Future Crops for Food, Feed, Fibre and Fuel

FP7-KBBE-2007-1

Grant agreement for: Coordination and Support Actions

Land use in EU-27 now, in 2020 and 2030

Lead contractor for this deliverable:

Institute for Fuels and Renewable Energy (PL)

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Deliverable no	2
Delivery date:	February 2010
Dissemination level:	Public

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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.

Work package 1 (WP1) "Land use in the EU-27" deals with land use assessment as both food and non-food cropping systems compete for the same available land resources. The deliverable titled "Review of the current situation for land use in the EU-27" presented the overview of the land use in the European Union in 2008. Now, the second deliverable comes, which presents the results of the land assessment available for non-food agricultural production systems in the EU-27 now, in 2020 and 2030.

The estimated areas of surplus land could be potentially used for non-food crop production in the future, however this would be decided under different aspects such as profitability of production, soil suitability, environmental impacts as well as social acceptability. These issues are out of this study, however they are considered in other work packages of the 4F CROPS project.

The deliverable is structured within six chapters. The Introduction is followed by land assessment methodology description, see chapter 1. It includes the explanation of a land allocation model, projections on future yields of crops and changes in the population. Chapter 2 includes description of the scenarios: the Base Case, scenario 2020 and 2030. Results of the assessment are presented in chapter 3, which is followed by the discussion of results in chapter 4. Finally some conclusions come.

1. Methodology and data

1.1. Introduction

Modeling non-food cropping systems, which can be implemented alongside the existing food crop systems is a complex issue, which would require system dynamic models to study the potential dynamics over time from a systems perspective. However, due to the type of the project (Coordination and Support Action), under which the deliverable is produced, the work is scheduled to be done as a desk study based on the existing models and literature review.

The assessment of land availability for non-food systems is performed with the use of a land allocation model elaborated by ECBREC team (IPiEO) under the EU-founded RENEW project (www.renew-fuel.com). The core of the model is kept unchanged, however, the input data and assumptions on scenarios are established new for the 4F CROPS project. The key assumption is that non-food crops can be cultivated only on a surplus land that is left after satisfying food and fodder production. The overview of the approach is presented in Figure 1.

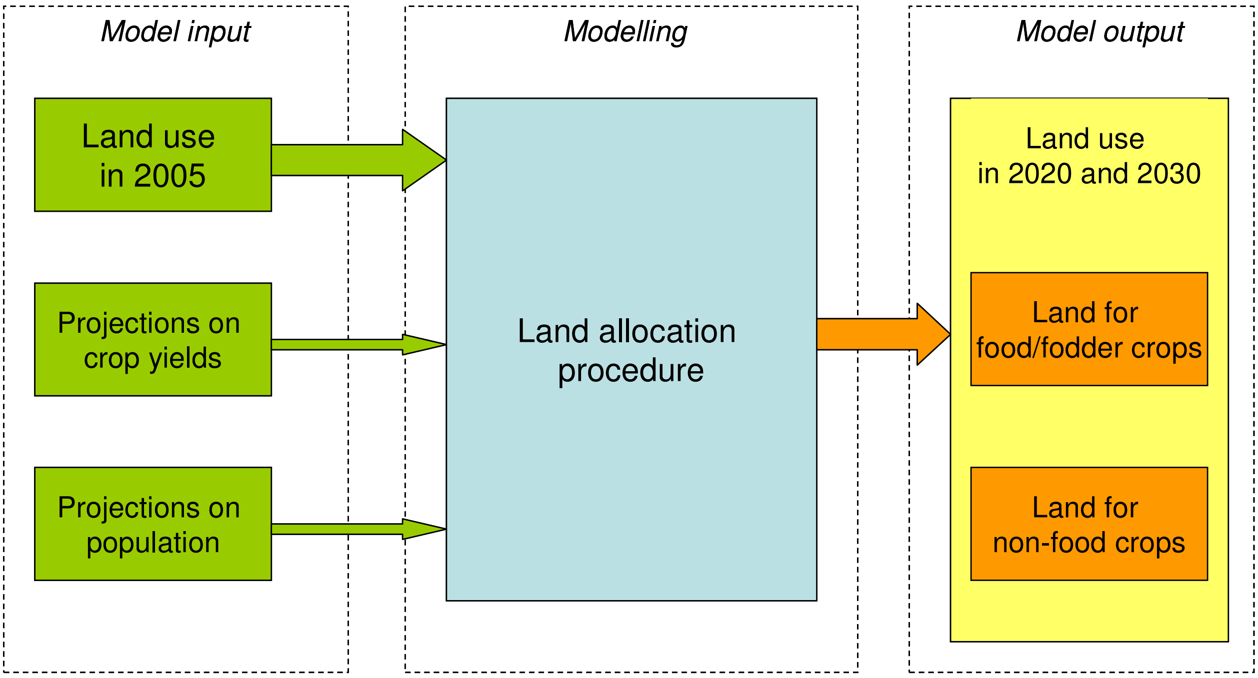

Figure 1. Overview of the land assessment approach used in the 4F CROPS project

1.2. Land allocation model

A land allocation model elaborated by ECBREC team (IPiEO) under the EU-founded RENEW project (www.renew-fuel.com) was originally used to estimate land available for energy crops (in 1000 ha) and calculate the energy crop production potential (in PJ) based on relevant energy crop yields. For the need of 4F CROPS project, the model is used to calculate the surplus land that can be available for non-food systems in the EU-27 not affecting food crops production. No specification is made how much of the estimated surplus land is used for specific non-food crops species.

The land allocation for 2020 and 2030 under 4F CROPS is based on a *Base Case* situation, which reflects the average situation for land use within the period 2003-2007 in the EU-27. The data for the Base Case are derived from EUROSTAT database and include statistical data on land use, crop production volumes and yields. The calculations are performed on NUTS-2 level regional level (with the exception of Germany, which is NUTS-1 level) and the results are aggregated into national (NUTS-0) level.

The land allocation model includes following modules:

- Land allocation for agricultural crops in the base case situation (2003-2007).
- Estimation of future crop production and yields.
- Land allocation for agricultural crops for the future scenarios (2020 and 2030).
- Land balancing (surplus land or land deficits estimated).

The modules are strongly linked to each other, see Figure 2. The description of the separate modules is presented below.

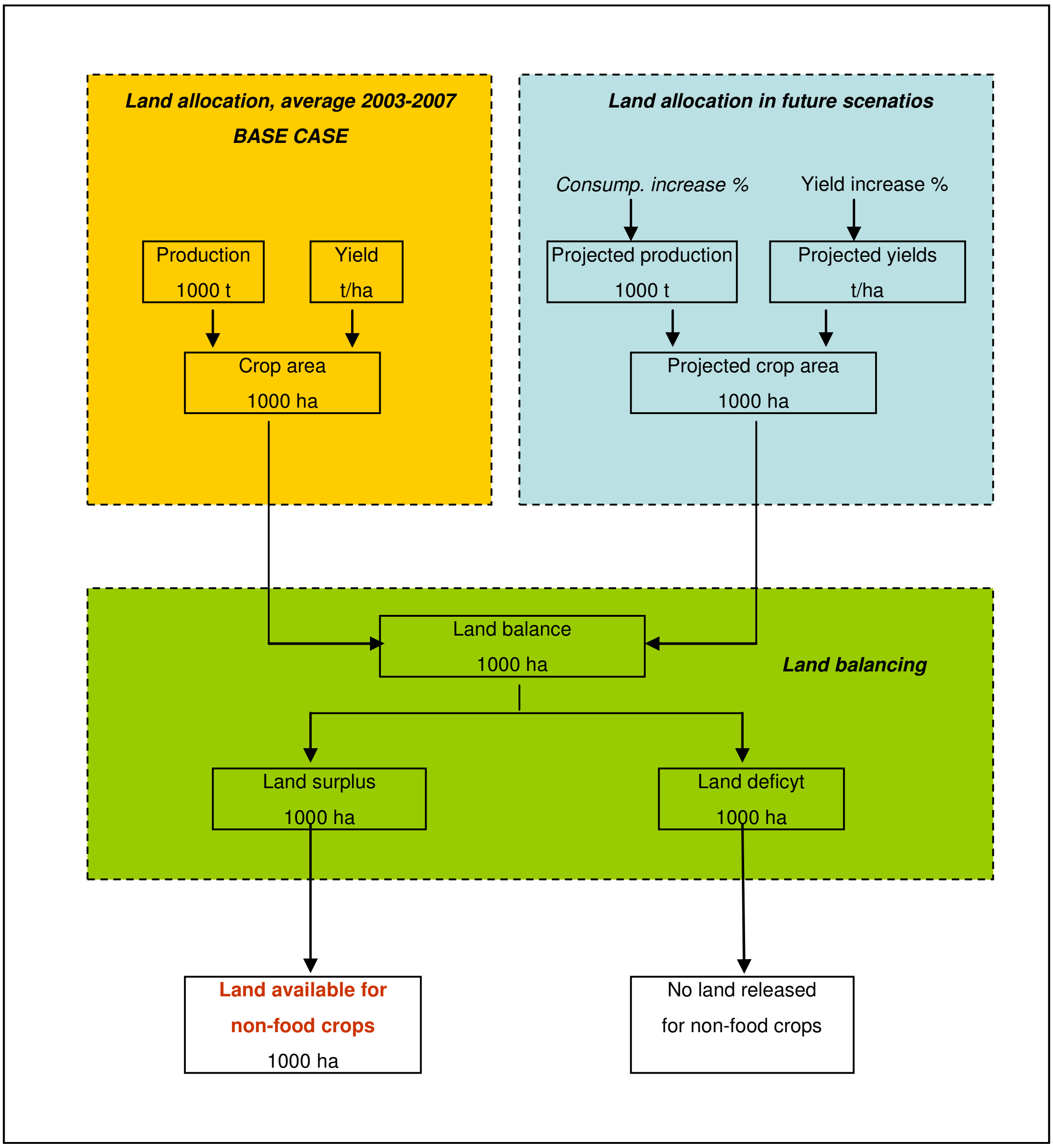

Figure 2. Overview of the land allocation model

Land allocation for agricultural crops in the Base Case. This reflects the Base Case land use situation in the EU-27 and is built on statistics on production (1000 t) and yields (t/ha). The mean values of 2003-2007 are used in order to avoid yield and production annual fluctuations. Apart from arable crops, data on fallow land, permanent crops and permanent grassland are included in the land allocation model and they are kept in the future scenarios as given in the Base Case statistics. Area that is currently under the energy crops is also included and fixed for the future scenarios.

