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SP2 – < SP2: STUDIES ON BIOMASS FEEDSTOCK AND OPTIMISATION FOR THE SELECTED VALUE CHAIN >

WP2.1 – <BIOMASS FEEDSTOCK OPTIONS>

Deliverable report

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Deliverable Identification	
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Deliverable Title:	Study and GIS maps on land use strategies matching the understudy biorefinery concept and biomass availability
Responsible Beneficiary:	CRES
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	Name	**Organization**	**Date**	**Visa**
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Dissemination level		
PU	Public	X
PP	Restricted to other programme participants (including the Commission Services)*	
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Content

Executive summary

Description of the deliverable objective and content

The aim of this deliverable is to study and map land use strategies for growing the selected crops that match the selected biorefinery concepts and value chains of the project.

The deliverable used the results of the on-going project 4FCrops and other relevant previous activities on the land uses and land availability in the EU27 level.

The identification of areas in Europe suitable for the cultivation of the selected crops was based on spatial distribution of parameters influencing conditions for cultivation (e.g. germination, growing, flowering, seed production, etc.). For that purpose the finding of available datasets regarding these parameters was necessary, as well as the classification in the following classes based on specific references available in literature:

- Climatic data sets
- Land use – Land cover data sets
- Elevation data set

Brief description of the state of the art

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

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

Deviation from objectives and corrective actions

The deliverable is delayed, due to technical problems in downloading and working with the several databases. This is the first version, containing information of available lands for the perennial crops. From the selected oil crops, only safflower is studied. The deliverable will be updated in month 44 and at the end of the project.

Innovation brought and technological progress

EuroBioRef used the results of the on-going project 4FCrops and other relevant previous activities on the land uses and land availability in the EU27 level to provide scenarios for land use strategies associated with promising non-food cropping systems taking into account the market demands of the bio- and chemical-industries involved in this biorefinery concept.

Analysis of the results

This deliverable reflects the climate requirements of the selected crops that have to be taken into account in order to define the suitable lands for their cultivation and exploitation for the various bio refinery options of this project.

Impact of the results

The results obtained by this deliverable will be used as a basis for refining the general strategies/approach for the project and define land use strategies for the selected crops in each Value Chain.

Related IPR

No IPR are included

Publishable information

This deliverable is public

Conclusion

The current available area for the cultivation of non-food crops as estimated in the 4Fcrops project (www.4fcrops.eu) was the sum of the current fallow land and the area that is being cultivated with energy crops. In order to estimate the available land in 2020 and 2030 three parameters were taken under consideration: a) current fallow land, b) current land area that is being cultivated with energy crops and c) the surplus land released from food and fodder crops.

The total available land is estimated at around 13.2 Mha, while in 2020 it is expected to increase up to 20.5 Mha. The projections for 2030 are even higher, reaching 26.2 Mha. The majority of the land available for non-food crops at present and for 2020 was recorded in Spain (3,600 ha), while in 2030 Poland will take the lead (4,100 ha). The top five countries in all timeframes are: Spain, Germany, Poland, France and Romania. These countries together with Italy, Bulgaria and Hungary are the eight European countries that at present can assure the 80.9 % of the total available land for non-food crops, the 81.7% in 2020 and in 2030 they could contribute the 84.5%.

The suitability of the crops for each environmental zone was mainly based on the climate requirements of each crop as they are defined by the crop ecology (areas of origin), biology (tolerance in abiotic stresses, etc.) and physiology (nutrients and soil requirements, growing season, radiation use efficiency, water and nutrients use efficiency, etc.)

- Cardoon is perennial oleaginous crop with Mediterranean origin and thus adapted in the drought conditions of the Mediterranean South Zone. There is no indication for growing this crop in northern zones.
- Miscanthus, a rhizomatous C4 perennial grass, has a broad genetic base and many varieties and hybrids are cultivated successfully in all environmental zones of Europe, except from the Nemoral, where the crop has no resistance to extreme cold at the transplanting year and Mediterranean South, where the crop has no resistance to extreme drought.
- Switchgrass is a perennial C4 grass that can be established by seeds. Like miscanthus, there are lots of varieties adapted in a wide range of climate conditions because the crop was grown for decades as pasture. It has higher tolerance to drought than miscanthus. It can grow in Atlantic Central and South zones, however it could also be grown in almost all zones.
- Giant reed is a lignocellulosic rhizomatous C3 perennial crop well adapted to warm-temperate or subtropical climates, but it is also able to survive short periods of frost; it prefers soils with abundant. It can grow in Mediterranean zone, where it originates from although there are indications that it can grow even in northern climates.
- Willow is grown mainly in the Continental climate zone as well as Nemoral, since it has a relatively high resistance to frost, however it has a high water requirement, and often water availability is a limiting factor for its production.
- Safflower is an annual oilseed crop grown throughout the semiarid region of the temperate climates in many areas of the world. Based on its climate requirements, it can be grown mostly in Bulgaria, Romania, France, Italy, Greece and Spain.

ANNEX I – Technical content

Introduction

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

Decoupling payments from production under the CAP came out to free the farmers' decisions on what to produce. Thereby the land use corresponds to the market situation for specific crops. The set-aside obligation proved to be very effective to promote non-food crops production. Putting production quotas and/or setting an intervention market price in specific crop markets had also a very strong and direct effect on crop areas. The recent specific policy targets such as biofuel targets proved to have an important impact on land use.

The potential availability of arable land for non-food crops in the EU was assessed with a land allocation model in the 4Fcrops project and is reported by Krasuska et.al, 2010. The available lands were estimated at three time frames: now, in 2020 and in 2030. That work included a large range of energy crops, classified as conventional, for the commonly grown crops all over the EU, and crops to be implemented as new in the existing farming systems. The conventional crops are: rapeseed, sunflower, soybean, safflower, sugar beet, grain sorghum, maize, flax, hemp, and kenaf that are commonly grown as rotational annual crops for food, feed, energy and other industrial uses. When used for non-food purposes their agro-climatic requirements should not be different from what they are when used for traditional purposes. The crops to be newly implemented in the existing farming systems include both, annual and perennial crops, like sweet and fiber sorghum, ethiopean mustard, reed canary grass, miscanthus, switchgrass, giant reed, cardoon, willow, poplar and eucalyptus.

The potential areas where the perennial crops studied in this project, miscanthus, switchgrass, giant reed, cardoon, willow are/will be grown in thus assessed in the previously mentioned report.

The selected oil crops are grown in Europe only marginally, in small plots or in gardens for ornamental reasons. Most of them are of tropic origin, like castor, cuphea, lesquerella, lunaria and safflower and thus suitable cultivation areas for these crops are limited in Europe, while crambe is closely related to rapeseed but less productive than rapeseed and thus does not attract the interest of the markets. Further to that, cuphea, lesquerella and lunaria still need experimentation on agronomic methods and plant breeding to improve crop characteristics in order to allow their industrial exploitation. Based on literature information and the results of 3-year field trials, it was decided that focus should be placed only in safflower, crambe and castor.

The identification of areas in Europe suitable for the cultivation of these three selected oil crops was based on spatial distribution of parameters influencing conditions for cultivation (e.g. germination, growing, flowering, seed production, etc.). For that purpose the finding of available datasets regarding these parameters was necessary, as well as the classification in the following classes based on specific references available in literature:

- Climatic data sets
- Land use – Land cover data sets
- Elevation data set

This first version of the deliverable contains detailed information on safflower and will be updated in M44 and M48 with information and maps of crambe and castor, since these are the selected crops for the Value Chains 1&2.

Methods and Materials

The land allocation model

As mentioned before, the land availability and suitability for the perennial lignocellulosic crops grown in this project was assessed in 4FCROPS project "Future crops for Food, Feed, Fiber and Fuel" (www.4fcrops.eu) that ended at the end of November 2010 and was coordinated by CRES.

The assessment of land availability for non-food systems was performed by EC BREC (PL) with the use of a land allocation model elaborated by ECBREC team (IPiEO) for the RENEW project (www.renew-fuel.com). The core of the model was kept unchanged; however, the input data and assumptions on scenarios were updated for the 4F CROPS project. The key assumption in this model is that the non-food crops can be cultivated only on a surplus land that is left after satisfying food and fodder production.

The land allocation for 2020 and 2030 in 4F CROPS was 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. Projections on future yield growth rates and population changes were also applied to calculate relevant yields and consumption demands for different crops in the future.

