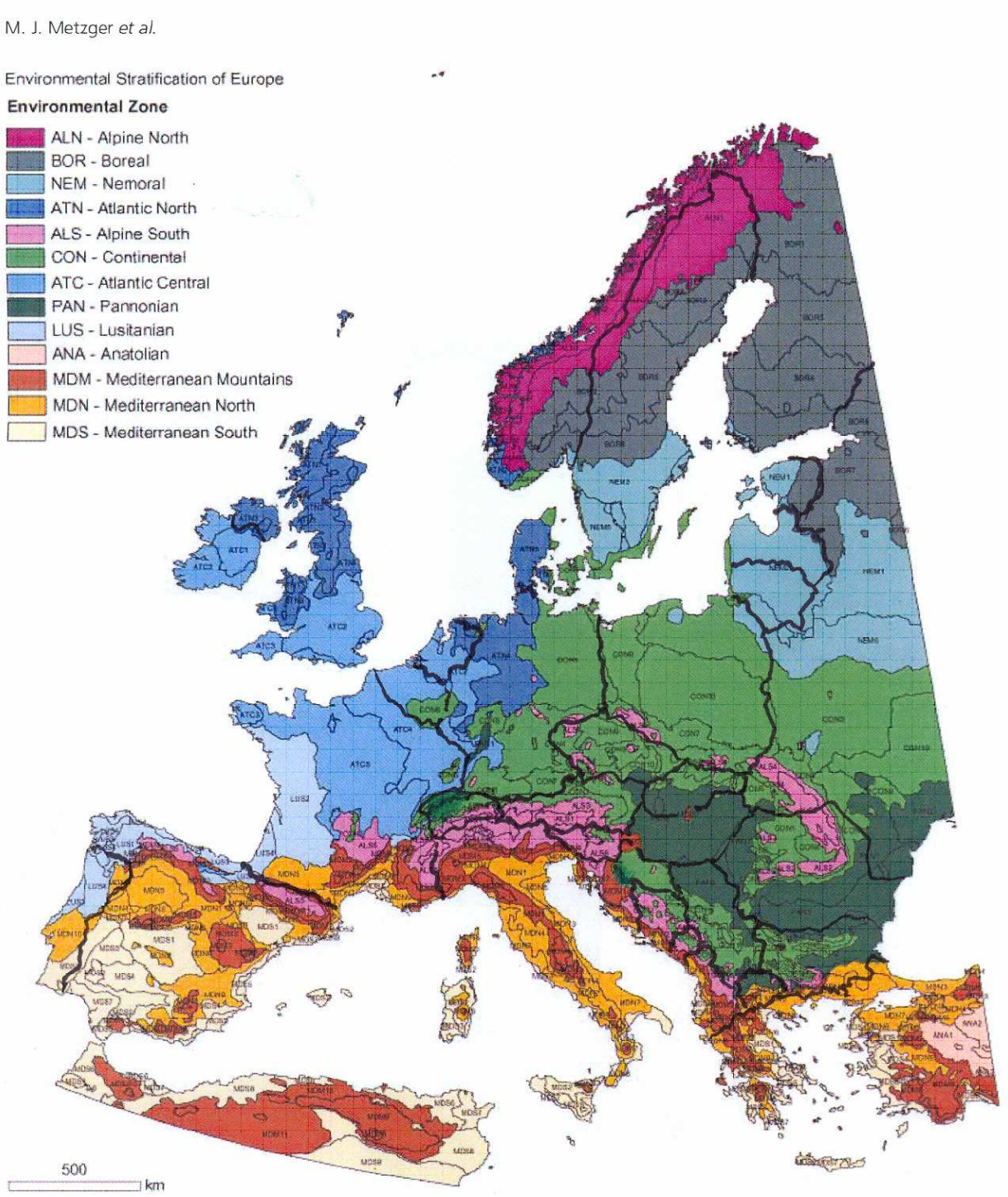

Figure 1. Environmental Stratification of Europe by Metzger et al. (2005)

3. Agricultural land use in the past

Last millennium

When analyzing the current land use patterns in Europe an insight into the past may lead to better understanding of the main land use drivers. Rabbinge and van Diepen (2000) analyzed the changes in the land use in Europe during the last millennium.

Looking into the past millennium there was expansion and contraction of the agricultural areas several times (Rabbinge and van Diepen 2000), see Figure 2. At the beginning of the Middle Ages more than 80% of the population was working in agriculture to produce enough food. Around 1400 the pandemic Black Death hit Europe, which reduced the European population with some 30% and for that reason the cultivated area contracted. After that a new period of expansion continued until the end of the 17th century. That time the cultivation area started to decrease as a result of the increase of productivity per ha due to better agricultural methods, i.e. new rotation systems and manure was widely applied and better grain varieties were introduced. International trade also affected the need for cultivation area. After some 100 years of contraction and stagnation, agricultural area expanded again as the European population increased more than productivity per ha. That continued until the middle of the 20th century.

In the middle of 20th century a first green revolution took place where productivity rise per ha of 4–15 kg grain equivalents per ha per year increased up to a level of 80–150 kg grain equivalents per ha per year. The sudden increase of productivity was possible due to a combination of factors, i.e. introduction of new varieties, better use of fertilizers, appropriate water management and appropriate crop protection. These factors led to a synergism that resulted in the increase of land productivity. Labour replacing machinery was widely applied. A surplus of cultivated land in Europe was noted for the next decades (Rabbinge and van Diepen 2000).

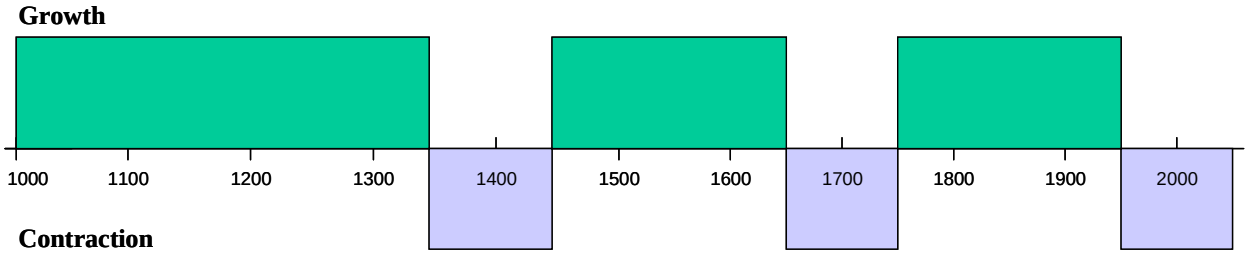

Figure 2. Expansion and contraction of cultivated area in Europe from 1000 to 2000 (Rabbinge and van Diepen 2000)

Last decades

There have been large changes in agriculture and its function over the last 5 decades. There was an enormous productivity increase in the early 1950s and 1960s. This resulted from the synergistic effect of the innovations from various disciplines.

Figure 3. shows the development of wheat (total) cultivation area, yields and annual production in the United Kingdom over the period 1961-2007. The cultivation area expanded two times (at the expanse of other cereals and break crops) and the yield level increased two times. This resulted in the total production output increase with four times. In Poland (Figure 4) there was an increasing trend in the yield level of wheat. The cultivation area was also increasing, however it was contracted significantly two times: in the early 1980s and than after 2000, which affected strongly the wheat production volumes.

It is important to notice that the yield of wheat in the UK is doubled in comparison to the yield of wheat in Poland. It is the evidence that for the land related agriculture the variation in production techniques within Europe is very significant. Nevertheless, the development is such that the variation is decreasing, as the tendency to reach optimal way of producing becomes more and more the objective of all farming systems. The Common Agricultural Policy is expected to stimulate the restructuring process of the agricultural sectors in the EU-12 in order to bring the crop production levels to its potentials.

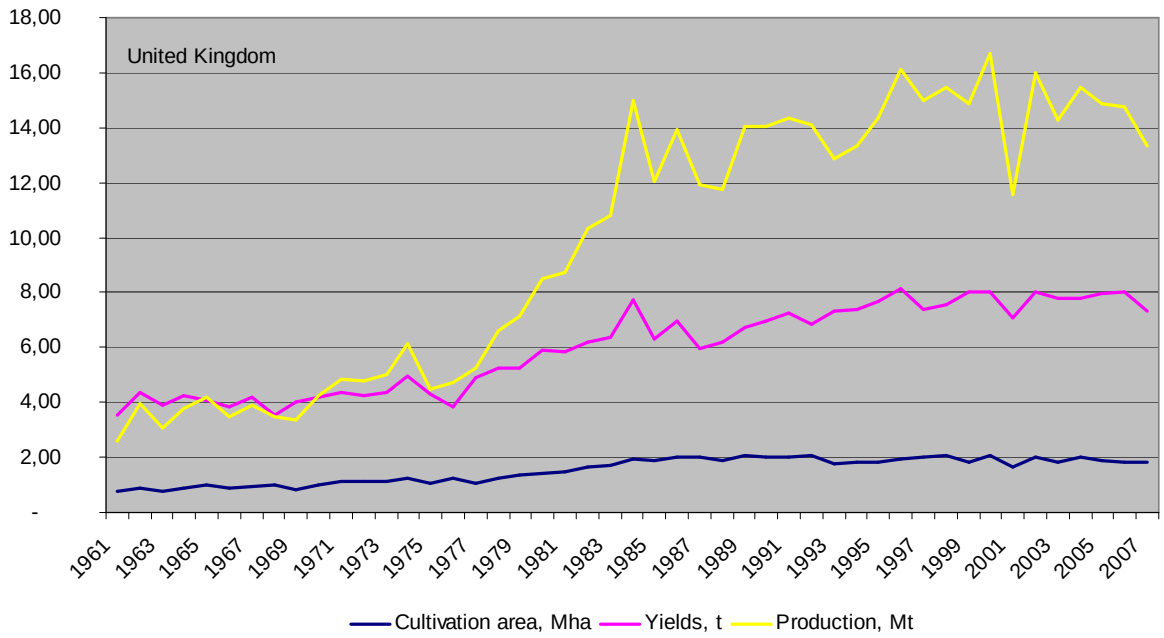

Figure 3. Wheat cultivation area, yields and annual production developments in the United Kingdom over the period 1961-2007 (FAO 2008)

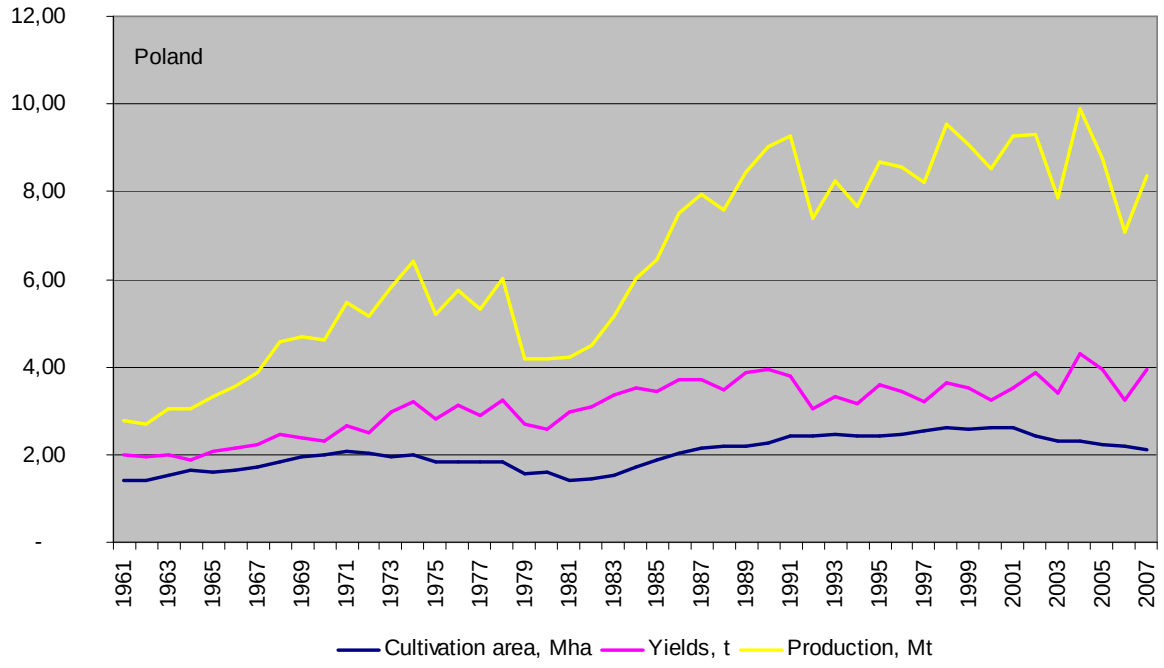

Figure 4. Wheat cultivation area, yields and annual production developments in Poland over the period 1961-2007 (FAO 2008)

Between 1975 and 2002, the arable land area increased sharply, especially in Ireland, France, the Netherlands. The trend intensified after 1990. The phenomenon can be linked with the Common Agricultural Policy reform of 1992. The cultivation of a maximum area of land proved financially advantageous, even land with poor farming potential was shifted for crop growing. On the other hand, Spain, Italy and the UK showed a decreasing trend in arable land area, especially after 1990. This is partially the effect of the introduction of set-aside obligation. Eurostat data before 2000 are not available for the EU-12 member states.

Arable land takes the form of large areas of open fields, which become more and more bleak and uniform. This trend is further accentuated by increased mechanization and attempts to improve productivity, causing farmers to increase their land, take down their walls, remove hedges and grub up isolated trees as well as removing fences. These large parcels of land are often without vegetation cover for part of the year, which poses increasing problems for the environment, such as soil erosion or the leaching of nitrates.

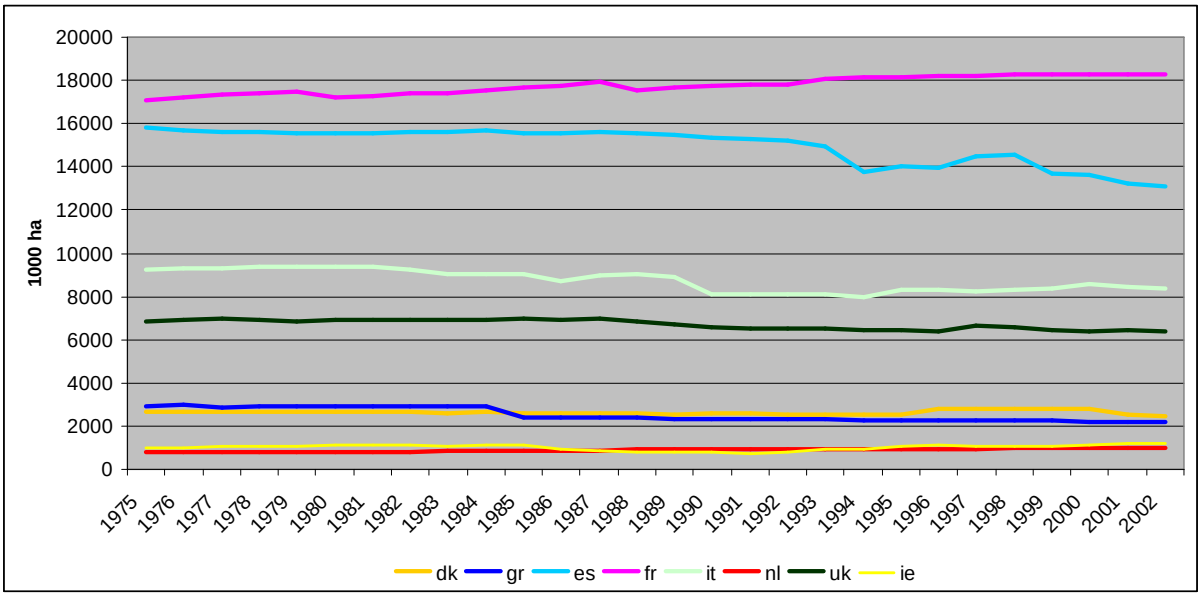

Figure 5. Arable land over the period 1995-2002 in selected EU member states (Eurostat 2008)

Changes in crop cultivation methods and the increased use of plant protection products in the 70s, against a backdrop of guaranteed prices and a cereal shortage in Europe, led to a rapid increase in the production of cereals (basically in the plains), see Figure 3 and Figure 4. There was a shift from secondary cereals (barley, oats, rye, etc.) towards common wheat and maize, given their higher yield potential and prices (Poiret 1999).

