SES6-CT-2003-502705

RENEW

Renewable fuels for advanced power-trains

Integrated Project

Sustainable energy systems

D.: 5.01.07 Energy crops potentials inventory results

Due date of deliverable:	03/2007
Actual transmission date:	09/2007
Start date of project:	01/2004
Duration:	48 months

Ewa Gańko, Grzegorz Kunikowski, Anna Wróbel

EC BREC

Institute for Fuels and Renewable Energy, PL

Revision 0 Draft 3

Project co-funded by the European Commission within the Six Framework Programme (2002-206)		
Dissemination Level		
PU	Public	X
PP	Restricted to other programme participants (including Commission Services)	
RE	Restricted to a group specified by the consortium (including Commission Services)	
CO	Confidential, only for the members of the consortium (including Commission Services)	

Contents

Abbreviations

AI	Active Ingredient
BtL	Biomass to Liquid
CAP	Common Agricultural Policy
DM	Dry Matter
EC	European Commission
EU	European Union
EUROSTAT	Eurostat Statistical Office of European Communities
FADN	Farm Accountancy Data Network
FAO	Food and Agriculture Organization of United Nations
GIS	Geographic Information Systems
LA	Land allocation
LU	Livestock unit
MSU	Mapping Suitability Units
N	Nitrogen
NUTS	Nomenclature of Units for Territorial Statistics
P	Phosphorous
SP	Starting Point (RENEW scenario)
S1	Scenario S1 (RENEW scenario)
S2	Scenario S2 (RENEW scenario)
UAA	Utilised Agricultural Area
UNO	United Nations Organization
WP 5.1	Work package 5.1 “Resources and potential assessment”
WP 5.2	Work package 5.2 “Life cycle assessment”
WP 5.3	Work package 5.3 “Economic assessment”
WP 5.4	Work package 5.4 “Technical assessment”

Introduction

This report is the deliverable D5.01.07 'Energy crop potential inventory results' prepared within the European project Renewable Fuels for Advanced Powertrains (RENEW), which is supported by the European Commission within the 6th Framework Programme. RENEW project investigates different production routes for so called biomass-to-liquid (BtL) automotive fuels made from biomass.

This report has been elaborated on WP5.1 "Biomass resources and potentials". The objective of this work package is the assessment of the potential biomass resources available for energy in Europe including BtL fuel production. <u>This report focuses on lingo-cellulose energy crops production potential in Europe</u>.

The energy crop production potential assessment together with residue biomass assessment (D5.01.03) constitute overall biomass resources and potential assessment in the RENEW project. The assessment includes RENEW scenarios defined in cooperation with other work packages.

The results represent total energy crop potential available for bioenergy related needs including BtL calculated on NUTS-2 regional level as well as aggregated into national level. The potential is presented in absolute numbers (PJ/year) as well as normalized per total land area (GJ/ha). The assessment results are presented at cartograms. Additionally, D5.01.07 <u>"Energy crop profiles" is attached to this deliverable</u>. They present detailed data on energy crop potentials for each of the EU countries.

The work performed under WP5.1 on potential assessment strongly refers to other work packages, i.e. WP5.2 "Life cycle assessment", WP5.3 "Economic assessment" and WP5.4 "Technical assessment".

This report has been elaborated under the support of WP5.1 partners:

- Centre for Renewable Energy Resources (CRES), Greece
- ESU-services (ESU), Switzerland
- Institute for Energy and Environment (IEE), Germany
- National University of Ireland (UCD), Ireland
- Lund University (LU), Sweden

1. Methodology for energy crop potential assessment

The energy crop potential assessment was performed with resource-focusing method based on land availability for energy crops and land productivity. Food, fodder and fibre production must be satisfied first, thus only the surplus land can be used for energy crops (food and fibre production not affected).

The assessment was performed for RENEW scenarios:

- Starting Point (SP): This is based on the current situation and is an estimation of the average biomass potential for the years 2000-2004.
- Scenario 2020: This is the projected situation for the year 2020 when the BtL industrial production plants will be under operation in Europe. In order to achieve this projection the average biomass potential of the year 2020 must be estimated. Two variations are included:

  (i) Scenario S1, which represents intensive biomass production based on high level of inputs, and

  (ii) Scenario S2, which represents a biomass production with minimal required level of inputs.

The assessment was performed at NUTS-2 regional level, and then the results were aggregated into country level (NUTS-0). For consistency in assessment, compiled input data from international databases were used. Agricultural data for the EU countries were collected from EUROSTAT and FADN database (Farm Accountancy Data Network). Data for Switzerland were derived from FAO database. The average data for the period 2000-2004 were used to avoid annual fluctuations.

Land allocation model was build to estimate available land for energy crops in each scenario (see section 1.1). The model works on statistical data, various input parameters and allocation rules integrated altogether. Based on the land available for energy crop the model calculates energy crop potential for respective energy crop yields. The energy crop yields were derived from WP5.3.

Additionally, energy crop suitability analysis was performed to evaluate the growing conditions of five energy crops in Europe. These crops are: willow, poplar, miscanthus, eucalyptus and switchgrass.

All the countries investigated were grouped into five European regions, see *Figure* 1. Project representatives of each of the regions were responsible for delivering regional specific data and verifying the results, see Table 1.

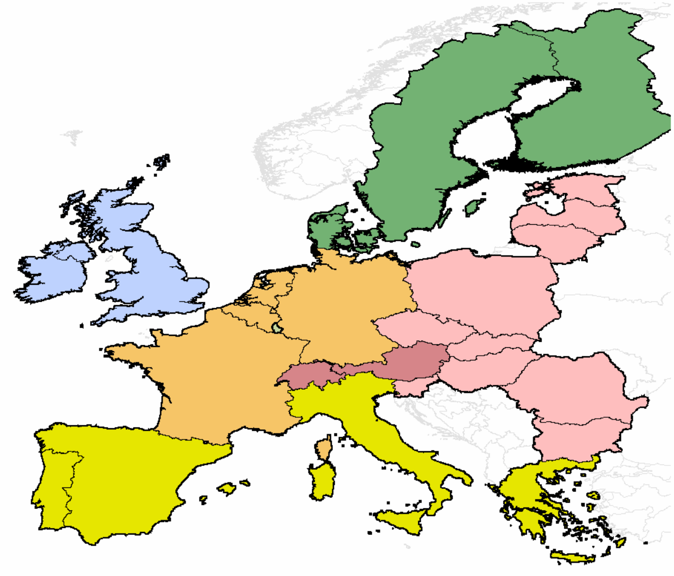


*Figure **1** European countries grouped into six regions*

Table 1 European regions and project partner's responsibility in the biomass potential assessment

European region	Countries	Project partner responsible
NORTH	DK, FI, SE	Lund University, SE
WEST	BE, DE, FR, LU, NL	IEE, DE
EAST	EE, CZ, HU, LT, PL, SK, SL, RO	EC BREC, PL
SOUTH	ES, GR, IT, PT	CRES, GR
ALPINE	AU, CH	ESU Services, CH
UK and IE	IE, UK	Dublin University, IE

1.1. Land allocation model

The Land Allocation model estimates land area available for energy crops (measured in 1000 ha) and calculates the energy crop production potential based on relevant energy crop yields.

Structure of the model

Land allocation should be understood as agricultural land allocation (in hectares) for specific crops production (in tonnes).

The model includes five components, which are strongly linked to each other:

- Module for land allocation for agricultural crops in the current situation (2000-2004).
- Module for the estimation of future crop production and yields.
- Module for land allocation for agricultural crops for the future scenario (2020).
- Module for land balancing (surplus land or land deficits).
- Module for the energy crop potential assessment.

The overall model structure is presented in Figure 2. Print screen of the model is presented in Annex A.

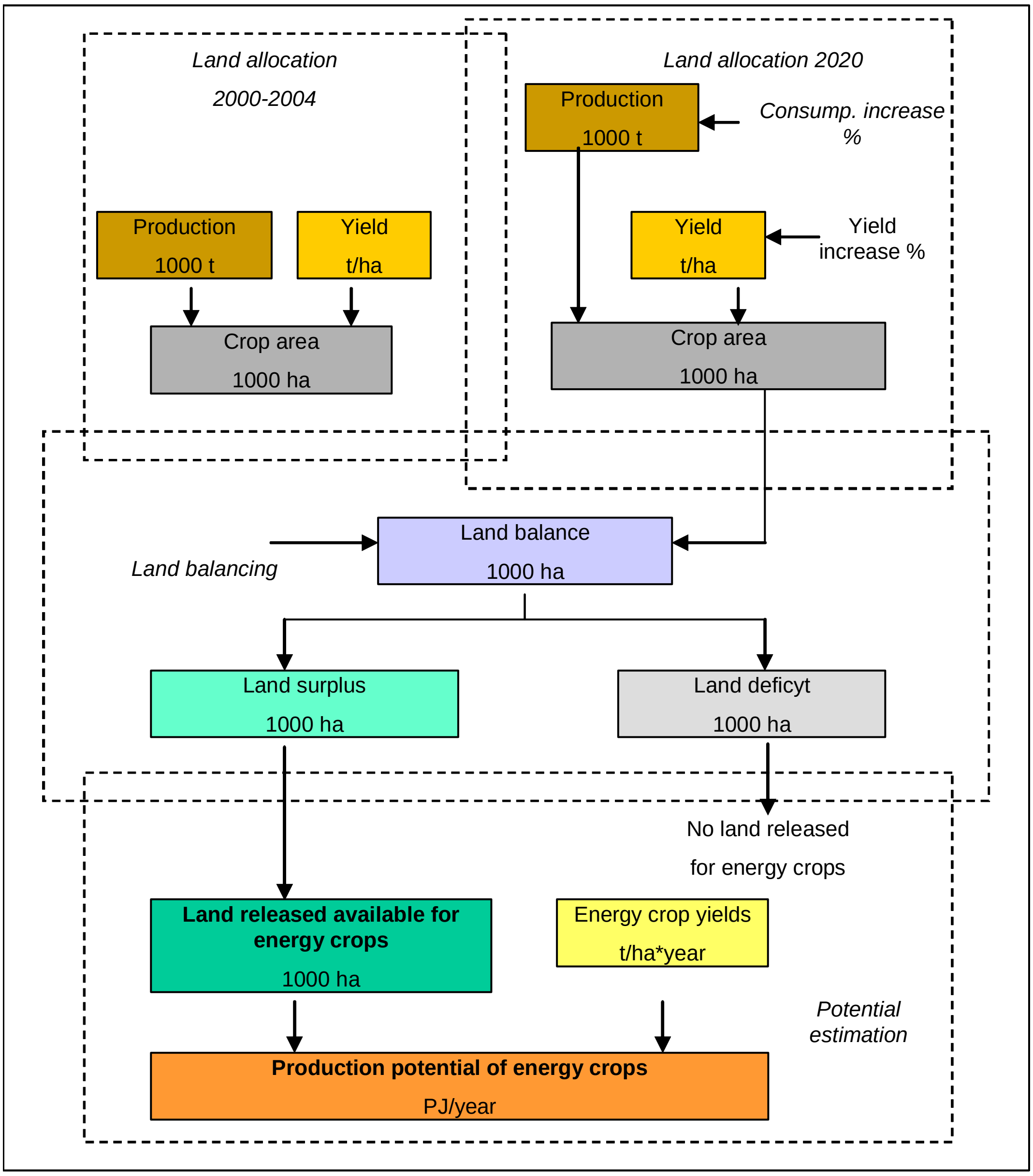


Figure 2 General overview of the main components of the Land Allocation model

Function of the modules

Module for land allocation for agricultural crops in the current situation: This module performs land allocation for arable crops in 2000-2004 on the basis of statistics on production (1000 t) and yields (t/ha). To avoid annual yield fluctuations the mean values of 2000-2004 were used. Apart from arable crops permanent crops, permanent grasses are included. Land allocation for 2000-2004 is a baseline for land allocation in 2020. In the module, the crops are grouped into several categories based on EUROSTAT classification, see Table 2.

Table 2 Land use structure and crop groups according to EUROSTAT classification

Utilized Agricultural Area									
Arable land							Permanent crops	Permanent grassland	Other
Cereals	Oilseeds	Industrial crops	Root crops	Fodder and grazing from arable land	Pulse	Fallow land			
Wheat, barley, rye, oats, maize grain	Rape seed, sunflower, Soya bean	Cotton, flax, tobacco, etc.	Potatoes, sugar beets, etc.	Maize fodder, etc.					

Module for the estimation of future crop production and yields: To estimate future crop yields, the NUTS-2 regions were classified as extensive or intensive agricultural production systems. This was based on inputs consumption (FADN database). Depending on the type of the agricultural system, the module applies different yield increase rates for the future scenarios, see section 1.2. Future food/fodder/fibre crop production was estimated with regard to population and 'per capita' food consumption forecasts, see section 1.2.

Module for land allocation for agricultural crops for the future scenario: Land allocation for 2020 was performed for the estimated future food/fodder/fibre crop production amounts and future yields. To avoid overlapping of crop areas or exceeding the total agricultural land strict allocation rules were applied:

- Compensating land deficits within the same crop category – if the cultivation area of a crop in 2020 was exceeding area of 2000-2004, the land deficit was compensated with land released from other crops within the same crop category (crop categories see Table 2).
- Setting to zero for a crop category - if deficit for a whole crop category occurred (area of 2020 exceeds the area from 2000-2020), they were not compensated by land released from another crop groups or from permanent grassland; no land for energy crops was available from this specific category.
- Setting to zero for whole arable land – if the arable land under crops estimated for 2020 (sum of cultivation areas required in 2020) was to exceed the arable land of 2000-2004 (including effect of the rules above), no arable land was released for energy crops.

Module for land balancing: Land areas available for energy crops in 2020 were estimated based on the changes in the land allocation between present situation (2000-2004) and year 2020. Food and fibre crop production cannot be affected, thus energy crops would only be developed on surplus land. Following land categories were dedicated for energy crops:

- Land released due to the crop productivity increase (relevant for food/fodder/fibre crops).
- Fallow land.
- Land released due to reduction of cereal and meat exports; relevant for net exporters.

Module for the energy crop potential assessment: ***Module for the energy crop potential assessment.*** Energy crop production potential was calculated as the available land (in 1000 ha) multiplied with energy crop yields (t/ha dry mass) and relevant low heating value (GJ/t). There was the opportunity to match the different types of available land (various land categories) with different energy crop yields based on soil quality classes. The following rules were accepted:

- For land areas released from arable crops, energy crop yields relevant for average soil quality were applied.
- On the fallow land and land released from permanent crops, energy crop yields relevant for poor quality soils were applied.

The energy crop production potential estimated for each NUTS-2 regions was finally aggregated into results at country level.

Model's simplifications

A model is a simplification of reality, and as such, certain details are excluded from it. The question is always what to include and what to exclude. The LA model was built to aid the development of future patterns of crop production on agricultural land in the sense of assessing the crop cultivation areas and production potential. The intention was to include only the most relevant components so that the model would not be too complicated and would support the understanding of future allocation of crop production.

Simplification used in the model will result in uncertainties discussed in sections 0 and 0. Following simplifications were used:

- The same yield growth rates (the yield growth rates of cereals) were applied for all crops.
- The national export/import balances were applied to all NUTS-2 regions of a given country at the same level.
- The consumption change rate defined for a country level was applied at the same value to all NUTS-2 regions.
- The cereals exports assumed to consist only of wheat (wheat yields were used to estimate the land area released from cereal exports).
- Land released from beef exports related only to permanent grassland (no change in arable crops).
- Using the same consumption change rate for all crops.
- The interactions between regions (trade) are not considered.

1.2. Assumptions for future scenarios

Two scenarios for the year 2020 were included:

- Scenario S1 represents intensive production based on high level of inputs; food and fibre production should not be affected.
- Scenario S2 represents biomass production with minimal required level of inputs (fertilizers, pesticides, etc.); food and fibre production should not be affected.

While defining the detailed assumptions on the scenarios for energy crops potential assessment various parameters' values were changed in the LA model. The change in the parameters directly affects the result of the model. Following parameters can be changed:

- Yield increase rates.
- Population change rate.
- Consumption change rate.
- Export surplus conversion rate for energy crop land.
- Permanent grassland conversion rate for energy crop land.

The Table 3 shows the summary of assumptions for scenarios S1 and S2. The justification of these is given below the table.

Table 3 Parameters into the LA model to determine the land availability for energy crops for scenarios S1 and S2

Parameter	Scenario S1	Scenario S2
Consumption change rates	From -1.89 to 15.63% depending on country	From -1.89 to 15.63% depending on country
Yield increase rates	10% for intensive system, 30% for extensive system	7% for intensive system, 20% for extensive system
Fallow land conversion rate	100%	100%
Export surplus conversion rate	30% for net exporters	No conversion
Permanent grassland conversion rate	1-10% depending on the beef export amount	No conversion

<u>Consumption change rate</u>

In order to estimate the demand for land area and the agriculture crop production for the year 2020, the population and 'per capita' food consumption forecasts are used. The forecasted rate of change in population for 2020 and aggregated 'per capita' consumptions (shown in grain equivalents (GE)) are derived from Thran et al. 2005, and are represented in Table 4. The population projections come from German Federal Statistical Office, the EC and the UNO.

The same consumption change rate is applied for scenarios S1 and S2.