The available land resources in each NUTS-2 region were allocated for the future crop production within the main crop categories (cereals, oilseeds, root crops, fodder and grazing crops). In the current situation (2003-2007), which is a background value for the future scenarios, two land categories were considered as available for non-food crops; fallow land and current land areas under energy crops.

The calculations were performed on NUTS-2 level regional level (with the exception of Germany, which is NUTS-1 level) and the results were aggregated into national (NUTS-0) level.

The land allocation model included the following modules (**Figure 1**):

- 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).

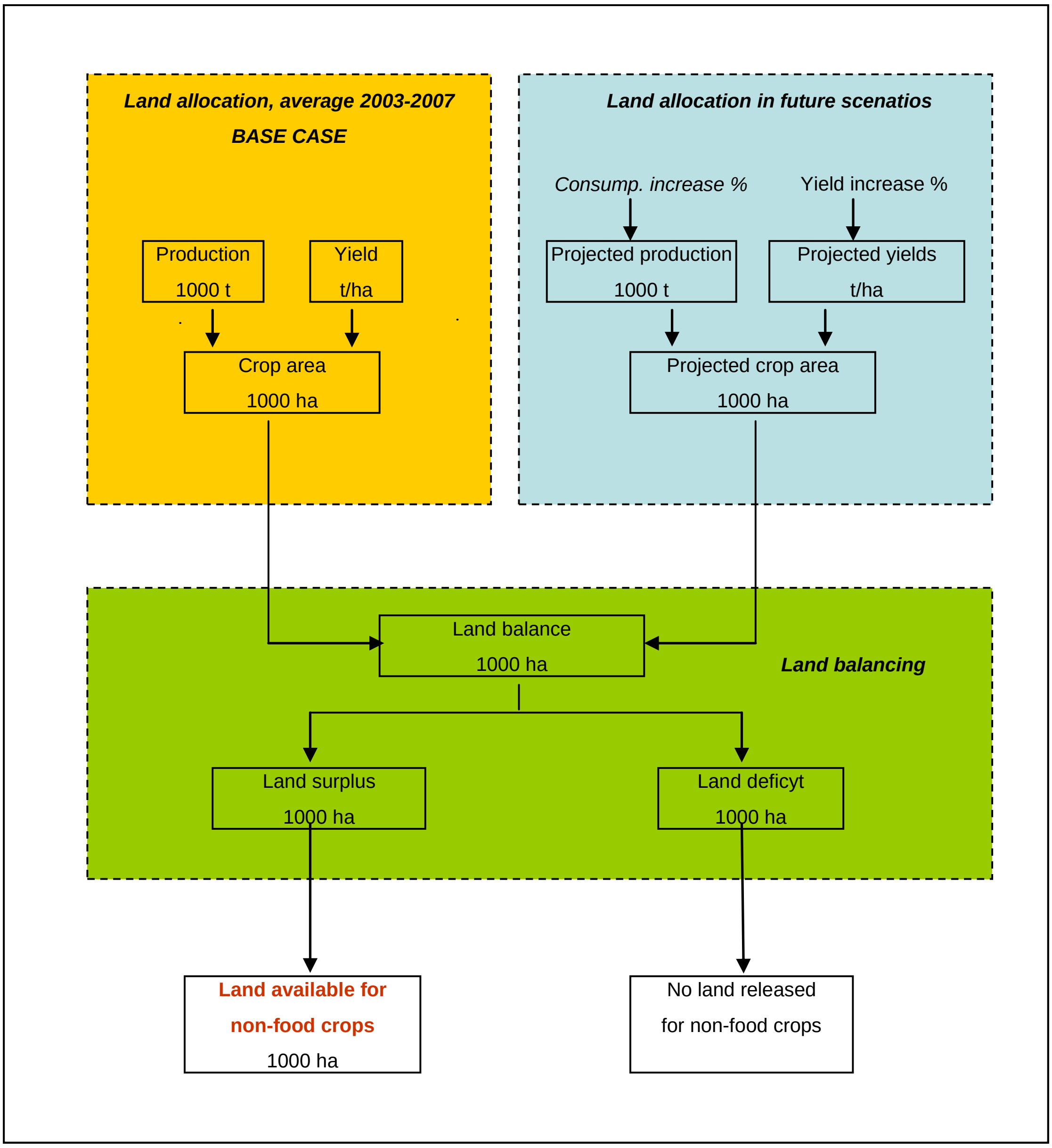

Figure 1. Overview of the land allocation model (Source: Krasuska et.al, 2010 from 4FCROPS).

Datasets

The identification of areas suitable for cultivation of safflower, crambe and castor in Europe was based on spatial distribution of parameters influencing conditions for cultivation (e.g. germination, growing, flowering, seed production, etc.). For that purpose the finding of available datasets regarding these parameters was necessary, as well as the classification in the following classes based on specific references available in literature:

- Climatic data sets
- Land use – Land cover data sets
- Elevation data set

Climatic datasets are available for downloading at the web-site of the European Climate Assessment & Dataset project, providing information about changes in weather and climate conditions, as well as the daily dataset needed to monitor and analyze these conditions. After selection, data included in the downloaded dataset reference:

- Daily Precipitation (Figure 2)
- Daily Temperature
    - Average (Figure 3)
    - Minimum (Figure 4)
    - Maximum (Figure 5)

Land use and land cover data derived from reliable databases, like EEA's database and Eurostat. EEA's Corine Land Cover programme provides dataset about land cover in Europe, classified in specific classes (Annex 2)

Selected attributes from this dataset reference areas where the crops could be established. More specifically, arable lands are classified in two main classes (Figure 6):

- Agricultural areas, Arable land, Non-irrigated arable lands
- Agricultural areas, Arable land, Permanently irrigated lands

The Eurostat's LUCAS (**L**and **U**se/**C**over **A**rea frame **S**tatistical survey) dataset provides information about cover/land use as well as agro-environmental and soil data identified through on-site observations of spatially selected geo-referenced points.

ETOPO1 is a 1 arc-minute global relief model of Earth's surface developed by the National Geophysical Data Center of the **N**ational **O**ceanic and **A**tmospheric **A**dministration (NOAA) in the US. Land topography and ocean bathymetry are included in this dataset. In the further process only land topography data will be used.

All available datasets and images presenting the spatial distribution of previous mentioned datasets, as well as reference data sources are presented below:

1. Climatic datasets

1.1. E-OBS gridded dataset, available to download at http://eca.knmi.nl/

E-OBS is a daily gridded observational dataset for precipitation, temperature and sea level pressure in Europe

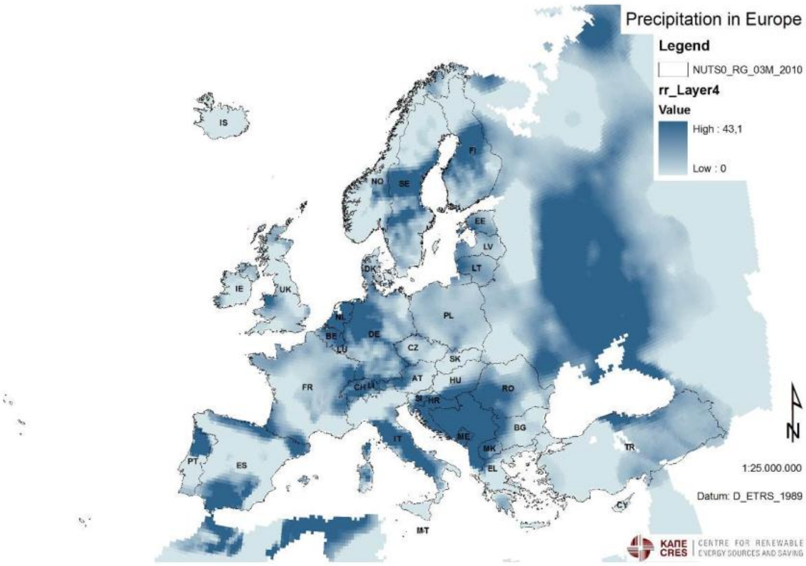

Figure 2. Spatial distribution of daily rainfall in Europe (combination of 365 days – layers, data source: ECA&D)