Agricultural land use is grouped into four main categories, including six categories of arable crops, see Table 1.

Table 1. Crop categories in the land allocation model

<table>
<tr><th colspan="9">Utilized Agricultural Area</th></tr>
<tr><th colspan="6">Arable land</th><th rowspan="2">Permanent crops</th><th rowspan="2">Permanent grassland</th><th rowspan="2">Other</th></tr>
<tr><th>Cereals</th><th>Oil and Industrial crops</th><th>Root crops</th><th>Fodder and grazing from arable land</th><th>Pulse</th><th>Fallow land</th></tr>
<tr><td>Wheat, barley, rye, oats, maize grain</td><td>Rape seed, sunflower, soya bean cotton, flax, tobacco, etc.</td><td>Potatoes, sugar beets, etc.</td><td>Maize fodder, etc.</td><td></td><td></td><td></td><td></td><td></td></tr>
</table>

Estimation of future crop production and yields. In order to estimate future yields of crops an assessment on yield increase rates has to be done, see section 2.2. Population forecast are used to calculate the future production of food crops, see section 1.4. Finally, the projected yields and future crop production volumes are used to calculate the land allocation in 2020 and 2030, which is performed in the next step.

Land allocation for agricultural crops in the future scenarios. The future land allocation is performed for the estimated future food and fodder crop production (1000 t) and future yields (t/ha). The allocation has to be done within the available agricultural land resources, which are kept constant. To avoid overlapping of crop areas or exceeding the total agricultural land strict allocation rules are applied:

- Compensating land deficits within the same crop category – if the cultivation area of a specific crop in the future scenario exceeds the area allocated to this crop in the Base Case, the land deficit is compensated with land released from other crops within the same crop category (for crop categories see Table 2).

- Setting to zero for a crop category – if land deficit for a whole crop category occurs (the area in 2020 or 2030 exceeds the area from the Base Case), it is not compensated by land released from another crop categories. Then, no surplus land is available from this specific category.

- Setting to zero for the whole arable land – if the arable land in the future scenarios 2020 or 2030 (sum of cultivation areas allocated to all food/fodder crops) exceeds the arable land of the Base Case (including the rules above), then, no arable land is released for non-food crops.

Land balancing. Surplus land that is considered potentially available for non-food crops in the future scenarios is and outcome of a land balancing procedure. It is based on the changes in the land allocation under food and fodder crops between the Base Case and the future situation. Following rules are used for the land balancing procedure:

- If the land area under a given crop decreases in the future compared to the Base Case, surplus land becomes available. However, in countries which are net importers of a given crops the released land is firstly allocated to domestic production and then only the surplus becomes available for non-food crops.

- If the land area under a given crop increases in the future compared to the Base Case, no land is released for non-food crops.

In a result of the land balancing procedure following land categories may become available for non-food crops:

- Land released from food/fodder crops due to the projected productivity increase.

- Fallow land (as it is in the Base Case)

- Land under energy crops (as it is in the Base Case).

The model calculates the total amount of surplus land, however it does not make any allocation of these areas under different types of non-food cropping systems.

1.3. Current and future crop yields

The estimation of future crop yields is a crucial element for the assessment of future land availability. Various approaches were used in different studies.

One common approach is making projections on future yields using past trends in yield development. It was used in REFUEL project (2008) and the EEA study on bioenergy potentials (2007). In other studies future yields growth rates are based on expert judgments, e.g. Ericsson and Nilsson (2006) and RENEW project (2007). However, the most sophisticated approach is building and using crop growth models. One example is AEZ crop grow model used for IMAGE model (FAO, 1981; IIASA and FAO, 2002) or WOFOST crop growth model used in the Crop Growth Monitoring System under the MARS project (2009) Monitoring Agriculture with Remote Sensing.

For the 4F CROPS project we use the projections on future crop yields derived from DG Agriculture “Prospects for agricultural markets and income in the European Union”. These prospects are published annually and include forecasts on cereals, oilseeds, sugar, meat and dairy products production, consumption and markets in the EU-27. In the publication from 2007 (DG Agriculture 2007) forecast on yields were included for the period 2007-2014. They were based both on the past trends in yields development as well as crop growth models. It was estimated that the cereal yields in the EU-27 will grow on average at a very modest rate of 0.8% per year. This would stand at 1.1% per year in the EU-12 and 0.5% per year in the EU-15. Maize yields would see a modest growth of 0.4% per year. Rapeseed yields are expected to show strong growth in yields of 1.8% per year.

Some explanation is given to those projections. Yield growth in the EU-15 slowed down considerably over the last decade. This could suggest that production is at the technological frontier even in the most competitive regions. Therefore, future annual gains in yields would appear limited. Apart from the limited gains from technological progress through the introduction of new varieties, the other main factors contributing to this development include the impact of higher production standards as well as increasing constraints on resources such as water availability in southern EU Member States. However, in the EU-12, yield growth had picked up shortly before and after accession, though at significantly lower rates than a fully fledged catch-up process would suggest (on account of the slower than expected structural change) (DG Agriculture 2007).

We use the GD Agriculture projections on the mid-term development of yields to estimate average yields for 2020 and 2030, which are in focus of the 4FCROPS project. For further explanations see chapter 2 in which the assumptions on scenarios are presented.

1.4. Population change

Prospects for population changes are used to estimate the food crop production in year 2020 and 2030 and the corresponding land needed. There is an assumption made that the change in population will directly affect the food production in each country. Future changes in the consumption patterns are not included in the land allocation modeling approach under the 4F CROPS project.

The population projections come from United Nations Organization and are presented in Table 4. In most countries there is a growing trend, with the highest increase in Ireland, Luxemburg, Cyprus, Spain. On the contrary, a very significant decrease in population is expected in Bulgaria, Lithuania, Latvia and Romania.

Table 2. Changes in population (UN 2009)

Country	2005	2010	2020	2030	2010*	2020*	2030*
	thousands	thousands	thousands	thousands	2005 =100	2005 =100	2005 =100
AT	8 232	8 387	8 539	8 637	102	104	105
BE	10 415	10 698	11 048	11 303	103	106	109
BG	7 739	7 497	7 017	6 469	97	91	84
CY	836	880	970	1 053	105	116	126
CZ	10 195	10 411	10 568	10 520	102	104	103
DE	82 409	82 057	80 422	77 854	100	98	94
DK	5 417	5 481	5 557	5 616	101	103	104
EE	1 347	1 339	1 333	1 301	99	99	97
ES	43 060	45 317	48 564	49 772	105	113	116
FI	5 244	5 346	5 496	5 544	102	105	106
FR	61 013	62 637	64 931	66 474	103	106	109
GR	11 064	11 183	11 284	11 234	101	102	102
HU	10 078	9 973	9 766	9 509	99	97	94
IE	4 187	4 589	5 145	5 573	110	123	133
IT	58 645	60 098	60 408	59 549	102	103	102
LT	3 416	3 255	3 058	2 909	95	90	85
LU	464	492	550	615	106	119	133
LV	2 292	2 240	2 153	2 049	98	94	89
NL	16 316	16 653	17 143	17 498	102	105	107
PL	38 198	38 038	37 497	36 187	100	98	95
PT	10 547	10 732	10 767	10 620	102	102	101
RO	21 635	21 190	20 380	19 489	98	94	90
SE	9 066	9 293	9 713	10 076	103	107	111
SL	2 001	2 025	2 053	2 037	101	103	102
SK	5 386	5 412	5 442	5 348	100	101	99
UK	60 261	61 899	65 090	67 956	103	108	113

* calculated by authors

2. Scenarios

2.1. Base Case

The Base Case reflects the average situation of land use in the EU-27 in the period 2003-2007. A five year period is considered to mitigate the effect of annual fluctuations. Yields of the main crops established for the Base Case (average for 2003-2007) will be the basis for the calculations of future crop yields in 2020 and 2030, see Table 3.

In the Base Case the land potentially available for non-food crops includes two categories: (i) fallow land and (ii) land cultivated with energy crops.

According to EUROSTAT, which is the main source of data for this analysis, fallow land is defined as all arable land included in the crop rotation system, whether worked or not, but with no intention to produce a harvest for the duration of a crop year. Fallow land may be: (i) bare land bearing no crops at all; (ii) land with spontaneous natural growth, which may be used as feed or ploughed in; (iii) land sown exclusively for the production of green manure (green fallow).

Apart from fallow land areas cultivated currently with energy crops counted as land available for non-food crops in the Base Case. Data on energy crops cultivation were derived from EABIOM database, see Table 4. For the purpose of the land allocation model, which operates on regional level, areas available for national level have been allocated into NUTS-2 level proportionally to the redistribution of total crop production across a country.