Table 4 Changes in population, 'per capita' consumptions and total food consumption in grain equivalents (GE) in % for European countries (Thran et al. 2005)

Country	Population Change		Change in consumption per capita		Food consumption change*
Year	2000-2010	2010-2020	2000-2010	2010-2020	2000-2020
Austria	1.47	1.17	4.80	0.00	7.58
Belgium/Luxembourg	2.75	2.22	1.40	0.00	6.50
Bulgaria	-6.89	-7.88	6.90	7.00	-1.89
Switzerland	n.d.	n.d.	n.d.	n.d.	7.58**
Czech Republic	-1.06	-2.22	3.20	5.50	5.33
Denmark	3.28	2.49	6.00	0.00	12.20
Estonia	-4.24	-2.83	5.40	5.00	2.98
Finland	1.8	1.1	3.30	0.00	6.32
France	3.17	1.1	3.20	0.00	7.64
Germany	1.07	-0.29	2.10	0.00	2.89
Greece	1.5	-0.65	7.10	0.00	8.00
Hungary	-2.97	-3.34	7.30	5.30	5.97
Ireland	8.63	4.36	2.00	0.00	15.63
Italy	1.53	-0.75	4.40	0.00	5.20
Latvia	-5.27	-5.29	5.70	5.70	0.24
Lithuania	-4.06	-4.29	8.10	5.00	4.23
Poland	-0.75	-1.69	6.60	5.40	9.63
Portugal	1.09	2.1	8.00	0.00	11.47
Romania	-3.75	-4.19	6.90	7.00	5.48
Slovakia	0	-0.93	-	5.60	4.62
Slovenia	-0.41	-2.14	6.50	3.90	7.84
Spain	0.17	-1.18	5.50	0.00	4.43
Sweden	3.63	3.51	5.70	0.00	13.38
The Netherlands	6.3	3.72	-1.50	0.00	8.60
United Kingdom	3.56	3.49	7.00	0.00	14.68

* aggregated by EC BREC
** the figures for Switzerland were assumed to be at the same level as for Austria (EC BREC)
n.d. – no data

The consumption change rates were used to calculate the future food production. They were used together with the import/export balances for estimating future production volumes of food and fodder crops in a given NUTS-2 region. Self-sufficiency of the countries and regions (all required crops produced domestically) is not considered; export/imports trends are expected to be continued.

Yield increase rate

The increase in yields would show a differentiated pattern among various regions in Europe. The current agricultural production system would determine greatly the future crop yields. To follow this assumption all regions (NUTS-2) are divided into two groups of agricultural production systems: extensive or intensive. The division is based on inputs consumption: (i) fertilizers, (ii) pesticides and (iii) fuel use. The data are derived from FADN and EUROSTAT databases. If the level of inputs consumption is below the one calculated as average for Europe, the agricultural system was classified as extensive, otherwise it was assumed to be intensive, see Annex C.

In Scenario S1 in regions of extensive production it is assumed that the yield growth is expected to reach 30% by 2020 (1.1% per year), whereas the intensive production regions should exhibit a lower growth of some 10% (0.5% per year). In Scenario S2 the yield growth rate is reduced with 30% compared to S1, which results in 20% increase rate for expensive production regions and 7% for intensive production regions, respectively.

As a reference for the estimation of the yield increase rate in S1, the DG Agriculture prospects on agricultural markets in Europe were used (DG Agriculture, 2006). In this document it is stated that yield growth in the EU15 countries (intensive production) slowed down considerably over the last decade and this would suggest that production is at the technological frontier even in the most competitive regions. Therefore, future annual gains in yield appear limited (0.5% per year). In the EU12 countries (extensive production) yield growth had picked up shortly before and after EU accession, though at significantly lower rates than projected (on account of the slower than expected structural change). Therefore, the further yield growth is assumed to be of 1.1% per year.

Energy crop yields

To harmonize the assessment with other RENEW work packages, i.e. WP5.3 'Economic assessment', the energy crop yields were derived from deliverable D5.03.04 "Energy crop production costs in the EU". These are yields typical for large-scale commercial plantations and are defined for several crops in three land quality classes, see Table5.

- Woody crops include: willow and poplar for all Europe except from southern countries, for which eucalyptus is considered relevant.
- Perennials grasses include: miscanthus for all countries, except from northern and southern Europe, for which reed canary grass and switch grass are more suitable, respectively.

Miscanthus has the largest yield development potential in the future among the analyzed crops.

Table 5 Perennial energy crops yields for large-scale plantations for Starting Point and Scenario 2020 for three classes of soil quality (D5.03.04)

Scenario	SP			S1			S2		
Soil quality	Poor	Average	Good	Poor	Average	Good	Poor	Average	Good
					WEST				
Woody crop	10.0	10.0	12.0	14.0	14.0	16.8	9.8	9.8	11.8
Grasses	8.0	16.0	25.0	12.8	25.5	40.0	9.0	17.9	28.0
					EAST				
Woody crop	7.0	9.0	12.5	9.8	12.6	17.5	6.8	8.8	12.3
Grasses	9.0	11.0	17.0	14.4	17.6	27.2	10.1	12.3	19.0
					NORTH				
Woody crop	7.5	9.0	11.0	10.5	12.5	15.5	7.4	8.8	10.8
Grasses	6.0	7.5	10.0	8.5	10.5	14.0	5.9	7.4	9.8
					ALPINE				
Woody crop	10.0	10.0	12.0	11.2	14.0	16.8	7.8	9.8	11.8
Grasses	8.0	11.0	16.0	12.8	17.6	25.6	9.0	12.3	17.9
					UK and IE				
Woody crop	11.0	13.0	14.0	15.4	18.2	19.6	10.8	12.7	13.7
Grasses	15.0	18.0	20.0	24.0	28.8	31.2	16.8	20.2	21.8
					SOUTH				
Woody crop[A]	5.6	7.0	8.4	7.8	9.8	5.6	5.5	6.9	8.2
Woody crop[B]	4.5	5.6	6.7	6.3	7.8	9.4	4.4	5.5	6.6
Grasses[A]	7.1	8.9	10.7	10.0	12.4	7.1	7.0	8.7	10.0
Grasses[B]	5.7	7.1	8.5	8.0	10.0	12.0	5.6	7.0	8.4

[A] – yields relevant for NUTS-2 regions of suitable growing conditions (regions in which cereals yields are over or at the level of the average for the country)

[B] - yields relevant for NUTS-2 regions of not suitable growing conditions (cereals yields below the average for the country)

Fallow land conversion rate

Fallow land may be: (i) bare land bearing no crops at all, (ii) land with spontaneous natural growth, (iii) land sown exclusively for the production of green manure (green fallow). It was assumed that in 2020 the area of fallow land would be kept at the same level as in the Starting Point. That was justified with the expectation that CAP would continue to prevent food overproduction in Europe. with regard to 0the fact that land availability is very curtail factor for energy crop potential development, it was assumed that 100% of fallow land is available for energy crops in Starting Point and both future scenarios, S1 and S2.

The category of fallow land commonly includes low quality land with poor growing conditions; however, that was not investigated directly in the assessment.

Export surplus conversion rate

For scenario S1 it was assumed that some land might be released from cereal and meat export reduction. Only cereal and meat exports are considered as other agricultural exports are far less significant. In the countries that are net exporters of cereal and meat it was assumed that the land equivalent of 30% of the export could be released for energy crops in 2020. The reduction in exports is in line with EU prospects to phase out export subsidies (DG Agriculture, 2006).

Permanent grassland conversion rate

Conversion of permanent grassland into bioenergy plantation was included for beef exporting countries. The conversion rate was estimated at maximum at 10% of permanent grassland, due to the risk of depletion of soil carbon stocks. Conversion of pasture to bioenergy plantations may lead to losses or gains in soil C, depending on the relative balance of organic inputs and decomposition rate under the old and new land uses (IEA Bioenergy, 2006). Due to this effect the conversion rate of 10% at maximum is used in the calculations. The assumption is confirmed by the level of changes in the area of permanent grassland observed in the statistics of different countries during the previous 15 years (EUROSTAT).

2. Methodology for energy crops suitability assessment

The target of the energy crop suitability analysis is the evaluation of geographically assigned agro-climate conditions for selected energy crops: willow, poplar, miscanthus, eucalyptus and switchgrass. The environmental characteristics of the species (climate and soil requirements) were matched with the terrain conditions to derive the quantitative, spatial assessment in the form of digital maps. The analysis was performed within Geographical Information Systems (GIS), the software enabling work with spatial, attribute data and statistics. The input special data are basically two geo-databases: TERRASTAT FAO (2002) and the European Soil Database (ESDB).

The methodology used for generating suitability maps consists of the following steps:

Step 1: Defining the Mapping Suitability Units (MSU).

- Grouping input thematic layers (thermal climates, soil depth, length of available growing period, etc.), represented in Annex D.
- Intersection input layers to merge thematic layers into a MSU map.
- Dissolving received spatial units using MSU attributes (to reduce number of polygons) and saving with individual codes and IDs.

The schematic diagram in Figure 3 presents the overview of the MSU layer building procedure.

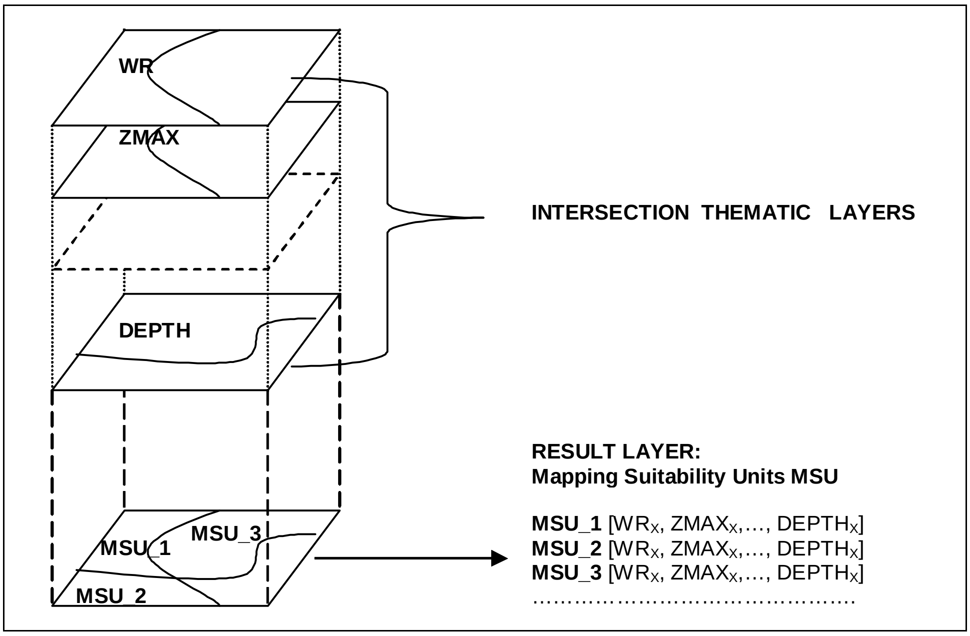


Figure 3 Generation of Mapping Suitability Units from input thematic layers

Step 2: Assessing the Suitability Values for respective crops.

- Evaluating importance (with importance weights) of the analyzed ago-climatic factors for each species.
- Evaluating suitability (with suitability weights) of respective attributes for each crop.
- Multiplying the value of factor's importance weight by suitability values for respective attributes; repeated for each attribute. Output values for each crop are represented by a respective sum of products.

The Annex E presents the evaluated agro-climatic factors and attributes. The importance weight scale for factors is 0-10 point. The attributes were evaluated with suitability weights 0-10 point scale, where 0 represents not suitable conditions and 10 refers to very suitable conditions. The final values are the sum of respective products (factors' importance weight multiplied by attribute' suitability weights). The importance and suitability assessment was based on a consultation procedure between experts from ECBREC, CRES and the Warsaw Agricultural University.

Step 3: Matching the Suitability Values (Step 1) with respective Mapping Suitability Units (Step 2).

- Assigning Suitability Values with Mapping Suitability Units.
- Linking spatial dataset with assigned Suitability Values.

Step 4: Editing suitability maps using classification schemes for mapping quantitative data.

The suitability maps present evaluation of terrain conditions for five energy crop species using four suitability classes:

- Not suitable
- Poor
- Average
- Good

There is also an additional class 'no data'. The classification is based on ready to use GIS scheme 'quartile', which makes the map comparison possible. The Annex E shows the energy crops Suitability Values distribution and thresholds for respective suitability classes.

The final suitability maps were produced as a result of calibration process. During the calibration process factors' importance weights and attributes' suitability weights were adjusted. Several 'intermediate' suitability maps were produced. Over- or under- estimation of the factors' and attributes' weights were identified when analyzing suitability maps for a given crop. The calibration process was repeated several times.

3. Results

3.1. Land for energy crops

Following land areas would become available for energy crops:

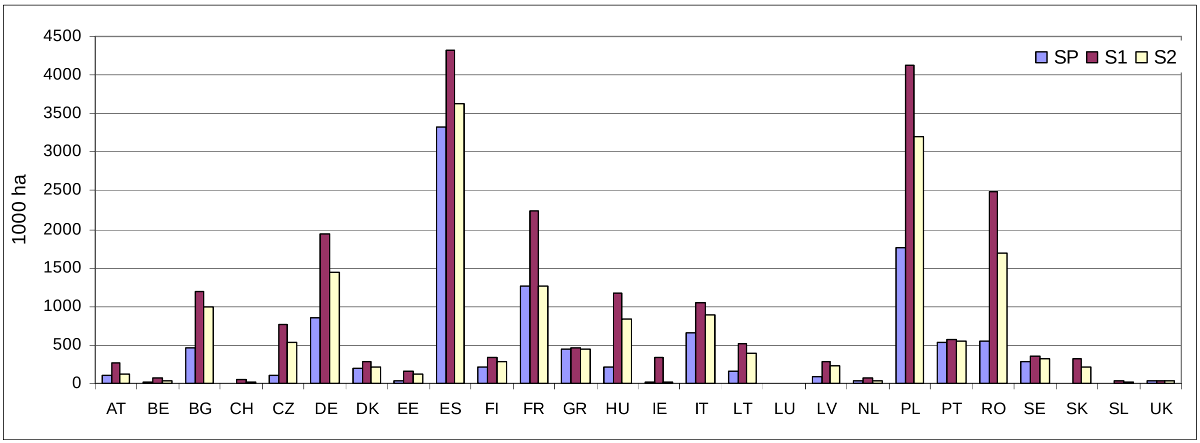
- SP: 1 350.2 thousand ha, which corresponds to 6.1% of total agriculture land.
- S1: 23 508.6 thousand ha, which corresponds to 12.5% of total agriculture land.
- S2: 17 556.8 thousand ha, which corresponds to 9.4% of total agriculture land.

Land availability is the most crucial factor for the energy crop production development. In Starting Point fallow land is considered as available for energy crops in all countries independently from the quality of these lands. Spain, with 3.3 Mha of fallow land is the leading country, next to other countries with considerably large fallow lands, like Poland, Denmark and France, see Graph 1 and Table 6 Land available for energy crop in 1000 ha in European countries for different scenarios.

In future scenarios additional land would become available as a result of agriculture productivity increase as well as reduction in grain and meat exports (only in S1). Countries of Central-East Europe have the greatest opportunities for crop productivity increase resulting in large areas released from food crops without affecting food supply. In EU15 countries, which already have had intensive crop production, less land would become available with regard to low rate of further yield increase. In these countries energy crops could grow on land released from food production as a result of reduction in exports. In S1 30% reduction in grain and meat exports is considered due to phasing out of export subsidies. France and Germany the leading grain exporters in the EU would offer large land areas. Moreover, in Ireland, which is having significant beef exports, the equivalent of 10% of permanent grassland would become available for energy cropping due to beef exports reduction.

United Kingdom is the only country, where high food consumption increase in the future totally dominates the effect of agriculture productivity increase resulting with no additional land available for energy crops in future apart from the existing fallow land.

Scenario S2 shows much less land availability for energy crops compared to S1 with regard to less intensive cultivation (low rate of land released from food crops) in Europe and no land being available from food exports reduction.