Agriculture was strengthened by scientific insight in the basic physical, chemical, physiological and ecological processes that together determine growth and production. These together with a detailed understanding of the genetic basis of various characteristics and the possibilities to effect them have created a new science based agriculture (Rabbinge and van Diepen 2000).

Since the fifties production with agro-ecosystems has been disconnected from land use for particular products (Rabbinge and van Diepen 2000). Production of flowers and vegetables in greenhouses, of mushrooms in closed containers, intensive cattle breeding, they are all typical examples of ways of producing that are similar to industrial processes. These ways of horticulture and agriculture are characterized by very high energy use and are used for the high valued products.

4. Overview of the current land use situation in the EU-27

4.1. Utilized agricultural land and arable land in the EU

The agricultural area covers 40% of total land in the EU-27 amounting at almost 175 Mha (data for 2006, Eurostat 2007). Agricultural land is dominant land use all over the Europe except from the northern territories over the 61° latitude North. In these regions climate is not suitable for cropping. Forestry is a dominant land use cover in Finland and Sweden. Moreover, mountain areas are primarily excluded from arable crops cultivation. Here considerable areas in Austria, Slovenia and Slovakia belongs.

The agricultural area includes arable land, permanent crops, grasslands and other land use categories of less importance. In the EU-27 arable land covers on average 61% of agricultural land, permanent crops 8% and permanent grassland and meadows 31%, respectively. Arable land covers more than 50% of agricultural land in all countries apart from Ireland, Portugal, Slovenia, the United Kingdom, Austria, Spain and Luxemburg, see Figure 6. Permanent crops have important contribution to land use mainly in the southern countries, especially in Greece and Cyprus. Permanent grassland and meadows are dominant land use in Ireland (>70% of agricultural land), but also in the United Kingdom, Slovenia, Austria (>50%) and Portugal (>40%). Permanent grasslands are very important in less-favorable areas, mountainous areas and foothills, when only stock-rising activities are possible.

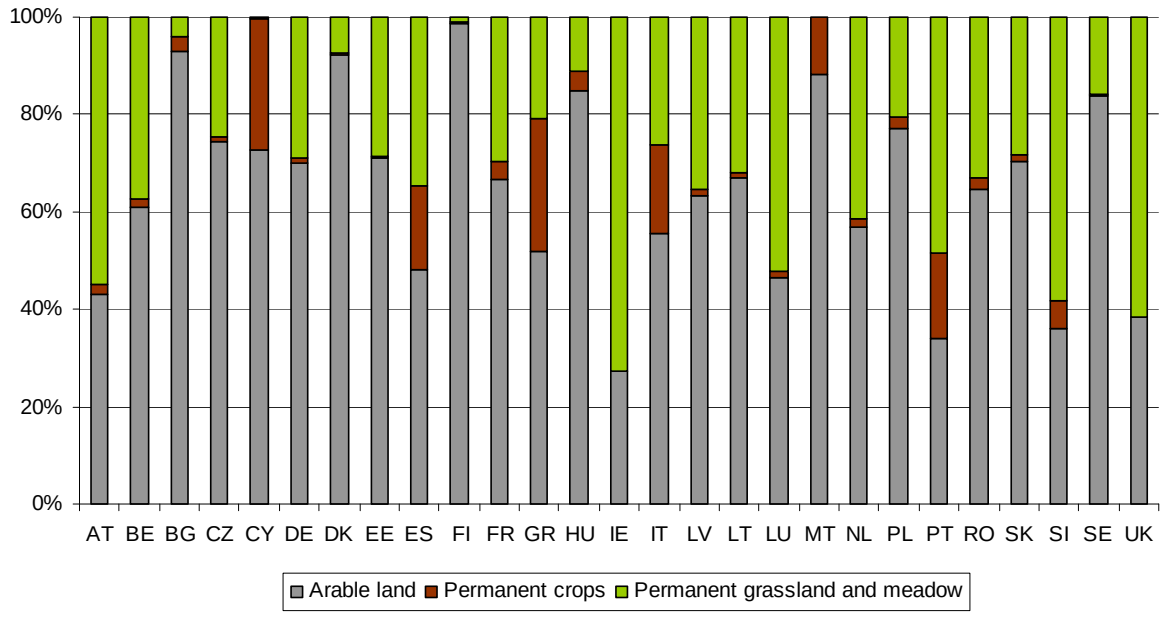

Figure 6. Share of arable land, permanent crops and permanent grassland and meadows in the total utilized agricultural area in EU-27 countries in 2006 (Eurostat 2008)

The distribution of agricultural land in total area on regional level in the EU-27 is presented in Figure 7. The lowest share of agricultural land (1-14%) was marked in Sweden and Finland, except from southern parts of both countries. The largest contribution of agricultural land to total area (65%-75%) is in the United Kingdom, northern part of France, in Denmark, Hungary and Romania, in south-eastern Italy. Also large parts of Poland, central France and Germany, Spain and Ireland are dominated with agricultural land (> 50%).

Arable land contribution to total agricultural land is presented in Figure 8. In Sweden, Finland, Denmark and in most of Bulgaria arable land covers over 90% of agricultural land. In most regions of Europe the contribution of arable land to total agricultural land is between 69 and 89%. The lowest contribution of arable land is in northern part of United Kingdom, whole of Ireland, in some Alpine regions of Austria, southern France and Spain, in central and southern Italy, in whole Portugal and southern Greece.

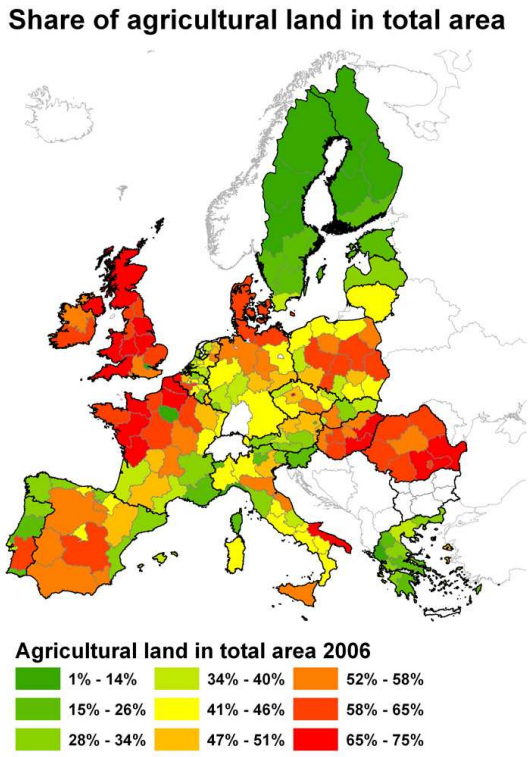

Figure 7. Share of utilized agricultural land in total area on regional level in the EU-27 in 2006 (based on Eurostat data)

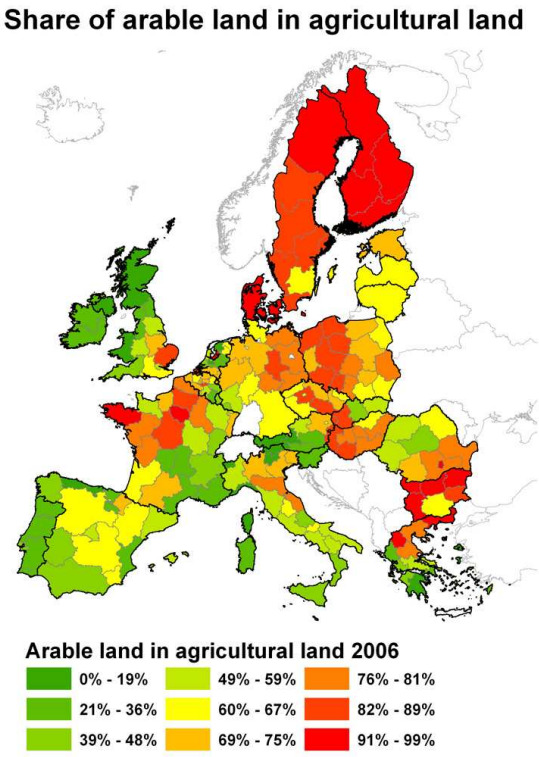

Figure 8. Share of arable land in agricultural land on regional level in the EU-27 in 2006 (based on Eurostat data)

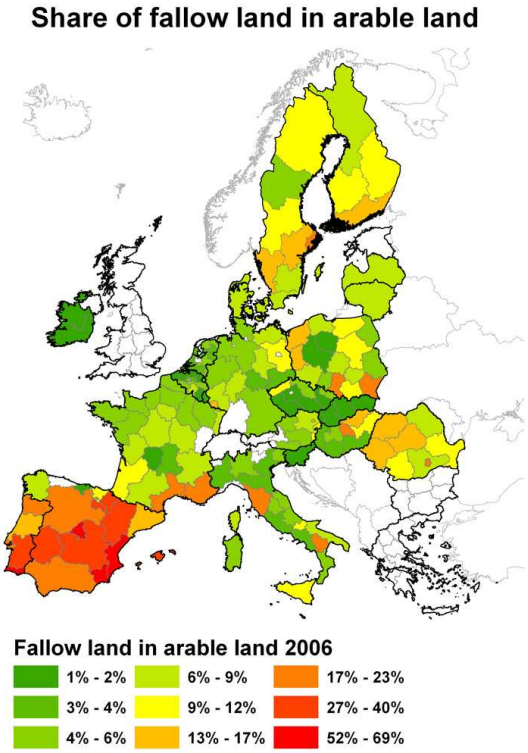

Figure 9. Share of fallow land in arable land on regional level in the EU-27 in 2006 (based on Eurostat data)

Figure 9 presents the contribution of fallow land to arable land. Total fallow land in the EU-27 amounts to 21.4 Mha, which covers 20% of arable land in 2006. In most regions it amounts from 4 to 9%. The largest share of fallow land is found in most regions of Spain and in southern Portugal. This is with regard to difficult crop growing conditions in dry climate. Also southern Poland, southern France and single regions of Italy, Hungary and Romania show fallow land contribution between 13 and 23%.

4.2. Main crops areas

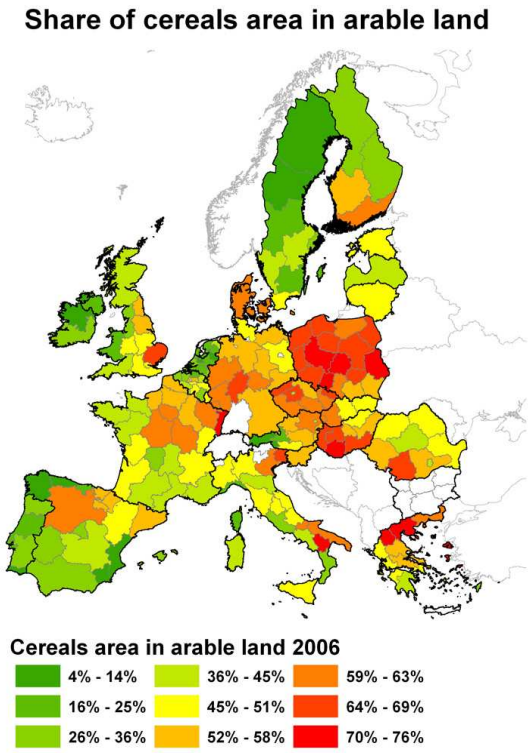

Figure 10. Share of total cereals area in arable land in EU-27 in 2006 (based on Eurostat data)

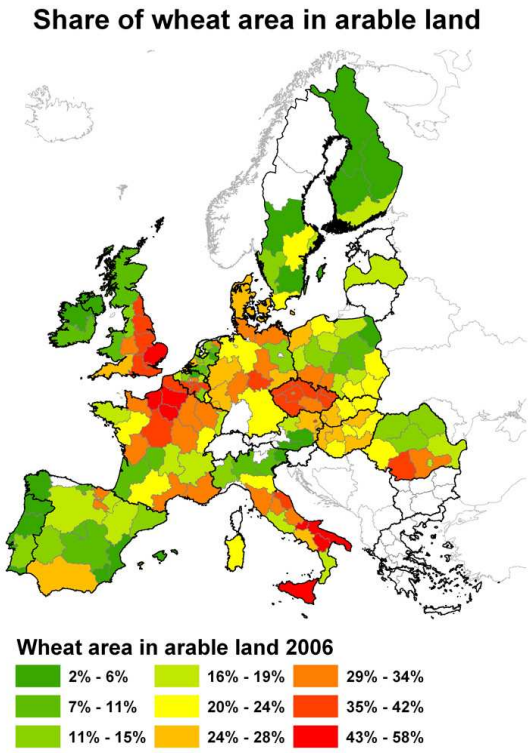

Figure 11. Share of total wheat area in arable land in the EU-27 in 2006 (based on Eurostat data)

Cereals are very important crops in Europe. In Poland almost all regions show very high cereal production area contribution to total arable land (>64%), see Figure 10. Also in some regions in the Czech Republic, Hungary, Romania, Greece, Italy and the UK cereals area cover between 64 and 76% of arable land. Among cereals wheat is the most important crop. Figure 11 shows the share of wheat (total) cultivation area in total arable land.