Table 3. Yields of main crops [t/ha] average for 2003-2007 used for the land allocation model in the Base Case (EUROSTAT)

Countries	Winter wheat	Spring barley	Grain maize	Winter rapeseed	Sunflower	Sugar beet	Potatoes
AT	5,00	4,53	9,79	2,87	2,57	63,88	30,39
BE	8,38	7,45	11,33	3,85	-	69,83	43,85
BG	2,80	2,59	3,27	1,53	1,32	19,76	15,70
CZ	4,96	4,37	5,86	2,58	2,25	47,78	21,45
DE	7,34	5,84	8,24	3,49	2,09	57,44	39,34
DK	7,00	5,12	-	3,40	-	57,50	38,59
EE	2,16	2,12	-	1,43	-	-	12,37
ES	2,66	2,54	9,64	1,39	0,97	68,20	27,33
FI	3,65	3,44	-	1,28	-	37,20	23,23
FR	6,69	6,12	8,49	3,24	2,33	79,82	42,73
GR	2,01	2,10	9,65	-	1,54	53,23	17,45
HU	3,98	3,45	5,81	2,24	2,17	48,56	23,42
IE	8,59	6,70	-	3,75	-	50,71	35,59
IT	3,44	3,67	8,87	1,74	2,07	48,25	24,46
LU	6,23	5,49	8,19	3,66	-	-	31,24
LT	3,75	2,84	3,39	1,87	-	41,45	13,12
LV	3,03	2,14	-	1,71	-	37,36	13,30
NL	8,35	6,02	11,59	3,72	0,00	64,48	42,71

Countries	Winter wheat	Spring barley	Grain maize	Winter rapeseed	Sunflower	Sugar beet	Potatoes
PL	3,76	3,07	5,49	2,57	1,58	44,10	18,34
PT	1,47	1,59	5,40	-	0,53	73,72	15,09
RO	2,42	2,19	3,36	1,34	1,29	26,65	14,27
SE	5,82	4,17	-	2,55	-	49,92	28,59
SI	4,20	3,60	7,12	2,30	1,44	43,35	20,99
SK	3,96	3,47	5,27	2,06	2,08	45,50	15,45
UK	7,78	5,84	-	3,16	-	50,37*	40,07*

Table 4. Area under energy crops [1000 ha] (AEBIOM 2007, AEBIOM 2009)

Countries	Total area under crops*	Short rotation forestry**	Herbaceous crops**
AT	19,63	0,1 willow	0,4 miscanthus
BE	7,56		
BG			
CZ	104,0		
DE	1 356,61	1,0 willow/poplar	0,3 miscanthus 500,0 crops for biogas
DK	47,90	3,0 willow	
EE			
ES	39,45		
FI	9,44		20,0 reed canary grass
FR	527,61	0,1 willow	1,3 miscanthus
GR			
HU	18,50		
IE	2,36		
IT	9,80	5,1 poplar	
LU			
LT			
LV			
NL	1,29		
PL	60,2	6,5 willow	1,5 miscanthus/grasses
PT	0,09		
RO			
SE	20,0***	13,0 willow	7,0 reed canary grass 0,8 hemp
SI	1,59		
SK			
UK	191,17	4,0 willow	1,0 miscanthus
Total	2 417,20		

* AEBIOM 2007; ** AEBIOM 2009; *** own estimation

2.2. Scenario 2020 and 2030

Land use assessment in 2020 and 2030 is based on the land allocation model described in section 1.2. The model is provided with the Base Case data on crop production and yields average for 2003-2007. In order to estimate the land use in 2020 and 2030 the model is also fed with data on future yields of crops and population changes.

Land allocation in 2020 and 2030 is performed for food and fodder crops based on the future consumption and crop productivity. Based on a difference between the Base Case land use and the estimated land use in 2020 and further 2030 land for non-food crops is calculated. Only surplus land, which is left after supplying food demand, is considered as land available for non-food crops.

The future changes in population till 2020 and 2030 are presented in section 1.4. They are recalculated into consumption change using relevant coefficients and supplied into the land allocation model.

The estimation of future crop yields are based on the GD Agriculture **Prospects for agricultural markets and income in the European Union** presented in section 1.3. The projections indicate that over the period 2007-2014 cereals would show an average yield growth rate of 0.8% for the EU-27. The underlying trend linked to technical progress in cropping as well as to new varieties would stand at 1.1 % per year in the EU-12 whereas the EU-15 should exhibit lower growth of some 0.5 % per year. Maize yields would see a modest growth of 0.4 %. Strong growth in rapeseed yields is expected at 1.8 % per year.

Under the 4F CROPS project we make an assumption that the yield increase trend defined by the GD Agriculture will be kept beyond 2014 till 2020 and further till 2030. These are moderate growth rates, which were assumed to be kept in a medium and long-time horizon. Table 5 presents annual yield growth rates used for calculations. They were estimated as following:

- For cereals the rates are kept as defined for EU-15 and EU-12 by the DG Agriculture prospects.
- For maize average value for the whole EU was given at 0.4% per year by the DG Agriculture. In order to estimate the relevant values for EU-15 and EU-12, an assumption is made that the yield growth rate in EU-12 is by 120% higher than for EU-15, which is the same proportion as for cereals.
- For rapeseed the average yield growth rate was estimated at 1.8% per year in a short-term which is relatively high compared to cereals. However, taking into account a longer horizon until 2020 and 2030 applied under the 4F CROPS project, we make an assumption that the rapeseed yield should grow with the same rates as cereals. Higher growth rates would be possible for varieties cultivated for biofuel production (not included in the allocation model).
- For other crops an annual growth is assumed at 0.5% in EU-15 and 1.1% in EU-12, which is the same as for cereals.

Table 5. Yield growth rates [% per year] for main crops.

	Average for EU-27	Average for EU-15	Average for EU-12	Source
Cereals	0,80	0,50	1,10	DG Agriculture (2007)
Maize grain	0,40	0,25	0,55	DG Agriculture (2007)
Rapeseed	0,80	0,50	1,10	Own estimation
Other crops	0,80	0,50	1,10	Own estimation

The rates presented in Table 5 are applied for a 15 year period from 2005 till 2020 and respectively for 25 year period from 2005 till 2030. The yields are calculated on a regional (NUTS-2) and country (NUTS-0) level. The basis for the calculations are the average yields of 2003-2007 used in the Base Case (see Table 3). Yields of the main crops in 2020 on a country level are presented in Table 6 and for scenario 2030 in Table 7, respectively.

The model performs land allocation for different crops in 2020 and 2030 based on the demand for domestic consumption using the estimated future yields. Strict allocation rules are obeyed, see section 1.2. Surplus land is released only when the land gains from future yield growth are exceeding the land required for compensating domestic food demand resulting from population changes. It was assumed that export of crops in the net-exporting countries is kept in 2020 and 2030 at the same level as in the Base Case. However, in countries which are net-importers of crops the released land is firstly allocated to domestic production and then only the surplus becomes available for non-food crops.

Fallow land is kept in the future scenarios the same as in the base case. Concerning the area cultivated with energy crops in the Base Case, it is assumed to be guaranteed for these type of crops also in the future. This is with regard to the already established bioenery markets and the development prospects in the future.

Finally, the total area of surplus land potentially available for non-food crops includes following land categories: (i) arable land released from food and fodder crops, (ii) fallow land and (iii) land under energy crops (as it is in the base case). It is not specified under which type of non-food crops these land will be used in the future.

Table 6. Projected average crop yields [t/ha] of selected main crops in scenario 2020

Countries	Winter wheat	Spring barley	Grain maize	Winter rapeseed	Sunflower	Sugar beet	Potatoes
AT	5,40	4,89	10,18	3,10	2,77	68,99	32,82
BE	9,05	8,05	11,78	4,16	-	75,41	47,36
BG	3,30	3,06	3,56	1,81	1,56	23,32	18,53
CZ	5,85	5,15	6,39	3,04	2,66	56,37	25,31
DE	7,92	6,30	8,57	3,77	2,26	62,03	42,49
DK	7,56	5,53	-	3,68	-	62,10	41,68
EE	2,55	2,50	-	1,68	-	-	14,60
ES	2,87	2,74	10,03	1,50	1,04	73,66	29,52
FI	3,94	3,72	-	1,38	-	40,18	25,09
FR	7,23	6,61	8,83	3,50	2,51	86,21	46,14
GR	2,17	2,27	10,04	-	1,66	57,49	18,85
HU	4,70	4,07	6,34	2,64	2,56	57,30	27,63
IE	9,27	7,24	-	4,05	-	54,77	38,44

Countries	Winter wheat	Spring barley	Grain maize	Winter rapeseed	Sunflower	Sugar beet	Potatoes
IT	3,72	3,96	9,22	1,87	2,23	52,11	26,41
LU	6,73	5,92	8,51	3,95	-	-	33,74
LT	4,43	3,35	3,70	2,21	-	48,91	15,48
LV	3,58	2,52	-	2,01	-	44,08	15,69
NL	9,02	6,50	12,05	4,02	-	69,63	46,12
PL	4,44	3,63	5,98	3,03	1,87	52,04	21,64
PT	1,58	1,71	5,62	-	0,57	79,62	16,30
RO	2,85	2,59	3,67	1,59	1,52	31,44	16,83
SE	6,29	4,50	-	2,75	-	53,91	30,88
SI	4,95	4,25	7,76	2,72	1,70	51,15	24,77
SK	4,67	4,09	5,74	2,43	2,45	53,69	18,23
UK	8,40	6,30	-	3,41	-	54,40	43,28

Table 7. Projected average crop yields [t/ha] of selected main crops in scenario 2030

Countries	Winter wheat	Spring barley	Grain maize	Winter rapeseed	Sunflower	Sugar beet	Potatoes
AT	5,65	5,12	10,38	3,24	2,90	72,18	34,34
BE	9,47	8,42	12,01	4,35	-	78,91	49,55
BG	3,66	3,40	3,76	2,00	1,73	25,89	20,57
CZ	6,49	5,72	6,74	3,37	2,95	62,59	28,10
DE	8,29	6,59	8,73	3,94	2,36	64,90	44,45
DK	7,91	5,79	-	3,85	-	64,97	43,61
EE	2,83	2,78	-	1,87	-	-	16,20
ES	3,00	2,87	10,22	1,57	1,09	77,07	30,88
FI	4,12	3,89	-	1,44	-	42,04	26,25
FR	7,56	6,92	9,00	3,66	2,63	90,20	48,28
GR	2,27	2,37	10,23	-	1,74	60,15	19,72
HU	5,22	4,52	6,69	2,93	2,85	63,61	30,67
IE	9,70	7,57	-	4,23	-	57,31	40,22
IT	3,89	4,15	9,40	1,96	2,33	54,52	27,64
LU	7,04	6,20	8,68	4,14	-	-	35,30
LT	4,91	3,72	3,90	2,45	-	54,30	17,19
LV	3,97	2,80	-	2,24	-	48,94	17,42
NL	9,44	6,80	12,29	4,21	-	72,86	48,26
PL	4,93	4,03	6,31	3,37	2,07	57,77	24,02
PT	1,66	1,79	5,73	-	0,60	83,30	17,05
RO	3,16	2,87	3,87	1,76	1,68	34,91	18,69
SE	6,58	4,71	-	2,88	-	56,41	32,31
SI	5,50	4,72	8,19	3,02	1,88	56,79	27,50
SK	5,18	4,54	6,06	2,70	2,72	59,61	20,23
UK	8,79	6,59	-	3,57	-	56,92	45,28

3. Results

The estimated areas of land available for non-food crops on a country level are presented in Table 8. In the Base Case the total area amounts 13.4 million ha and increases up to 20.2 million ha in 2020 and 24.6 million ha in 2030. In the Base Case situation 27% of the total land potentially available for non-food crops in the EU is found in Spain. Significant contribution is also given from Germany, France and Poland. In Scenario 2020 these four countries cover over 60% of the total area that could be available for non-food crops. In 2030 also Romania is projected to join the group of leading countries with the larges areas of surplus land.