Graph 1 Land available for energy crop in European countries for different scenarios

Table 6 Land available for energy crop in 1000 ha in European countries for different scenarios

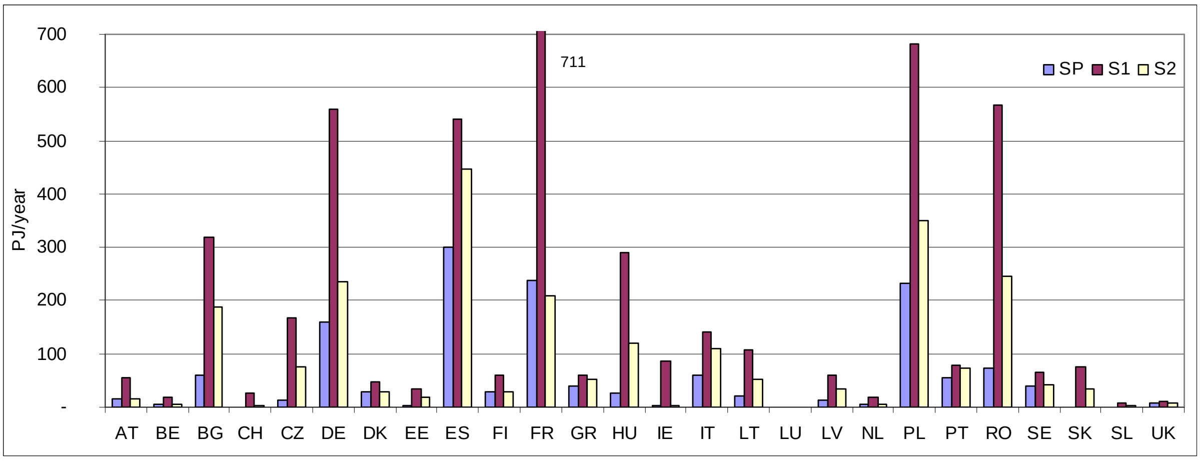
Countries	SP	S1	S2
AT	106,3	274,2	123,7
BE	26,3	70,5	37,4
BG	454,1	1 187,0	995,3
CH	4,0	56,5	15,8
CZ	99,7	769,8	538,0
DE	846,3	1 945,1	1 449,0
DK	200,0	284,9	218,7
EE	28,3	165,9	123,8
ES	3 320,2	4 325,3	3 624,9
FI	211,0	334,5	280,0
FR	1 262,4	2 248,2	1 262,4
GR	440,5	465,6	440,5
HU	204,7	1 169,9	837,3
IE	14,4	338,3	14,4
IT	654,8	1 052,9	892,2
LT	164,5	520,9	393,8
LU	1,7	5,5	1,9
LV	97,3	284,2	234,4
NL	27,2	79,6	32,3
PL	1 768,5	4 128,9	3 196,6
PT	541,6	568,3	556,1
RO	551,2	2 484,6	1 693,0
SE	283,0	356,0	326,0
SK	4,6	324,6	220,3
SL	-	34,0	15,5
UK	37,9	33,4	33,4
Total	11 350,2	23 508,6	17 556,8

3.2. Energy crop production potential

The available land creates space for different energy crops cultivation. Perennial crops represent significant opportunities for productivity increase in the future, with special focus on miscanthus having very high yield development potential.

Energy crop yields relevant for the energy crop production potential assessment were presented in section 1.2. These are yields typical for commercial plantations for three different soil qualities. In the production potential assessment the yields typical for poor soils are relevant for fallow lands, while the yields on average soils are assigned for lands released from food crops. The yields on good soils were not used in the model as good soils should be primarily allocated for food production.

The energy crop future production potential in PJ/year is presented in Graph 2. The greatest potential can be found in countries of the largest agriculture land areas. Spain together with Poland and France contribute to half of the total potential estimated for Starting Point. In future scenarios the group representing the largest potential for energy crop production is extended with Romania, Germany, Bulgaria and Hungary. The results represent the potential energy crops production, which could be developed in each of the countries.



Graph 2 Energy crop potential in European countries for different scenarios

Table 7 Energy crop potential in PJ/year in European countries for different scenarios

Countries	SP	S1	S2
AT	16,0	54,7	15,6
BE	4,9	18,4	4,7
BG	59,8	319,9	186,8
CH	0,6	25,5	2,7
CZ	13,1	166,4	75,3
DE	159,1	560,2	235,8
DK	28,2	46,8	27,6
EE	3,7	33,9	17,1
ES	299,7	541,8	446,6
FI	29,4	58,8	30,0
FR	237,3	711,5	207,7
GR	40,3	60,6	53,1
HU	26,9	288,8	120,0
IE	3,0	86,9	2,6
IT	61,0	139,8	119,6
LT	21,6	107,1	52,2
LU	0,5	0,9	0,3
LV	12,8	60,2	33,5
NL	5,1	18,3	4,5
PL	232,7	682,0	350,3
PT	55,8	78,2	73,6
RO	72,5	566,8	246,2
SE	39,9	64,9	42,0
SK	0,6	76,9	35,1
SL	-	8,8	2,9
UK	7,8	9,7	6,8
Total	1 432,5	4 787,8	2 392,6

The biomass potential distribution on NUTS-2 regional level for energy crops is presented in Figure 4 - Figure 6. This is an average regional specific potential in GJ/ha calculated as potential normalized by total land area in each region.

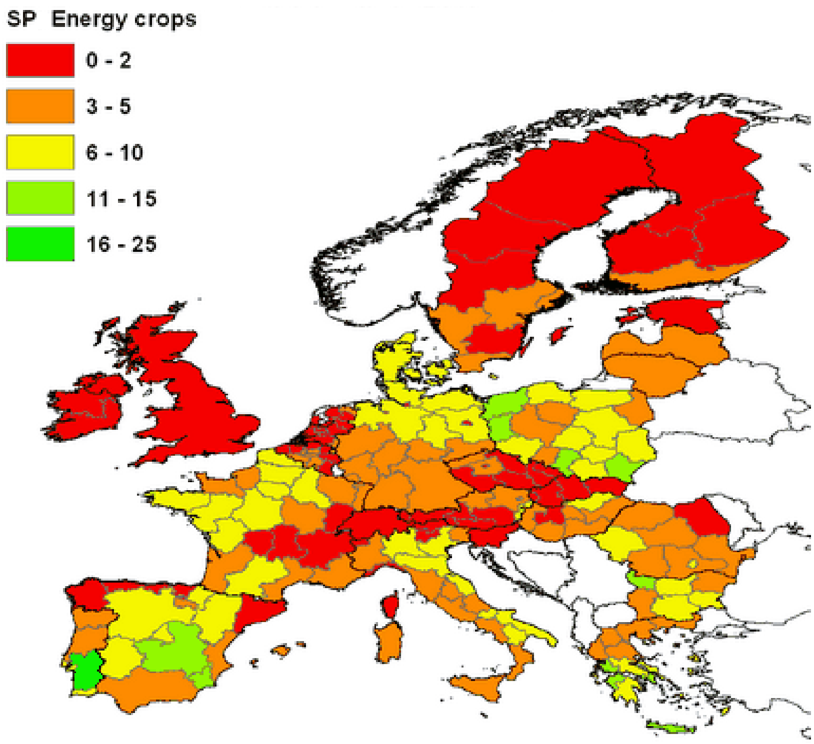


Figure 4 Energy crop regional specific potential in GJ/ha of total land for SP

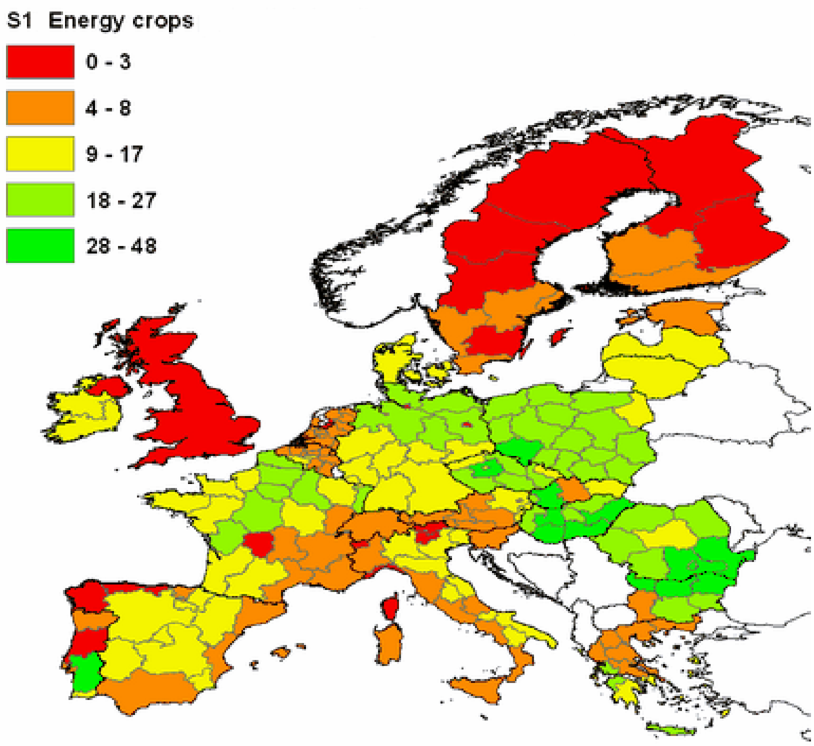


Figure 5 Energy crop regional specific potential in GJ/ha of total land for S1

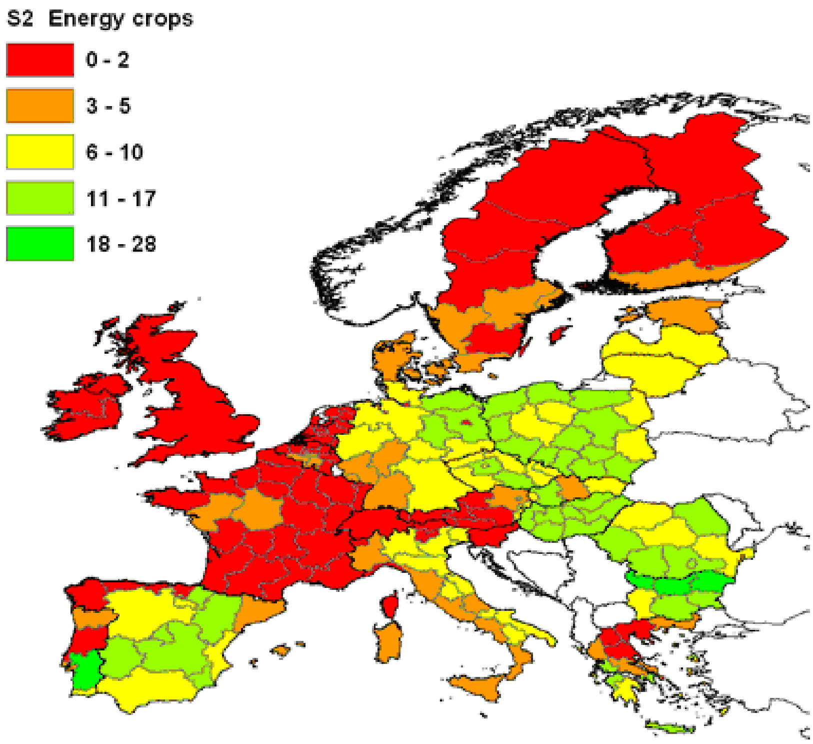


Figure 6 Energy crop regional specific potential in GJ/ha of total land for S2

In Starting Point most of the regions represent energy crop potential at the level of 3-5 and 6-10 GJ/ha. Regions with the highest regional specific potential over 16 GJ/ha are found in Portugal, Spain, Greece, Poland and Bulgaria, which is in line with high share of fallow land in these regions. The potential distribution across Europe presents significant changes between Starting Point and Scenarios S1 and S2. In future scenarios regions of Central-East Europe gain much land in favour of energy crop production, which is an effect of agriculture productivity increase and considerably low food consumption increase. Moreover, in scenario S1, significant potential of energy crop production would be also developed in agricultural regions of France and Germany, mainly as a result of reduction of cereal exports and corresponding land conversion into energy crop plantations. The region specific potential in S1 is at the level of 18-27 GJ/ha in most of the selected regions, reaching over >30 GJ/ha in the most biomass reach provinces located in Hungary, Romania, Bulgaria and Poland. In Scenario S2 the area specific potential are considerably lower, which is the effect of lower land availability and low energy crop yields compared to S1.

3.3. Energy crop suitability analysis

With regard to different agro-climatic and soil conditions in Europe energy crop suitability maps were prepared as an additional element of the potential assessment, see Figure 7 - Figure 9. A set of site conditions, i.e. soil water regime, length of growing period, above see attitude, etc., were evaluated with regard to the requirement for selected energy crops species and resulted with four suitability classes: not suitable, poor, average, and good.