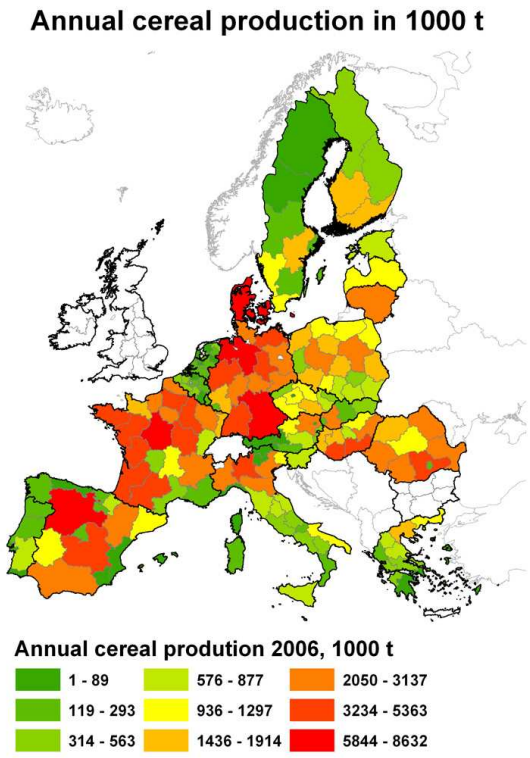

Figure 12. Annual cereal production in the EU-27 in 2006 (based on Eurostat data)

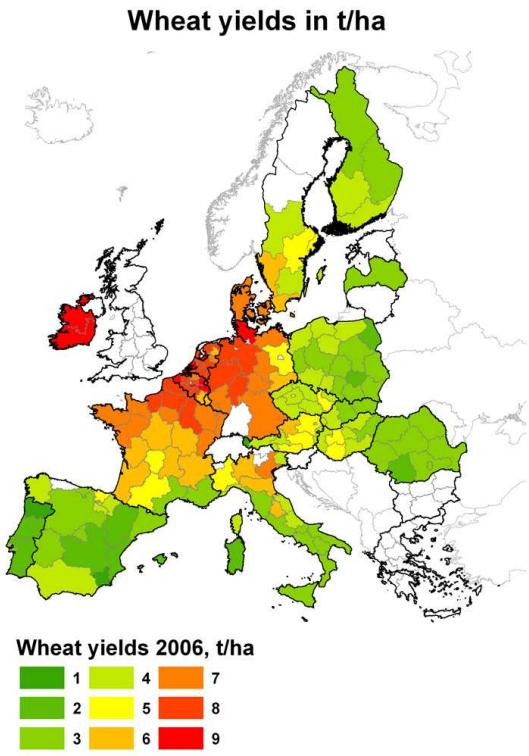

Figure 13. Wheat yields in the EU-27 in 2006 (based on Eurostat data)

The distribution of cereals production volumes (Figure 12) is very different from Figure 10. The largest cereals production is found in France and Germany, while in Poland, which has very high contribution of cereals area to arable land, cereal production output does not belongs to the largest values in Europe. It should be noted that the production of cereals in Figure 12 is determined by the share of cereal area, the size of the regions and the yields of cereals per ha. In Poland and other EU-12 countries the yields are much lower than in the central-western Europe, see Figure 13. There are huge differences in land productivity across Europe. The highest wheat yields are found in northern France and north-western Germany and reached 8-9 t/ha on average in 2006. In southern and central-eastern Europe the yields amounted to 2-4 t/ha on average. In the south low participation is the main limiting factor, whereas in the central-eastern Europe the relatively low yields are related to less favorable organizational and economic conditions in the farming sector. However, the development is such that the variation in productivity is decreasing. The Common Agricultural Policy is expected to stimulate the restructuring process of the agricultural sectors in the EU-12 in order to bring the crop production levels to its potentials.

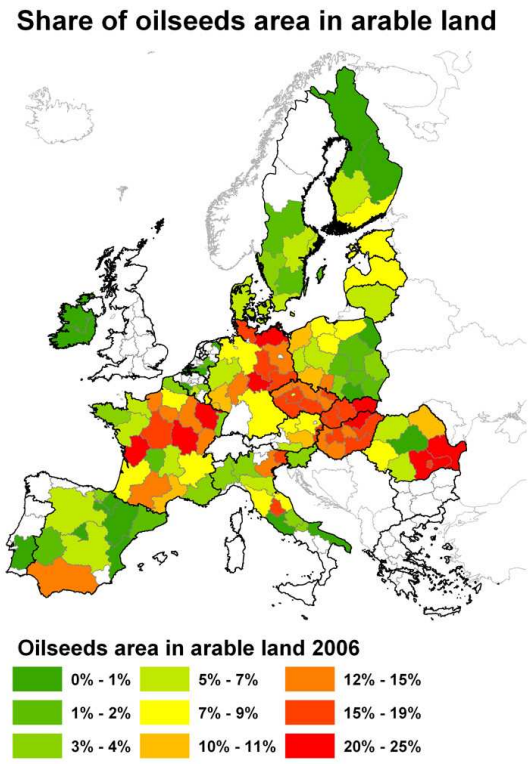

Figure 14. Share of oilseed area in arable land in 2006 in EU-27 (based on Eurostat data)

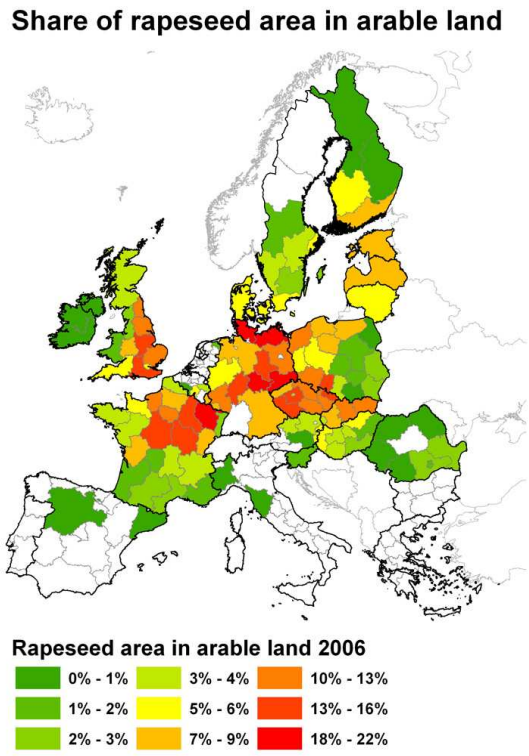

Figure 15. Share of rapeseed area in arable land in 2006 in EU-27 (based on Eurostat data)

Oilseeds cultivation area in Europe reaches 25% at maximum in the arable land, see Figure 14. Rapeseed remains the fourth most important crop by area in the EU, after wheat, maize and barley. Rapeseed is the most important oil crop in most of Europe, apart from Hungary, Romania, Bulgaria and south of Europe, where sunflower is the most important oilseed. In 2006 almost half of the European rapeseed production was used for biodiesel production with regard to the biofuel promotion. The largest share of rapeseed in the cultivation area is found in northern and central Germany, in northern and central Germany, in the Czech Republic, in central and north-east France, in south-east of the UK, see Figure 15. It may be noticed that the regions of high contribution of rapeseed are the regions of high contribution of wheat area to the arable land – these two crops commonly exchange each other in the rotation cycles.

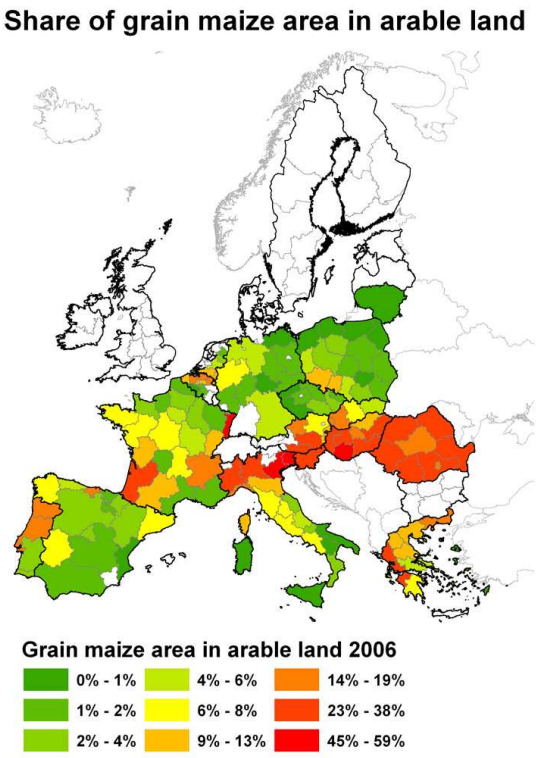

Figure 16. Share of maize for grain area in arable land in 2006 in EU-27 (based on Eurostat data)

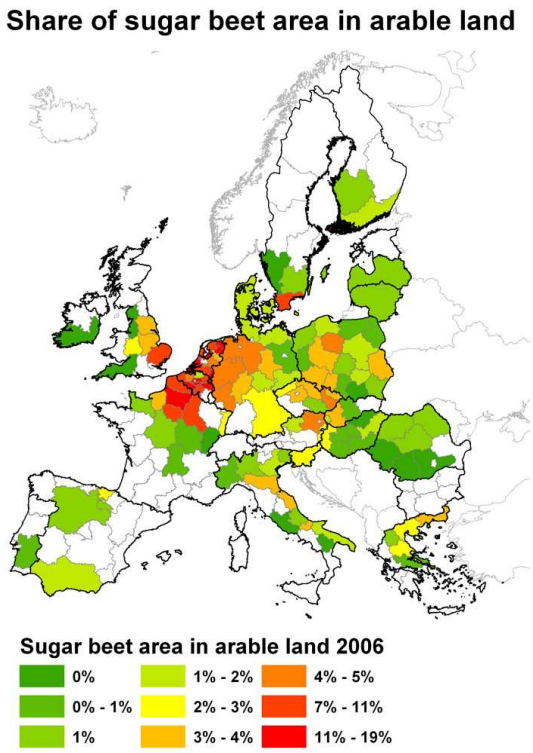

Figure 17. Share of sugar beet area in arable land in 2006 in EU-27 (based on Eurostat data)

Figure 16 presents the share of maize for grain cultivation area in arable land. The regions with the values between 23-59% lies in a horizontal line starting from northern Italy and to whole Romania. Also south-west region of France has vary high maize grain contribution.

Sugar beet area has the largest contribution to arable land in north-east of France, Belgium, Netherlands, north-west of Germany and south-east region of the UK. In these regions sugar beet is grown in rotation with wheat and rapeseed, see Figure 11 and Figure 15.

4.3. Large changes in crops areas in 2008

Year 2008 is very specific in Europe concerning changes in arable crop areas compared with 2007. The changes are larges than in previous years, thus, they are discussed in this deliverable. With regard to the fact that the international statistics for agriculture in 2008 are not available yet, this chapter is fully based on the "Statistic in focus" vol. 59 by Eurostat published in the early 2008.

Table 2 presents changes in main crops sown areas in the EU-27. For some crops there is strong growing tendency while others crops' areas shrink. The larges changes between 2008 and 2007 were the increase in durum wheat and maize grain areas and the decrease in peas area. The largest change between 2008 and the average for 2003-2007 was for peas, rapeseed and sugar beet.

Table 2. Changes in cultivation areas of selected crops in the EU-27 (based on Eurostat 2008)

Crop	% change 2008/2007	% change 2008/2003-2007
Cereals	5.7	2.6
Common wheat	5.4	4.9
Durum wheat	12.6	-7.9
Barley	2.3	1.6
Grain maize	10.0	-3.1
Triticale	-2.9	-1.0
Peas	-13.4	-35.5
Sugar beet	-6.8	-19.3
Rapeseed	-3.1	23.9

Cereals

The cereal area has increased with 5.7% up to app. 60 Mha. This is a response to the very high price increase for cereals observed in 2007 and the beginning of 2008. This happened due to an imbalance between supply and demand for cereals worldwide. The increase in area was partly made possible by important reduction in fallow land.

The common wheat area is estimated to increase to 23.1 Mha in comparison with 2007. France and Germany, the two largest producers of common wheat, increased their areas by 5.3% and 7.3%, respectively. The United Kingdom, the third largest producer, and Romania both increased their areas by around 12%. Common wheat production is forecast to rise to 123.7 million tonnes (+10.5%).

The area under durum wheat showed the biggest increase +12.6% in comparison with 2007, reaching 3.2 Mha. This increase is mainly due to the two largest producers of durum wheat, Italy and Spain, which increased their areas with about 8.6% and 19.6%, respectively. However, the total EU-27 area under durum wheat for 2008 remains 7.9% below the average

area of the last five years. The total production of the EU-27 for this cereal is expected to reach 9.6 million tonnes (+40.8%)

Barley cultivation area is estimated to increase slightly with 2.3% to 14 Mha. Production in the EU is expected to reach 57.6 million tonnes (stable in comparison with 2007). Finally, the area under grain maize was estimated to increase by 10%, to reach 8.9 Mha. Romania have the greatest area under grain maize (2.7 Mha). Production in the EU is expected to reach 56.7 million tones, which is +17.6% compared with 2007.

The main reasons to the changes in cereal areas were the prices at record levels. This was affected by several factors: (i) global commodity demand driven by record economic growth rates, changes in dietary patterns (meat) in many parts of the world; (ii) the development of biofuels market; (iii) the significant slow down in cereal yield growth in the EU (unlike many other producing regions). Additionally, in 2007 the agricultural sector has been hit by a series of adverse climatic conditions in many regions. There was a heat wave in central and eastern Europe, unusually abundant rainfall in North-West Europe as well as very low temperatures in Ukraine and Russia, which considerably affected the level of crop production in these countries. All these factors resulted in a fall in global stocks to their lowest in more than 10 years. In the EU two successive lower than average harvests in 2006/07 and 2007/08 helped to clear the cereal intervention stocks.

Protein crops

There is a strong decrease in the protein crop and peas area with 13.4% to 556,000 ha. Despite an increasing demand for protein crops (mainly for animals) the area is constantly decreasing. For the two largest producers of peas, France and Spain, a large decrease is observed of 17.5% and 13.4%, respectively. The EU production in 2008 is estimated to reach 1.4 million tonnes (-7.4% in comparison with 2007).

Rapeseed

There was decrease in the area under rapeseed by 3.1 % in the EU-27 in comparison with 2007, i.e 6.3 Mha in 2008. This area is still significantly above the 2003-2007 average (+23.9%). The largest producers of rapeseed, France, Germany and Poland, decreased their area under rapeseed by 7.4% (to 1.5 Mha), 8.4% (to 1.4 Mha) and 6.1% (to 748,000 ha), respectively. However, some other countries seem to continue to devote more area to this crop: the United Kingdom (+9.6%, 605 000 ha), Romania (+21.5%, 382 000 ha). The EU production of rapeseed in 2008 was estimated to reach 18.2 million tonnes, as in 2007.

Sugar beet

Due to the reform of sugar regime, the area under sugar beet is estimated to decrease by 6.8% within the EU in comparison with 2007 (-19.3% relative to the 2003-2007 average), dropping to 1.7 Mha. The decrease is widespread. France, the largest sugar beet producer, decreased its area strongly this year (-10.7%). Hungary, Spain and Italy also present severe reductions in their areas (-65%, -26.3% and -17%, respectively). The EU production of sugar beet in 2008 is expected to be 108.5 million tonnes, which represents a fall of 11.8% relative to the 2003-2007 average and a decrease of 5.4% in comparison with 2007.

4.4. Mid-term prospects for crop areas

The DG Agriculture prepares annually "Prospects for agricultural markets and income in the European Union". The update published in March 2008 includes market projections for cereals, oilseeds, meat and dairy products in the EU-27 for the period 2007 – 2014. The projections are established under a specific set of assumptions. This chapter presents the medium term prospects on the land use for main crops in the EU-27 based on the document published in March 2008 (DG Agriculture 2008).

Cereals

An increase in cereal area is projected from 56.6 Mha in 2007/08 up to 60.3 Mha in 2008 (+6.5%), see Figure 18. This is a combined effect of the record price levels in 2007/08 and the removal of the set-aside obligation in 2008/09. The mobilization of fallow area in favour of cereal sector is expected to reach 1.2 Mha. The other part of the area would come from other crops, mainly fodder. From 2009 onwards, EU cereal area would slightly decline and stand at 59 Mha by 2014. However, additional cereal production for energy use would also take place on set-aside land for around 1 Mha.