The estimated areas of surplus land could be potentially used for non-food crops production, however this should be decided under different aspects such as profitability of production, soil suitability, environmental impacts as well as social acceptability. These issues are out of this study, however they are considered in other work packages of the 4F CROPS project.

Table 8. Land potentially available for non-food crops (1000 ha) in Base Case, scenario 2020 and Scenario 2030

Countries	Base Case (2003-2007)		Scenario 2020		Scenario 2030	
	1000 ha	% of Total	1000 ha	% of Total	1000 ha	% of Total
AT	118	0,9	152	0,8	191	0,8
BE	34	0,3	35	0,2	34	0,1
BG	513	3,8	1 036	5,1	1 326	5,4
CZ	220	1,6	466	2,3	758	3,1
DE	2134	16,6	3 084	15,3	3 727	15,1
DK	226	1,7	282	1,4	377	1,5
EE	25	0,2	42	0,2	112	0,5
ES	3616	27,0	3 616	17,9	3 616	14,7
FI	238	1,8	300	1,5	367	1,5
FR	1772	13,2	2 505	12,4	3 078	12,5
GR	441	3,3	446	2,2	452	1,8
HU	280	2,1	1 018	5,0	1 445	5,9
IE	20	0,1	21	0,1	21	0,1
IT	493	4,2	595	2,9	778	3,2
LU	2	0,0	2	0,0	3	0,0
LT	149	1,1	473	2,3	630	2,6
LV	97	0,7	278	1,4	388	1,6
NL	27	0,2	27	0,1	27	0,1
PL	1198	9,0	2 792	13,8	2 792	11,3
PT	426	3,2	429	2,1	432	1,8
RO	671	5,0	1 642	8,1	2 857	11,6
SE	301	2,3	315	1,6	346	1,4
SI	3	0,0	3	0,0	4	0,0
SK	10	0,1	233	1,2	375	1,5
UK	220	1,6	430	2,1	502	2,0
TOTAL	13 234	-	20 221	-	24 637	-

3.1. Base case

Land available for non-food crops in the Base Case includes two categories of land: (i) fallow land, which is land that is not seeded or planted, and (ii) land cultivated with energy crops, which are crops dedicated for fuel and energy production. Table 9 presents results for the national level.

Spain with its huge resources of fallow land is found to have the largest areas potentially available for non-food crops. These covers large areas of fallow land which are under the rotation with cereals and other arable crops, however unproductive marginal land is also included within this land category. In Spain the total estimated surplus land amounts over 14% of the agricultural utilized area, which is the highest ratio among all analyzed countries. The second leading country is Germany with total area potentially available for non-food crops estimated at almost 2.2 million ha. In Germany over 60% of the total estimated land was land covered with energy crops amounting 1.4 million ha on average in the period 2003-2007. The area increased further amounting at 1.6 million ha in 2009 (FNR 2010). Together with fallow land the area under energy crops in Germany amounted in the Base Case 13% of utilized agricultural area.

Large areas of fallow land exceeding 1.0 million ha are found in France and Poland. These are countries with huge resources of agricultural land and very high level of food self-sufficiency. The area of fallow land is found on almost the same level in both countries and have rather small contribution to the total agricultural land. In France the land cultivated with energy crops amounted over 0.5 million ha in the period 2003-2007 and it is the second largest area of energy crops in the EU after Germany.

In Greece, Portugal and Finland fallow land has high contribution to the total agricultural area exceeding 10%. Also it has a high contribution in Bulgaria and Sweden. These areas are predominantly covered by low quality land, which was excluded from agricultural production due to insufficient productivity. Especially in the southern part of Europe water availability is a strong limiting factor, thus, it should be considered that these areas only party could be used for non-food crops production.

Table 9. Estimated areas of land potentially available for non-food crops in the Base Case situation

Countries	Fallow land	Land under energy crops	Total	Percent of utilized agricultural area
	1000 ha	1000 ha	1000 ha	%
AT	98,4	19,6	118,1	3,6
BE	26,7	7,6	34,3	2,5
BG	513,1		513,1	9,8
CZ	115,8	104,0	219,8	6,0
DE	777,4	1 356,6	2 134,0	12,5
DK	178,3	47,9	226,2	8,4
EE	24,8		24,8	3,4
ES	3 576,5	39,5	3 616,0	14,3
FI	228,5	9,4	237,9	10,5
FR	1 244,4	527,6	1 772,0	6,3
GR	440,5		440,5	11,5
HU	261,5	18,5	280,0	4,8
IE	17,5	2,4	19,9	0,5

IT	483,6	9,8	493,4	3,5
LU	1,6		1,6	1,2
LT	149,1		149,1	5,7
LV	97,3		97,3	5,7
NL	25,5	1,3	26,7	1,4
PL	1 137,9	60,2	1 198,1	7,4
PT	425,5	0,1	425,6	11,2
RO	671,2		671,2	4,6
SE	281,4	20,0	301,4	9,6
SI	1,3	1,6	2,9	0,6
SK	10,4		10,4	0,5
UK	29,1	191,2	220,2	1,3
TOTAL	10 817,0	2 417,2	13 234,2	7,3

3.2. Scenario 2020

In the future scenarios the land potentially available for non-food crops includes fallow land and land cultivated with energy crops (as it is in the Base Case) plus land released from food and fodder crops due to the expected productivity increase and future consumption changes. The average assumed yield increase rate of 0.5% per year in the EU-15 countries and 1.1% in the EU-12 will result with crop productivity increase by 8% and 18% compared to the Base Case, respectively. Table 10 presents the estimated land areas in 2020.

In 2020 the area potentially available for non-food crops reaches almost 20% of total agricultural area in Bulgaria, which is the highest ratio among all analyzed countries. It is also very high in Germany, Hungary, Lithuania, Poland and Latvia amounting 16-18% of total agricultural land. In absolute terms the largest areas of surplus land would be available in Spain and Germany exceeding 3 million ha, in Poland and France exceeding 2 million ha and in Romania and Bulgaria exceeding 1 million ha.

In Spain the surplus land includes fallow land and the land under energy crops as it is in the Base Case situation (mainly cereals for bioethanol production). The area cultivated with energy crops was included in scenario 2020 according to the assumption that this area would be also guaranteed for this type of crops in the future. Thus, the land released from cereals in Spain (39,500 ha) presented in Table 10 in fact reflects the land cultivated with energy crops in the Base Case. It is estimated that no extra land would be released from cereals in Spain the future. This results from the fact that Spain imports large volumes of grain to supply domestic consumption (over 9 million tons) and any land that would be released with regard to the productivity increase would be first used to supply the domestic consumption needs. At the same time, the consumption will grow as it is projected that Spain will have significant population increase in the future (13% compared to 2005). The same mechanism was found in Belgium, Estonia, Greece, Ireland, Italy, Luxemburg, the Netherlands and Portugal. These countries are strongly dependant on cereals import, thus no significant land areas would be released from cereals on favour of non-food crops in the future. In these countries, apart from small areas released from other crops, fallow land is the main category of land that would be available for non-food systems in the future. Special focus should be given to Ireland which has the highest increase rate of the population (23% compared to 2005). This will result with significant consumption growth in the future.

Germany would offer in 2020 the second largest areas available for non-food crops after Spain. Significant land areas would be released from different group of food/fodder crops (see Table 10), however, it should be noted that land resources included in the respective categories include both: (i) land released from food/fodder crops with regard to expected productivity increase, as well as (ii) the area under energy crops as it is in the Base Case. For example land released from cereals (788,000 ha) comprises of land released due to yield increase (543,000 ha) and land kept under cereals for bioethanol production (245,000 ha) as it is in the Base Case. Land released due to the effect of higher yields in the future would be available for non-food crops. It is strengthen by the effect of the population decrease in the future, which creates opportunity to release some more land for non-food cropping systems.

In Poland and France the total area available for non-food crops exceeds 2.5 million ha in each case. It includes large resources of fallow land over 1 million ha in each country as well as the land released from different crops categories. In Poland it was estimated that 1.2 million ha will be released from cereals, which is the largest amount of land released from cereals among all countries. This is the effect of combined factors: large cereal cultivation area in Poland, expected yield increase rate (1.1% per year) and future population shrunk. In France the area released from food crops includes significant areas cultivated with energy crops in the Base Case (0.5 million ha). The released land resources are lower compared to Poland as the expected yield increase rate in lower (0.5% per year) and the consumption will grow together with the population growth.

In Romania and Bulgaria the combination of productivity growth (on average 1.1% per year) and strong population decrease (9% in Bulgaria and 6% in Romania till 2020 compared to 2005) would make significant land areas available in the future for non-food production. Similar mechanism would take place in Hungary, Latvia and Lithuania.