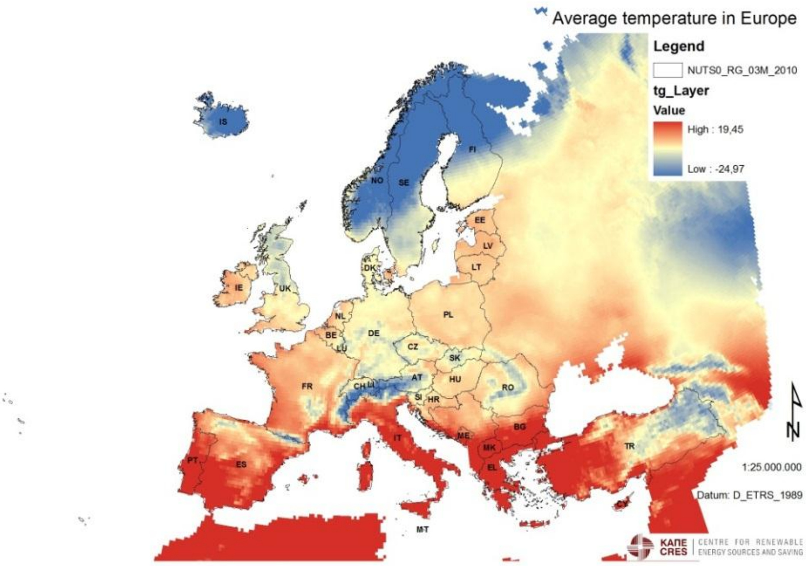

Figure 3. Spatial distribution of daily average temperature in Europe (combination of 365 days – layers, data source: ECA&D)

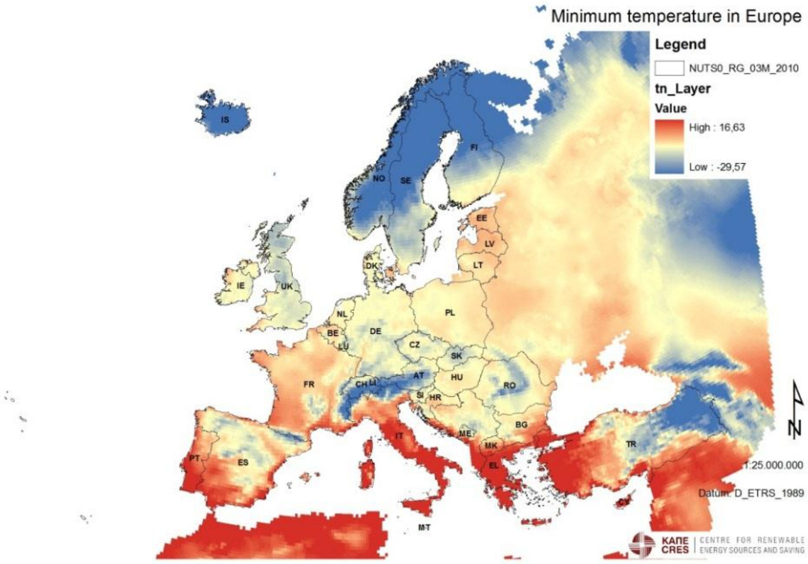

Figure 4. Spatial distribution of daily minimum temperature in Europe (combination of 365 days – layers, data source: ECA&D)

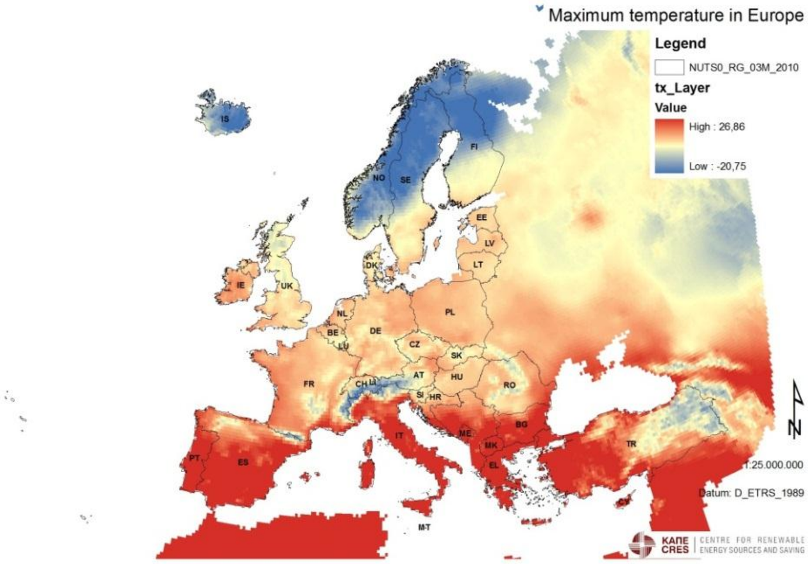

Figure 5. Spatial distribution of daily maximum temperature in Europe (combination of 365 days – layers, data source: ECA&D)

2. Land use – Land cover datasets

2.1. Corine land cover 2000 data, version 16 (04/2012), available to download at http://www.eea.europa.eu/

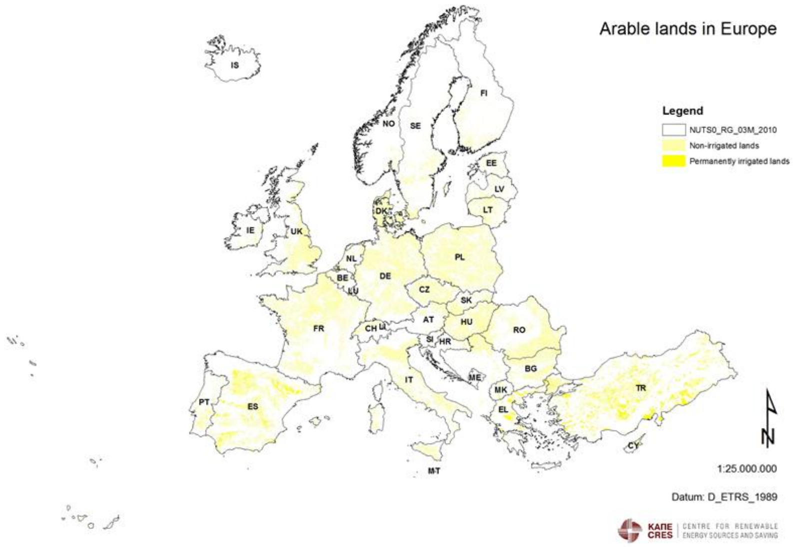

Figure 6. Arable lands in Europe (data source: EEA, CLC2000 data)

2.2. LUCAS 2009, Land Use/ Cover Area frame statistical Survey (Figure 7), available to download at http://epp.eurostat.ec.europa.eu/portal/page/portal/eurostat/home

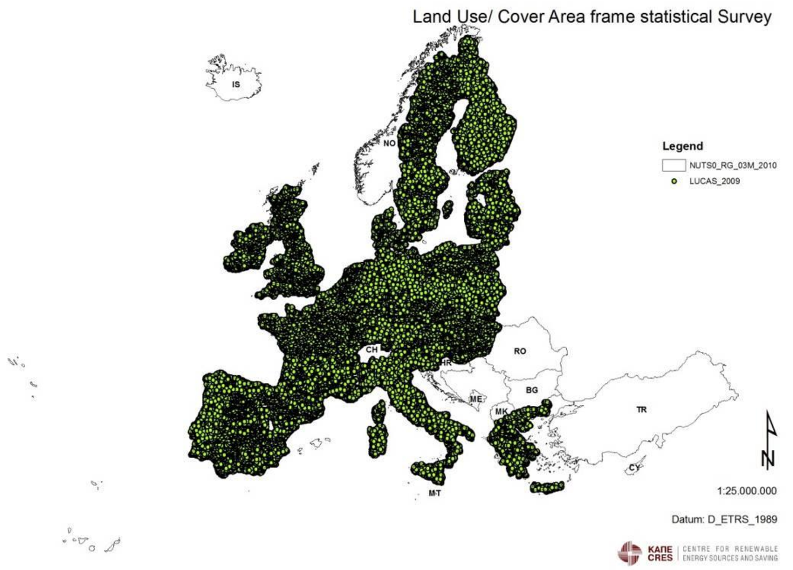

Figure 7. Land Use/ Cover Area frame statistical Survey in Europe (data source: EUROSTAT)

3. Elevation dataset

3.1. 1-Minute Gridded Global Relief Data (ETOPO_1), available to download at http://www.ngdc.noaa.gov/mgg/global/ (Figure 8)