There would be only a slight change in the area allocation between different cereals. Soft wheat area would increase moderately thanks to the expansion of soft wheat production for energy on set-aside land (0.7 Mha by 2014). Total wheat area including soft and durum wheat would not change much from 2007 until 2014 amounting at around 25 Mha, see Figure 19. Total wheat production would rise from 122.4 Mt in 2007 up to 145.6 Mt in 2014 (+19%). Barley, which has favorable export conditions, would stabilize at around 13.7 Mha. Rye area would slightly increase to 2.7 Mha over the medium term.

Maize production will increase stimulated by favorable global market conditions for coarse grain. Figure 20 shows that the total maize area of the EU-27 should increase from 8.1 Mha in 2007 to 9.6 Mha in 2014 (+18.5%) mainly thanks to four main producing countries in Central and Eastern Europe. This development would take place despite the introduction of set-aside in 2011 and 2014 in the EU-10 and EU-2 respectively. In addition, the production of maize for energy use on set-aside land would rise to app. 0.3 Mha by 2014. Total maize production would rise from 45.7 Mt in 2007 67.3 Mt in 2014 (+47%), see Figure 20.

The land allocation for cereals would reflect the situation of EU and global price levels. High cereal prices are foreseen to continue for the early part of the projection period until market stocks in the EU replenish. After that EU cereal prices would stay on a higher level than seen in the last decade though at much lower levels than those recently observed (2007/08). The growth in global food demand and the development of new market outlets, can be reasonably expected to maintain prices at sustained levels.

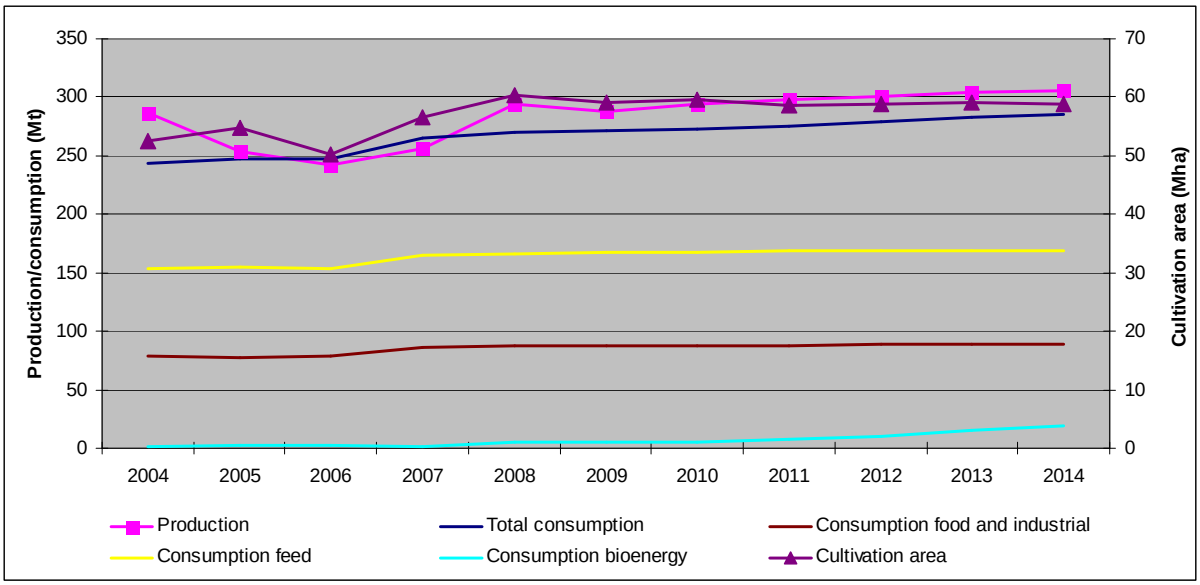

Figure 18. Total cereal production, consumption and cultivation area developments in 2004-2014 in the EU-27 (based on DG Agriculture 2007)

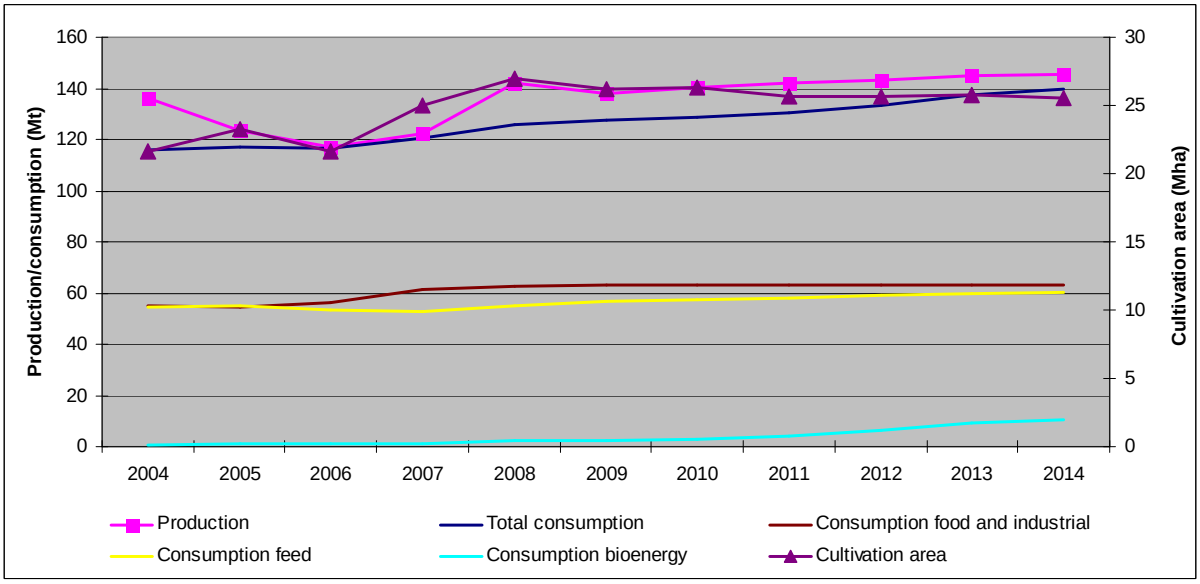

Figure 19. Wheat production, consumption and cultivation area developments in 2004-2014 in the EU-27 (based on DG Agriculture 2007)

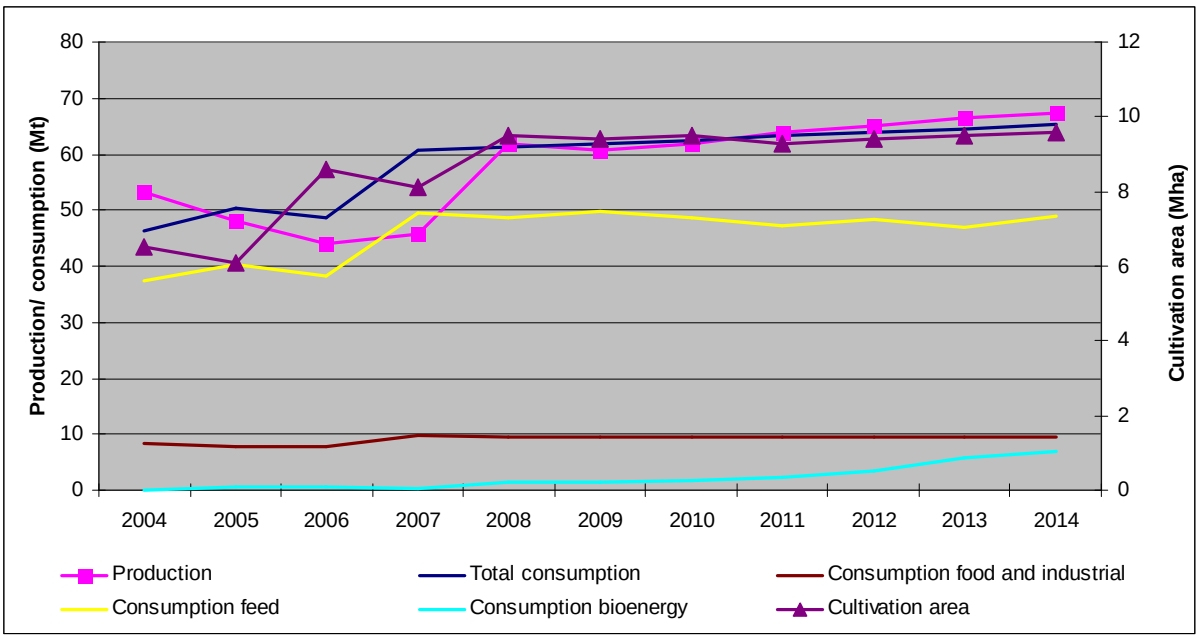

Figure 20. Maize production, consumption and cultivation area developments in 2004-2014 in the EU-27 (based on DG Agriculture 2007)

Oilseeds

The rapeseed production in expected to increase supported by the recent growth in the use of rapeseed oil for biodiesel. The non-food use of rapeseed oil has now become more important than the food use. Total production in the EU-27 is estimated to increase to 32.6 Mt by 2014 (Figure 21) supported by the expansion in oilseed area and the strong growth in rapeseed yields (1.8% per year).

In 2006 oilseed area was around 7.5 Mha of which 0.8 Mha on set-aside land. It increased greatly in 2007 and 2008 up to 9.5 Mha, however the high cereal prices should limit further expansion of oilseed area in the EU. The area on non-food oilseed is expected to remain stable at 1 Mha in 2014 due to the constraints imposed by the Blair House agreement (with a maximum of 1 Mt of soybean meal equivalent).

From 2009 onwards the expansion of rapeseed area in the EU would be constrained by the rotational limits reached in most of its producing regions. New varieties of sunflower could widen market opportunities for biodiesel, however the yield potential of this oilseed seems limited due to the constraining water availability in the main producing regions.

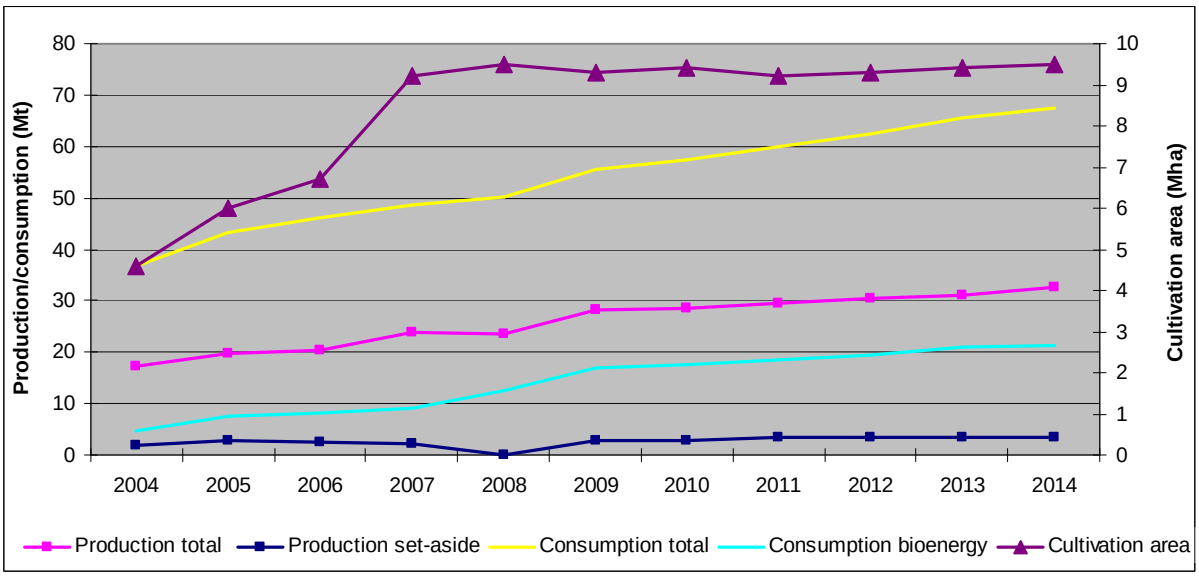

Figure 21. Oilseeds production, consumption and cultivation area developments in 2004-2014 in the EU-27 (based on DG Agriculture 2007)

Sugar beet

The sugar sector undergoes a reform aiming at lowering sugar production by 6 Mt until 2015. Decline in the quota of sugar production as well as in the minimum procurement price of sugar beet influenced much the area under sugar beet in the EU. It shrank from 2.2 Mha in 2005 up to 1.7 Mha in 2007 (-29%) and it should stabilize at 1.5 Mha in the next years. The areas released are allocated for cereals and rapeseed cultivation.

Set-aside

The rate of obligatory set-aside is adopted on a yearly basis. After a reduction to 5% for the 2004/05 marketing year, the obligatory set-aside rate returned to 10% in 2005/06. The rate of obligatory set-aside is set at zero for 2008/09. Then it is assumed to remain fixed at a level of 10% for the rest of the period until 2014. For EU-12 Member States, apart from Malta and Slovenia, which opted for the single area payment scheme, the set-aside obligations would only apply from 2011 onwards (and from 2014 onwards in Bulgaria and Romania).

Set-aside area increased up to 7 Mha in 2007, of which 4 Mha came from obligatory set-aside. From 2011 onwards, the EU-10 should add 1 Mha of obligatory set-aside. Bulgaria and Romania would contribute for a further 0.5 Mha of obligatory set aside from 2014. Obligatory and voluntary set-aside area in the EU-27 would amount in total to 8.7 mln ha in 2014, see Figure 22.

High cereal prices and tight market situation in cereal sector combined with the obligatory set-aside rate put to zero in the marketing year 2008/09 resulted in a mobilization of about 1.7 Mha of arable land, of which 1.5 Mha was allocated for cereals.

The increasing demand of feedstock from the biofuel and bioenergy sector is foreseen to stimulate the production of cereals for energy purposes on obligatory set-aside land in intensive production regions. The expected developments in biofuel markets should lead to a non-food oilseed area of around 0.9 to 1 Mha and to about 1.1 Mha for non-food cereal and sugar beet on set-aside land by 2014.

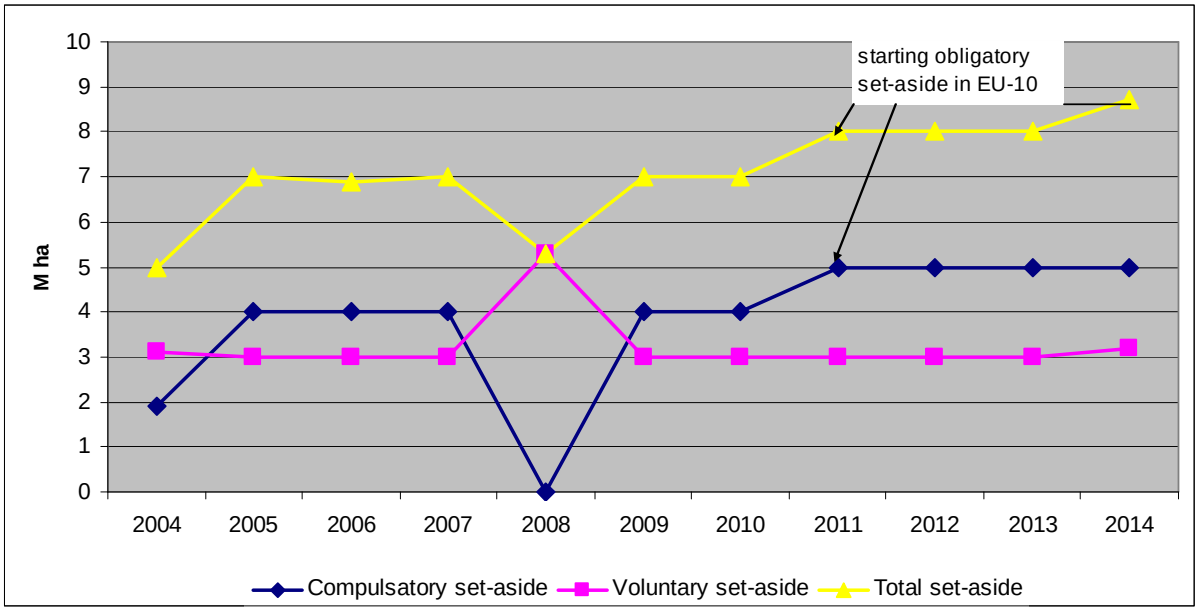

Figure 22. Set-aside land in the EU-27 over the period 2004-2014 (based on DG Agriculture 2007)

5. Drives for land use change

5.1. Common Agricultural Policy mechanisms

CAP reform

In June 2003 the EU concluded a major reform of the European Common Agricultural Policy (CAP). The reform completely redesigned the agricultural support. It shifted the CAP from paying farmers subsidies that encourage over-production, towards measures that support sustainable farming, rural development and the environment. The core of the reform is decoupling, which means the payments are no longer linked to production levels, but will instead depend on land being kept in good environmental and agricultural conditions.