Austria, Denmark, Finland, Sweden and the UK belong to a group of countries where some areas of surplus land become available in the future, however they are quite limited with regard to the assumed low yield increase rates (0.5% per year) on one site and the expected population increase on the other site. In the UK, the surplus areas released from cereals, oil and industrial and root crops includes the energy crops areas as they are in the Base Case (191,000 ha).

In the Czech Republic and Slovakia relatively large areas of land are released compared to the agricultural areas of these countries. This results from the assumed productivity increase (1.1% per year) and moderate consumption increase.

Table 10. Estimated land areas potentially available for non-food crops in 2020

Countries	Land released				Fallow land	Total	Percent of utilized agricultura l area
	from cereals	from oil and industrial crops	from fodder and grazing	from rood crops			
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%
AT	27,2	15,2	8,9	2,2	98,4	151,9	4,6
BE	3,8	4,2	-	-	26,7	34,6	2,5
BG	311,4	204,2	-	7,5	513,1	1 036,1	19,8
CZ	165,9	109,6	61,1	13,3	115,8	465,6	12,8
DE	787,9	776,3	677,9	65,0	777,4	3 084,4	18,1
DK	62,4	18,0	19,5	3,8	178,3	281,9	10,5
EE	-	14,6	-	2,5	24,8	41,9	5,7
ES	39,5	0,1	-	-	3 576,6	3 616,1	14,3
FI	38,4	12,8	18,4	1,5	228,5	299,7	13,2
FR	587,8	530,3	56,5	86,4	1 244,4	2 505,3	9,0
GR	0,1	-	3,2	2,1	440,5	445,9	11,7
HU	486,7	214,9	40,9	14,5	261,5	1 018,4	17,4
IE	2,4	0,7	-	-	17,5	20,6	0,5
IT	0,1	42,9	61,2	6,8	483,6	594,7	4,2
LU	-	0,6	-	-	1,6	2,2	1,7
LT	196,8	35,9	69,1	22,3	149,1	473,3	18,1
LV	79,3	18,2	71,1	12,4	97,3	278,4	16,3
NL	-	1,8	-	-	25,4	27,2	1,5
PL	1 205,5	188,1	120,8	139,8	1 137,9	2 792,0	17,3
PT	-	3,0	0,7	0,0	425,5	429,3	11,3
RO	398,9	392,8	127,8	50,8	671,2	1 641,6	11,3
SE	16,4	11,5	4,8	0,8	281,4	314,8	10,0
SI	-	1,7	-	-	1,3	3,1	0,6
SK	112,7	67,2	35,2	7,2	10,4	232,6	11,7
UK	221,5	136,5	5,0	37,7	29,2	429,7	2,6
TOTAL	4 744,5	2 801,0	1 382,0	476,6	10 817,1	20 221,2	11,2

3.3. Scenario 2030

In 2030 additional land would be released in almost all countries compared to 2020. The average crop productivity will increase with 13% compared to the Base Case for EU-15 countries and 31% for the EU-12 countries, respectively. The largest surplus areas would be found in Germany amounting to 3.7 million ha. Then comes Spain and France each having over 3 million ha, Romania and Poland each having more than 2.5 million ha and Bulgaria and Hungary with over 1 million ha potentially available for non-food crops production.

In Germany the expected productivity increase with 13% from the Base Case together with the population decrease (94% in 2030 compared to 2005) will result in large areas of land released from cereals, oil and industrial crops, fodder and root crops. The area released from cereals is compared to that found in Romania and Poland and belongs to the largest in the EU. The same as in scenario 2020 it includes the land cultivated with grain for bioethanol in the Base Case. The area released from oil and industrial crops and fodder crops is the largest compared to all other countries, however it includes areas under rape and maize for bioenergy production as they are in the Base Case.

Spain, the same as in 2020, would only offer fallow land for non-food production. High imports of cereals and projected population growth do not allow any additional land to be released from food and fodder crops. The expected productivity increase cannot compensate the future consumption increase. The same situation will take place in Ireland.

In Poland and Romania as well as Bulgaria the land rereleased from food and fodder crops is a combined effect of the productivity increase with 31% compared to the Base Case as well as very significant population decrease over the 25 year period. In Bulgaria the population will fell with 16% compared with the Base Case, for Romania it is 10% and for Poland 5%, respectively. In Bulgaria the surplus land for non-food crops would amount to 25% in 2030. Such high rates are also projected for Hungary and Lithuania.

In Luxemburg, the Netherland, Portugal and Slovakia fallow land would be the main surplus land in 2030. The same as in 2020 the grain import dependency does not allow any surplus land to be released from cereals for non-food crops as any land released due to productivity growth would be first converted for fulfilling domestic consumption. Some land would be release from other crops categories, but these are relatively small areas. In Greece the grain import dependency would be fulfilled with domestic production and some extra land would be released in 2030 from cereals. The same mechanism would take place in Italy.

Table 11. Estimated land areas potentially available for non-food crops in 2030

Countries	Land released				Fallow land	Total	Percent of utilized agricultura l area
	from cereals	from oild and industrial crops	from fodder and grazing	from rood crops			
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%
AT	48,6	22,9	16,2	4,5	98,4	190,6	5,8
BE	3,7	3,9	-	0,0	26,7	34,2	2,5
BG	485,1	315,1	-	12,4	513,1	1 325,6	25,4
CZ	340,6	169,2	109,1	23,7	115,8	758,3	20,8
DE	1 237,0	803,1	790,8	118,5	777,4	3 726,7	21,9
DK	122,8	30,5	38,6	6,5	178,3	376,6	14,0
EE	16,9	22,8	43,7	4,2	24,8	112,4	15,3
ES	39,5	0,2	-	-	3 576,6	3 616,2	14,3
FI	76,8	19,6	39,2	3,1	228,5	367,2	16,1
FR	885,0	697,3	157,2	93,9	1 244,4	3 077,8	11,0
GR	0,4	-	6,3	4,6	440,5	451,8	11,8
HU	764,5	331,5	64,6	22,8	261,5	1 444,9	24,7
IE	2,4	1,2	-	-	17,5	21,1	0,5
IT	43,9	68,8	165,3	16,1	483,6	777,7	5,5
LU	-	1,0	-	-	1,6	2,5	2,0
LT	290,6	55,0	101,5	33,4	149,1	629,6	24,1

Countries	Land released				Fallow land	Total	Percent of utilized agricultura l area
	from cereals	from oild and industrial crops	from fodder and grazing	from rood crops			
	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	1000 ha	%
LV	127,6	29,2	114,5	19,7	97,3	388,4	22,8
NL	-	2,1	-	-	25,4	27,4	1,5
PL	1 205,5	188,1	120,8	139,8	1 137,9	2 792,0	17,3
PT	-	4,7	1,2	0,1	425,5	431,6	11,4
RO	1 267,5	602,3	231,9	84,3	671,2	2 857,2	19,7
SE	31,1	18,3	13,7	1,3	281,4	345,7	11,0
SI	-	2,7	-	-	1,3	4,1	0,8
SK	188,3	104,4	59,6	12,5	10,4	375,2	18,8
UK	261,3	173,2	-	38,5	29,2	502,1	3,1
TOTAL	7 439,0	3 666,9	2 074,1	639,8	10 817,1	24 636,9	13,7

4. Sensitivity analysis

To be completed

5. Discussion of results

5.1. Model limitations

The land allocation model calculates the surplus land based on the land use average for 2003-2007 and assumptions on future productivity growths and consumption changes. When looking at the results we have to be aware that the model has several limitations, e.g.:

1) the quality of land is taken into account only indirectly,
2) the economic competitiveness of crops is not considered,
3) the macroeconomic effects are not included,
4) the Common Agricultural Policy regulations are considered indirectly,
5) the effect of changing consumption patterns is not included,
6) the effect of climate change was not taken into account.

The quality of land is strongly affecting the crop growing conditions. This factor is indirectly incorporated in the land allocation model by the yield of food/fodder crops: in regions of better soils the statistical yields are commonly higher than in areas of average or low soil quality. However, no direct specification on soil quality and its suitability for specific crops was included in the model. It should be noted that the land estimation produced as an outcome of the model is given by areas released per crop categories per regions and countries, however its quality is not defined. One can only make a rough assumption that the fallow land is commonly of lower quality that the land released from food crops.

The model does not include the effects of crops profitability and its competitiveness with other crops. One important issue are the production cost, which are specific to farms, regions and countries as they are strongly affected by the economic condition and organization structure of agriculture. This will likely change in time with the most visible effects in the Central-East countries recovering from the transition from soviet period. Changes towards more optimal farming structure may result in reallocation of crop production within different farms and consequently even between regions. This effect was not included in the model. The relative profitability of crops, which is strongly linked to the market conditions, may result in expanding some crops areas on the expense of others, even with the effect of shifting some crops between regions or even outside the Community. These effects are not included.

The macroeconomic environment may have a significant impact on agricultural production, for example the financial and economic crisis may put pressure on rural economy and affect strongly the agricultural commodity market, which in tern will lower the specific crop production. These effects are not included in the model as too much uncertainty is combined with such projections. The international trade policies are not included directly, however the model assumes that the main grain exporting countries, such as Germany and France will keep exports on a similar level in the future as in the base case while the net importing countries will try to produce as much as possible domestically on the released grounds.

The Common Agricultural Policy has a very strong impact on shaping the agricultural production across the EU. It affects the profitability of production by offering farmers area or farm payments or dedicated crop/product subsidies. It also puts limitations on production in the form of production quotas. Their effects are reflected in the base case land use (average of 2003-2007), which is the basis for future land availability assessment, however no impacts of future CAP measures were included in the land allocation model for the future scenarios.