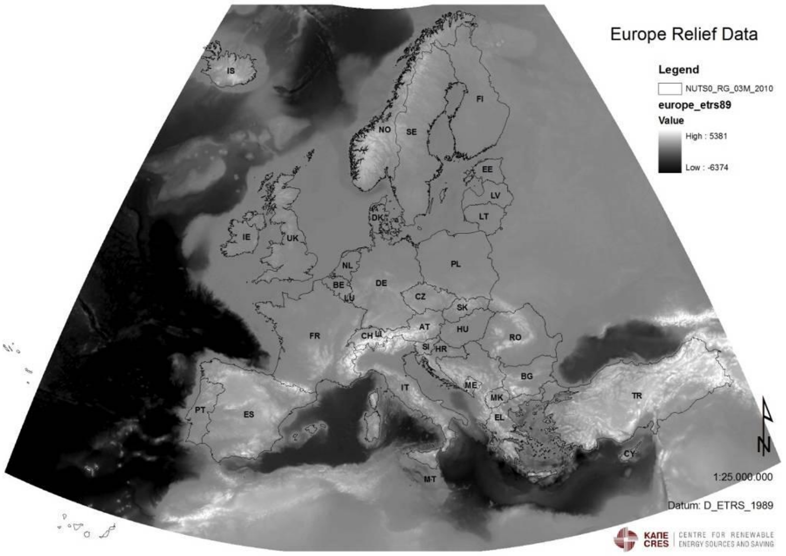

Figure 8. Relief data for Europe (data source: NGDC, NOAA)

Determination of selection criteria

The selection process for the identification of agricultural areas in Europe suitable for the cultivation of oil crops (safflower, crambe and castor) will be based on the determination of specific criteria, influencing the planting, emergence and growth of the oil crops and finally the production of seeds and oil. Determination of selection criteria is presented in Table 1 and it is based on literature, as reported in D1.2.1

Table 1. Selection criteria for the oil crops (safflower, crambe and castor)

Parameters	Safflower	Crambe	Castor
Climatic*	Precipitation (R_{total}) Temperature (T_{avg})	Precipitation (R_{total}) Temperature (T_{avg})	Precipitation(R_{total}) Temperature (T_{min}, T_{max}, frost free period)
Topographic	Altitude		
Soil	Soil depth Drainage Texture pH	Soil depth Drainage Texture pH	Soil depth Drainage Texture pH

*Climatic data (precipitation and temperature) only for the year 2012

Determination of values for specific parameters or description of specific quantitative parameters, in order to identify areas in Europe promising for the cultivation of safflower, crambe and castor are based on literature and are presented below:

1. Safflower

1.1. Climatic

1.1.1. 800mm ≥ R_{total} ≥ 380mm, during growing season

1.1.2. 16^{o}C ≥ T_{avg} ≥ 15^{o}C, during period of seed germination[1]

1.1.3. 25^{o}C ≥ T_{avg} ≥ 20^{o}C, during period of flowering and seed formation[2]

1.2. Topographic

1.2.1. Alt<1100m

1.3. Soil

1.3.1. SD > 1 m

1.3.2. Well drained soils

1.3.3. Texture: sandy, sandy-loam, clay-loam, loam

1.3.4. 5,5 ≤ pH ≤ 8

Where:

T_{avg} = daily average temperature, in ^{o}C

R_{total} = total annual rainfall, in mm

Alt = altitude, in m

SD = Soil depth, in m

[1] Seed germination period for safflower was determined from day 274 to day 304 (October)

[2] Flowering and seed formation period for safflower was determined from day 121 to day 151 (May)

2. Crambe

2.1. Climatic

2.1.1. $800mm \geq R_{total} \geq 380mm$, during growing season

2.1.2. $T_{min} \geq -4^{o}C$, during seedling stage and early flowering[3]

2.1.3. $25^{o}C \geq T_{avg} \geq 15^{o}C$, during main vegetative period

2.2. Topographic

2.2.1. Alt<1100m

2.3. Soil

2.3.1. SD > 1 m

2.3.2. Well drained soils

2.3.3. Texture: sandy, sandy-loam, clay-loam, loam

2.3.4. $5,5 \leq pH \leq 8$

Where:
T_{avg} = daily average temperature, in ^{o}C
R_{total} = total annual rainfall, in mm
Alt = altitude, in m
SD = Soil depth, in m

3. Castor

3.1. Climatic

3.1.1. 1000mm ≥ Rtotal ≥ 450mm

3.1.2. If [Rtotal < 300mm] Then [irrigation is required]

3.1.3. FFP not≥ 120 days

3.1.4. Tmin > 15oC

3.1.5. Tmax < 40oC, during period of flowering4

3.2. Soil

3.2.1. SD > 0,5 m

3.2.2. Well drained soils

3.2.3. Texture: loam to sandy-loam

3.2.4. Moderate coarse to fine texture

3.2.5. Not tolerant to alkali soils

3.2.6. Tolerant to semi arid soils

3.2.7. 5,5 ≤ pH ≤ 8 or more

3.2.8. pH <5 have to be limed

Where:
FFP = frost free period
T_{min} = daily minimum temperature, in ^{o}C
T_{max} = daily maximim temperature, in ^{o}C
R_{total} = total annual rainfall, in mm
SD = Soil depth, in m

[3] Seedling stage until early flowering for crambe was determined from day 305 to day 336 (December) for autumn sowing and 106 to day 136 (15 April to 15 May) for spring sowing
[4] Flowering period for castor was determined from day 152 to day 181 (June)

Selection process

The first step of this selection was to exclude all areas not having climatic data for all days of the year 2012, like Sicily in Italy and Peloponnese in Greece (Figure 9). This was decided in order to avoid wrong estimations or calculations for variables like the total annual precipitation.

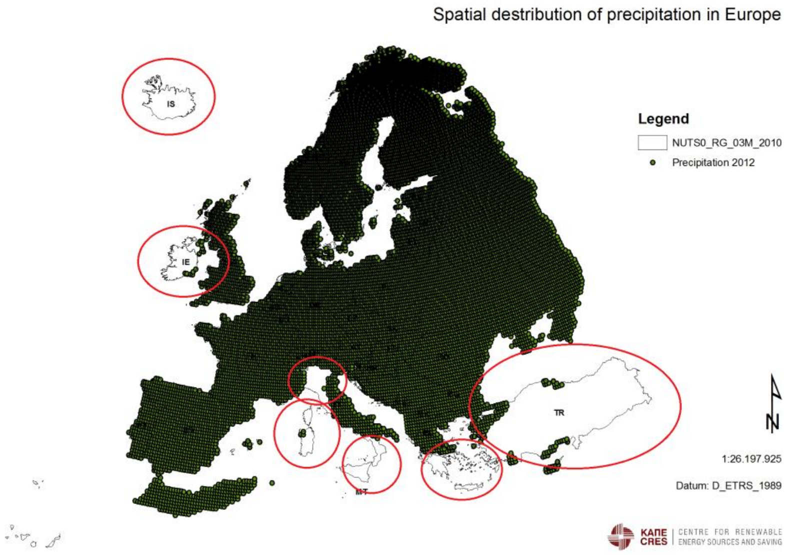

Figure 9. Spatial distribution of daily precipitation in Europe with data for all days of the year 2012 and areas with missing data (in red cycle)

The work was based on the spatial process that is presented below (Figure 10). All geo-data were plotted using the **E**uropean **T**errestrial **R**eference **S**ystem 1989 (ETRS89).

Figure 10. Flow diagram of the spatial process

The total annual precipitation was calculated by summarizing the daily data for precipitation. The spatial distribution of total annual precipitation in Europe is presented in Figure 11.