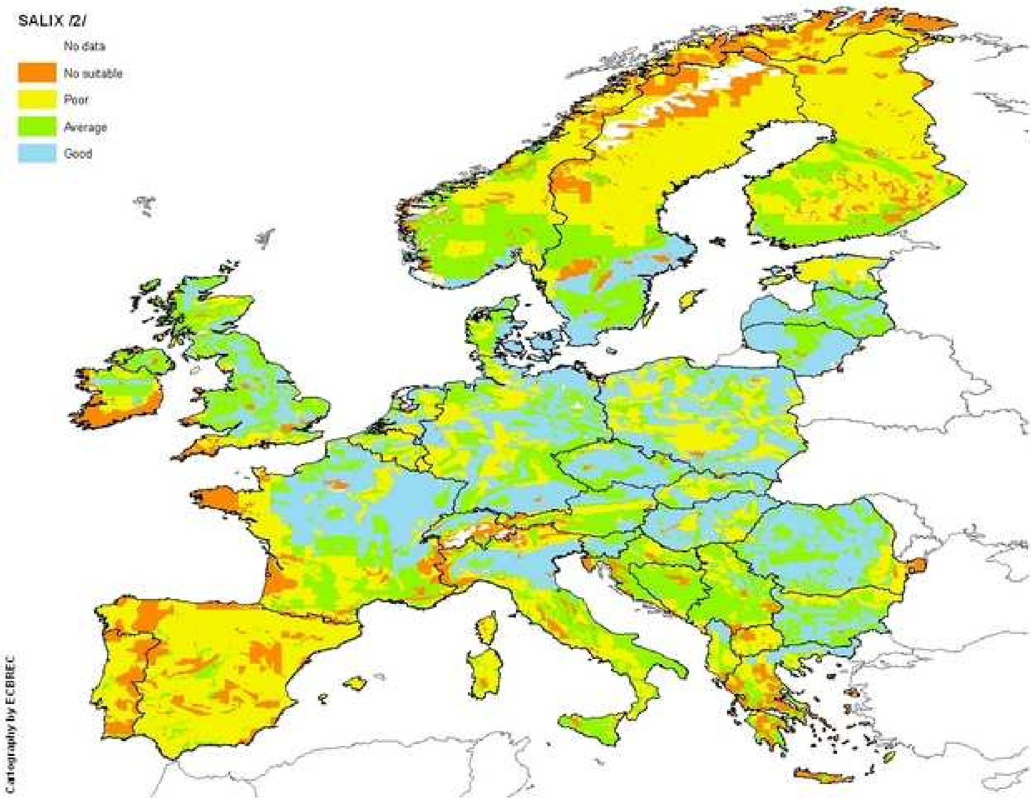


Figure 7 Suitability map for willow

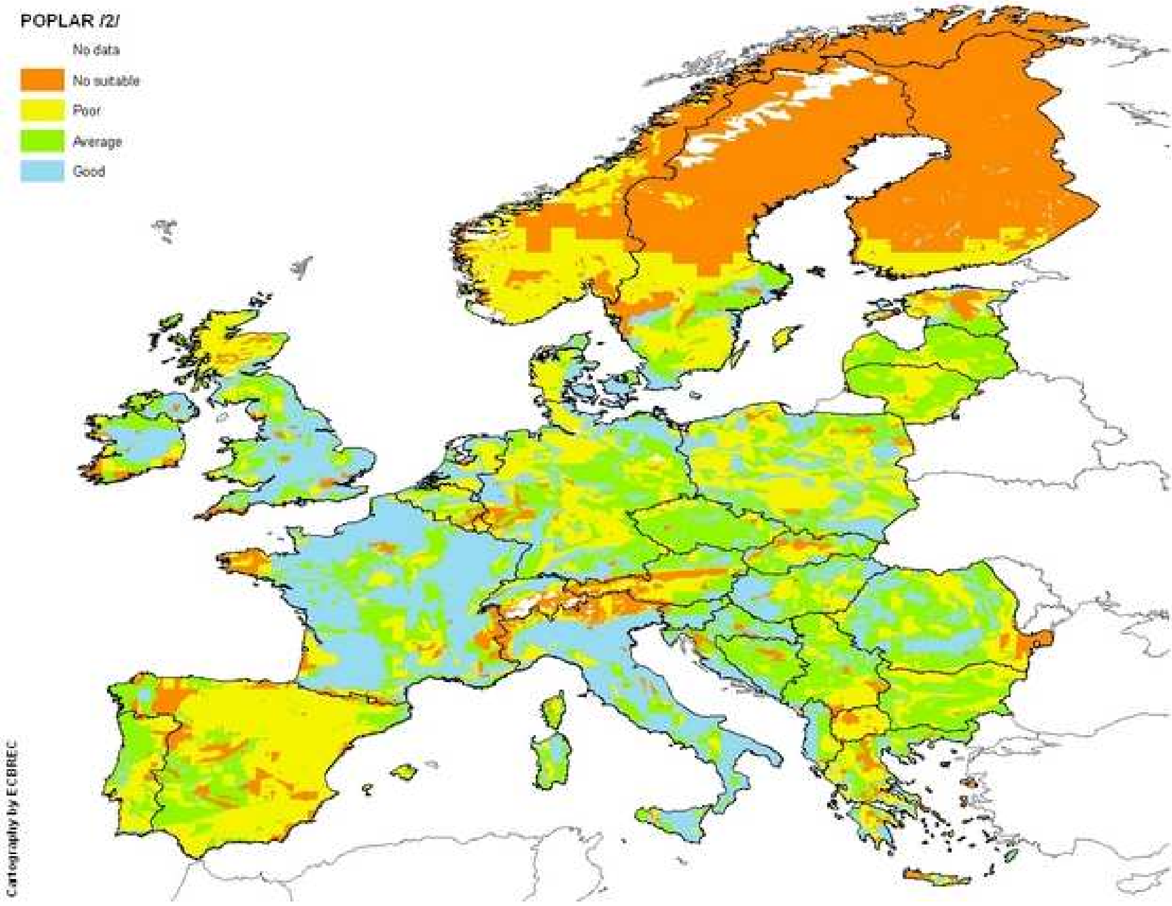


Figure 8 Suitability map of poplar

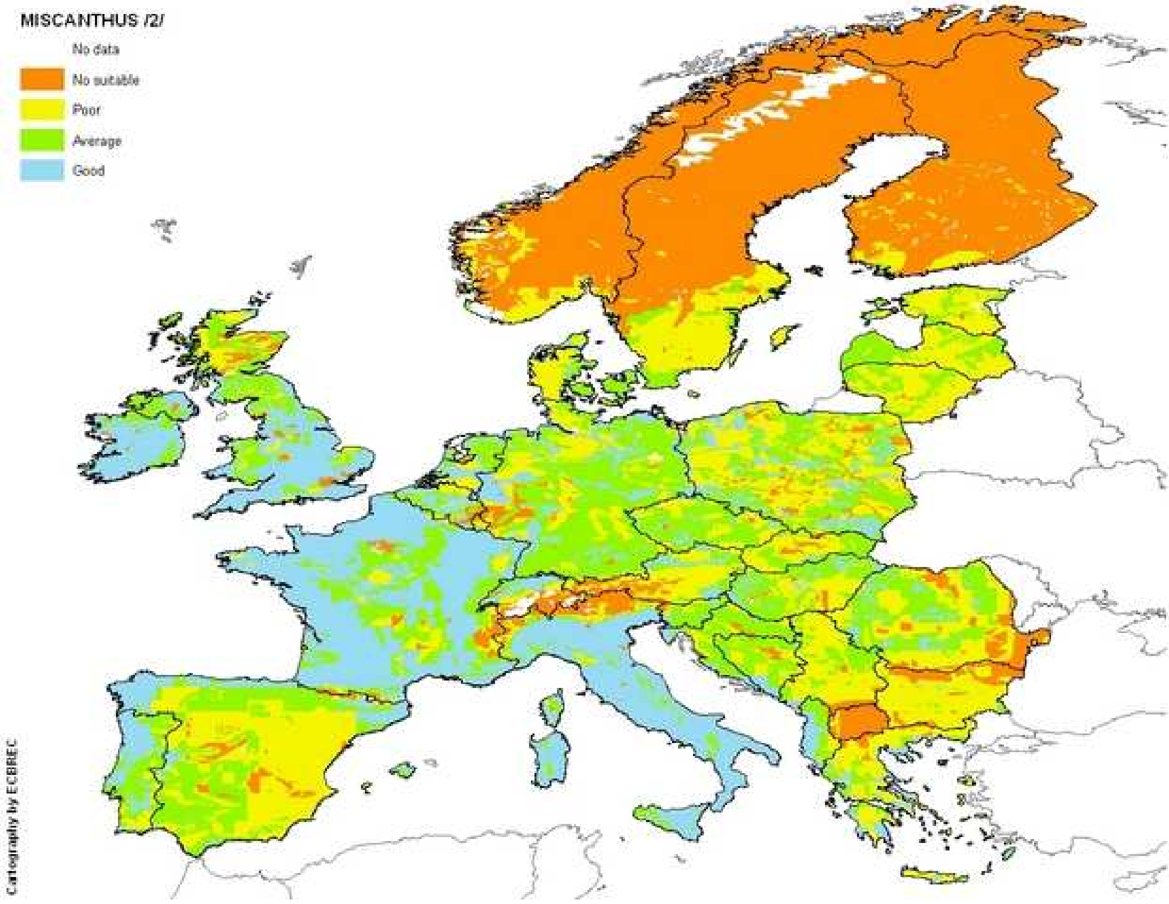
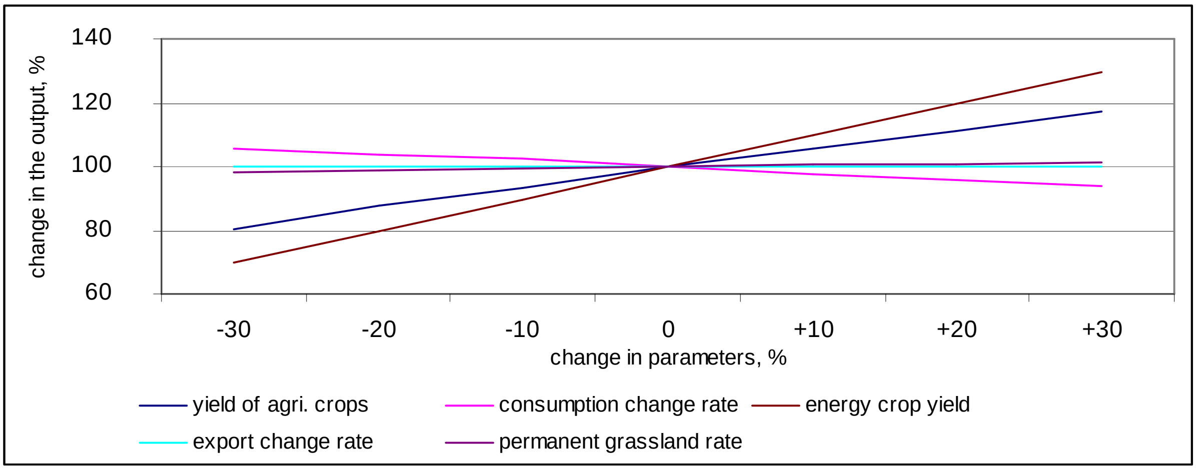


Figure 9 Suitability map for miscanthus

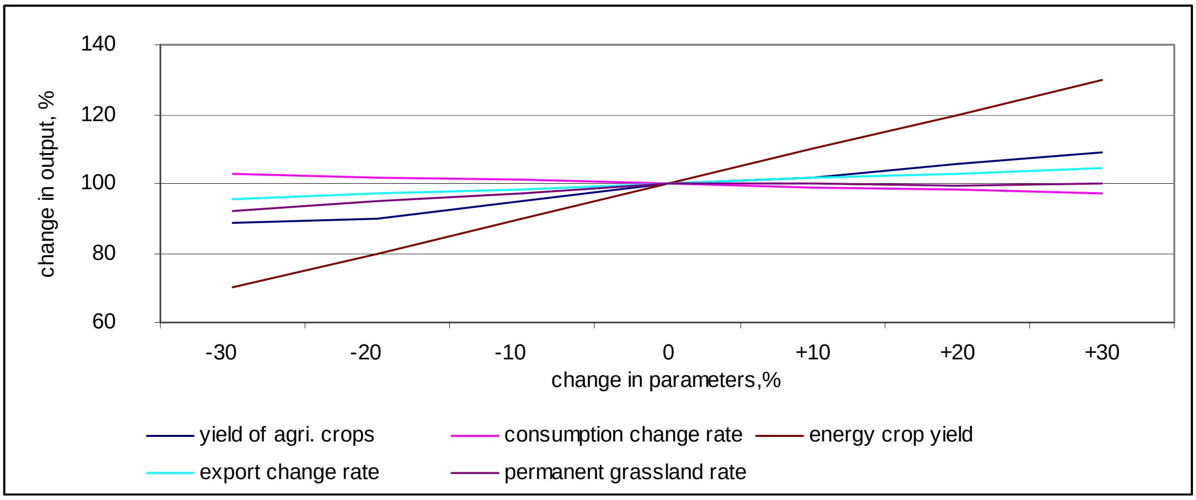
3.4. Sensitivity analysis

The LA model comprises a series of equations, input factors, parameters, and variables aimed to characterize the situation of agricultural production in Europe in the future. Assumptions on future situation are subject to many sources of uncertainty including absence of information and partial understanding of the driving forces and mechanisms. This uncertainty imposes a certain limitation on the confidence in the output of the model.

To identify the input parameters that mostly contribute to the outputs variability of the LA model, see Graph 3 and Graph 4. The charts are presented for Poland and Germany for S1 scenario used as a base case of the sensitivity analysis.



Graph 3 Output variability of the LA model due to the change in parameters for Poland



Graph 4 Output variability of the LA model due to the change in parameters for Germany

Energy crop yield is an input parameter which affects the output of the model the strongest. The increase rate of food/fibre crops' yields comes in the second place, although this parameter has a stronger effect on the final result in the extensive producing countries, like Poland, than in the intensive producing regions, e.g. Germany. This is because of the higher accepted value of this parameter for extensive regions (30%). The consumption change rate, export change rate and permanent grassland conversion rate has much weak effect on the model outcome. The effect of changes in the export change rate for Germany is bigger than for Poland represented. This is because of the fact that Germany exports significant amounts of cereals, while Poland is a net cereal importer. Also the permanent grassland conversion rate in Germany contributes much to the variability of final result than in Poland, due to larger permanent grassland area in Germany.

The linear dependence is slightly foulted for the parameter of the strongest influence (yield of energy crops). This is the effect of the allocation rules applied in the model, which manage land compensation within one crop category and among different crop categories and prevent overlapping of crop areas or exceeding the total agricultural area.

4. Discussion of results

Effects on the energy crop cultivation area

Total land available for energy crops have been estimated due to different factors influencing branches connected with agriculture. The assessed amounts of land for energy species consist, both on the national level and the NUTS-2 level, of land released from cereals, industrial crops, and fodder from arable land, root crops, fallow land and permanent grasslands. For all of these compounds some estimation has been established.

Land released from agricultural crops due to productivity increase has been assessed according to the predictions about biotechnology progress and improvement in production standards, which are to result in higher crop yields. As a consequence less land is expected to be necessary for food and fodder production in the future. However, the level of technical development is difficult to predict and may have different results among countries, mainly due to their economic position.

Population and diet are main factors shaping the demand for food. The population is expected to decrease moderately within the next decades in most countries (United Nations, 2003). However, for food consumption patterns the trend in Europe during the past decades was to increase the land area per calorie produced (Gerbens-Leenes and Nonhebel, 2002). This was due to growing consumption of meat, diary products and beverages. If such trend continues in Europe, the land release possible due to increased crop productivity will have to be used for animal foodstuff mainly. Such situation was analyzed by Yamamoto et al. 2001, who established a scenario for 2100, in which the energy crop potential was estimated at zero as all the land in Europe and globally was reserved for food production.

Considering the estimated food production there are also other elements that should be pondered, for example the RENEW analysis does not include factors like the changes of supply and demand for meat caused by possible outbreak of epidemic among animals.

Food production is given priority in our analysis; however, the countries are not expected to be self-sufficient in food production within the investigated time horizon. The current trends in agriculture export/import are assumed to continue until 2020. However, some changes in exports may happen due to the growing demand for grain in the developing countries of South East Asia (DG Agriculture, 2006).

In Scenario S1 the net exporting countries (cereals and meat) were assumed to convert some of the land from reducing export surpluses into bioenergy plantations. The conversion rate was assumed at 30%. However, the rate may be much less as agricultural exports are subsidized and constitute an important contribution to the national budget in some countries, e.g. Poland, Romania, and France.

The estimated available areas for energy crop production may be reduced in case a part of agricultural imports are to be produced domestically on the released land. Such assumption was not included in the potentials analysis in RENEW. This would have the strongest influence on the final result in countries, which are leading net cereal importers, e.g. Spain, Italy, The Netherlands, Belgium, and Portugal.

The land competition between energy crops and several other kinds of non-food land-uses, such as fiber, chemicals, infrastructure, afforestation schemes, nature conservations, etc. was not included in this analysis. However, regarding the biorefinery development prospects, the land use for bio-material production might also be of a growing importance in European agriculture in the future decades. Additionally the competition for land between lingo-cellulose crop and other types of energy crops was not considered.

The growing expectation with regard to biomass as a source of sustainable energy would place additional restrictions on the possible cultivation of energy crops in the next decades (Cramer et al., 2007). Large-scale energy crop production will have to comply with biodiversity, environment, traditional land use applications, local prosperity requirements, etc. This will impose additional limitations on the potentially available cultivation areas and yield achieved.

Effects on the energy crop yields

The assessment of energy gained in all the countries have been done by calculating the land available for energy crops and the possible yield to be obtained. In some countries where the amount of available land was found to be relatively big, the level of overall energy crop potential occurred to be not corresponding and on the contrary, countries with not much surplus land appeared to have higher potential. These discrepancies were the results of two different yield levels relevant for average and poor quality soils used in the LA model. The other aspect that influenced mentioned numbers was geographical position. The same or relevant species provide various yield levels in different agro-climatic zones of Europe.

It is important to understand realistic differences between two scenarios presented for the future (S1 and S2). Nowadays, energy species produce changeable amounts of biomass, depending on many factors. The yields of energy species for scenario S1 were derived from deliverable D5.03.04, which shows yields of well-managed commercial plantations. The yields for 2020 were assumed due to the expected improvement in plantation management schemes and cultivation of high yielding varieties. However, it is known that due to different fertilization level as well as water, soil and climate conditions at the cultivation site, the yield gained may grow even higher or decrease significantly.

In Scenario S2 the yields were reduced with 30% compared to S1 to reflect the requirement to minimize the environmental negative effects of intense agriculture. Considering the fact that the current area of lingo-cellulose energy crop plantations in Europe is very insignificant and the analyzed time frame is relatively short, the assessment of scenario S2 may be regarded as more realistic. The experience of Swedish farmers with cultivating willow shows that the expected yields have not been achieved on commercial plantations. The yields were projected to be at the level 12 t DM per ha per year, however, they occurred to be only 6 t DM/ha on the existing plantations (Larsson, 2007).

Spain and Poland are the leading countries considering the energy crop potential. In both of them as well as in France the available land for energy crops comprises large areas of fallow land. At this point it is important to consider that in reality total fallow land cannot be completely adapted for energy plantations. Even if energy crops are assumed to be tolerant to various not appropriate conditions and do not have high soil requirements, some areas would occur to be not suitable for establishing energy plantations due to unreasonably low yields. In Poland fallow land comprises large areas of poor sandy soils with defective water conditions, which will produce extremely low yields. Similarly, in Spain large areas would require irrigation if used for energy crop plantations.

5. Implementation aspects

The implementation strategies of the BtL biofuel chains development are analyzed in the scope of WP5.3 “Economic assessment”. However, some aspects of energy crop cultivation development in Europe are mentioned here. This refers to lingo-cellulose crops.

Perennial lignocellulosic crops production is still marginal in Europe and exists mainly due to the political and financial support provided by the member states. Throughout Europe there are certain cases, namely in Sweden, Finland, UK and Poland, see Table 8. In other countries some plantations exists, but the area is negligible.

Table 8 Plantations area (in hectares) for lingo-cellulose perennial energy crops in selected countries, data for 2006

Country	Salix	Reed Canary Grass	Miscanthus	Reference
England	1,180		3,356	DEFRA, 2006
Sweden	15,000	3,500		Fagernas, 2006
Finland		17,200		Jarvenpaa, 2007
Poland	7000			ARiMR, 2006

The economic framework conditions seem to be the most crucial for the establishment and development of large-scale energy crop production in Europe. Even if large areas of land are available in Europe nowadays (set aside land and fallow land) they are not utilized for energy crop cultivation. This is due to a set of various risks to the farmers when lingo-cellulose energy crop cultivation is still a new activity in Europe. Ericsson et al. (2005) and Rosenqvist et al. (2000 indicate financial risks typical for the early stages of energy crop introduction, such as: (i) a considerably high plantation establishment cost compared to annual crops, (ii) the lack of income from the plantation until 3rd of 4th year, when the first commercial harvest take place, (iii) a long time on the return on the investment, (iv) lack of long-term stability of bioenergy policy in Europe, which is crucial for multi-annual crops.

An important barrier is also a general lack of knowledge and experience with permanent energy crops, especially woody crops, among conventional farmers. Farmers should be precisely informed about the crop specific cultivation requirements, as well as all the advantages and consequences of growing energy species on their land. The study of Rosenqvist et al. (2000) on willow cultivation in Sweden showed an important role of active information and agricultural advisory to stimulate the farmer’s willingness to grow a new crop. This was also confirmed by a study of Sinnisov (2006) on prospects on willow cultivation in Poland, in which lack of knowledge among farmers was causing reluctance towards establishing energy plantations.

A farm related factor, such as farm size, strongly affects the opportunity to cultivate energy crops. In Poland, where the average farm area is 8.4 ha, the conditions for large-scale plantations establishment are currently limited. However, the ongoing process of structural changes in Polish agricultural sector, stimulated by the implementation of CAP in 2004, would create better opportunities for commercial energy crop cultivation. This is due to the increasing land productivity and higher share of larger farms. However, the time frame for such changes may extend 2-3 decades.

The market for biomass from lingo-cellulose plantations is not well developed so far in most European countries. There is ‘no-win’ situation in place. There is no energy crop being cultivated in a specific region, which means that a market cannot develop. As there is no market, then there is no demand. In the early stages of energy crop introduction the long-term contracts between buyers of biomass and the producers would be one measure to reduce the biomass outlet and price risk (Helby et. al 2003). In regions, where the biomass market is established already (mainly based on forestry biomass), the systems must be adapted to wider biomass flow as well as simplified, to make entering the market more convenient, especially for small companies and energy crop plantations.