Population and diet are the main factors shaping the demand for food. The population is expected to increase moderately within the next decades in most countries, which will be combined with food consumption growth. This was included in the land allocation model. However, changes in diet, which may have some impact on the land use were not included. During the past decades the land area per calorie produced increased in the EU, which was due to growing consumption of meat, diary products and beverages (Gerbens-Leenes and Nonhebel, 2002). Now the EU population is characterized with affluent lifestyle. Food packages include not only food to fulfill basic physiological needs, but also satisfy social and cultural demands. This includes beverages such as tea, coffee, beer, wine, etc. These products shell not impact much the land use in EU as their production is already well established in (wine and beer) or it is imported to a great extend from outside the EU (coffee, tea, etc.).

The land allocation model used under the 4F CROPS project does take into account the effects of climate change impact on the land use. Sophisticated models have been developed so far to understand and investigate this relationship, such as those used by the Intergovernmental Panel on Climate Change (IPCC). However, so far the impacts of climate change on the land use are very intricate and not well understood. There is still high uncertainty on models predictions as several various studies produced very different scenarios.

5.2. Uncertainty on future yields

The estimation of future land use in the EU is subjected to uncertainty. It occurs when it is not possible to exactly describe the future outcome. In this study it is combined with the forecasts on future crop productivity and future population change which are incorporated in the land allocation model.

The yield growth rates applied for land allocation model were defined on an aggregated level for two groups of countries EU-15 and EU-12 without differentiations among countries within each group. It reality the yields will differ between countries and regions. This will be much related to the economic conditions and farming structure of the agricultural sector. In regions of large and specialized farms the biotechnology progress and improvement in production standards is likely to be implemented much faster compared to regions where small self-subsistence farms dominate. However, exact projections on the yields development in specific regions and even countries were not available from a unique source, thus, a simplified approach was used under this study.

It was assumed that in the EU-12 countries cereal yields will show 120% higher growth rate than in the EU-15. This results from the fact that the EU-12 countries have much lower yields, e.g. the winter wheat yield in Poland is 3.76 t/ha in the Base Case while in the neighboring country, which is Germany, it amounts 7.34 t/ha. This shows high potential for future productivity growth in Poland. However, much uncertainty is involved in the rate with which the productivity will be growing in reality. It is much related to the change of the farming structure which is a long-term and difficult process to be assessed exactly. It should be also noted here that with the assumed growth rates the yields in the EU-12 countries will not reach the base case yields of EU-15 within the investigated period till 2020 and 2030.

Another source of uncertainty is combined with the impact of climate change on the crop yields. In the projects ATEAM and ACCELERATES 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 results showed 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) 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. Negligible effects of climate change will occur in the rest of Europe. However, the presented results show the climate change has rather a minor impact on yields compared to other factors such as the technological development.

5.3. Suitability of fallow land for non-food crops

According to EUROSTAT classification and definitions fallow land is all arable land included in the crop rotation system, whether worked or not, but with no intention to produce a harvest for the duration of a crop year. It includes both, the land that lies fallow only during one year as well as land that has been left fallow for several years. This land may be land left with no crops at all, or land with spontaneous natural growth, or land sown exclusively for the production of green manure. However, these are not differentiated in the statistics.

As presented in the results in many cases fallow land is the main land category available for non-food crops in the Base Case as well as in scenario 2020 and 2030. Spain was found to have the largest areas of fallow land in the EU amounting 3,576 thousand ha in the Base Case (average data for 2003-2007). A characteristic of this land is presented below based on the results from national agricultural survey (ESYRCE 2009).

Fallow land is commonly included in the crop rotation – in a give year it is left fallow while in a following season it is shifted for crop production. Table 12 presents the origin of the surfaces cropped in 2008 in Andalucía. In each raw the surface cultivated with a specific crop is broken down on a percentage basis according to the crops grown on the same land in the previous year. For instance 26.6% of the land used to grow wheat in 2008 was also used for wheat in the previous year, 2.5% was used for barley, etc. In this particular case 17.4 % was left fallow the previous season. Conversely, 10.7 % of the land left fallow in 2008 was cropped with wheat in 2007 and 51.8 % was fallow in 2007. The cells of fallow land in 2008 and 2007 where they cross each other indicates the percentage of fallow land which is carried-over as fallow from one season to the next. Therefore, this large proportion of fallow land is on a long rotation scheme; it is not abandoned or unproductive land (Cadorniga 2010).

Table 12. Crop change matrix: Origin of the surfaces cropped in 2008 in Andalucía (ESYRCE 2009)

	Crop in 2007																				
	Winter cereals																				
Crop in 2008	Wheat	Barley	Oats	Rye	Total	Corn	Other Cereals	Pulses	Tubercules	Sugar beet	Sunflower	Cotton	Other Industr crops	Forages	Horticultura & Flowers	Total Herbaceous	Fallow	Trees	Other associatns	Other surfaces	TOTAL
Wheat	26.6	2.5	0.9		30.1	0.3	1.3	6.4	0.1	1.6	32.2	3.8	1.2	1.5	1.1	79.5	17.4	0.7	0.0	2.4	100.0
Barley	19.5	26.9	6.9		53.2	0.2	0.7	2.2	0.0	0.0	2.7	0.7	0.1	2.3	0.6	62.7	32.4	1.2		3.7	100.0
Oats	13.4	14.4	23.0	0.1	50.9	0.2	0.7	0.1	0.1		0.4	0.2	0.1	5.4	0.3	58.3	30.3	2.0		9.4	100.0
Rye	89.9				89.9											89.9				10.1	100.0
Winter Cereals total	24.3	8.4	3.7	0.0	36.3	0.2	1.1	5.1	0.1	1.2	23.9	2.9	0.9	1.9	0.9	74.6	21.4	0.9	0.0	3.1	100.0
Corn	9.7	1.1	0.1		10.8	38.7	1.8		3.9	2.2	4.0	16.1	1.2	3.6	9.4	91.6	6.5	0.5		1.4	100.0
Other Cereal Grains	11.6	6.3	1.2		19.0	1.3	54.7	0.0	0.0		2.7	0.5		4.3	1.3	83.8	15.1	0.2		0.9	100.0
Pulses	51.5	10.4	2.6		64.4	2.8	1.0	22.2	0.0	0.0	0.4	0.1		0.8	0.1	91.9	6.1	0.0		2.0	100.0
Tuberculs	7.0	0.2	0.0		7.1	5.0		0.0	31.5	4.4	3.4	15.5	0.3	0.4	16.6	84.2	10.5	3.9	0.1	1.3	100.0
Sugar beet	14.2				14.2	0.1	1.8	1.0		32.7	7.3	30.0			2.7	89.8	8.8	1.4		0.1	100.0
Sunflower	66.2	3.9	0.4		70.5	0.5	0.6	0.5	0.1	0.8	15.7	3.6	0.5	0.1	0.8	93.7	4.5	0.3	0.0	1.5	100.0
Cotton	25.9	1.0	0.0		26.9	6.4	0.6	0.3	2.1	15.9	8.9	29.0	0.4	0.1	3.7	94.3	5.1	0.3		0.2	100.0
Other Industrial crops	56.3	3.8			60.1	5.9					4.1		24.6	0.0	3.1	97.8	1.7	0.1		0.3	100.0
Forages	8.9	2.9	4.4		16.1	0.3	2.1	2.4	0.0	0.4	0.4	0.3	0.2	54.0	0.6	76.9	13.4	0.6		9.1	100.0
Horticulture&Flowers	5.7	0.9	1.2		7.9	1.5		0.0	3.7	2.9	1.1	2.3	0.2	0.8	63.6	84.2	5.5	2.4	0.4	7.6	100.0
Total Herbaceous	31.7	6.2	2.5	0.0	40.4	1.4	3.3	3.6	0.7	2.0	17.4	4.4	0.7	3.8	3.7	81.4	14.9	0.7	0.0	2.9	100.0
Fallow	10.7	10.9	4.3		25.9	0.2	1.2	0.7	0.1	0.1	0.7	0.2	0.4	3.3	0.6	33.5	51.8	1.7	0.0	13.0	100.0
Trees	0.2	0.2	0.0		0.5	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.1	0.1	0.9	0.5	96.7	0.0	1.9	100.0
Other Associations									0.9		1.5	0.1		1.6	7.2	11.3	5.1	3.8	23.1	56.6	100.0
Other Surfaces	0.1	0.1	0.1		0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.1	0.4	0.4	0.5	0.0	98.6	100.0
TOTAL	5.5	1.5	0.6	0.0	7.7	0.2	0.6	0.6	0.1	0.3	2.8	0.7	0.1	0.8	0.7	14.7	5.0	21.4	0.0	58.9	100.0

Table 13 presents data on fallow land for six selected Spanish regions as average values for the period 2006-2008. If we take as an example Castilla y León we see that 52% of the fallow land of one year is used for winter cereal the next season and the land transferred from fallow to cereal cropping amounts to 17% of the total cereal surface of the season. Further, 40% of fallow land in a given season was kept fallow in the previous season. In general terms, this 17% might be considered as a fallow proportion needed for a good agricultural performance, so called 'technical fallow'. The land kept fallow more than one year could be, most of it, classified as 'environmental fallow' (Cadorniga 2010).

It is important to note that the areas of fallow land given in the EUROSTAT statistics also include land resulting from the set-aside policy in the EU-15 countries. However, the surface of fallow land in Castilla y León in years 1983 and 1984, well before the set-aside obligation was launched, was similar to what we have nowadays amounting 800 thousand ha in 1983 and 703 thousand ha in 1984, respectively (compare with data in Table 13). This means that large areas were left fallow on a voluntary basis and the set-aside obligation didn't mobilized any significant additional areas.