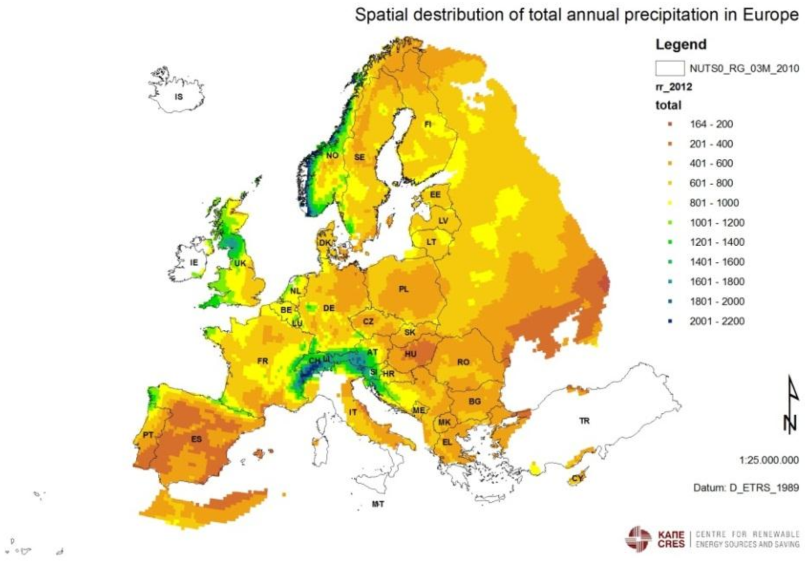

Figure 11. Spatial distribution of total precipitation in Europe

Results

Availability of lands based on the land allocation model

The current available area for the cultivation of non-food crops, as estimated by Krasuska et.al, was the sum of the current fallow land and the area that is being cultivated with energy crops. In order to estimate the available land in 2020 and 2030 three parameters were taken under consideration: a) current fallow land, b) current land area that is being cultivated with energy crops and c) the surplus land released from food and fodder crops.

At present, the total available land is estimated at around 13.2 Mha for the EU-27, the 80% of which is covered by fallow land and the rest by currently grown energy crops. In 2020 it is expected to increase up to 20.5 Mha, while for 2030 the projections are even higher, reaching 26.2 Mha.

The majority of the land available for non-food crops at present and for 2020 is recorded in Mha), while in 2030 Poland will take the lead (4.1 Mha). The top five countries in all timeframes Spain, Germany, Poland, France and Romania (

Figure 12). These countries together with Italy, Bulgaria and Hungary are the eight European countries that at present can assure the 80.9 % of the total available land for non-food crops, the 81.7% in 2020 and in 2030 they could contribute the 84.5%.

In the present situation, the largest land potential is found in Spain and refers to fallow land. The second leading country is Germany with over 2 Mha of available land for non-food crops, which on the contrary includes land already used for energy crops (1.3 Mha) in addition to 0.8 Mha of fallow land. France and Poland also have more than 1 Mha of fallow land each.

In 2020 and 2030, the additional available land is expected to be released from food and fodder crops due to increase of crop productivity per land unit and population changes. In this time frame, it is projected that the leading countries with the largest available land resources will be Germany, Spain, France, Poland and Romania; with Bulgaria and Hungary joining the leading group in scenario 2030. In Spain, only fallow land will still be available for non-food crops, whereas in Poland around 1.8 Mha of surplus land are expected to be additionally released from food/fodder production in 2020 and 2.9

Mha in 2030. Romania, Hungary and Bulgaria follow the same pattern due to the current low annual yield growth rates for main agricultural crops that allows higher growth rates in the future.

Nevertheless, France and Germany would also offer significant amounts of surplus land released from cereals and other crops, because the projected lower yield growth rates (compared to those of EU-12) are compensated by the increased arable lands and large farming size as well as the high food self-sufficiency.

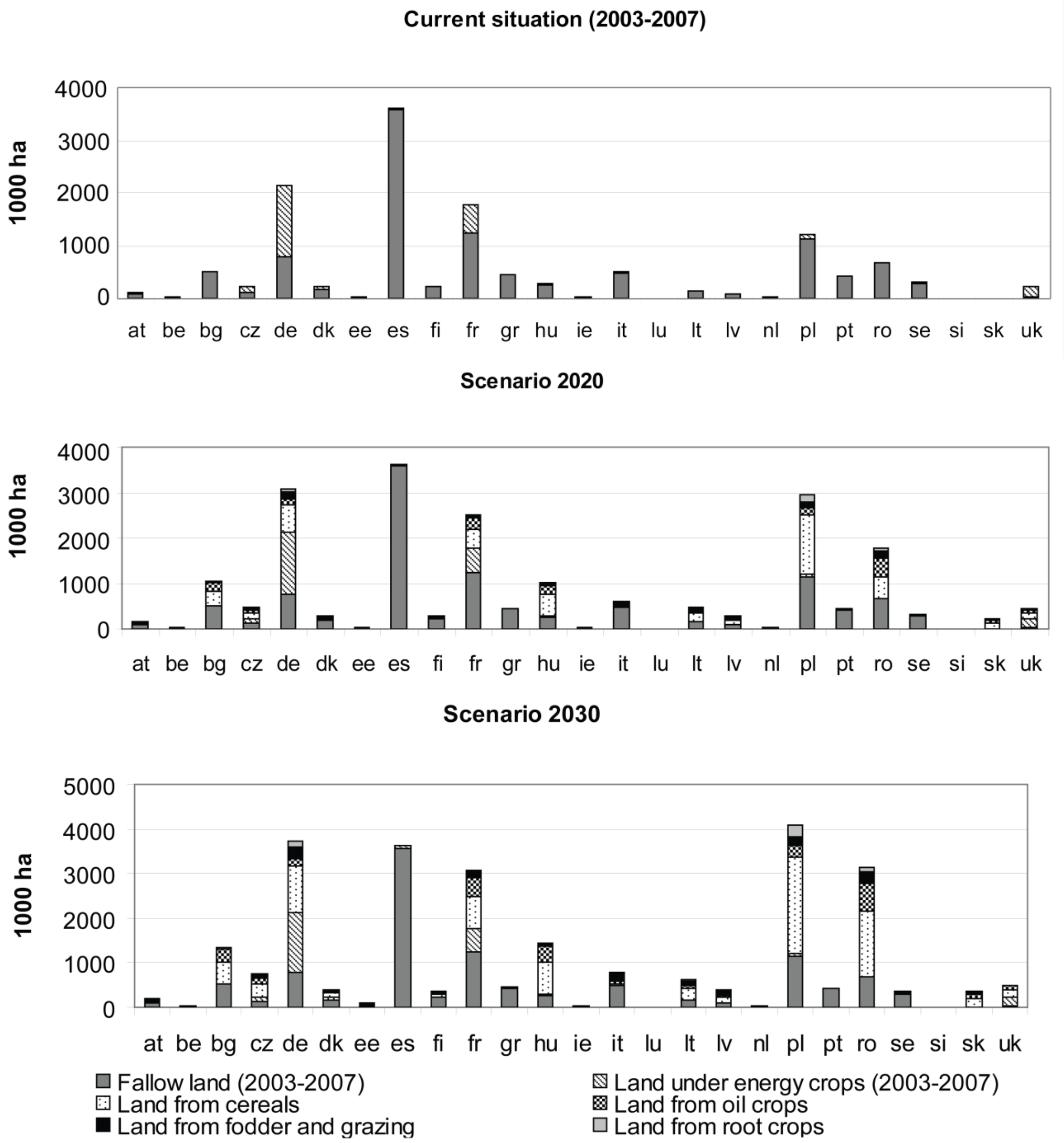

Figure 12. Available land for the cultivation of energy crops at present, in 2020 and in 2030 (Source: Krasuska et.al, 2010).

Significant differences in the availability of land between the NUTS-2 regions across the EU are also reported (Figure 13).

In the current situation the surplus land contribution to the total agricultural land is below 9% in most regions, with the highest values found in central Spain and southern Greece, showing the high importance of fallow land in these regions. In scenario 2020 the share of surplus land in most regions would increase up to the range of 14-21% of total agricultural land and 22-42% in 2030, respectively.

Large regions with the highest percentage of land potentially available for energy crops (over 20%) are located in central and eastern Spain, in central and eastern Germany, western Poland, Hungary, and Bulgaria.