Very important aspects that should be taken into consideration when analyzing the possible development of energy crops plantations are public opinion and political stability of regulations considering bioenergy sector.

The public opinion towards development of large-scale energy plantations should be checked with the alternations in land management. The biomass production on agriculture land should be approved and welcomed by the local community. This is an important aspect of biomass sustainable production in Europe (Cramer et al., 2007).

A long-term stability of bioenergy policy is crucial to stimulate the energy crop production in Europe. The agricultural and energy policy are of scope here. Several legal measures have been introduced on the European Union level as well as on national governments level to stimulate the production of 'green' energy and use of biofuels in transportation sector. However, there is a strong need to harmonize the regulations of both agriculture and energy policies and assure long-term stability of thee regulations to create viable opportunities for the development of energy plantations and the biomass based enterprises on a wide-scale in Europe.

6. Comparison with other studies

Several existing studies represent result on energy crop production potentials. Table 9 presents the aggregated energy crop potentials from RENEW and the previous studies. These are resource focused studies. The studies differ from each other, as well as from RENEW, in several aspects, such as methodological approach, the level of analysis, types of energy crops investigated and time frame.

Table 9 Energy crop potential assessment according to RENEW and other studies; aggregated results

Scenarios	EU regions	Potential, EJ/year	Yield, t/ha*year	Area, Mha
		RENEW*		
Starting Point	EU15	1.0	5.6-13.0	8.0
2000-2004	EU12	0.4	7.0-9.0	3.4
Scenario S1	EU15	2.5	10.5-18.2	12.4
2020	EU12	2.3	9.8-12.6	11.1
Scenario S2	EU15	1.3	8.6-10.6	9.3
2020	EU12	1.1	7.1-11.3	8.2
		Thran et.al (2005)**		
CP Scenario 2000	EU15	0.9	A mixture of crops investigated	5.1
	EU12	0.2		2.4
E+ Scenario 2000	EU15	0.5		2.8
	EU12	0.1		1.2
CP Scenario 2010	EU15	2.6		14.3
	EU12	0.8		6.9
E+ Scenario 2010	EU15	0.8		3.6
	EU12	0.3		1.9
CP Scenario 2020	EU15	5.7		29.8
	EU12	1.9		15.1
E+ Scenario 2020	EU15	1.9		8.9
	EU12	0.7		5.1
		Ericsson and Nilsson (2006)***		
Scenario 1	EU15	1.4	10.2	7.3
2010-2020	EU12	0.5	5.9	4.3
Scenario 2A	EU15	3.4	10.3	18.4
2020-2040	EU12	1.8	9.2	10.7
Scenario 2B	EU15	4.1	12.4	18.4
2020-2040	EU12	2.1	11.0	10.7
Scenario 3A	EU15	9.4	10.3	51.4
>2040	EU12	5.6	9.2	34.7
Scenario 3B	EU15	11.3	12.4	51.4
>2040	EU12	6.8	11.0	34.7
		Hall et al. (1993)		
-	EU15	11.4	15.0	38.0
		Johansson et al. (1993)		
2025	EU15	9.0	15.0	30.0
	EU12	4.0	10.0	20.0
2050	EU15	9.0	15.0	30.0
	EU12	12.0	15.0	40.0
		Fischer and Schratten-Holzer (2001)		
2050	EU15	11.0-14.0	5.6-7.1	110.0
	CEEa	3.9-5.0	10.7-13.8	20.0
		Yamamoto et al. (2001)		
2050	EU15	16.0	15.0	53.0

Scenarios	EU regions	Potential, EJ/year	Yield, t/ha*year	Area, Mha
	F. USSR+CEEb	21.0	15.0	70.0
2100A	EU15	4.0	15.0	13.0
	F. USSR+CEE	5.0	15.0	10.7
2100B	EU15	0.0	-	0.0
	F. USSR+CEE	0.0	-	0.0

*results of potentials in PJ/year and yields presented for SRC and Miscanthus (lower values in the ranges represent SRC, higher – Miscanthus)

**CP scenario: Current Policy scenario; Scenario E+: Environmental scenario. Potentials of 'wet' energy crops for biogas aggregated with 'dry' crops for solid biofuels. Annual crops investigated.

*** Permanent energy crops investigated

a – Central East Europe

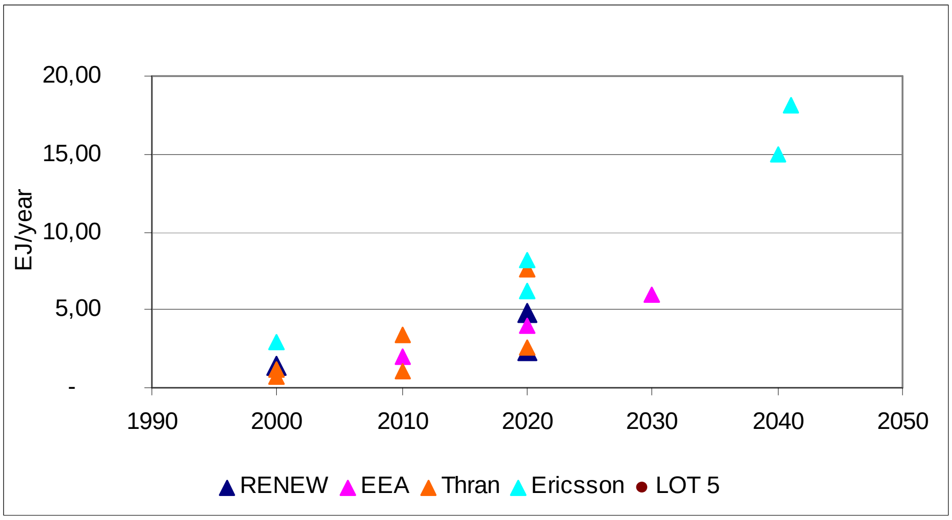
b – former USSR includes areas in both Europe and Asia

In each study the time frame is defined, except that by Hall et.al (1993). Most of the studies as well as RENEW use projections on population and the demand for food to assess the energy crop plantation areas, whereas the study of Ericsson and Nilsson (2006) and Hall et al. (1993) do not use modeled projections and the assessments are based on fixed assumptions regarding energy crop plantation areas.

The estimation of the plantation areas are approached in different ways. The study of Thran et al. (2005), Johansson et al. (1993) and Yamamoto et al. (2001) assumed countries self-sufficiency as well as the Scenario 3 in the study by Ericsson and Nilsson (2005). Hall et al. (1993) assumed that energy crops are grown on 10% of crop land, woodland and permanent pastures. In the RENEW approach the import/export trends are expected to stay as currently with possible partial export surplus reduction and land conversion into bioenergy plantations in the future scenarios.

The assumptions on energy crop yields are based on current agricultural crops yields. In the Ericsson and Nilsson study they are defined as 50% higher then the wheat yields. In the study of Thran et al. (2005) the energy crops yields are established based on projected technical progress. The same approach is used by the previous studies. In RENEW the energy crop yields were provided by regional partners as yields to be achieved under present conditions, and not yields that can be achieved in optimized field trials (D4.03.04). Projections on the future yield increase were based on more highly bred plants, higher knowledge among the farmers how to grow the crops and better plantation management standards.

The RENEW energy crops potential estimates are close to the results of Thran et al. study (2005) and Ericsson and Nilsson study (2006). The energy crop cultivation area in RENEW for the future scenarios is lower than in the study of Thran et al. (2005) in the CP scenario and Ericsson and Nilsson study (2006), but this is compensated with higher assumed yields of energy crops. Generally the aggregated potential for EU15 is higher than for EU 12 in most studies, which results from larger agricultural land areas in the EU15.



Graph 5 Comparison of energy crop potential assessment by RENEW and other studies

7. Summary and conclusions

The energy crop potential for Europe and the available land for energy crops estimated for RENEW scenarios is presented in Table 10.

Table 10 Available land and energy crop potential assessment in Europe

Scenario	Land area, 1000 ha	Potential, PJ/year
Starting Point 2000-2004	11 350.2	1 432.5
Scenario S1 2020	23 508.6	4 787.8
Scenario S2 2020	17 556.8	2 392.6

Energy crops production potential shows strong dependence on the available land for their production. In the Starting Point energy crops could be cultivated on fallow land, which will not affect food and fibre production. This land category commonly includes poor quality soils.

In future scenarios S1 and S2 the ongoing agriculture productivity increase in Europe (yield increase per ha) would make considerable areas available for energy crops from common crops. This would be possible without disturbing food supply. Central and East European countries, which have large opportunities for further crop productivity increase, could release significant areas for energy crops cultivation. In the EU15 countries the yields has already reached the technological frontier and no significant agriculture areas would be released except from land available from food exports reduction. This would result in large areas available in France, Germany and Ireland (only in scenario S1). Population and consumption changes have been included.

Perennial ligno-cellulose energy crops, such as short rotation coppice or perennial grasses, present high yielding potential based on further research in crop breeding as well as learning and scale effects at the plantation management stage. However, the current cultivation area of lingo-cellulose crops for energy use is less than 100 000 ha in Europe. There are considerable barriers for wide scale development of perennial crops, which are regarded as new type of crops for existing farming system based on annual crops. Thus, specific farmers-targeted programs are required to overcome the risks related with perennial crops implementation.

Energy crop suitability for specific agro-climatic and soil conditions would determine the yields and thus the competitiveness of production. A range of suitable crops is available for Europe, however, the regions of Southern Europe characterized with large abandoned areas of marginal soils and low participation would require development of specially adopted energy crops, capable of growing in arid climate. In general, the competitiveness of energy crops with other agriculture crops will determine its development. As for any other crop, energy crops yields are strictly determined by soil quality, thus energy crop may compete for the same land with cereals. The relative prices of grain and energy crops will determine what is cultivated and where it is cultivated – higher grain prices will push energy crop production onto poorer soils.

The spatial distribution of biomass potential across Europe shows high diversification among countries. Generally countries of large areas of agricultural land present large energy crop development potential. There is also significant diversification in the potential among the NUTS-2 regions of one country. Regions with high share of fallow land in total land and opportunities for yield increase are considered most suitable for development of energy crops production. These regions may be regarded as promising BtL fuel production plants locations.

References

ARiMR, 2006: Department for Direct Area Payments. Agency for Modernization and Restructurisation of Agriculture. Warsaw

CODED, 2007: The Eurostat Concepts and Definitions Database. On line: http://circa.europa.eu/irc/dsis/coded/info/data/coded/en/all.htm

Cramer J. et al., 2007: Testing framework for sustainable biomass. Final report from the project group 'Sustainable production of biomass' Creative Energy. Energy Transition. June 2007.

DEFRA, 2006: Creating value from renewable materials. A strategy for non-food crops and uses. Two year progress report. Department for Environment, Food and Rural Affairs. November 2006

DG Agriculture, 2006: Prospects for Agricultural Markets and Income in the European Union 2006-2013. July 2006

D5.01.03: Residue biomass potentials inventory results. RENEW project deliverable. EC BREC, Poland. December 2006.

D5.03.04: Energy crop production cost in the EU. RENEW project deliverable. Lund University, Sweden. December 2006.

D5.03.10: Implementation strategies. RENEW project deliverable to be prepared. IEE, Germany. Scheduled for December 2007.

Ericsson K., Nilsson L. 2006: Assessment of the potential biomass supply in Europe using a resource-focused approach. Biomass and Bioenergy, 2006. 30: p. 1-15

Ericsson K., Rosenqvist H., Ganko E., Pisarek M., Nilsson L. 2006: An agro-economic analysis of willow ciultivation in Poland. Biomass and Bioenergy 30 (2006):16-27.

European Comission, 2007: A Renewable Energy Roadmap: paving the way towards a 20% share of renewables in the EU's energy mix by 2020. Press release: MEMO/07/13. Brussels, 10 January 2007.

EUROSTAT: European Statistic Database. On line: http://epp.eurostat.ec.europa.eu/portal/page?_pageid=0,1136206,0_45570464&_dad=portal&_schema=PORTAL

FADN: Farm Accountancy Data Network. On line: http://ec.europa.eu/agriculture/rica/dwh/index_en.cfm

Fagernas L. et al. 2006: Bioenergy in Europe: opportunities and barriers. Bioenergy NoE report. VTT, 2006.

Fischer G. and Schrattenholzer L. 2001: Global bioenergy potentials through 2050. Biomass and Bioenergy 2001; 20:151-159

Gerbens-Leenes P. W. and Nonhebel S. 2002: Consumption patterns and their effects on land required for food. Ecological Economics 2002; 42:185-199

Hall D. O., Rosillo-Calle F, Williams R H and Woods J. 1993: Biomass for energy: supply prospects. In: Johansson T B, et al. editors. Renewable Energy - Sources for Fuels and Electricity. Island Press, Washington D.C., 1993, p. 593-651

Helby P. et al., 2003: Market development problems for sustainable bio-energy systems in Sweden. (The BIOMARK project), IMES/EESS Report no. 38, Environmental and Energy Systems Studies, Lund University, Lund, Sweden.

Jarvenpaa M. 2007: Field energy crops experience from Finland. MTT. Presentation at *Agroenergy workshop* under Network of Excellence *Overcoming Barriers to Bioenergy*. & November 2007, Paris.

Johansson T. B., Kelly H, Reddy A. K. N. and Williams R. H. 1993: A renewables-intensive global energy scenario (appendix to chapter 1). In: Johansson T B, et al. editors. Renewable Energy - Sources for Fules and Electricity. Island Press, Washington D.C., 1993, p. 1071-1142

Larsson S., 2007: Personnel communication by Karolina van Hulst. Agrobransle AG May 2007. Sweden.

LOT5, 2003: Bioenergy's role in the EU Energy Market. Biomass availability in Europe. Report to the European Commission. CRES, BTG, ESD.

Niewiadomski et al., 1992: Słownik agro-bio-techniczny [Agro-bio-technical dictionary]. Polish Asssosiation of Agrociotechnical Science. Lublin 1992.

Rosenqvist, H., Roos, A., Ling, E., Hektor, B. 2000. Willow growers in Sweden. Biomass and Bioenergy 18(2):137-145.

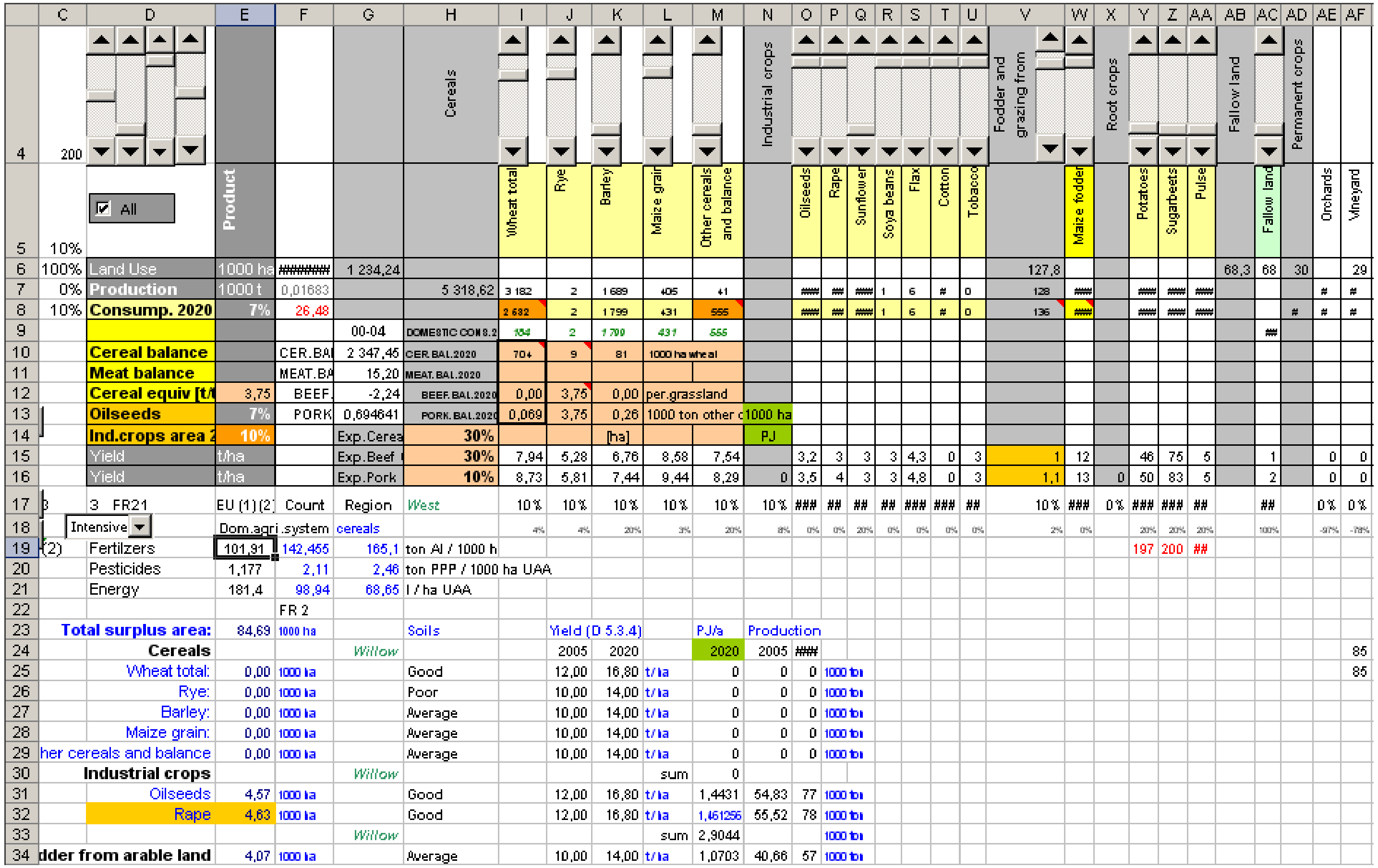
Sinnisov L. 2006: Barriers to dedicated energy crop cultivation in Poland. The case of willow in the Grudziądz region. Master thesis at the IIIEE Lund University.2006

TERRASTAT FAO, 2002: Documentation of Global land resources GIS models and databases for poverty and food insecurity mapping. Land and Water Digital Media Series, FAO, 2002.