The Single Area Payment is the main element of the reformed CAP. Decoupling direct payments from the production brings farmers closer to the market. It means food that people want is provided, rather than driving the farmers to over-produce specific commodities. The cross-compliance rules mean farmers must meet the requirements of certain EU environmental directives in order to qualify for subsidy.

Set-aside regulation was altered in the CAP reform. Farmers applying for the area payment are subject to set-aside part of their land from production and receive compensation for this obligation. The set-aside obligation is fixed as a proportion of the area dedicated to arable crops. The basic rate of obligatory set-aside is fixed at 10%. The land set-aside can be used to produce materials for manufacture that are not directly intended for human or animal consumption, provided that effective control systems are applied.

Non-food production on agriculture land has become of a great concern in agricultural policy. Non-food crops can be grown both on a normal land regime and on a land set-aside. The specific case are energy crops, which are crops for the production of biofuels and electrical and thermal energy from biomass. In order to support bioenergy CAP implemented payments for energy crops (EC 1782/2003). Energy crops that are grown on agricultural land that is not part of the set-aside area are eligible for an annual aid for energy crops of 45 € per hectare. Only farmers who have a contract with an energy-crop processing plant are eligible for the payment. Energy crops grown on a set-aside land are not eligible for the extra aid payment.

The total area under energy crops in the EU was around 1.6 million hectares in 2004 and is estimated in 2.5 Mha in 2005 (Vinnini et. all 2006), which represents nearly 3% of the total arable land in the EU-25, while energy crop area under specific support schemes accounts for 1.5% of total arable land. Around 35% of the total energy crops area in 2005 was cultivated under the non-food on set-aide, see Table 3. Around 23% was represented by the area under the aid for energy crops, while the remaining 42% would be cultivated outside the two regimes.

The energy crops area is concentrated in Germany, France and the United Kingdom, which together have more than 90% of the total EU-15 area, see Table 3. The crucial role is played

by Germany, where around 60% of the total energy crop area is concentrated. The quite relevant role play the Czech Republic and Poland, covering an area of 184,292 ha, around 7% of the total EU-25 area.

Table 3. Area under energy crops in EU-27 member states in 2005 in 1000 ha (Vinnini et. al. 2006)

	Total	Energy crop scheme	Non food on set aside regime	Without spec. Regime
Austria	19.63	7.91	9.37	2.36
Belgium	7.56	2.59	4.07	0.91
Bulgaria	-	-	-	-
Cyprus	-	-	-	-
Czech Republic	104.0	0.0	0.0	104.0
Denmark	47.90	17.34	24.81	5.75
Estonia	-	-	-	-
Finland	9.44	8.31	0.00	1.13
France	572.61	135.40	376.2	1.00
Germany	1356.61	235.60	341.00	780.00
Greece	-	-	-	-
Hungary	18.50	18.50	0.0	0.0
Ireland	2.36	1.61	0.47	0.28
Italy	9.80	0.29	8.34	1.18
Latvia	-	-	-	-
Lithuania	-	-	-	-
Luxembourg	-	-	-	-
Malta	-	-	-	-
Poland	60.2	3.67	0.0	56.53
Portugal	0.09	0.08	0.00	0.01
Romania	-	-	-	-
Slovak Republic	-	-	-	-
Slovenia	1.59	0.14	1.45	0.0
Spain	39.45	25.61	9.11	4.73
Sweden	37.45	29.34	3.61	4.49
The Netherlands	1.29	0.05	1.09	0.15
United Kingdom	191.17	88.59	79.58	23.0
EU 27	2479.66	575.03	859.10	1045.53

Decoupling impact on land use

It is expected that until 2012 around 90% of the total amount of direct payments is granted in the form of decoupled income support (DG Agriculture 2005). In the "Agricultural prospects for agricultural markets and income for 2005 – 2012. Update for the EU-25. Scenario analysis on decoupling" (2005) three scenarios of the implementation of reformed CAP were included to show the impact on crop and livestock production. Here we focus only on the changes in crop areas, however these are strictly combined with livestock production and changes in agricultural incomes. The scenarios are:

- Reference situation 2012.
- Full decoupling.
- Full coupling of direct payments.

In the reference situation 2012 about 90% of the total amount of EU-25 (Bulgaria and Romania were not included in the analysis) direct payments are decoupled. As far as the arable crop sector is concerned, only France and Spain grant an amount of 25% of the direct support in the form of coupled payments. Ireland, the UK, Germany, Luxembourg, Italy and Greece have additionally chosen to fully decouple direct income transfer in the beef and sheep sectors. The EU-10 countries are assumed to apply the fully decoupled payment scheme plus national "top-ups" in 2012. The output of the reference scenario is presented in Figure 24 and Figure 24.

The results showed that total oilseed acreage and set-aside and fallow land would slightly increase in the reference situation 2012, mainly at the expense of total cereal acreage. The biggest amount of EU-25 cereal production would be harvested in northern France, eastern England, north-western Germany, western Poland and Hungary. These regions would show shares of cereals in crop rotation of more than 50% and yield levels of up to 10 t/ha.

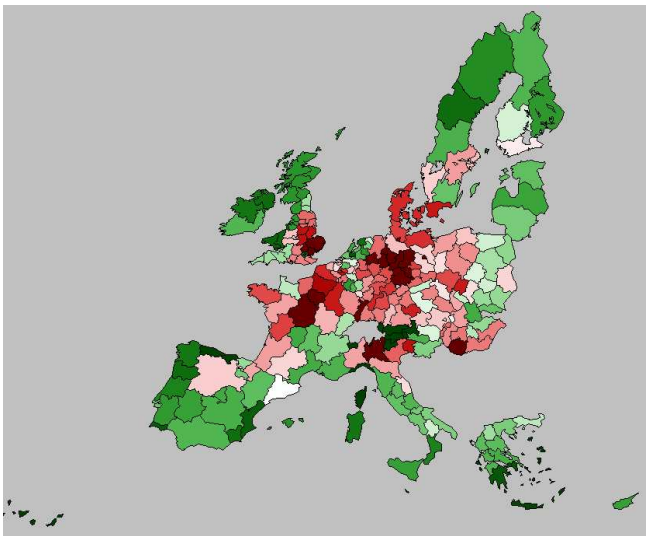

Figure 23. Reference situation 2012: regional cereals production in the EU-25 in t/ha of agricultural area (from dark green over white to dark red: 0.1 to 1.7 to 5.2 t/ha) (DG Agriculture 2005)

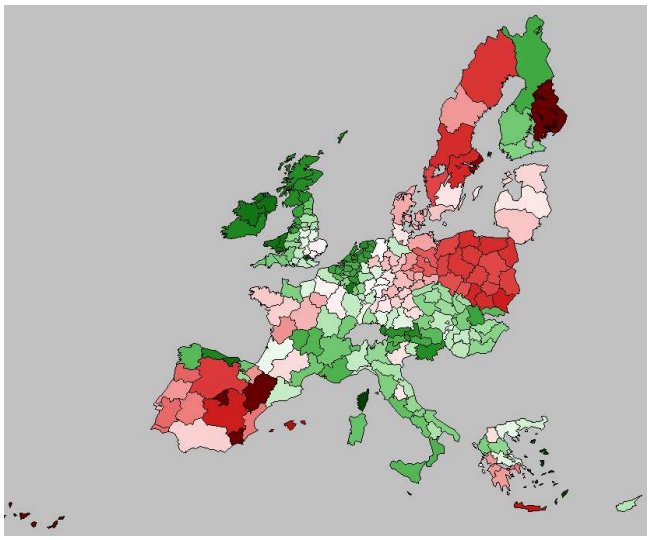

Figure 24. Reference situation 2012: regional share of set-aside and fallow land in crop rotation in the EU-25 in percent (from dark green over white to dark red: 1 to 8 to 29%) (DG Agriculture 2005)

The full decoupling scenario assumes that EU-15 countries decouple their direct payments to the maximum. For the EU-10, the fully decoupled regionalized payment scheme remains unchanged. Figure 25 shows the regional changes of cereal area in comparison to the reference situation 2012.

In comparison to the reference scenario, full decoupling of direct payments in 2012 would not lead to major changes regarding total cereal and oilseed area as well as set-aside and fallow land, because direct payments for arable crops have been already fully decoupled in the framework of the current policy implementation, only France and Spain are keeping 25% of arable crop payments coupled. Figure 25 shows, total cereals acreage would particularly decline in French and Spanish regions due to full decoupling in 2012. However, cereal area would also drop in Ireland, the UK and Italy, countries where fodder acreage would expand thanks to the higher profitability of beef production. A different reaction would be observed in the Benelux countries, in Portugal, Austria and Scandinavia, where total cereal acreage would increase thanks to a favorable development of cereal prices and the substitution of fodder on arable land by cereals.

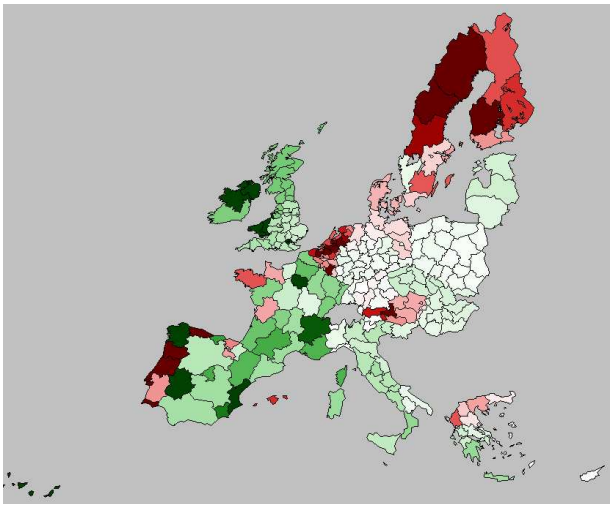

Figure 25. Full decoupling 2012: regional change of cereal acreage in EU-25 in comparison to the reference situation in percentage (from dark green over white to dark red: -3 % to 0 % to 1 % change) (DG Agriculture 2005)

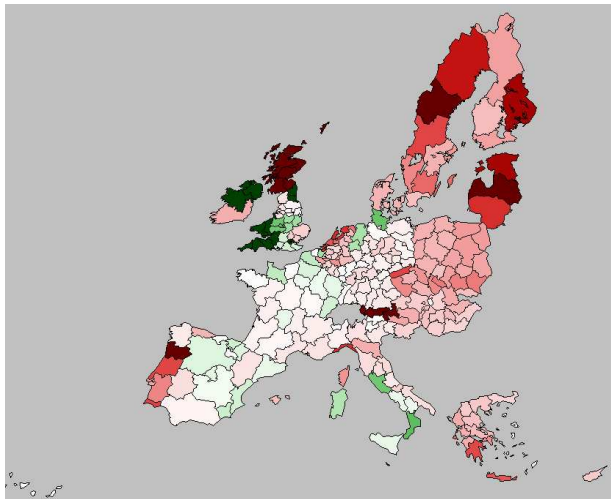

Figure 26. Full coupling 2012: regional change of cereal acreage in EU-25 in comparison to the reference situation in percentage (from dark green over white to dark red: -7 % to 0 % to 5 % change) (DG Agriculture 2005)

The full coupling scenario assumes that both EU-15 and EU-N10 countries couple their direct payments to the maximum extent in line with the effective CAP provisions. Member states are assumed to "couple" as follows: Italy, Greece, Portugal and Austria would keep 40% of the durum wheat premium coupled, whereas all other countries would opt for a 25% coupling of the arable crop premium. Figure 26 shows the regional changes of cereal area in comparison to the reference scenario 2012.

The full coupling scenario in 2012 in comparison to the reference situation showed that the overall EU-25 cereal and oilseed acreage would increase by 0.6% and 0.3% respectively, whereas set-aside and fallow land would decrease by 0.8%. Figure 26 shows the increases in cereal area would mainly take place in countries that have fully decoupled direct payments in the reference situation. Cereal area would also rise in marginal regions where set-aside and fallow land or fodder acreage are substituted.

The overall picture would change a little if Bulgaria and Romania are included in the analysis. These are one of the largest cereal producers in the EU-27. Full decoupling will start from 2014 and would result in dropping of the cereal acreage while full coupling would increase further the cereals cultivation area in both countries.

5.2. Food demand and food consumption patterns

An increase in food demand and dietary shifts are substantial factors rising claims on agricultural land. The EU-27 countries are characterized with affluent lifestyle. Food packages include not only food to fulfill basic physiological needs, but also satisfy social and cultural demands. In the EU-27 social and cultural requirements of food play a significant role on the land requirements.

Gerbens-Leenes et al. (2002) distinguish food requirements on three levels:

- The basic level: energy requirements.
- Subsistence level: food requirement optimal from a nutritional point of view.
- Cultural level: food requirements resulting from actual consumption patterns.

Cultural requirements contain a broad variety of food also with low nutrient density, for example coffee, cakes and chocolates, or higher amounts of foods than required on the subsistence level. On a cultural level various consumption patterns can be assessed among the UE-27 countries (Table 5). Food items were put into five categories: (i) beverages, (ii) fats, (iii) meat, (iv) dairy and eggs, (v) cereals, potatoes, vegetable and fruit.