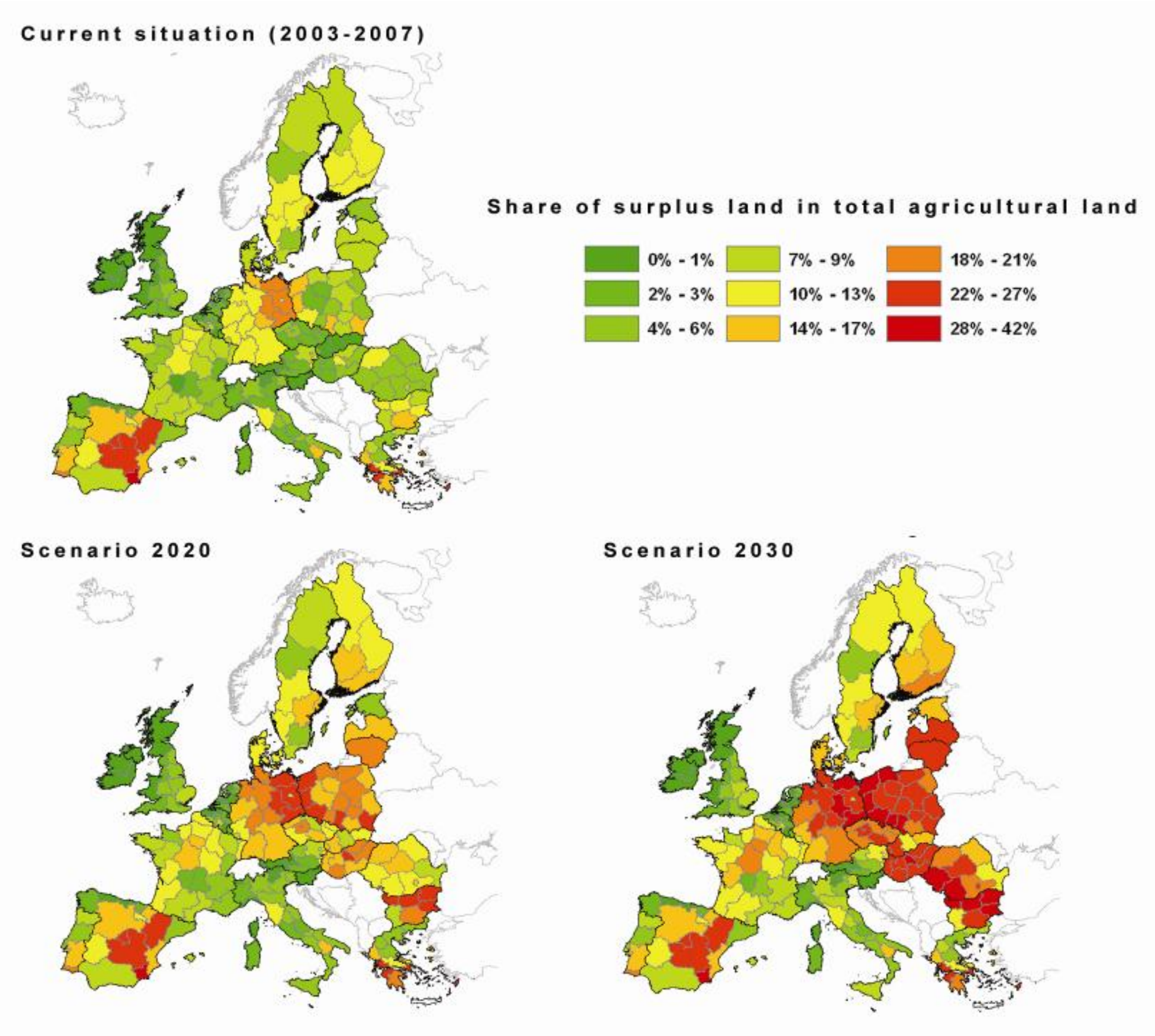

Figure 13. Share of surplus land in total agricultural land at present, in 2020 and in 2030 (Source: Krasuska et.al, 2010).

Land suitability for the lignocellulosic crops

Estimations on the land availability of the lignocellulosic crops were based on their main climate requirements. Metzger et al. elaborated a climatic stratification of the environment of Europe in thirteen environmental zones. The stratification was based on climate data, data on the ocean influence and geographical position (northing); soil data were not distinctive at the level of Europe, as the soil classification systems differ for each country (Figure 14).

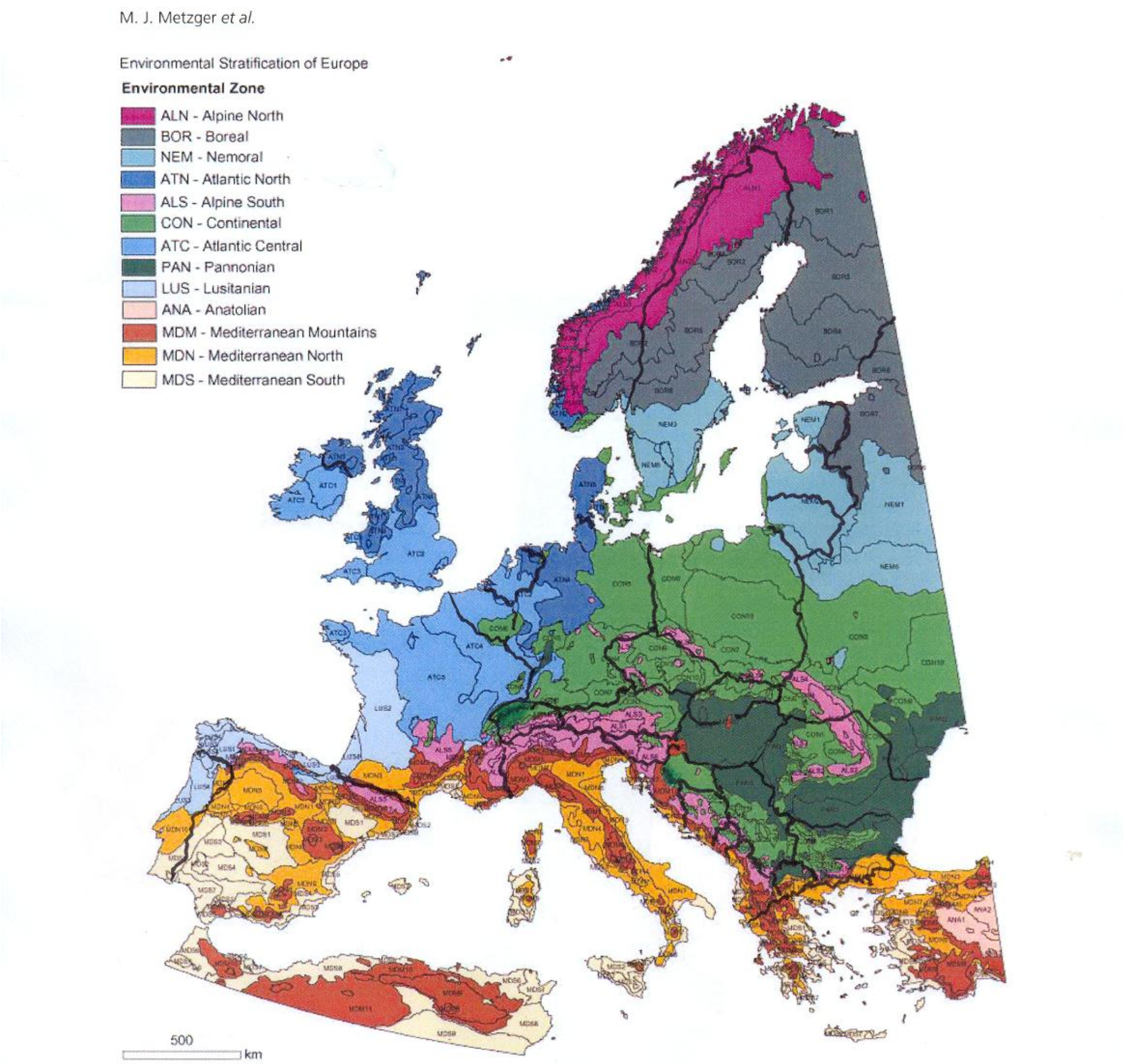

Figure 14. Environmental Stratification of Europe by Metzger et al. (2005)

Seven zones were selected as being more suitable for growing the studied crops (Table 2):

- Nemoral, covering the southern part of Scandinavia, the Baltic states and Belarus. It is characterised by limited precipitation, low temperatures but also high temperature range during the growing cycle of the crops.
- Continental, which covers most part of Europe and is characterised by high temperatures in summer time and very low in winter time, followed by relatively high precipitation.

- ❖ Atlantic Central and North are influenced of the Atlantic Ocean and the North Sea, with rather low temperatures in summer and winter, abundant rainfalls and satisfactory length of growing period.

- ❖ Lusitanian, which covers the southern Atlantic area and has rather high summer temperatures and mild winters.