Thran D. et al. 2005: Sustainable strategies for biomass use in the European context. Study for the German Federal Ministry for the Environment, Nature Conservation and Nuclear Safety. Institute for the Energy and Environment.

United Nations 2003: World population prospect: the 2002 Revision Population Database. United Nations Population Divisions. 2003.

Annex A: Land allocation model print screen



Annex B: Agricultural production system classification

Three types of agricultural production inputs were used to help to characterize the agricultural production system in Europe. These are fertilizers use, pesticide use and energy use (diesel) in agricultural production.

Statistical data on expenditures on agricultural inputs were taken from FADN; data on inputs consumption (fertilizers, pesticides and energy) were taken from EUROSTAT database. EUROSTAT database offers statistical data only for national level (NUST-2), while FADN database on NUTS-2 level. These data were set together into calculations to achieve the inputs consumption (in tons per ha or liters per ha) for NUTS-2 regions.

For fertilizers the following calculation procedure was used:

1)

$$\text{share of regional expenditures in national expenditures for fertilizers} = \frac{\text{regional expenditures for fertilizers [€/t]}}{\text{national expenditures for fertilizers [€/t]}}$$

2)

$$\text{regional fertilizers consumption [t AI]} = \text{total national fertilizers consumption [t AI]} \times \text{share of regional expenditure for fertilizers}$$

3)

$$\text{fertilizers consumption [t AI / 1000 ha]} = \frac{\text{fertilizers consumption [t AI]}}{\text{agricultural area [1000 ha]}}$$

The same was used for pesticide use.

For calculating the diesel use in liter per 1000 ha of agricultural land following equation was used:

$$\text{energy consumption in region [l of diesel/ha]} = \frac{\text{regional expenditures for energy [€/ha]} \cdot 1000\,\text{[ha]}}{\text{national diesel oil price [€/1000 l]}}$$

The mean valued for Europe were calculated as break values, on which the classification was performed. If the level of inputs was below the break value, the agricultural system was classified as extensive, otherwise it was assumed intensive. The EU15 countries were classified as ones of intensive production system, while the EU12 countries extensive ones.

Table B1. Break values (mean values for Europe) for inputs use

Inputs	Values
Fertilizers use in tons of active substance per 1000 ha	101.91
Pesticide use in tons of active substance per 1000 ha	1.18
Diesel use in liters per 1000 ha	181.40

Annex C: Agro-climatic input maps

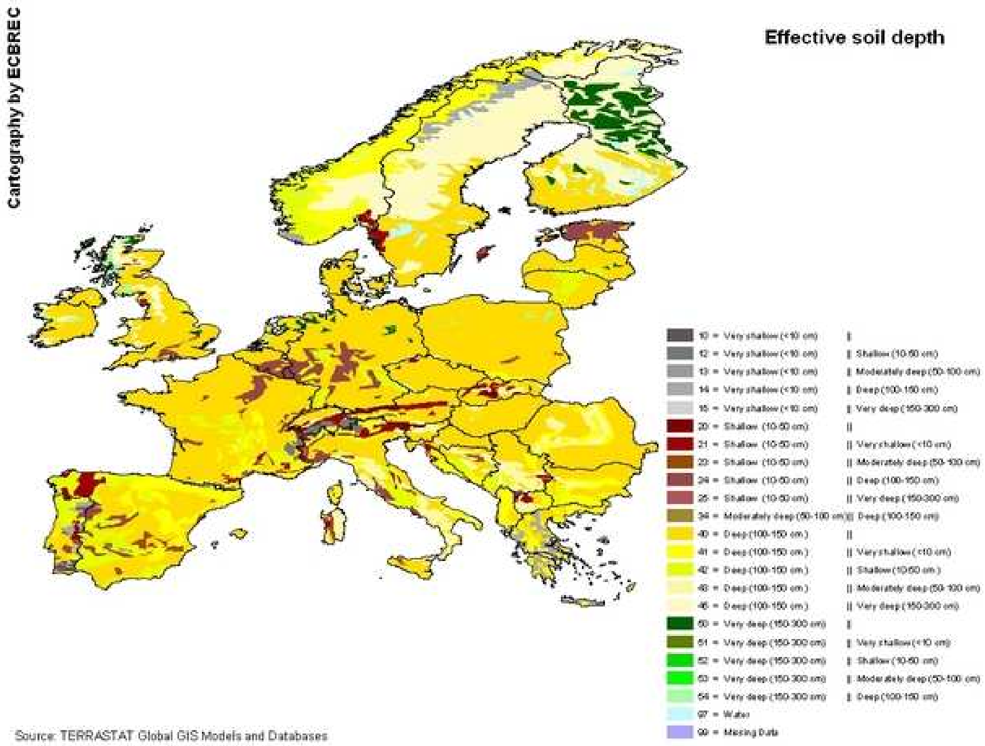


Figure C1. Input map: Effective Soil Depth

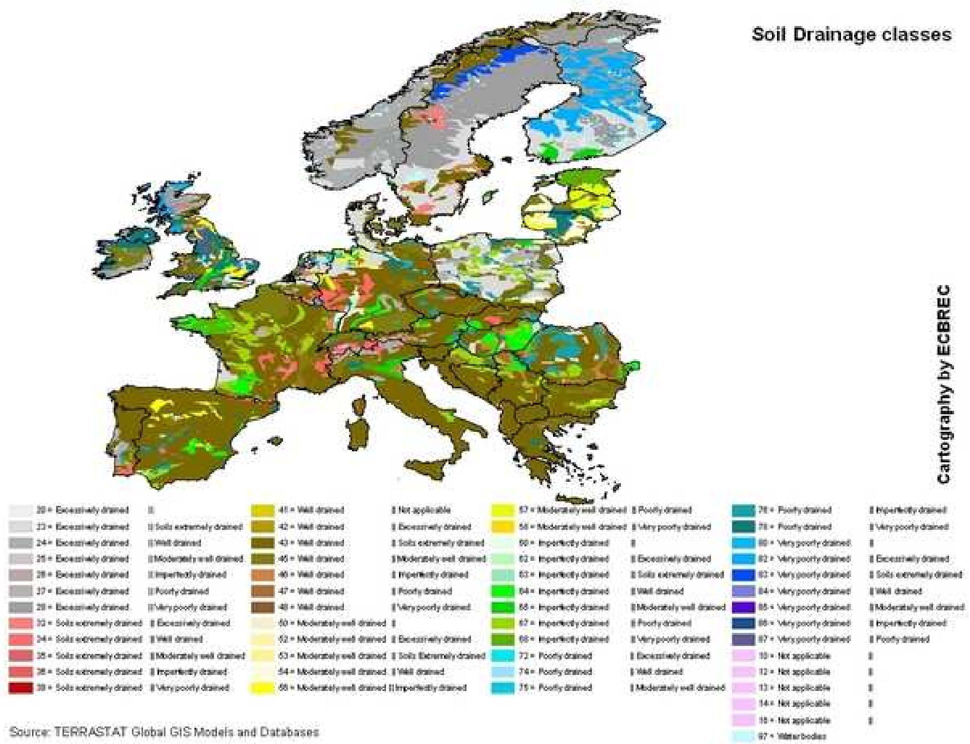


Figure C2. Input map: Soil Drainage classes

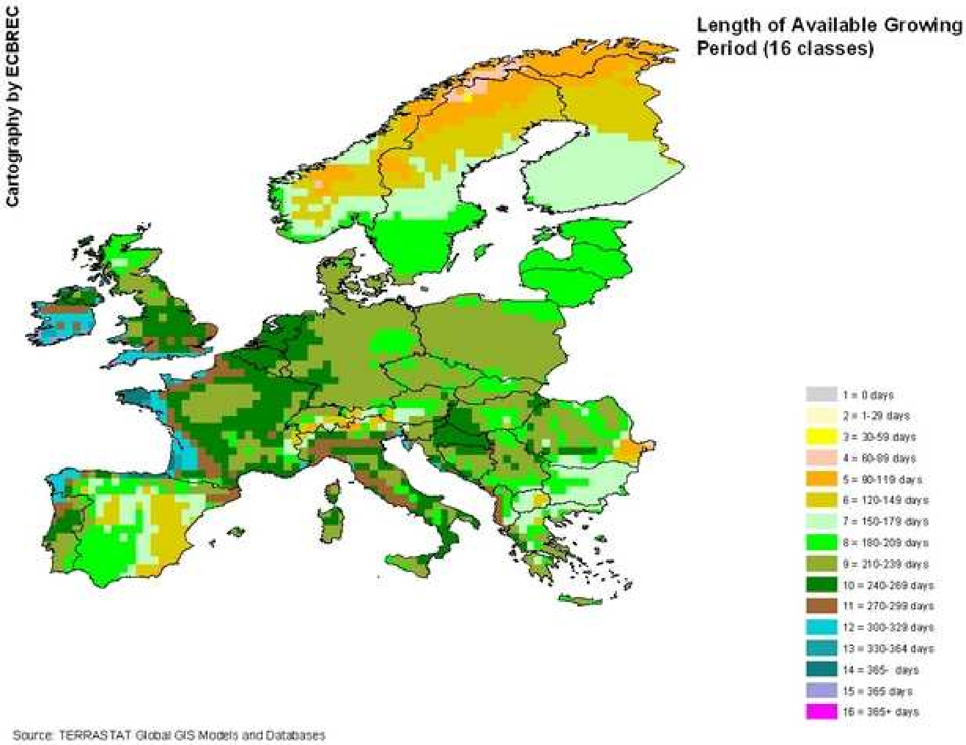


Figure C3. Input map: Length of Available Growing Period (16 classes)

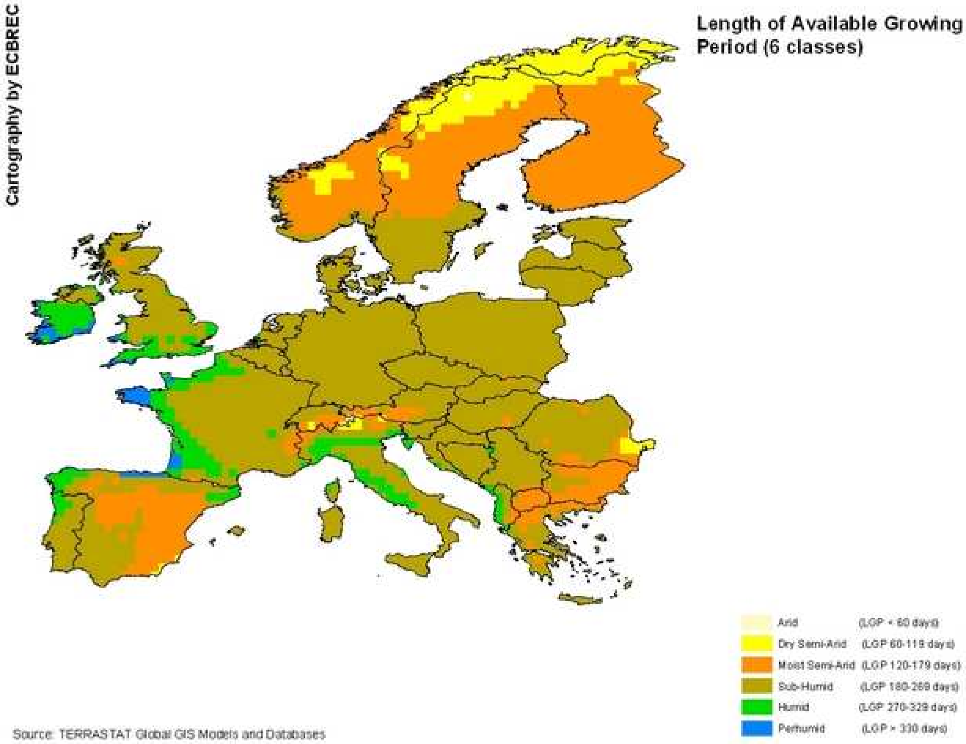


Figure C4. Input map: Length of Available Growing Period (6 classes)