Table 4. Per capita food consumption per countries in the EU-27 in grammas per day, data average for 2001-2003 (FAO 2008)

	Beverages				Fats	Meat				Diary and eggs				Cereals, potatoes, vegetables and fruits			
Country	Beer	Wine	Coffee	Tea		Bovine	Pig	Other	Poultry	Eggs	Milk	Butter	Cheese	Wheat	Potatoes	Vegetables	Fruit
Austria	309	80	18	1	25	51	200	3	47	35	205	14	57	214	171	191	115
Belgium	278	74	13	1	35	54	100	6	64	34	183	17	43	275	240	277	75
Denmark	261	91	24	1	26	73	179	2	54	46	91	5	63	290	215	199	48
Finland	243	25	31	1	3	50	91	3	40	24	342	12	43	216	194	136	44
France	82	141	15	1	12	75	103	16	71	42	173	23	67	269	181	299	83
Germany	317	66	18	1	21	31	146	11	38	34	185	18	55	229	201	196	101
Greece	101	72	12	0	1	53	86	4	51	25	216	3	67	378	188	362	94
Ireland	522	36	5	8	10	69	116	5	77	19	562	8	27	271	326	167	53
Italy	73	141	15	0	13	66	118	16	48	31	91	8	61	415	110	287	119
Luxembourg	289	171	36	1	5	120	128	8	138	23	615	0	26	215	134	268	143
Netherlands	218	45	25	3	16	56	118	8	32	48	303	6	54	209	251	185	56
Portugal	165	139	11	0	26	44	116	3	70	28	252	6	26	275	352	310	96
Spain	183	95	10	0	6	42	180	10	76	39	275	2	20	242	219	246	94
Sweden	156	45	27	1	12	60	100	7	34	29	211	10	49	224	146	145	60
United Kingdom	276	47	7	6	10	53	70	2	80	31	341	9	27	269	339	167	55
EU 15 average	231,5	84,5	17,8	1,7	14,7	59,8	123,4	6,9	61,3	32,5	269,7	9,4	45,7	266,1	217,8	229,0	82,4

	Beverages				Fats	Meat				Diary and eggs				Cereals, potatoes, vegetables and fruits			
Country	Beer	Wine	Coffee	Tea		Bovine	Pig	Other	Poultry	Eggs	Milk	Butter	Cheese	Wheat	Potatoes	Vegetables	Fruit
Cyprus	121	47	13	0	5	19	126	5	101	34	362	3	17	248	117	304	62
Czech Republic	430	28	10	1	10	21	116	11	63	41	105	12	37	270	211	145	52
Estonia	202	19	15	1	3	34	81	0	57	32	346	9	25	188	335	182	54
Hungary	200	92	12	1	49	15	135	3	90	46	215	3	27	315	189	227	35
Latvia	128	19	11	1	17	25	59	1	40	33	390	7	13	2	380	195	36
Lithuania	203	19	10	1	11	33	73	0	35	34	298	8	15	348	338	210	24
Malta	107	9	8	4	26	53	86	11	56	33	242	3	37	462	209	221	65
Poland	192	5	8	2	16	17	132	1	51	31	94	12	35	299	356	229	42
Slovakia	246	21	10	0	22	24	88	2	70	34	75	8	24	305	199	144	50
Slovenia	181	38	17	0	15	60	109	1	81	24	237	3	29	244	159	140	74
Bulgaria	128	13	8	0	9	28	93	2	50	28	327	1	11	364	93	244	41
Romania	153	62	5	0	11	20	69	2	49	35	543	1	4	452	251	292	48
EU 12 average	190,9	31,0	10,6	0,9	16,2	29,1	97,3	3,3	61,9	33,8	269,5	5,8	22,8	291,4	236,4	211,1	48,6

Large differences in the consumption of specific foods were apparent:

- Beverages: both in the EU-15 and EU-12 beer has the biggest consumption. In Ireland there is the highest beer consumption, which is about seven times more than in Italy. Wine consumption is the highest in Luxembourg and is thirty four times bigger than in Poland. The average consumption of tea and coffee is higher in the group of EU-15 than in the EU-12. The highest consumption of tea is found for Ireland and the UK.

- Fats: on average the consumption of fats was larger in the EU-12 than in the EU-15. In Hungary a citizen eats on average forty nine times more fats than a Greek citizen.

- Meat: pork has the highest consumption among all meats. In the EU-15 the largest consumption of pork per person is in Austria and in EU-12 it is Hungary and Poland respectively. Pork consumption is two times more than bovine in the EU-15 on average and three times more in the EU-12, respectively. Luxembourg is the larger meat consumer per capita and Latvia is the lowest.

- Diary and eggs: for eggs there are no large differences in consumption among the EU citizens. The highest consumption of milk and its products is in Luxemburg and is Ireland, the lowest in Poland and Slovakia. Consumption of butter, cheese and fruits was almost two times more on average in the EU-15 than in the EU-12. Use of cheese in Romania was sixteen times less than in France.

- Wheat, potatoes, vegetables and fruit. Countries of EU-15 and EU-12 showed similar level of average wheat, potatoes and vegetable consumption per capita, however significant differences can be found among countries. Latvia has extremely low wheat consumption. Check the data once again for LV

In Europe regional differences are mainly caused by variation in the consumption of meat and different drinking habits, consumption of butter, cheese and fruits. Not only meat, but also fats and beverages consumption require large agricultural land areas. Specific land requirements for these food items are shown in Table 5.

Table 5. Specific land requirements per food item in m² per year per kg (Gerbens-Leenes 1999)

Food item	Specific land requirement (m^2 year kg^{-1})
Beverages	
Beer	0,5
Wine	1,5
Coffee	15,8
Tear	35,2
Fats	
Vegetable oil	20,7
Margarine	21,5
Low fat spread	10,3
Meat	
Beef	20,9
Pork	8,9
Chicken filet	7,3
Milk products and eggs	
Whole milk	1,2
Butter	13,8
Cheese	10,2
Eggs	3,5
Cereals, sugar, potatoes, vegetable and fruits	
Cereals	1,4
Sugar	1,2
Potatoes	0,2
Vegetables	0,3
Fruits	0,5

Figure 27 shows that consumption changes over time had large consequences for land requirements in the Netherlands (Gerbens-Leenes et al. 2002). Based on yields in 1990 Dutch land requirements for food rose from 72 land units in 1950 to 100 in 1990 (+38%). Between 1950 and 1960 the rise was due to higher consumption of livestock products, fats and beverages. Between 1960 and 1990 the rise was mainly caused by higher consumption of meat and beverages while the consumption of fats, dairy and eggs stabilized.

The land requirement for specific food items changed over time. Between 1950 and 1960 the land requirement for the category of fats rose by 14%, but then remained stable. The land requirement for the category of meat only doubled, despite the increase in the consumption. This relatively low rise was due to the shift from beef consumption, which has a relatively large specific land requirement, to poultry, which has a relatively small land requirement. In the category of dairy and eggs, the land requirement rose by 13% in the period 1950–1960 and then stabilized. Smaller milk consumption and a shift towards varieties with lower fat content and related smaller land requirements was compensated by higher cheese consumption, which has a large specific land requirement. The land requirement for the category of cereals, sugar, potatoes, vegetables and fruits (c.s.v.f) remained the same. In 1950 the land requirement for foods from livestock production systems was 44% of the total; in 1990 this contribution had risen to 47%, whereas the contribution of the category of beverages had risen from 4 to 12%.

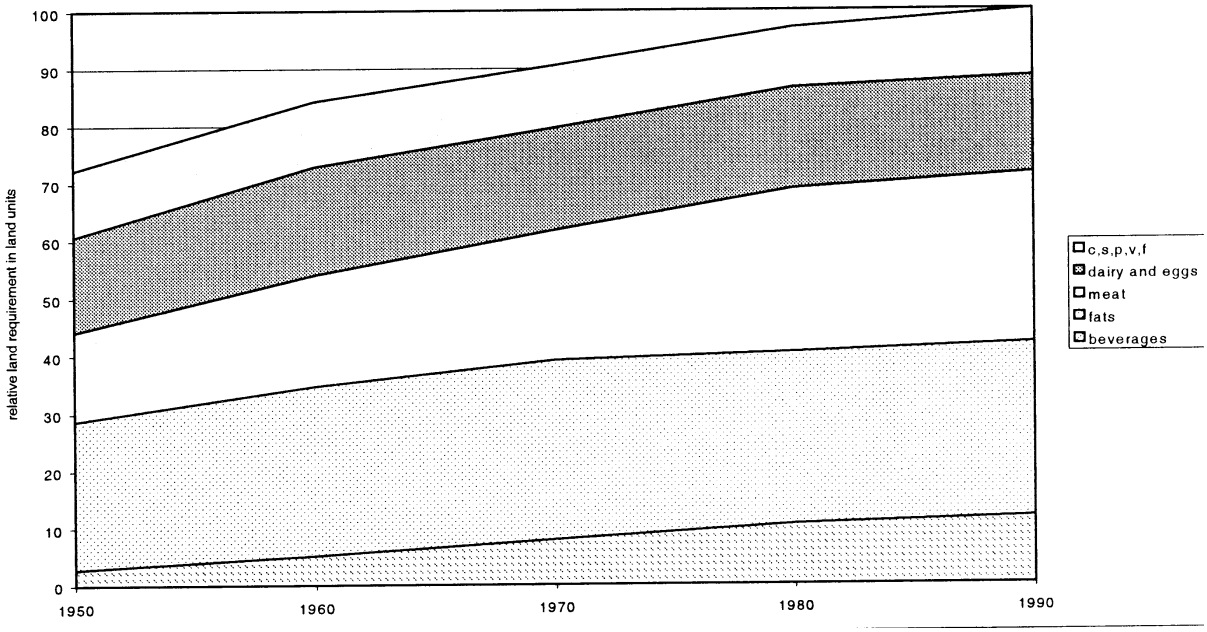

Figure 27. The development of the relative per capita land requirement in the Netherlands during the period 1950–1990 based on 1990 yields for the five consumption categories: beverages; fats; meat; dairy and eggs; and cereals, sugar, potatoes, vegetables and fruits (c, s, p, v, f) (see text for the explanation of land units) (Gerbens-Leenes et al. 2002)

Jobsevan Putten (1995) has shown that Belgian and Dutch households belonging to the upper classes consume less meat than lower-class households. However, if consumption is regarded as expenditure on food, the upper classes prefer more expensive types of meat, such as veal and lamb, while the lower classes buy the cheaper pork. It can therefore be expected that if affluence increases further in the EU, meat consumption will stabilize but beverage consumption will probably rise accordingly, generating land claims.

In the near future, the impact of the growth in the population on the land requirements would be limited in the European Union, however the consumption patterns will form a very important factor for land requirements, especially dietary changes in the direction towards the higher consumption of beverages, fats and foods of animal origin. The shifts towards more affluent diets, especially in the EU-12 would have substantial effect.

5.3. Demand for biobased materials

by Harriette Bos, Wolter Elbersen, Christiaan Bolck from Wageningen UR-BBP (NL)

Introduction

The application of biobased resources in non-food products such as materials is as old as humanity. However, with the rise of the petrochemical industry, many products that were previously made from biobased resources, are now based on petrochemical feedstock. Nevertheless, there are a number of products that are still, and probably always will be, based on biobased resources, like paper and (construction) wood.

Next to that, there are recent developments in for instance industrial biotechnology and green chemistry where new, high performance products are made from biobased resources, and which in turn replace petrochemical products.

Applications of biobased resources

Biobased resources are applied in a wide variety of products, ranging from soaps, paints, plastics, building materials to specialty chemicals and pharmaceuticals. A convenient way to categorize the variety of applications can be made by realizing that biomass supplies us with:

- Materials, using the materials just as they grow in nature, with only slight modification:
  - fibres for paper, fabrics and composites,
  - wood for timber.
- Substances, using the plant as a factory and isolating the substances, which can then be modified in order to get the desired functionality:
  - starch for plastics, glues and additives,
  - bio-oil for paints, inks and transport fuels.
- Building blocks, breaking down the biomass into building blocks to make something new:
  - lactic acid for additives and polymers,
  - ethanol for fuel and plastics,
  - furans for resins and fuels.

The logic of this classification comes from the fact that the industries and industrial chains involved are different, and this is of importance for the 4F CROPS project:

- Materials from biomass:
  - Mostly old established applications and relatively simple processes.
  - Can be big (f.i. Paper industry), but also a lot of SME.
- Substances from biomass:
  - Often using relatively simple chemical conversions.
  - Partly in present food industry (f.i. AVEBE), also SME.
- Chemical building blocks from biomass:
  - Mostly combination of white biotechnology and chemistry.

- New products and processes.
- Focal point of the chemical industry.
- Biggest potential for biomass applications.

Of course there are grey area's in between these three different classes, but as a general framework of thinking it is very useful. Also it helps to design non-food chains starting from the application and not from the crop, which is a more fruitful approach (Bos et al. 2008). An important observation is furthermore that the three different groups will have different requirements concerning the crops that are needed and thus ask for a different approach in designing the non-food crop chains.

Present size of non-food application of biobased resources

The size of non-food market has been investigated by Wageningen UR based on the Eurostat production data of the EU-25 for 2005. In this work the same approach was taken with respect to the categorization of the applications as proposed in the previous paragraph. The results of this project are given in Table 6.

Table 6. Registered production value for biobased products in EU-25 in 2005 (Nowicki et al 2007)

	Number of product categories	Percentage product categories registered	Total registered value* (billion €)	Present share Biobased ** (billion €)	Potential share Biobased ** (billion €)
Materials from biomass	323	78%	250.6	187.7	211.6
Substances from biomass	101	60%	47.9	23.2	38.5
Building blocks from biomass	356	33%	155.2	34.5	81.6
Totals	780	55%	453.7	245.3	331.8

* excluding the confidential data
** of the non-food, non-feed component, based on expert estimation

In this work an estimation was made of the production values of the present production of materials partly or fully based on biobased resources. For this, from the over 4000 products in the Eurostat-Nace database, 780 products were selected that are presently partly of fully biobased or that could potentially be made from a biomass resource (last column). As can be seen in the table there is a very substantial non-food market, with a size in the same range as the EU food market.

A drawback of the database is that a relatively large proportion of the production data are confidential, for competitive reasons, so not all products are actually registered. On the other hand the database also includes some double counting. However, the work gives a good idea of the size of the non-food biobased market. It is concluded that especially in the group

building blocks from biomass there is a large potential for growth compared to the present size of this application group.

Crop demand for non-food applications

From the product database, a relatively detailed estimation can be made concerning the crops that are presently used for this application. More important, the crops that in the future may be used to fulfil the non-food product demand can be estimated starting from the end products. This work is presently being undertaken within the framework of the 4F CROPS project. It will be approached in the first step by estimating the demand for the main composing elements of biomass: carbohydrates, oils, proteins and other. This can be further specified in a next step, towards cropping possibilities. This work will be reported the beginning of 2009.

Not included as yet is the demand for products that do not yet exist, as they are obviously not included in the Eurostat database. Within workpackage 6, that will start in 2009 these issues will be addressed.

The work underlying this part of the workpackage was presented as key lecture at the first workshop of the 4F CROPS project in Bologna, on the 17th of September.

5.4. Demand for bioenergy and biofuels

Recently, an increasing number of actions have been taken to promote renewable energy in the European Union. Bioenergy is of major interest as it is estimated to have the greatest technical potential in a short and medium-term in most of the European countries among the renewable energy resources. It can contribute to energy security, boost economy, and reduce environmental impacts including global warming.

Bioenergy and biofuels are promoted by several policies, including:

- While Paper on energy policy.
- White Paper on RES & Action Plan.
- Green Paper on security of energy supply.
- Directive 2001/77/EC on renewable electricity.
- Directive 2003/87/EC on emission trading.
- Directive 2003/30/EC on liquid biofuels.
- Directive 2004/8/EC on cogeneration.

The major legislation stimulating the development of renewable energy are the Directives 2001/77/EC on renewable electricity and Directive 2003/30/EC on liquid biofuels.

The target of the Directive 2001/77/EC are to establish a framework to increase the share of green electricity from 14 to 22% of gross electricity consumption in the EU-15 by 2010, to help to double the share of renewable energy from 6 to 12% of gross inland energy consumption in Europe by 2010. The 22% target set initially for the EU-15 become 21% for the enlarged Union.