- ❖ Mediterranean North and South, covering the southwest part of Europe and North Africa. It has short precipitation periods and long hot and dry summers. The length of the growing season is long and air temperatures favourable for growing a wide number of crops. However summer drought is a limiting factor that imposes the use of irrigation for crop survival and achieving high crop yields

Table 2. Suitability of crops for the several climatic zones

Crops	Climatic zones	Countries
Cardoon	Mediterranean South	FR, GR, IT, PT, ES
Giant reed	Mediterranean North	FR, GR, IT, PT, ES
	Mediterranean South	FR, GR, IT, PT, ES
Miscanthus	Continental	AT, BE, BG, CZ, DK, DE, HU, LT, LU, PL, RO,SK
	Atlantic North	DK, DE, IE, NL, UK
	Atlantic Central	BG, FR, DE, IE, NL, UK
	Lusitanian	FR, PT, ES
	Mediterranean North	FR, GR, IT, PT, ES
Switchgrass	Atlantic North	DK, DE, IE, NL, UK
	Atlantic Central	BG, FR, DE, IE, NL, UK
Willow	Nemoral	EE, FI, LV, LT, PL, SE
	Continental	AT, BE, BG, CZ, DK,DE, HU, LT, LU, PL, RO,SK
	Atlantic North	DK, DE, IE, NL, UK
	Atlantic Central	BG, FR, DE, IE, NL, UK
	Lusitanian	FR, PT, ES

The suitability of the crops for each environmental zone was mainly based on the crop ecology (areas of origin), biology (tolerance in abiotic stresses, like in drought or frost) and physiology (nutrients and soil requirements, growing season, radiation use efficiency, water and nutrients use efficiency, etc.)

- ❖ Cardoon is perennial oleaginous crop with Mediterranean origin and thus adapted in the drought conditions of the Mediterranean South Zone. There is no indication for growing this crop in northern zones.

- ❖ Miscanthus, a rhizomatous C4 perennial grass, has a broad genetic base and many varieties and hybrids are cultivated successfully in all environmental zones of Europe, except from the Nemoral, where the crop has no resistance to extreme cold at the transplanting year and Mediterranean South, where the crop has no resistance to extreme drought.

- ❖ Switchgrass is a perennial C4 grass that can be established by seeds. Like miscanthus, there are lots of varieties adapted in a wide range of climate conditions because the crop was grown for decades as pasture. It has higher tolerance to drought than miscanthus.

- ❖ Giant reed is a lignocellulosic rhizomatous C3 perennial crop well adapted to warm-temperate or subtropical climates, but it is also able to survive short periods of frost; it prefers soils with abundant

- ❖ Willow is grown mainly in the Continental climate zone as well as Nemoral, since it has a relatively high resistance to frost, however it has a high water requirement, and often water availability is a limiting factor for its production.

Land suitability for safflower cultivation

In order to meet requirements of climatic criterion 1.1.1, concerning the total precipitation during the growing season and the average temperatures during seed germination, flowering and seed formation, it was necessary to calculate the total precipitation only for the growing season and not for the whole year, summarizing daily precipitation data only for the days of the growing season. The result is presented in Figure 15.

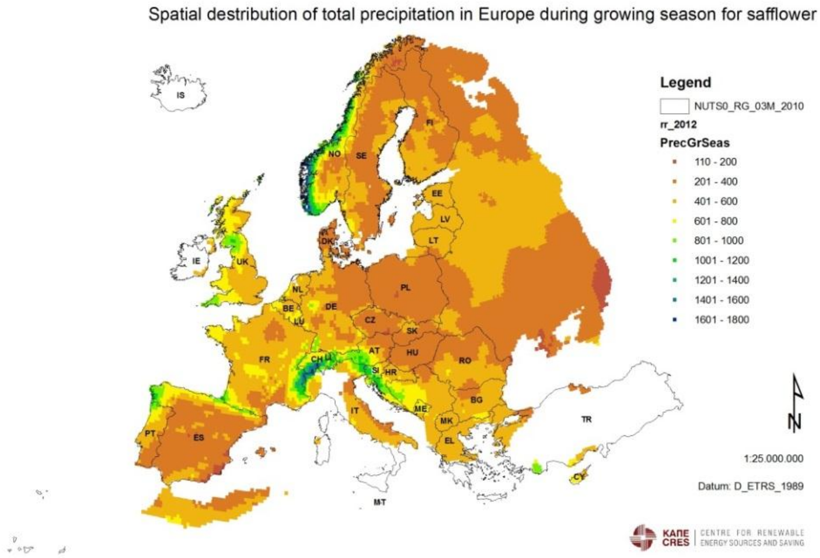

Figure 15. Spatial distribution of total precipitation in Europe during growing season for safflower

According criterion 1.2.1, only areas with altitude lower than 1100 m are suitable for the cropping of safflower. Using topographic data from global elevation dataset, after ‘masking’ on boundaries of EU27+, areas with elevation lower than 1100m were selected and plotted (Figure 16).

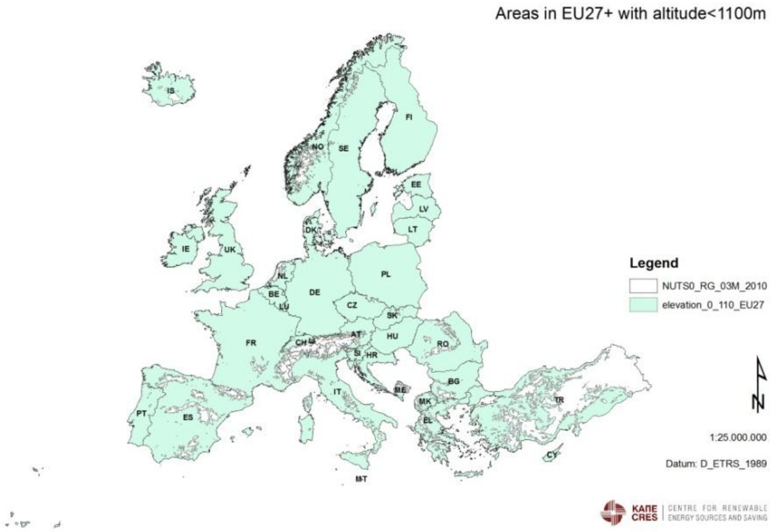

Figure 16. Areas with altitude lower than 1100m in EU27+

The next step of this spatial analysis process was to identify areas fulfilling requirements of both 1.1.1 and 1.2.1 criteria using the method of spatial intersection. The result of this process is presented in Figure 17, showing the distribution of total precipitation during the growing season of safflower in areas with altitude lower than 1100m.

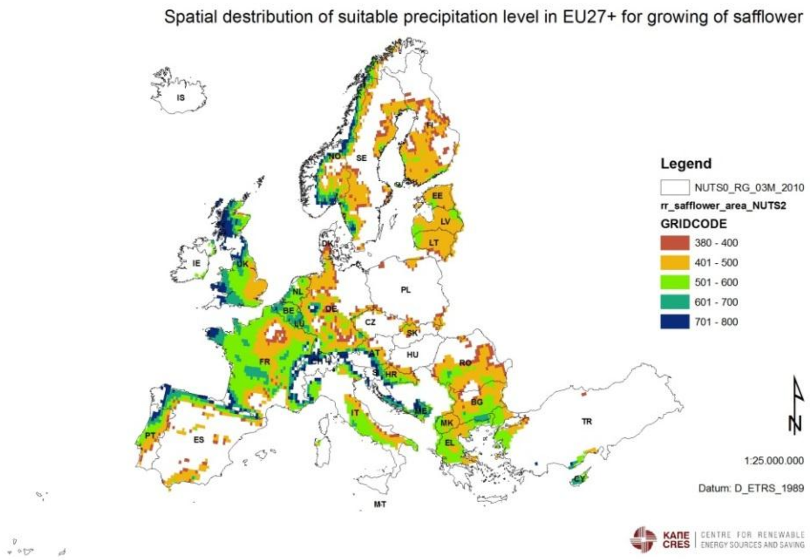

Figure 17. Spatial distribution of total precipitation in Europe during growing season for safflower, in areas with altitude lower than 1100m

Intersection, between arable lands (CLC) and areas matching 1.1.1 and 1.2.1 criteria, was also used for selection of irrigated and non-irrigated lands with precipitation during growing season suitable for cultivation of safflower (Figure 18 and Figure 19).