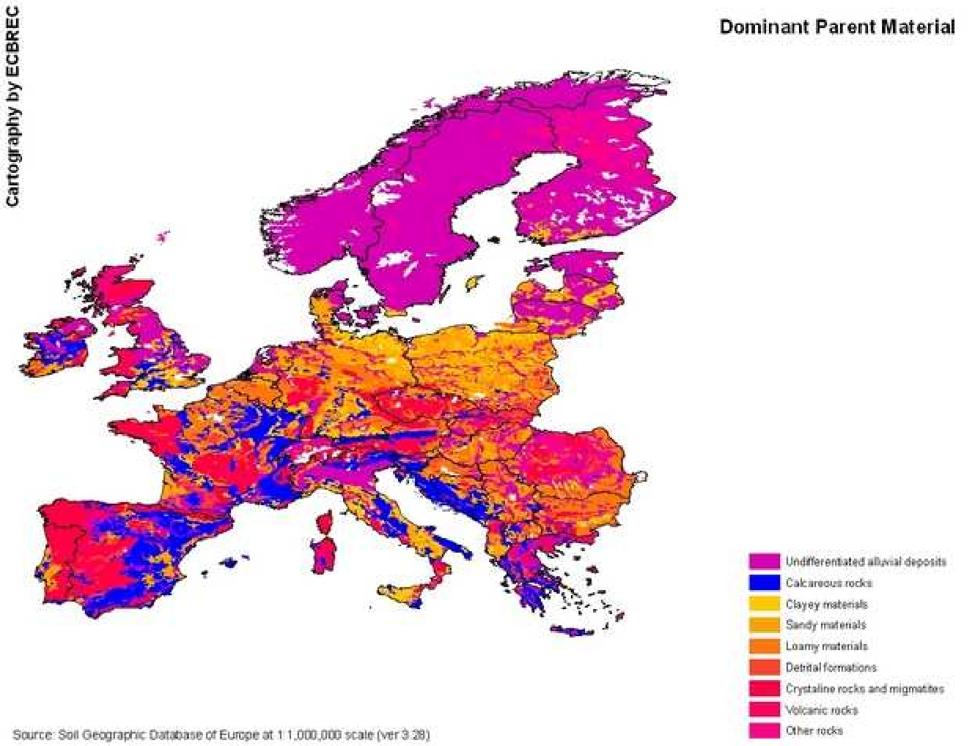


Figure C5. Input map: Dominant Parent Material Code

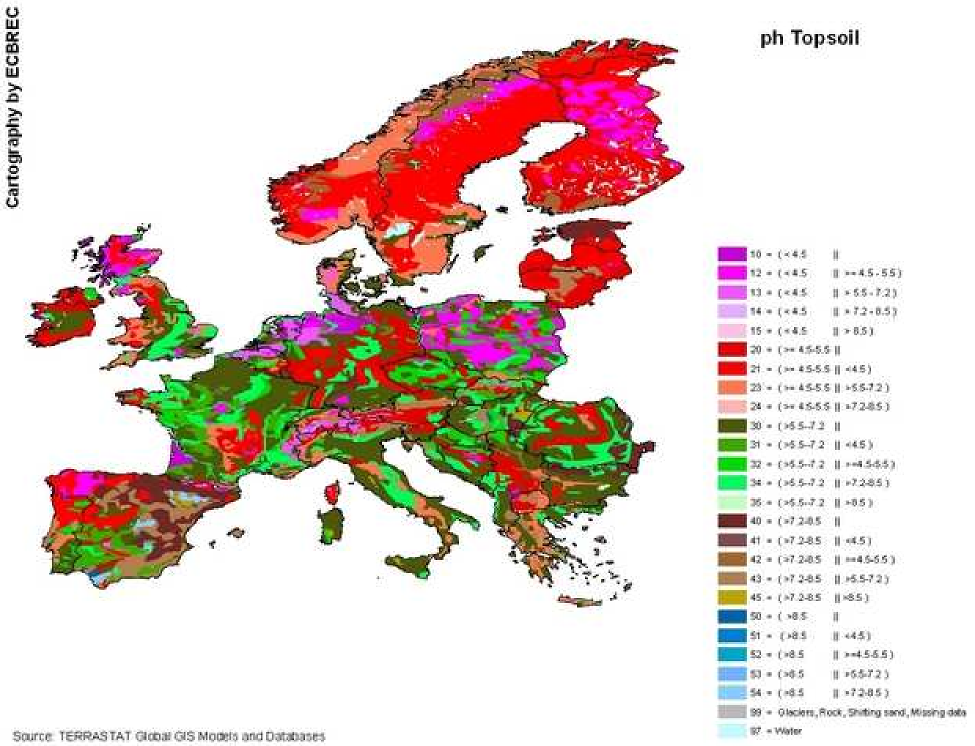


Figure C6. Input map: pH topsoil

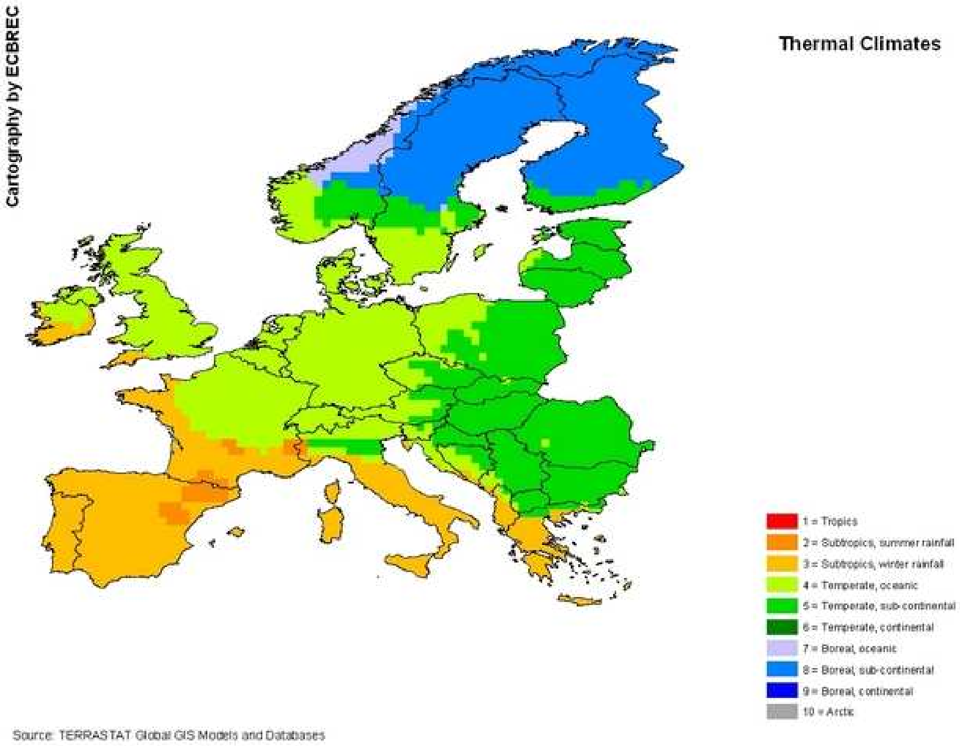


Figure C7. Input map: Thermal Climates

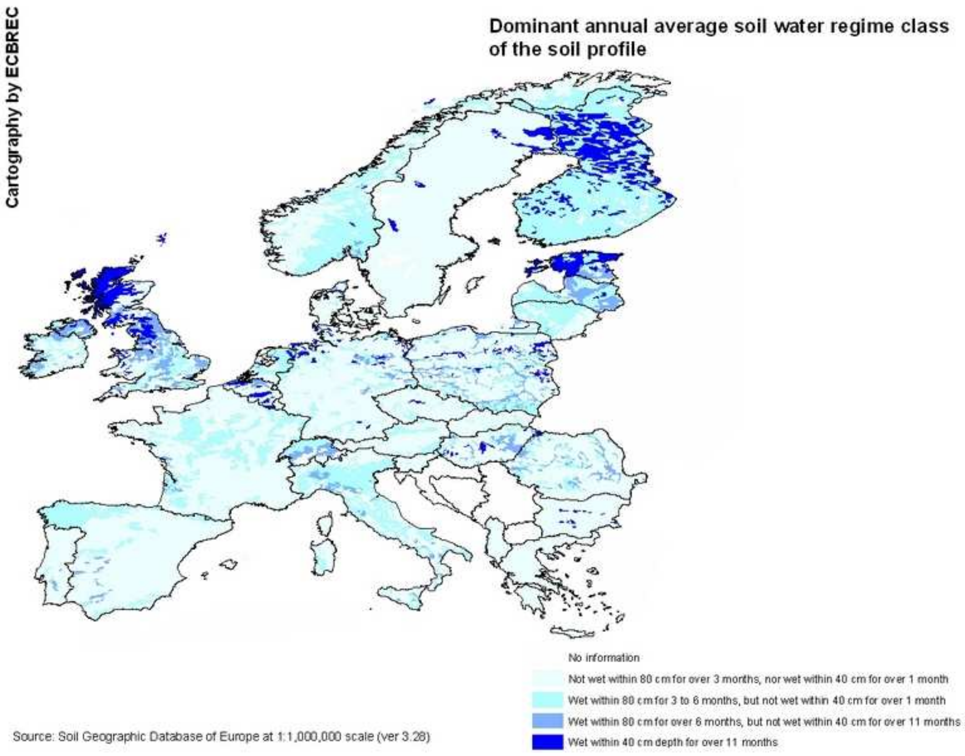


Figure C8. Input map: Dominant annual average soil water regime class of the soil profile

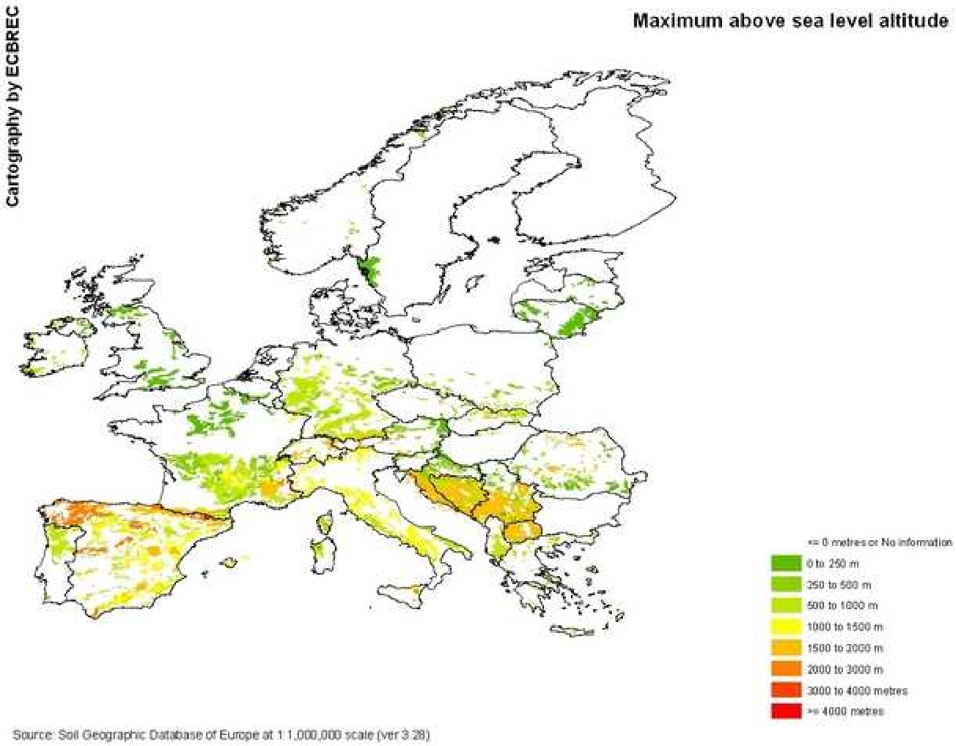


Figure C9. Input map: Maximum above sea level altitude

Annex D: Agro-climatic factors and their evaluation

Table D1. Agro-climate factors used for definition of Mapping Suitability Units

Values	Factors and attributes	Comments
WR	Dominant annual average soil water regime class of the soil profile	
0	No information	The factor gives information about the depth and the length of the soil moisture. This parameter is important when analyzing abilities of growing plants that are susceptible to drought or to overwatering. In some cases this factor may be crucial.
1	Not wet* within 80 cm for over 3 months, nor wet within 40 cm for over 1 month	
2	Wet within 80 cm for 3 to 6 months, but not wet within 40 cm for over 1 month	
3	Wet within 80 cm for over 6 months, but not wet within 40 cm for over 11 months	
4	Wet within 40 cm depth for over 11 months	
ZMAX	Maximum above sea level altitude(*)	
250	0-250 m	To which height above the sea, particular species is able to grow normally. For some plants climatic conditions which appear stronger with the increasing height (like wind, changing temperatures) are impossible to be overcome. Due to this fact some species are limited by the altitude, while some others are expected to supply relatively smaller biomass yield
500	250-500 m	
1000	500-1000 m	
1500	1000-1500 m	
2000	1500-2000 m	
3000	2000-3000 m	
4000	3000-4000 m	
5000	>=4000 m	
DRAIN CODE	Soil Drainage classes	
1	Excessively drained	The soil drainage class indicates the possibility to evacuate excess moisture form a soil based on the soil unit's classification name, the soil phase(s) indicated for the dominant unit and the slope class. Soil drainage is indicated by 7 classes from very excessive to very poorly drain. Some of analyzed species are not tolerant to water that does not soak deeper into the soil.
2	Soils extremely drained	
3	Well drained	
4	Moderately well drained	
5	Imperfectly drained	
6	Poorly drained	
7	Very poorly drained	
8	Not applicable	
PHW_T	pH Topsoil	pH is a measure for the acidity of the soil. Five major pH classes are recognized each of which has a specific agronomic significance
1	<4.5	extremely acid soils
2	4.5-5.5	Very acid soils suffering often from Al toxicity. Some crops like tea or pineapple are tolerant to these conditions
3	5.5-7.2	acid to neutral soils which are the best pH conditions for nutrient availability for the majority of species
4	7.2-8.5	acidity indicative of carbonate rich soils
5	>8.5	
THCLI	Thermal Climates	The thermal climates were obtained through classifying monthly temperatures corrected to sea level.
1	Tropics	All months with monthly mean temperatures, corrected to sea level, above 18℃
2	Subtropics, Summer	One or more months with monthly mean Northern hemisphere:

Values	Factors and attributes	Comments	
	rainfall	temperatures, corrected to sea level, below 18 C but above 5℃	rainfall in April-September rainfall in October-March Southern hemisphere: rainfall in October-March rainfall in April-September
3	Subtropics, winter rainfall		Northern hemisphere: rainfall in October-March rainfall in April-September Southern hemisphere: rainfall in April-September rainfall in October-March
4	Temperate, oceanic	At least one month with monthly mean temperatures, corrected to sea level, below 5°C and four or more months above 10°C	Seasonality less than 20℃ (**)
5	Temperate, sub-continental		Seasonality 20-35℃ (**)
6	Temperate, continental		Seasonality more than 35℃ (**)
7	Boreal, oceanic	At least one month with monthly mean temperatures, corrected to sea level, below 5℃ and more than one but less than four months above 10℃	Seasonality less than 20℃ (**)
8	Boreal, sub-continental		Seasonality 20-35℃ (**)
9	Boreal, continental		Seasonality more than 35℃ (**)
10	Arctic	All months with monthly mean temperatures, corrected to sea level, below 10℃	
LGP	Length of Available Growing Period (16 classes)	LGP refers to the number of days within the period of temperatures above 5℃ when moisture conditions are considered adequat e. Under rain-fed conditions, the begin of the LGP is linked to the start of the rainy season. The growing period for most crops continues beyond the rainy season and, to a greater or lesser extent, crops mature on moisture stored in the soil profile	
1	0 days		
2	1-29 days	Desert conditions with no possibility for rain fed agriculture	
3	30-59 days		
4	60-89 days	Only very few crops (millet) can give at the most marginal yields and most crops require irrigation	
5	90-119 days		
6	120-149 days	Rain fed cropping becomes possible for dryland crops such as sorghum but remains marginally for maize for instance	
7	150-179 days	Corresponds with the corn belt	
8	180-209 days	Areas that allow in good years two crops	
9	210-239 days		
10	240-269 days		
11	270-299 days	Considered perhumid and may offer opportunities for multiple cropping but also have constraints at harvest time for many crops	
12	300-329 days		
13	330-364 days		
14	365- days		
15	365 days		
16	365+ days		
LGP_CODE	Length of Available Growing Period (6 classes)		
1	Arid (<60 days)	This indicator is a simplified version of the full 16 LGP classes which capture the main groups of climates.	
2	Dry, semi-arid (60-119)		
3	Moist, semi-arid (120-179)		
4	Sub-humid (180-269)		

Values	Factors and attributes	Comments
5	Humid (270-329)	
6	Perhumid (>330)	
MAT11	Dominant Parent Material Code	
1	Undifferentiated alluvial deposits	It gives information about the kind of rock that has formed particular soils. Within this factor 9 main classes are taken into consideration. Parent material indicates the class of the soil informs about many features of the ground, like fertility, ability to keep water or the saturation. The ability of soil for agricultural uses can be defined and translated to requirements of each species analyzed.
2	Calcareous rocks	
3	Clayey materials	
4	Sandy materials	
5	Loamy materials	
6	Detritial formations	
7	Crystalline rocks and migmatites	
8	Volcanic rocks	
9	Other rocks	
DEPTHW	Effective Soil Depth	
1	Very shallow (<10cm)	The effective soil depth is the depth to which micro-organisms are active in the soil, where roots can develop and where soil moisture can be stored. As such it is an essential indicator of soil health, which provides information that can be used to decide about the utility of the soil. This factor has been taken into consideration when analyzing the root length.
2	Shallow (10-50 cm)	
3	Moderately deep (50-100cm)	
4	Deep (100-150cm)	
5	Very deep (150-300cm)	
9	Water	

(*) The source data for ZMAX (Maximum above sea level altitude) – ESDB database has significant shortage for the ZMAX factor, what is visible in the respective input map

(**) Seasonality refers to the difference in the mean temperature value of the warmest and coldest month

Table D2. Evaluating agro-climate factors and their attributes

			poplar	Salix	Miscanthus	eucalyptus	panicum
WR	VALUE	Dominant annual average soil water regime class of the soil profile	4	7	8	6	6
	0	No information					
	1	Not wet* within 80 cm for over 3 months, nor wet within 40 cm for over 1 month	3	5	2	3	4
	2	Wet within 80 cm for 3 to 6 months, but not wet within 40 cm for over 1 month	5	6	6	7	7
	3	Wet within 80 cm for over 6 months, but not wet within 40 cm for over 11 months	6	2	3	3	6
	4	Wet within 40 cm depth for over 11 months	8	8	10	8	9
ZMAX	VALUE	Maximum above sea level altitude	0	0	0	0	0
	250	0-250 m	10	10	10	10	10
	500	250-500 m	10	10	10	10	10
	1000	500-1000 m	10	10	10	9	8
	1500	1000-1500 m	9	9	7	7	0
	2000	1500-2000 m	7	7	0	0	0
	3000	2000-3000 m	1	0	0	0	0
	4000	3000-4000 m	0	0	0	0	0
	5000	>=4000 m	0	0	0	0	0
DRAIN_CODE	VALUE	Soil Drainage classes	6	3	4	5	3
	1	Excessively drained	6	3	0	1	9
	2	Soils extremely drained	9	6	0	3	9
	3	Well drained	10	10	10	5	10
	4	Moderately well drained	10	10	10	8	10
	5	Imperfectly drained	8	8	8	8	8
	6	Poorly drained	6	5	7	5	5
	7	Very poorly drained	4	5	5	3	2
	8	Not applicable	0	0	0	0	0
PHW_T	VALUE	pH Topsoil	5	5	5	5	7
	1	<4.5	0	0	0	0	0
	2	4.5-5.5	5	6	5	8	5
	3	5.5-7.2	10	10	10	10	9
	4	7.2-8.5	3	3	6	3	4
	5	>8.5	0	0	0	0	0
THCLI	VALUE	Thermal Climates	5	6	6	7	5
	1	Tropics	1	0	10	9	10
	2	Subtropics, Summer rainfall	9	1	10	10	10
	3	Subtropics, winter rainfall	9	2	10	9	9
	4	Temperate, oceanic	10	10	7	0	0
	5	Temperate, sub-continental	10	10	4	0	0
	6	Temperate, continental	8	8	2	0	0
	7	Boreal, oceanic	6	5	0	0	0
	8	Boreal, sub-continental	0	4	0	0	0
	9	Boreal, continental	2	1	0	0	0
	10	Arctic	0	0	0	0	0
LGP	VALUE	Length of Available Growing Period (16 classes)	7	6	6	7	6
	1	0 days	0	0	0	0	0
	2	1-29 days	0	0	0	0	0
	3	30-59 days	0	0	0	0	0

			poplar	Salix	Miscanthus	eucalyptus	panicum
	4	60-89 days	0	0	0	0	0
	5	90-119 days	0	1	0	0	0
	6	120-149 days	1	6	0	0	2
	7	150-179 days	2	9	0	0	3
	8	180-209 days	3	10	1	0	5
	9	210-239 days	5	10	5	0	9
	10	240-269 days	8	10	8	6	10
	11	270-299 days	10	8	10	9	10
	12	300-329 days	9	4	10	10	10
	13	330-364 days	7	0	10	10	10
	14	365- days	2	0	10	9	9
	15	365 days	2	0	10	9	9
	16	365+ days	2	0	10	9	9
LGP_CODE	VALUE	Length of Available Growing Period (6 classes)	4		5	0	0
	1	Arid (<60 days)	0		0	2	5
	2	Dry, semi-arid (60-119)	1		0	3	9
	3	Moist, semi-arid (120-179)	9		3	8	9
	4	Sub-humid (180-269)	10		8	10	10
	5	Humid (270-329)	8		10	10	10
	6	Perhumid (>330)	4		10	8	8
MAT11	VALUE	Dominant Parent Material Code	4	4	4		
	1	Undifferentiated alluvial deposits	10	10	6		
	2	Calcareous rocks	6	6	6		
	3	Clayey materials	6	5	7		
	4	Sandy materials	7	7	10		
	5	Loamy materials	4	2	6		
	6	Detritial formations	9	9	6		
	7	Crystalline rocks and migmatites	4	4	5		
	8	Volcanic rocks	6	5	8		
	9	Other rocks	7	7	7		
DEPTHW	VALUE	Effective Soil Depth	6	7	5	4	4
	1	Very shallow (<10cm)	0	0	0	0	0
	2	Shallow (10-50 cm)	0	1	0	3	4
	3	Moderately deep (50-100cm)	5	5	10	5	10
	4	Deep (100-150cm)	8	9	6	6	10
	5	Very deep (150-300cm)	10	10	3	10	10
	9	Water	0	0			

Suitability classification scheme

There are four most common classification schemes for quantitative data mapping available in ArcGIS :

- Natural breaks
- Quartile
- Equal interval
- Standard deviation

For the analysis the first two options were considered. In the first one 'natural breaks' the break points are identified by the software by looking for groupings and patterns inherent in the data. The features are divided into classes, which boundaries are set where there are relatively big jumps in the data values. In the second option 'quartile' each class contains an equal number of features. A quartile classification is well suited to linearly distributed data (Minami, 2000).