The Directive 2003/30/EC on liquid biofuels aims at promoting the use of biofuels or other renewable fuels to replace diesel or petrol for transport purpose in each member state. The directive sets a European target of 5.75% substitution of conventional fuels with biofuels by December 2010.

On 23 January 2008, the European Commission has published a Proposal for a Directive [COM (2008)19 final] on the promotion of the use of energy from renewable sources for the 27 European Member States. The directive is a part of a Energy and Climate package accepted by the European Council in December 2008.

This law will take the superior position in the renewable energy promotion. The Directive has been designed to boost the use of renewable energy in the EU to 20% by 2020. National targets are laid down in the Directive in order to meet that goal. Additionally, each member state shall have a minimum, binding 10% target for the share of energy from renewable

sources in transport in 2020. the Directive will stimulate both, the use of biomass for bioenergy and transportation biofuels.

Table 7. Renewable energy targets for the EU

Sector	Measurement	Target
RES electricity	Percentage contribution to gross electricity consumption	21% by 2010 (Directive 2001/77/EC)
RES heat	Share of renewable energy used in heating and cooling (not specified further)	20% by 2020 (proposed by Parliament)
RES transportation	Percentage contribution of bio-fuels and other renewable fuels on the total quantity of fuels placed in the market	5.57% by 2010 (Directive 2003/30/EC) 10% by 2020 (RES Directive)
RES overall target	Percentage contribution to the EU gross inland energy consumption	20% by 2020 (RES Directive)

As mentioned above bioenergy is estimated to have the leading position in the development of renewable energy usage. The European Environmental Agency report (2006) showed that biomass from agriculture provides the largest bioenergy potential in a long-term. The environmentally-compatible bioenergy potential from agriculture could reach up to 142 MtOE by 2030, compared to 47 MtOE in 2010 (EEA 2007). This potential is contingent upon assumptions regarding the farmland area available for energy crop production in each member state, the competition with food and export markets, the impact of environmental constraints and the yield of the assumed bioenergy crops. Approximately 85% of the potential estimated by EEA will come from only seven member states (Spain, France, Germany, Italy, the United Kingdom, Lithuania and Poland). Total land area corresponding to the estimated potential is 14 Mha in the EU-25 in 2010 and app. 20 Mha in 2030. Land areas available for energy crops per country for three scenarios corresponding to year 2010, 2020 and 2030, respectively, are presented in Figure 28.

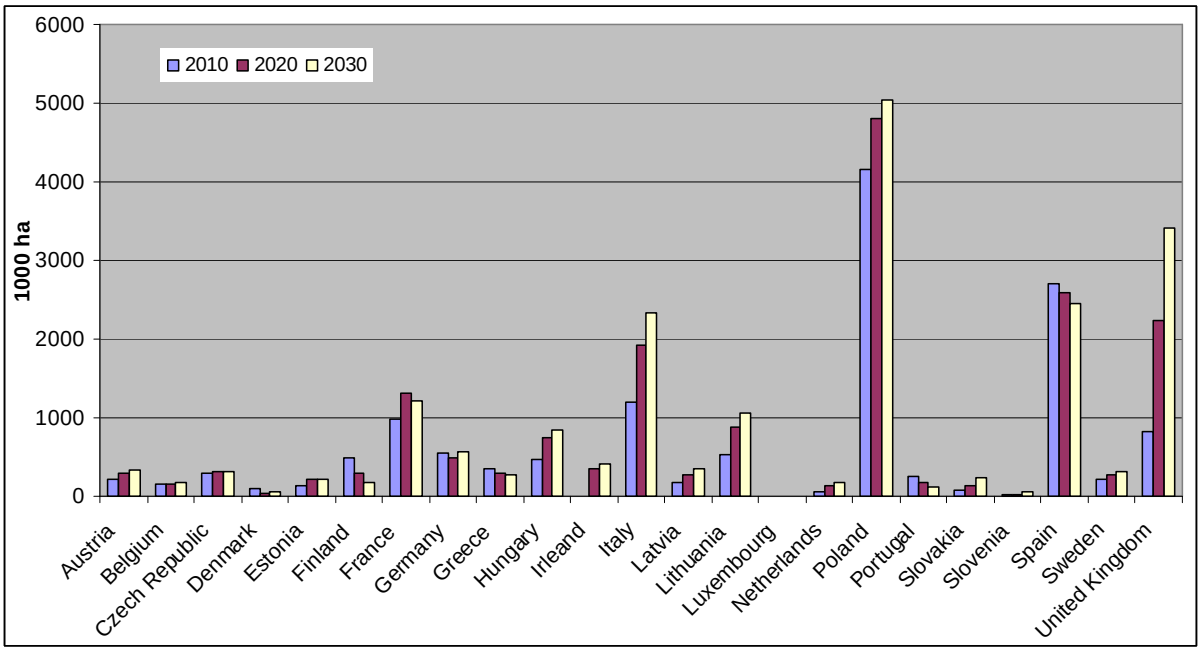

Figure 28. Area available for energy crops corresponding to environmentally compatible bioenergy potential for EU-25 (based on EEA 2007)

Today, most agricultural bioenergy production is linked to the first-generation biofuels. These are oil crops and sugar and starch crops which are converted into transportation biofuels. The main examples for large-scale commercial energy crop production are oil seed crops for bio-diesel or cereals for bio-ethanol in e.g. France, Germany, Austria and Italy. The total area of oilseeds cultivated for biodiesel in the EU-15 was estimated at 1.23 Mha in 2005, for cereals it was 134,000 ha respectively (Vannini et. all 2006). These examples mostly exist due to the political and financial support given. However, other energy pathways related to heat and electricity are gaining importance. The production of short rotation coppice (SRC) for heat and power in the UK, Sweden and Finland has also made considerable progress.

It is expected that there will be a shift from first-generation biofuels (plant oil, biodiesel and ethanol from cereals, sugar beet or potatoes) into second-generation biofuel production from ligno-cellulosic material. The second-generation biofuels can use various feedstock, including agriculture and forestry residues as well as dedicated energy crops. Perennial energy grasses (PEG) and short rotation coppice (SRC) are key examples for such crops and usually characterized by high yields per hectare as well as mostly low environmental pressures. However, sustainable methods in biomass cultivation, harvesting, transportation as well as technological breakthrough in refining processes are needed before commercialization of these next generation biofuels from non-food feedstock can take place.

It can be expected that PEG and SRC become more important in the crop mixes after 2010 when new technologies enter the market and bio-heat options are further developed. Nevertheless, even if the cultivation of PEG and SRC are often considered as a very promising renewable energy option for the future, their actual implementation in Europe at the end of 2008 was still very limited. Current plantations are mostly grown on an

experimental basis, with the exceptions of the UK, Sweden, Finland and to some extent Italy (Barto 2006).

According to the investigation of AEBIOM (2007) the total area of perennial crops in the EU-25 amounted to some 50,000 ha in 2006. This included short rotation coppice and perennial grasses. Short rotation coppice area mainly willow plantations in Sweden (12,500 ha), Poland (9,000 ha) and the United Kingdom (4,000 ha). Miscanthus is cultivated in Italy (7,500 ha), United Kingdom (4,000 ha), Austria (3000 ha) and Ireland (150 ha). In Finland there are considerable large areas of reed canary grass cultivated on peat lands (12,000 ha).

5.5. Climate change impact

by Andrea Monti, Department of Agroenvironmental Science and Technologies, University of Bologna (IT)

Interactions between climate change and land use are very intricate and not well understood as they depend on decisions at different scale levels, from farmers to global organizations, as well as on the choice of model driver parameters: technological and demographic developments, food and feed demands, social and economic opportunities, land use and crops competitions, environmental challenges, protected areas etc. Furthermore, when the assessment of land use is restricted to European lands, it is important to take into account how this can be influenced by global trade outside of Europe. That is, the assessments on land use climate change relationships should involve not only the reciprocal influences, but also the global market demand which may be sometime prevalent against climate change toward driving land use changes. To obviate this, global trade simulating models should be used.

A further difficulty in the analysis of climate change - land use/cover relationships is that climate change generally causes counteracting and/or feedback effects on crop productivity and thus in turn on land use. The rise in atmospheric CO_2 concentration, for example, may increase the crop yield, especially in C_3 crops, but at the same time, it will lead to higher greenhouse effects and water shortage, especially in southern Europe, which in turn will negatively affect the crop productivity. Whether and to what extent the rise in CO_2 will offset the more severe drought conditions is still a controversial matter. A recent study reported that the average crop yield across Europe will change from -3% to +1% due to climate change, from +11% to 32% due to the increase in atmospheric CO_2, from +25% to +136% due to the advances in technology (Ewert et al. 2005; Rousenvell et al. 2005; 2006). Though these findings greatly changed in relation with specific environmental conditions, the authors estimated that, depending on orientation towards sustainable agricultural systems, from 50% to 67% less land will be used for crop production over the next 50-70 years.

A look forward

Intergovernmental Panel on Climate Change (IPCC) provided amassing evidence that increase in atmospheric GHG concentrations leads to a rise of temperature while altering the patterns of rainfall and climate factors for a large part of Europe, see Figure 29 and Figure 30. There is a wide consensus that this will occur rapidly and accompanying land use change shall be expected accordingly. However, the influence of climate change upon land use is not unequivocal: there is a still high uncertainty in land use model predictions (Pontius and

Malanson 2005) as several recent studies produced very different scenarios (Brower and McCarl 2006).

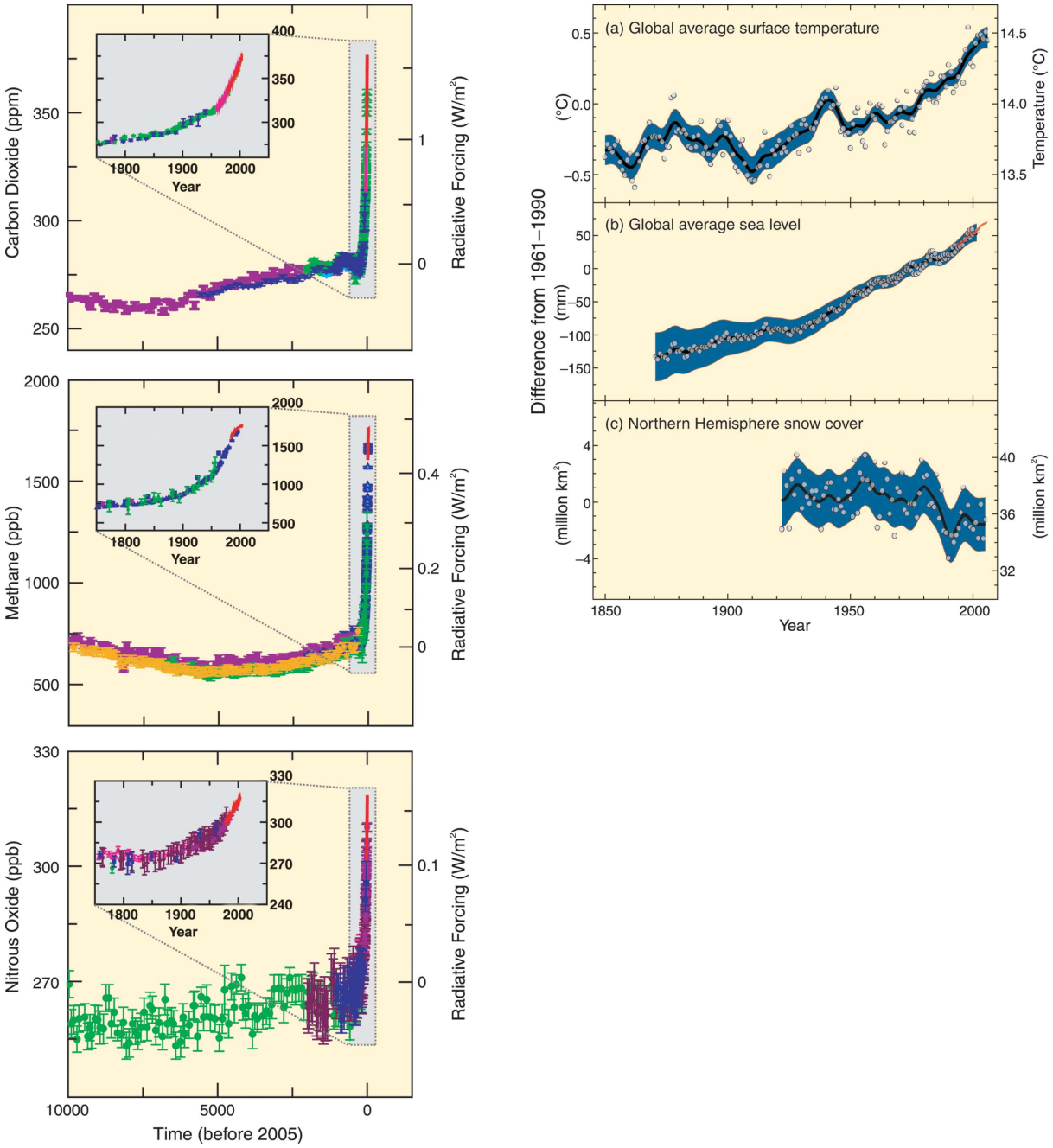

Figure 29. Hockey stick patterns of CO2, methane and nitrous oxide (right) and their consequences on air temperature, sea level and snow cover (IPCC 2007)

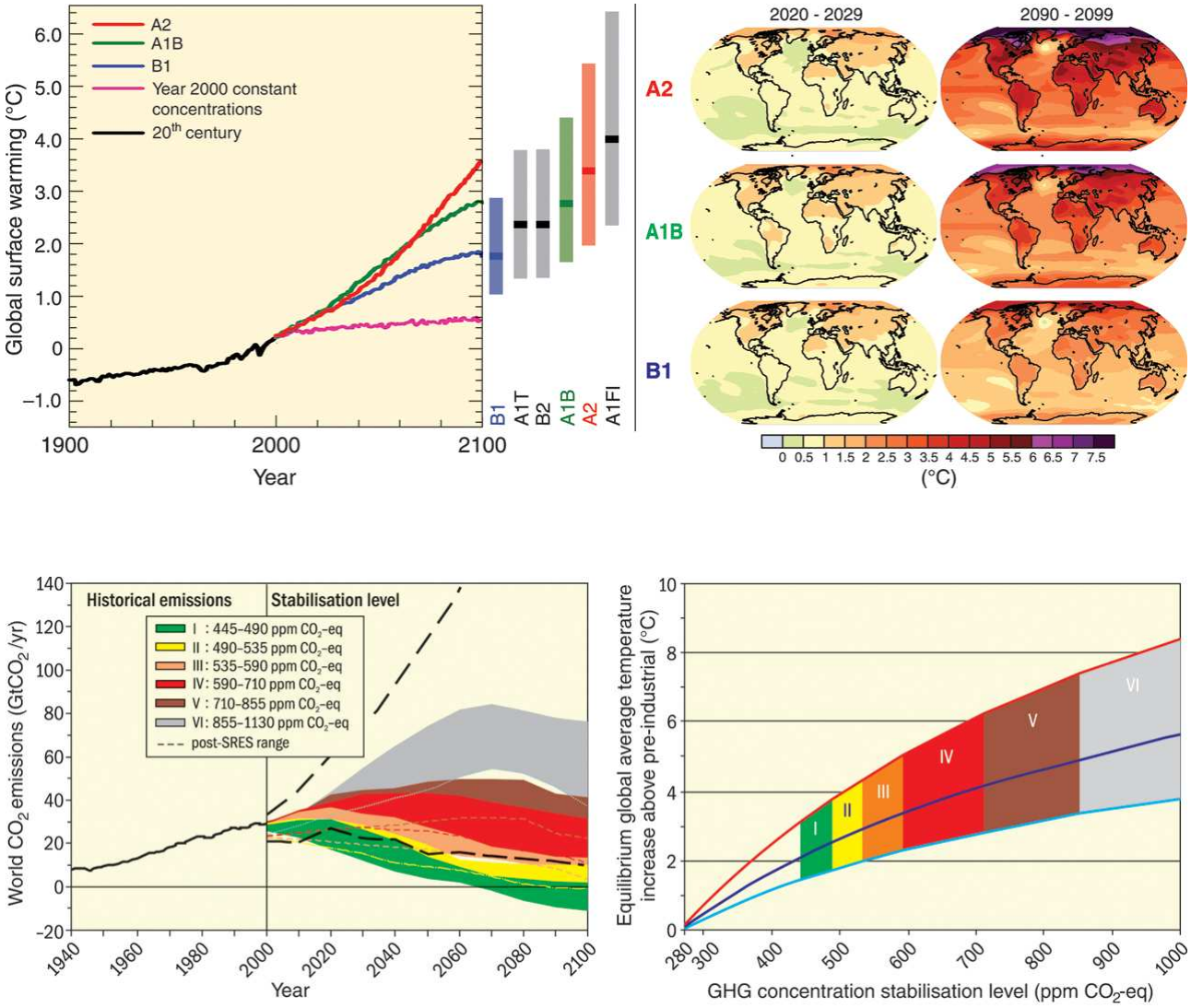

Figure 30. Projections of global warming and CO2 emissions according to different scenarios (IPCC 2007)