Table 13. Fallow land and its transformations; data average for the period 2006-2008 (own calculation based on ESYRCE statistics)

Regions	Fallow land	Fallow land used for winter cereals in the next season	Total cereal area originating from fallow land	Fallow land which was kept fallow in the previous season
	1000 ha	%	%	%
Aragon	514	60	40	34
Castilla y León	716	52	17	40
Castilla-la Mancha	1064	56	42	38
Extremadura	250	26	41	62
Andalucia	363	40	22	44
Región de Murcia	257	32	50	53

In Poland fallow land was also found to be a very important land that potentially would be available for non-food crops amounting 1,138 thousand ha in the Base Case. Much of this area is covered with multi-annual fallow as leaving land fallow for one-year as a part of crop rotation is not common in Poland. Fallow land has been often withdrawn from crop production due to insufficient economic profitability. In 2002 the total area of fallow land in Poland amounted 2.7 million ha, which was to a great extend the effect of economic transformation in the agricultural sector and poor economic conditions of farming. However, shortly after the EU accession in 2004 large proportion of these lands was brought back to agricultural production in order to receive the area payments available under CAP. So far the set-aside obligation is not implemented in Poland as well as in the most of new member states, thus, the land is commonly left fallow voluntarily.

The quality of fallow land is commonly below the average. If fallow land is a part of crop rotation or it is kept in according to the good agricultural practice, it may be considered suitable for non-food crops production, however the yields would be typically on a modest level due to the poor quality of these lands. Either in Spain, Poland or other countries, fallow land is commonly characterised with unflavoured water conditions or poor soil quality.

However, fallow land also includes marginal lands that were withdrawn from crop production for several years and are considered unproductive land. These type of land would not be suitable for non-food crops in most cases. This would include land degraded with soils erosion, shallow soils, salty soils, slops, etc.

In more general terms, whether or not the fallow land could be used for non-food cropping systems is much related to the profitability of non-food crops production. Currently, fallow land with the actual uses is in most cases marginally profitable or unprofitable. Non-food products may develop on these lands only if the profitability can be improved. One possible solution would be to minimize the input to improve the overall production profits.

5.4. Comparison with other studies

Land assessment for crop production systems different from food production has been performed in previous studies. In many cases the potential area available for energy crop production was investigated. Five previous studies were used to compare results on the land assessment with the results received under 4F CROPS project, see Table 14. The results are presented in 1000 ha and have been aggregated for EU-25 (Cyprus and Malta were excluded), however the both studies of EEA (2006 and 2007) do not include Bulgaria and Romania. All studies used a resource focused approach.

The methodology and the assumptions used are the most crucial factors for the outcomes. In both, the 4F CROPS project and RENEW project a land allocation model was used to estimate the available land, however the assumptions were different. The most important factors were the assumptions on crop productivity increase as well as on the land categories that could be available for non-food/energy crops. In S1 scenario of RENEW, apart from fallow land and land released due to productivity increase, a conversion of cereal exports and permanent grassland into arable land for energy crops was also considered. The yields increase was assumed by 10% in EU-15 and 30% in EU-12 starting from 2002. In the study of Ericsson and Nilsson (2006) the land available for energy crops was based on a 10% set-aside rate in EU-15, which was increased up to 25% in the EU27 in order to maintain the EU15's ratio of arable land utilization (0.18 ha/capita) in 2020-2040. In the long-term scenario > 2040 it was assumed that energy crops would be grown on agricultural land that is not required for food production, i.e. surplus agricultural land, assuming that 0.24 ha/capita is required for food production. This method resulted in extremely high estimations.

A special focus should be given to the results of the studies of EEA (2006, 2007). They both included a sophisticated modeling approach including assumptions of future productivity increase and liberalization of agricultural markets. Great attention was made to avoid increasing the pressure from agriculture to the environment, thus lower yields were defined for environmentally oriented farming and permanent grassland was excluded from bioenery crop production. Both studies give relatively moderate results on the land availability for bioenery crops. The results of the EEA study (2006) are with about 20% lower compared to results for scenarios 2020 and 2030. When the EEA study (2007) is compared the results are the 10% lower for 2020 and 20% lower for scenario 2030, respectively. However, the studies of EEA (2006 and 2007) do not include Bulgaria and Romania, which both should contribute significantly to the land assessment.

Table 14. Comparison of land assessment results between 4 FCROPS and four selected previous studies

Study/ time scope	Land assessment (1000 ha)	Comments
4 F CROPS project		
Base Case (2003-2007)	13 234	Land assessment based on land allocation model. Surplus land available for non-food crops after satisfying food and feed demands. No conversion of permanent grassland into arable land. If land released in the future it is first used to supply domestic food demands, then only surplus would be available for non-food crops.
2020	20 221	
2030	24 636	
EEA (2006) How much bioenergy can Europe produce without harming the environment?		
2010	12 964	Land assessment for energy crops – land that is not needed for feed of food production. Assumptions on productivity increases and further liberalization f agricultural markets. At least 30% of agricultural land is dedicated to "environmentally-oriented farming" in 2030. Permanent grassland is not transformed to arable land. 3% of intensively cultivated area is set aside for ecological compensation by 2030. Liberalization of agricultural sector. The modelling of the released and set-aside land area based on CAPRISM model. HEKTOR model used to model the land needed to produce food and fodder to fulfill domestic demands.
2020	16 169	
2030	19 268	
EEA (2007) Estimating the environmentally compatible bioenergy potential from agriculture.		
2010	13 936	It is based on the EEA (2006) study. A CAPRISM scenario was modified into "environmentally compatible" scenario. Avoiding increased environmental pressure from agriculture due to increase biomass demand for food and energy purposes was a key factor for this study. The basis was a scenario assumption that a large share of environmentally-oriented framing with lower crops yields will exist.
2020	17 952	
2030	20 125	
Ericsson, Nilsson (2006) Assessment of the potential biomass supply in Europe using a resource-focused approach.		
2000	11 649	Area for energy crops estimated based on following assumptions: In 2000: 10% of arable land In 2020-2040: 25% of arable land In the period over 2040: agricultural land that is not required for food production, which claims 0.24 ha/capita.
2020-2040	29 122	
>2040	78 720	
RENEW project		
Starting Point (2000-2002)	11 350	Land assessment based on land allocation model. Only surplus land available for energy crops. In S1 (intensified scenario) the available land includes: land released from food crops as a result of productivity increase, fallow land, land converted from 30% of cereal exports, land converted from 1-10% of permanent grassland. In S1 (sustainable scenario): land released from food crops as a result of productivity increase and fallow land.
2020 (S1)	23 509	
2020 (S2)	17 557	

The results on land assessment on a country basis are presented in Figure 3. The studies of EEA (2006 and 2007) used a similar methodology and can be easily compared while 4F CROPS project used a completely different approach. However, the general overview is that countries with large agricultural land areas were found to be the major suppliers of land available for non-food crops in all three studies. The specific exception is Germany with huge reduction of land availability found between the results of the EEA (2006) study and (2007) and the UK, for which the results of 4F CROPS project show much lower land available than the EEA studies. Bulgaria and Romania were only investigated under the 4F CROPS project.

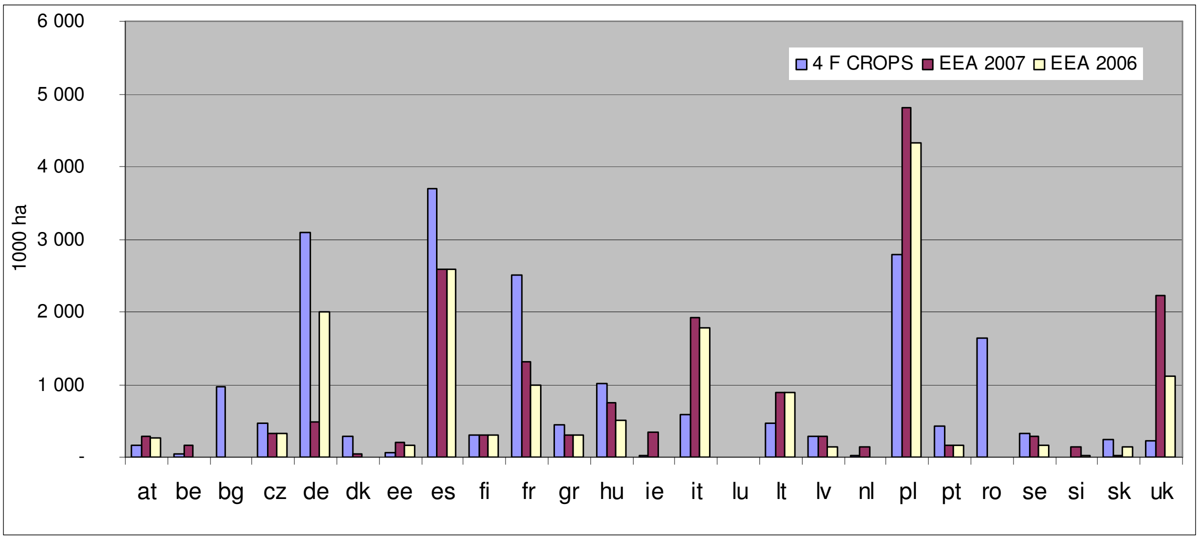

Figure 3. Comparison of the results on land available for non-food crops in 4F CROPS project and EEA studies (2006) and (2007)

6. Summary and conclusions

Non-food cropping systems offer significant opportunities for various products introduction on the markets in the EU. Bioenergy development has already gained ground as a measure to address the problem of climate change and improve the energy security. Interest in natural fibers is also increasing due to the environmental concerns, resulting in a growing market for biodegradable materials. At the same time new bio-based products are being developed in chemical industry, i.e. plastics, adhesives and paints.

Land availability is the most crucial factor for the development of non-food crops systems. This should happen without affecting food supply. With regard to that the land estimation performed under the 4F CROPS project was based on the assumption that only surplus land after satisfying food and feed demand would be available for non-food crops. The land assessment was performed with the use of a land allocation model, which allocates agriculture land for different food and fodder crops based on the future demand for food and future yields of crops. The assumption on future crop yields were kept on a moderate levels to avoid increase in the pressure from agriculture on the biodiversity and natural resources. Land assessment was performed at a NUTS-2 regional level and the results have been aggregated into national level.