The quartile scheme was accepted. The histograms below present classification for suitability maps for five classes.

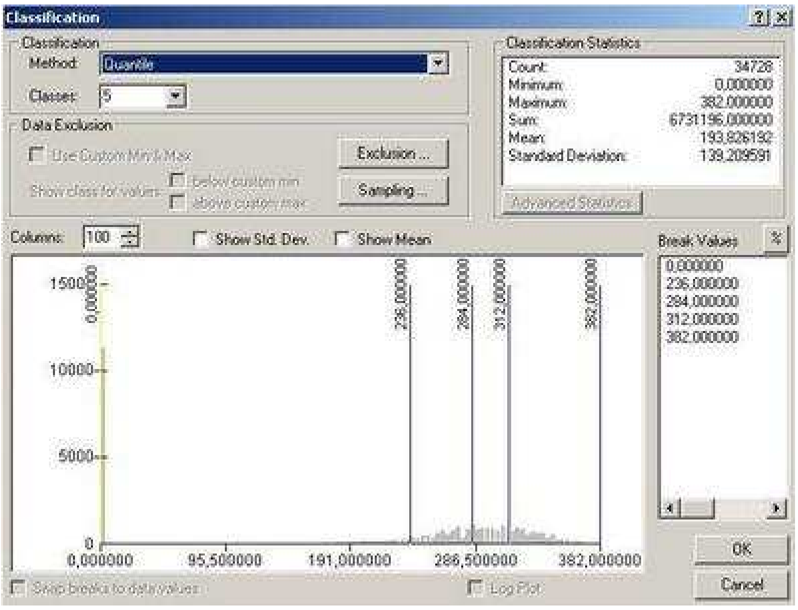


Figure E1. Suitability classification for poplar

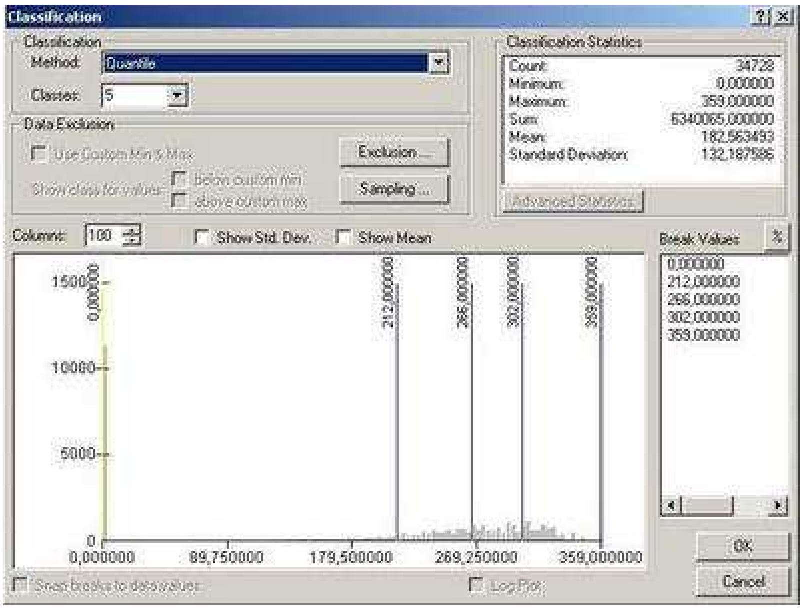


Figure E2. Suitability classification for salix

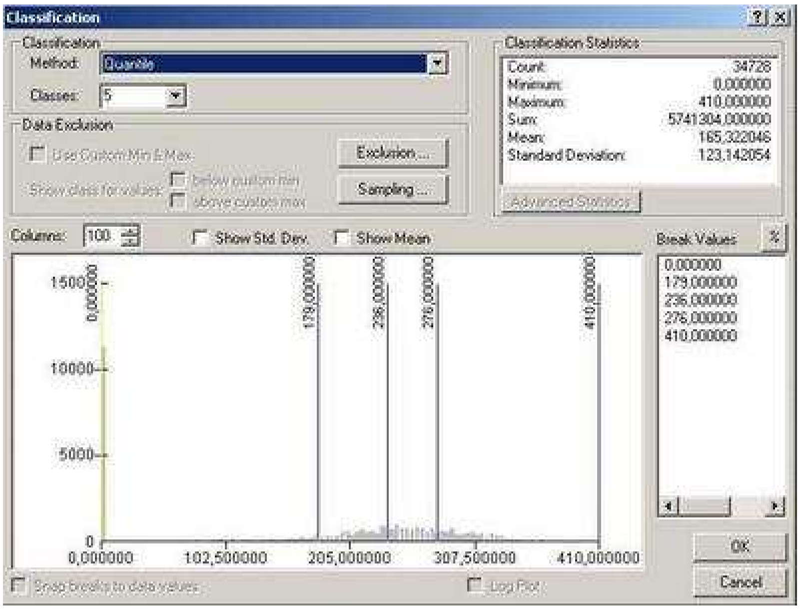


Figure E3. Suitability classification for Miscanthus

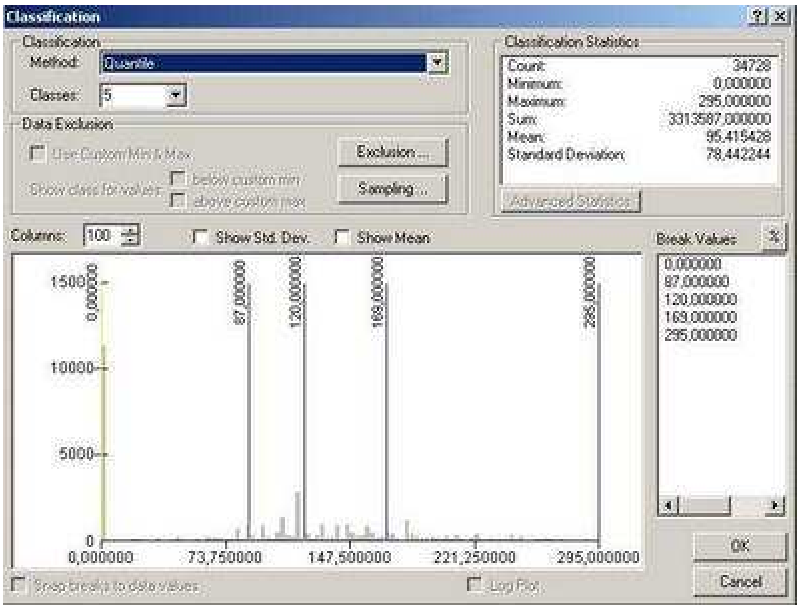


Figure E4. Suitability classification for eucalipthus

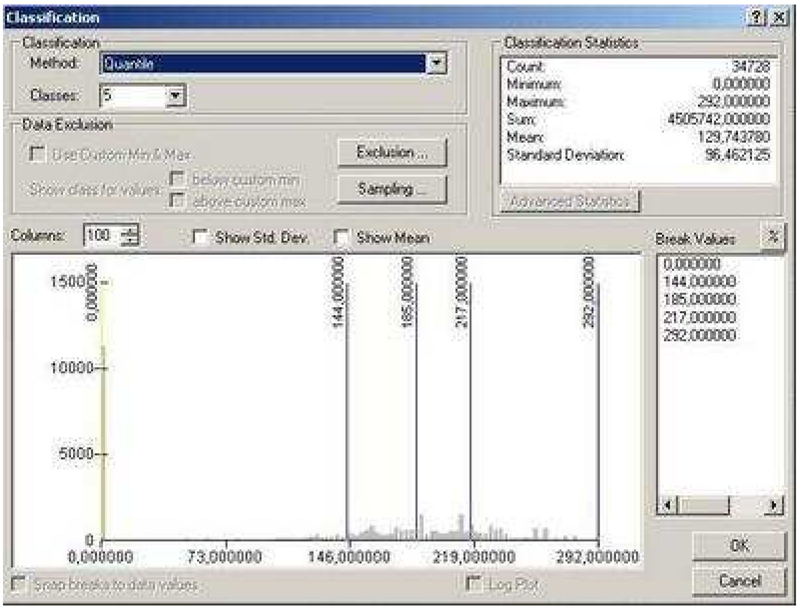


Figure E5. Suitability classification for swichgrass

Annex E: Available land and potentials distribution

Table E1. Land available for energy crops in 1000 ha in Scenario S1

Countries	Cereals	Industrial crops	Fodder from arable land	Root crops	Fallow land	Permament grassland	Total available land
AT	64,0	3,6	3,8	1,7	106,3	94,8	274,2
BE	3,3	0,9	8,6	5,1	26,3	26,3	70,5
BG	454,6	267,4	-	11,0	454,1	-	1 187,0
CH	18,3	0,8	-	0,6	4,0	32,8	56,5
CZ	364,0	144,3	112,1	22,8	99,7	27,0	769,8
DE	611,8	82,7	106,8	48,5	846,3	249,1	1 945,1
DK	66,6	-	-	-	200,0	18,4	284,9
EE	64,1	14,2	54,8	4,6	28,3	-	165,9
ES	507,0	87,7	50,0	11,0	3 320,2	349,5	4 325,3
FI	105,3	4,3	20,9	2,1	202,0	-	334,5
FR	837,6	74,9	62,9	10,4	1 262,4	-	2 248,2
GR	13,6	8,3	1,3	1,9	440,5	-	465,6
HU	684,6	210,8	20,4	17,6	204,7	31,8	1 169,9
IE	3,3	-	-	-	14,4	320,6	338,3
IT	269,5	39,9	77,6	11,2	654,8	-	1 052,9
LT	200,4	25,5	77,2	24,3	164,5	29,1	520,9
LU	2,6	0,2	0,9	0,0	1,7	-	5,5
LV	90,6	7,4	73,5	15,4	97,3	-	284,2
NL	4,6	0,0	4,3	1,2	27,2	42,3	79,6
PL	1 733,6	150,8	106,2	193,2	1 761,5	183,6	4 128,9
PT	26,7	-	-	-	541,6	-	568,3
RO	1 236,4	420,8	214,6	61,5	551,2	-	2 484,6
SE	91,5	-	-	-	264,5	-	356,0
SK	180,2	75,9	52,8	11,2	4,6	-	324,6
SL	19,2	4,5	-	1,0	-	9,3	34,0
UK	-	-	-	-	33,4	-	33,4
Total	7 653,3	1 624,8	1 048,6	456,2	11 311,2	1 414,5	23 508,6

Table E2: Land available for energy crops in 1000 ha in Scenario S2

Countries	Cereals	Industrial crops	Fodder from arable land	Root crops	Fallow land	Permament grassland	Total available land
AT	17,4	0,0	0,0	0,0	106,3	0,0	123,7
BE	9,6	0,1	0,7	0,7	26,3	0,0	37,4
BG	335,5	197,6	0,0	8,1	454,1	0,0	995,3
CH	11,8	0,0	0,0	0,0	4,0	0,0	15,8
CZ	257,5	93,6	72,7	14,6	99,7	0,0	538,0
DE	463,4	49,0	63,3	27,1	846,3	0,0	1 449,0
DK	18,7	0,0	0,0	0,0	200,0	0,0	218,7
EE	46,2	9,5	36,7	3,1	28,3	0,0	123,8
ES	236,4	40,7	23,2	4,4	3 320,2	0,0	3 624,9
FI	74,1	0,6	2,9	0,4	202,0	0,0	280,0
FR	0,0	0,0	0,0	0,0	1 262,4	0,0	1 262,4
GR	0,0	0,0	0,0	0,0	440,5	0,0	440,5
HU	476,6	132,2	12,8	11,0	204,7	0,0	837,3
IE	0,0	0,0	0,0	0,0	14,4	0,0	14,4
IT	175,2	22,9	35,1	4,2	654,8	0,0	892,2
LT	146,4	16,6	50,5	15,8	164,5	0,0	393,8
LU	0,0	0,0	0,1	0,0	1,7	0,0	1,9
LV	67,2	5,4	53,6	10,9	97,3	0,0	234,4
NL	5,1	0,0	0,0	0,0	27,2	0,0	32,3
PL	1 186,4	81,3	57,3	110,1	1 761,5	0,0	3 196,6
PT	14,5	0,0	0,0	0,0	541,6	0,0	556,1
RO	701,2	265,9	135,6	39,1	551,2	0,0	1 693,0
SE	61,5	0,0	0,0	0,0	264,5	0,0	326,0
SK	125,2	49,1	34,1	7,3	4,6	0,0	220,3
SL	12,3	2,6	0,0	0,6	-	0,0	15,5
UK	0,0	0,0	0,0	0,0	33,4	0,0	33,4
Total	4 442,4	967,2	578,5	257,4	11 311,2	0,0	17 556,8

Table E3: Energy crop potential in PJ/year

Countries	Starting Point			Scenario S1			Scenario S2		
	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale	SRC	Miscant.	Triticale
AT	16,0	15,6	16,5	54,7	62,2	127,4	15,6	17,2	12,2
BE	4,9	3,9	4,5	18,4	24,6	72,2	4,7	5,5	3,9
BG	59,8	75,2	54,7	319,9	402,6	200,1	186,8	218,1	108,6
CH	0,6	0,6	0,6	25,5	30,4	58,2	2,7	3,3	2,1
CZ	13,1	16,5	12,0	166,4	229,1	112,5	75,3	102,7	50,9
DE	159,1	124,6	145,6	560,2	744,5	415,3	235,8	275,3	162,4
DK	28,2	29,4	31,0	46,8	168,2	38,8	27,6	33,0	22,9
EE	3,7	4,7	3,4	33,9	46,7	23,4	17,1	24,3	11,8
ES	624,2	672,0	342,6	995,3	1 197,7	465,8	578,3	695,6	270,3
FI	29,4	23,3	31,3	58,8	46,7	48,7	30,0	23,0	24,2
FR	237,3	185,8	217,1	711,5	1 128,6	608,9	207,7	289,5	196,8
GR	82,8	89,2	45,5	110,8	133,5	51,5	72,1	87,0	32,9
HU	26,9	33,9	24,6	288,8	446,6	222,0	120,0	186,0	90,0
IE	3,0	4,0	3,2	86,9	147,9	78,4	2,6	4,5	2,4
IT	123,1	132,5	67,6	246,2	295,3	118,4	137,7	165,5	61,3
LT	21,6	27,2	19,8	107,1	148,9	73,0	52,2	72,9	35,7
LU	0,5	0,4	0,3	0,9	1,3	0,7	0,3	0,3	0,3
LV	12,8	16,1	11,7	60,2	250,6	41,0	33,5	46,7	22,9
NL	5,1	4,0	4,7	18,3	20,3	14,1	4,1	4,5	3,4
PL	232,7	293,9	212,1	682,0	957,8	463,1	350,3	494,5	238,4
PT	101,8	109,6	55,9	127,3	153,5	58,7	89,1	107,4	41,1
RO	72,5	91,3	66,4	566,8	877,6	438,0	246,2	382,7	190,0
SE	39,9	31,8	40,9	64,7	51,1	53,7	41,7	25,2	27,1
SK	0,6	0,8	0,6	76,9	105,3	52,1	35,1	48,0	23,7
SL	-	-	-	8,8	12,2	17,8	2,9	4,0	1,9
UK	7,8	10,5	7,5	9,7	14,8	7,8	6,8	10,3	5,5
Total	1 907,6	1 996,7	1 419,9	5 446,9	7 697,9	3 861,4	2 576,4	3 327,0	1 642,7