These contrasting results can be explained by the intricate relationships between factors. For example, food and feed demands are projected to increase rapidly, and these will likely affect land use to an even more extent than climate change thus making the projections on land use further unclear. Climate change will in turn affect the productivity of crops (Ewert et al. 2005), which influences the agricultural land use (Rounsenvell et al. 2005), and this, again, will affect climate change thereafter through the emission and sequestration of GHG from soil and productive processes. Recent studies using the fully coupled Department of Energy Parallel Climate Model (DOE-PCM) (Meehl et al. 2005) to simulate combined land cover and atmospheric forcings have in fact shown that future land use, and land cover, will be important drivers of climate change. Nonetheless, the role of land use and land cover change in altering regional temperatures, precipitation, vegetation, and other climate variables has been mostly ignored. As a result, IPCC (Intergovernmental Panel on Climate Change) simulations on climate change can be expected to be significantly worse from those based only on air composition change (Feddema et al. 2005; Pielke 2005). For example, Feddema et al. (2005) reported that even minor deforestation can alter local rainfall patterns and the

conversion of forests to agriculture will probably lead to a significant warming well above the predicted 2°C. Again, Guo and Gifford (2002) reported that soil carbon stocks increased by 18% after land use changes from crop to grasslands, while it decreased up to 59% when pasture was converted in cropland. These results were also corroborated by more recent studies proving substantially different environmental impacts of perennial and annual crop systems (Fargione et al. 2008). That land use and land cover will act as major drivers of climate patterns should not surprise as NASA reports that "between one-third and one-half of our planet's land surfaces have been transformed by human development". Therefore, a not clear hierarchical relationship seems to be between climate change and land use, indeed a sort of "Catch 22" (Heller 1961) mutual influence between them likely exists.

Projections of land use

We refer to a number of recently published studies on land use scenarios undertaken within the framework of the European Union funded research Projects ATEAM and ACCELERATES (Rounsevell et al. 2005; Ewert F. et al. 2005; Tuck et al. 2006; Rounsevell et al. 2006). These studies assumed the following hierarchical competition on land use: protected areas > urban > cropland > grassland > bioenergy crops > commercial forest > non actively managed lands (or surplus lands mostly represented by abandoned lands). Briefly, urban land is geographically limited by housing demand and by land use planning policies. Bioenergy crops rank below food production, the latter being reasonably assumed to take precedence over energy demand. In addition, the proximity to urban centers for efficient heat use was taken into account for a coherent allocation of bioenergy crops. An assumption was made that European protected areas will progressively increase up to 20% by 2080. The hierarchy is also adjusted according to productivity differences with latitude and crops. For example, in northern latitudes, forests prevail over agriculture because in these areas agricultural productivity is too low.

The methodology was based on different marker storylines of the IPCC of Special Report on Emission Scenarios (SRES) (Nakicenovic et al. 2000) integrated with climate change scenarios derived from HadCM3 model (Mitchell et al. 2004). Each SRES storyline describes different situations in term of socio-economic, demographic, technological and environmental conditions. The influence of global market demands outside Europe was taken into account by the use of IMAGE model which predicts global demands for animal products, food crops, grass and fodder species, wood and biofuel crops.

The effect of climate change (not including CO_2) was calculated from the change in yields between the baseline and each future climate scenario. Average crop yield in each grid cell was estimated by an empirical model based on the environmental stratification of Europe as given by Metzger et al. (2006), see chapter 2. Briefly, each yield value (Eurostat 2000) was associated to the relative stratification class through the intersection of the geographical location of each class with crop yield. Changes in crop yield were modeled accounting for effects of climate change, CO_2 increase and technology development assuming that these effects were additive. The effects of increasing atmospheric CO_2 concentrations were calculated by the relative yield change per unit increase in CO_2 and the difference between the today and future CO_2 concentration (Amthor 1998). The latter was estimated to be from 417 to 427 µmol mol^{-1} in 2020 (best and worse scenario, respectively) and from 518 to 766 µmol mol^{-1} in 2080 (HadCM3 model). The relative yield change per unit CO_2 concentration was set to 0.08%. The effects of climate change on crop yield were calculated from the strong

correlation between crop yield at regional level (Eurostat 2000) and environmental strata (Metzger et al. 2006). Changes in climatic conditions generated by HadCM3 model (Mitchell et al. 2004) were used to calculate changes in the distribution of environmental strata and thus in turn of changes in the distribution of crop yields, see Figure 31.

Overall, the results show that the increases in crop productivity in 2020 will be from 25% to 41% (from 43 to 163% in 2080), mostly due to technological development and to a lesser extent to CO_2 increase (about 4% in 2020; from 12% to 32% in 2080, depending on scenario) and climate change (about 1%, irrespective of time scale). Climate change and increasing CO_2 concentration increase crop yields compared to the baseline in north Europe while decreasing yields in southern Europe, especially in Spain, Portugal and south Italy and secondary in France and north Italy, see Figure 31. Negligible effects of climate change will occur in the rest of Europe. Due to technological development a large reductions in land use for food and feed production was estimated, which were partially offset by forest land, protected areas and energy crops lands, see Figure 32. Variations in urban areas are conversely negligible. In the two last scenarios of Figure 32 the abandoned lands (surplus) are strongly reduced as it is assumed that the policy towards limiting crop productivity are adopted to cope with land abandonment. Measures could be the promotion of extensive cropping systems, organic farming and the replacement of food crops with energy crops. Importantly, in all scenarios crop land declines mostly due to the technology development. However, how this interacts with land use and climate change relationships is not understood and therefore should be considered more explicitly in future researches.

European Commission has planned to strongly increase the investment on bioenergy crops in short term as important renewable alternatives to replace fossil fuels. Therefore, reliable land use change scenarios should always include these crops along with the traditional ones. In this regard, a recent study (Tuck et al. 2006) have derived maps of the potential future distribution of 26 energy crops (oil, starch and solid biofuel crops) in Europe, based on crop adaptability and tolerance to the climatic conditions as predicted by SRES emission scenarios (IPCC). A limit of this study was that potential crops distribution was estimated on the base of growth temperature and rainfall, while soil type, slope yield and markets were not take into account. Overall, the results show that the possibilities to successfully grow oilseeds, cereals, starch crops, and solid biofuels are expected to increase in north Europe, mostly due to higher summer temperatures, and decrease in southern Europe (e.g. Spain, Portugal, southern France, Italy, and Greece) due to water shortage. These trend is initially slightly visible (2020) and then it becomes much more pronounced (2080 scenarios) according to other global climate models (e.g. CSIRO2, PCM and CGCM). Spain appears particularly affected by climate change, which causes a drastic decline of many temperate crops in this area. Therefore, there is evidence that the choice of bioenergy crops in southern Europe will be restricted to a very small number of crops (e.g. sorghum, sunflower and miscanthus) unless alternative agronomy strategies (e.g. earlier sowing) or selection programs will provide new genotypes with higher drought adaptability. However, it should be underlined that other solid biofuels were not included in this analysis which can be expected to be more tolerant than miscanthus to drought (e.g. giant reed and switchgrass).

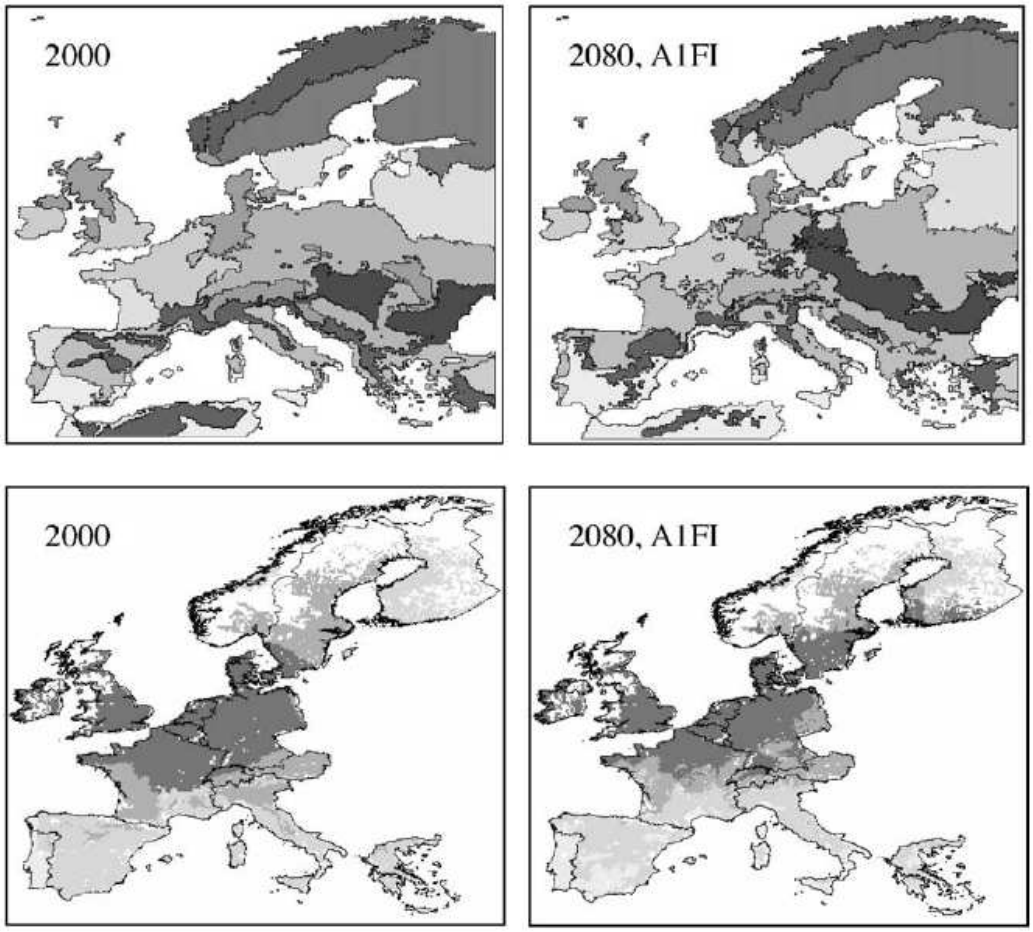

Figure 31. Distribution of environmental zones (top figures) and wheat yields (bottom figures) in 2000 and 2080. Same colors indicate same environmental zones or yield levels, the latter increasing from white to black

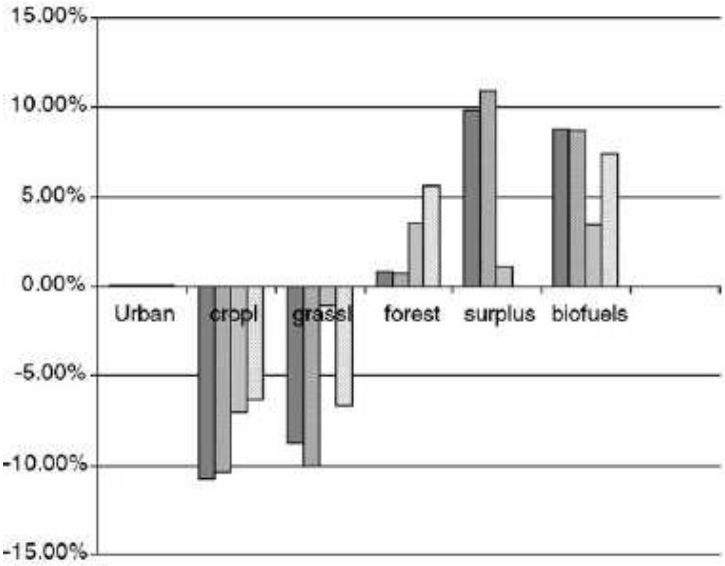

Figure 32. Projections of competitive land uses. Bars indicate four different scenarios according to SRES scenarios elaborated by IPCC (Rounsenvell et al. 2006). Surplus land indicate "non actively managed lands" mostly represented by abandoned agricultural lands

6. Conclusions

The land use fulfills thee main functions: social, economic and environmental. Here are some conclusions of this study concerning the land use structure in the EU-27:

- Land use defined as the area of different crop types is shaped in relation to climatic and soil conditions, traditional land use patterns, farming structure, and organizational and economic conditions in the agricultural sector.

- The main driving forces for land use change in Europe are: demand and supply for certain crops, rules of the Common Agricultural Policy and the global market situation for land derived products.

- Agricultural land use on a regional and national scale is the sum of decision making on farm level. Farmers seek to maximize their profits.

- Decoupling payments from production under the Common Agricultural Policy came out to free the farmers decisions what to produce. The land use areas increase if the demand increase. Thus, the land use corresponds to the market situation for specific crops.

- Ingeneration in specific crop market, such as putting production quotas and/or setting an intervention market price, has a very strong and direct effect on land use. One example is the sugar sector reform, which resulted in a large reduction of sugar beet area across the whole of EU.

- The set-aside obligation proved to be a very effective mechanisms of reducing food overproduction in Europe. Simultaneously it is very effective in promoting non-food crops production.

- Specific policy targets related to land derived products, such as transportation biofuel targets has an important impact on land use in the EU. The area of crops for production of biofuels is increasing. Energy crops are predominantly cultivated on an obligatory set-aside land.

- The global market situation affects the crops areas in the EU. One example is the demand exceeding supply on the global cereal market in 2007, which resulted with extended cereal cultivation areas in the EU in 2008. However, the changes are within the crop rotation limits.

- The EU citizens have affluent diet with broad variety of food items. Changes in the demand for food in accordance in the land use come from the shifts in the diet rather than from growth of the EU population. Meat consumption is expected to stabilize while the cultural requirements will further rise (consumption of beverages).

- Climate change would have an impact on land use, however the mechanisms are not well understood so far. The future projections show crop yields increasing in the north of Europe while decreasing yields in southern Europe.

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