Land availability is the effect of combined factors. Fallow land and land under energy crops cultivation that available currently would be commonly extended in the future with additional land released from food crops. The area released is primarily affected by the future productivity increase, however it is also depend on the direction of the changes in population and the food import/export balances. In countries where population is projected to grow the surplus land would be released only if the effect of productivity increase predominates the future consumption growth. It was additionally considered whether the import/export balance need to be compensated for domestic consumption, which means that in countries where crops are imported, any released land was allocated first to compensate the needs of domestic consumption (within a respective crop category). Finally, only the surplus land was available as an outcome of the land allocation procedure.

The total area of land available for non-food crops in the Base Case (which reflects the average situation from 2003-2007) was estimated at 13.2 million ha, which includes fallow land (80%) and land cultivated with bioenergy crops (20%). In 2020 the total land available would amount 20.2 million ha and would increase up to 24.6 million ha in 2030, respectively. In the future scenarios the total estimated land include following categories: (i) fallow land, (ii) land under energy crops (area from 2003-2007), and (iii) land released from food and feed production due to future yields increase.

Spain with its huge resource of fallow land (3.6 million ha) was found to be the leading country in the Base Case, see Figure 4. Germany, which has the largest area of energy crops (1.4 million ha), together with fallow land was placed on the second position with total land amounting 2.1 million ha. France and Poland with fallow land over 1 million ha (plus energy crops area in France) also create large opportunities for non-food cropping systems. Land which is currently used for energy crop production was assumed to be guaranteed for this type of crops also in the future as the bioenery and biofuels markets have been well established already.

In scenario 2020 the structure of land available for non-food crops is differentiated among countries, see Figure 5. Spain would offer the largest land area, which would be almost 100% the fallow land. The second leading country would be Germany with 3.0 million ha of surplus land in total, including large fallow land, land released from cereals, land released from oil and oil and industrial crops, land released from fodder crops and land released from rood crops. Poland would offer 2.8 million ha in total and France 2.5 million ha, including fallow land as well as significant areas released from food crops, mainly cereals. Important contribution would come also from Romania (1.6 million ha), Bulgaria and Hungary (each of them offering over 1.0 million ha).

In 2030 additional land would be available compared to 2020, see Figure 6. In a longer period the yields are expected to grow further and more land would be released from different food and fodder crops. The leading countries would be Germany having in total 3.7 million ha and Spain with 3.6 million ha of surplus land. While in Germany large areas would be released from various food crops, in Span only fallow land would be available. France, Poland and Romania would offer huge potentially available for non-food systems, each having more than 2.5 million ha. Hungary would offer almost 1.5 million ha of surplus land, the same for Bulgaria.

Next to the leading countries there is a group of countries that would offer only small areas of land for non-food systems. Here belong countries of little areas of agricultural land as well as countries which have high food import dependency or the high population increase in the future.

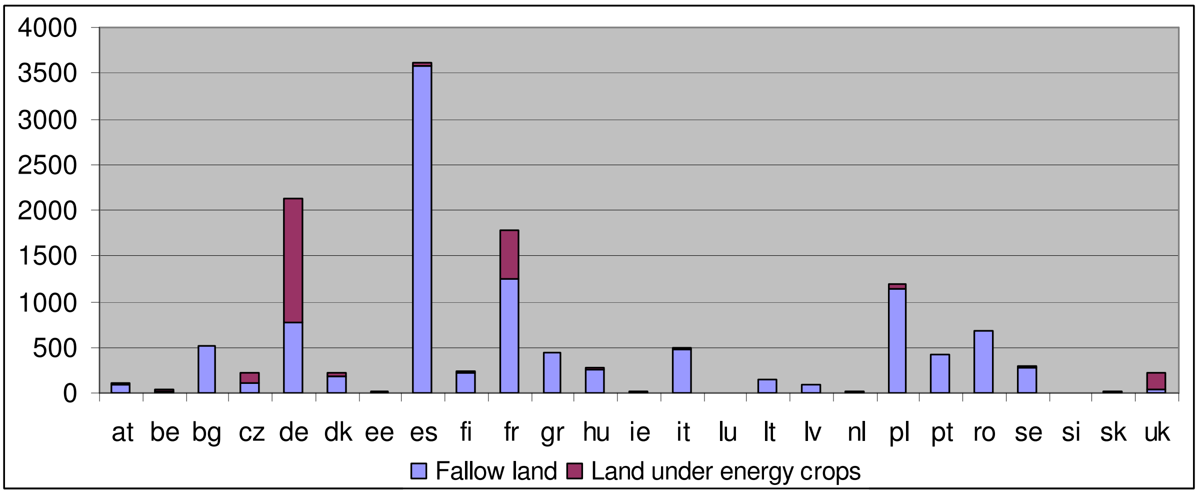

Figure 4. Land available for non-food crops in 1000 ha in the Base Case

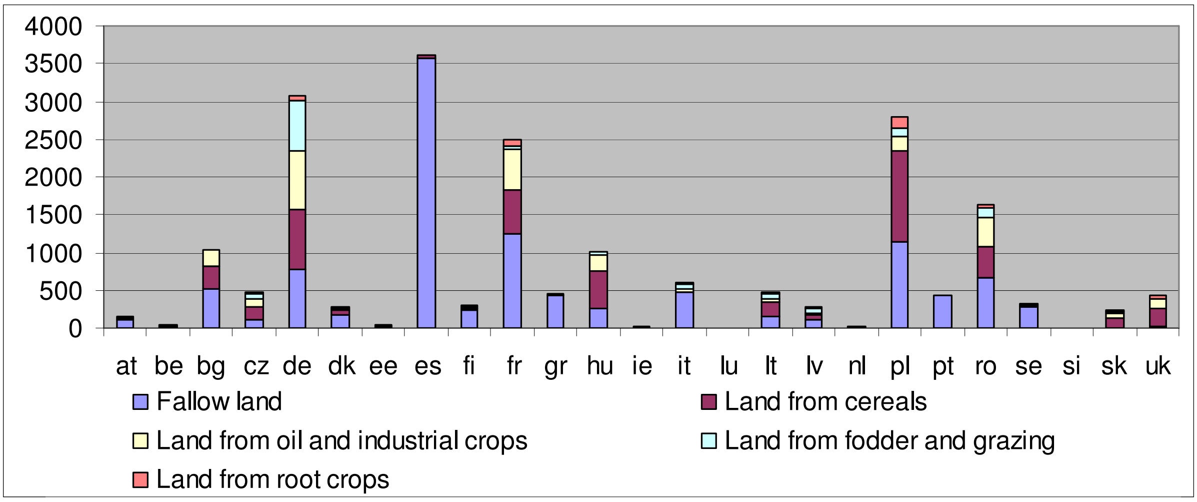

Figure 5. Land available for non-food systems in 1000 ha in scenario 2020

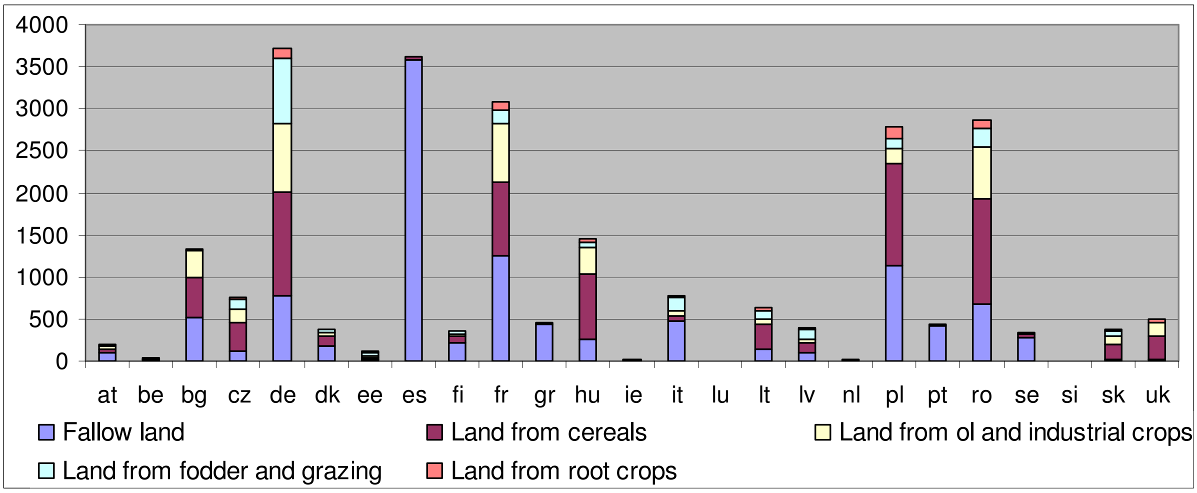

Figure 6. Land available for non-food crops in 1000 ha in scenario 2030

The future yields of food and fodder crops most strongly affect the results, with cereal growth rates having the strongest impact as cereals are the dominant crop category in all analyzed countries. EU-12 countries are characterized with higher future yield growth rates (with 120%) compared to the EU-15, which is reflected in the estimated land availability. Generally, countries with large areas of cereals and other arable crops, such as Germany, France, Poland, Hungary, Romania and Bulgaria are characterized with large potential of land released from food and fodder crops in future scenarios. However, in the UK and Italy, which also have significant agricultural land resources, the future land availability for non-food crops would be limited due to the requirement for compensation of grain imports (Italy) and significant population increase (UK).

Fallow land is the main land category potentially available for non-food in the Base Case as well as in the future scenarios in most countries. This category includes both compulsory set-aside land as well as voluntary fallow land. The largest area is found in Spain amounting 3.6 million ha, which is over 14% of total agricultural utilized area. Fallow land in Spain is commonly a part of the crop rotation, both annual as well as long-term rotation schemes. On the contrary, in Poland fallow land (1.1 million ha) comprise mainly of land that has been withdrawn from crop production with regard to insufficient productivity of crops on these lands. Still it might be brought back to crop production, however considerable costs would be required. Fallow land is commonly land of below quality than average, also including areas of marginal land.

The estimation of land availability shows total area that would be potentially available for non-food cropping systems. However, crop suitability for different land areas as well as land allocation for specific non-food crops was not investigated under this deliverable. Land use for non-food crops would be much related to the profitability of this type of production.

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