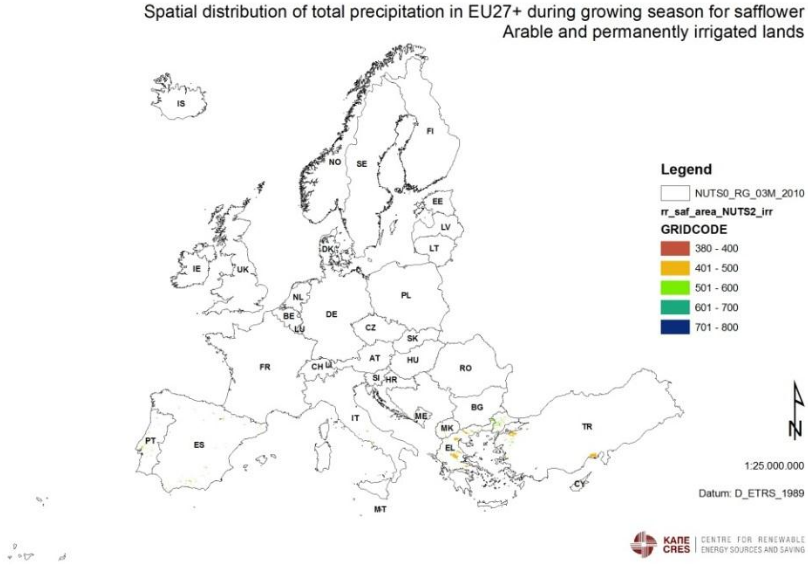

Figure 18. Arable and permanently irrigated lands in EU27+, suitable for growing of safflower and distribution of total precipitation during growing season

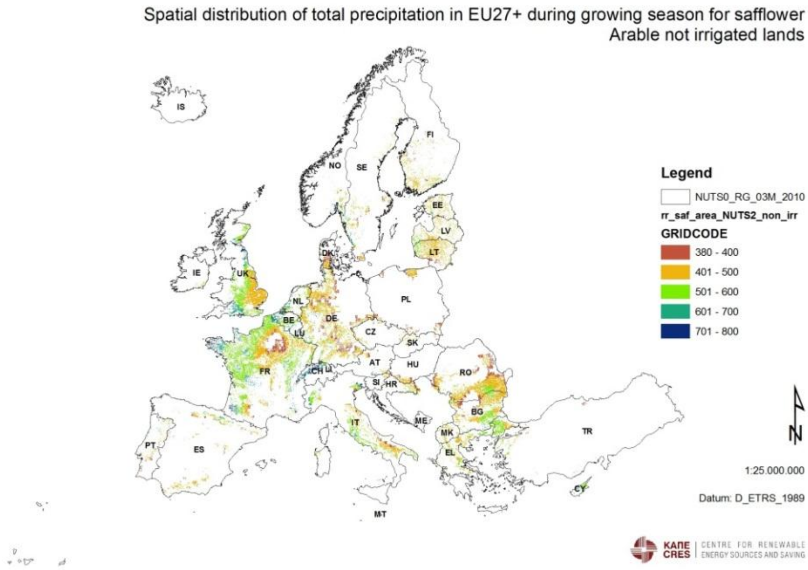

Figure 19. Arable and non- irrigated lands in EU27+, suitable for growing of safflower and distribution of total precipitation during growing season

The spatial distribution of arable lands in EU27+, where the precipitation level is suitable for cropping of safflower is the product of matching the two results produced in the previous process (Figure 20).

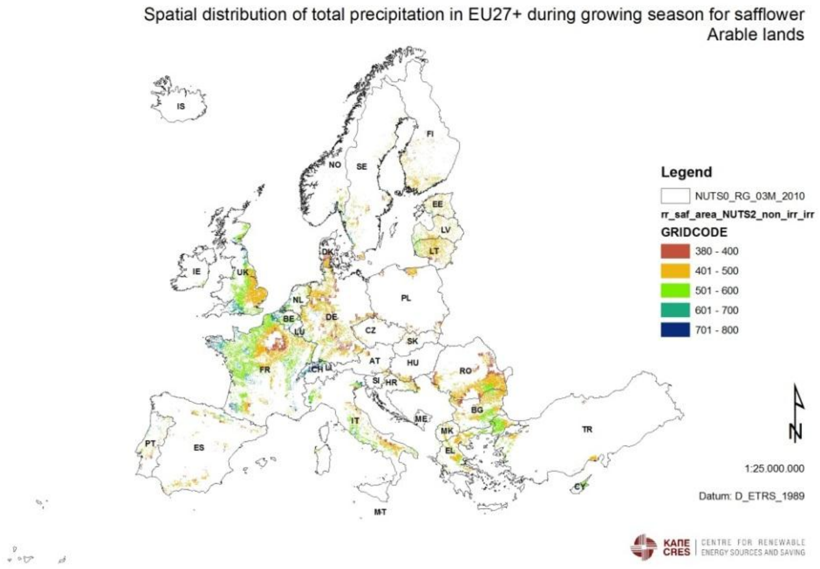

Figure 20. Arable agricultural lands in EU27+, suitable for growing of safflower and distribution of total precipitation during growing season

The next step of this work was to include criterion 1.1.2 – temperature requirements in the selection process. To do so, a crucial parameter had to be taken into account: the planting date of safflower.

Planting date is a crucial factor for safflower.

Although the crop is frost-tolerant in the seedling stage, withstanding temperatures of -7 °C, it does best in areas with warm temperatures and sunny, dry conditions during the flowering and seed-filling periods [Oelke et al, 1992]. Early spring sowing is done in April/May in areas which have at least 120 days of frost free periods, and hot summers. Planting prior to April 10 usually shows no advantage since cool soil temperatures (below 4 °C) prevent germination and encourage seedling blight. Planting after May 20 increases the risk of fall frost injury and diseases that reduce seed yield and quality. The crop may not mature if planted after mid-May [Oelke et al, 1992].

In the temperate regions of the Mediterranean basin (Greece, Turkey, Lebanon) safflower can be sown either in October-December as a winter crop, or in March-April as a spring crop [Koutroubas et al, 2008; Dordas and Sioulas, 2008; Dordas and Sioulas, 2009; Istanbulluoglou, 2009; Istanbulluoglou et al, 2009]. Early planting allows the crop to take full advantage of the entire growing season [Yau, 2007].

Further to that, under water scarce regions as Mediterranean region, spring sown safflower is more sensitive to water than winter sown safflower. In addition winter sowing is more preferable to spring sowing in order to meet vegetable oil requirements [Istanbulluoglou et al, 2009].

For that purpose it was necessary to use dataset of spatial distribution of daily average temperature (Figure 3) in order to calculate the average temperature for three different planting dates across Europe. More specifically, it was calculated for potential planting in October, in April and in early May.
Data produced in this process were analyzed, based on requirements of selection criterion 1.1.2. The result of that analysis is the calculation of spatial distribution of average temperature suitable for seed germination of safflower for three different planting dates: October (Figure 21), April (Figure 22) and early May (Figure 23).

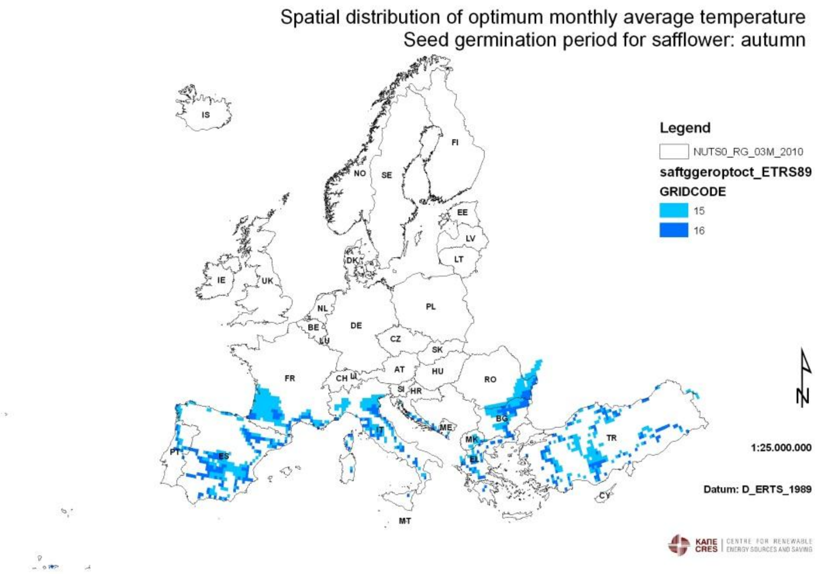

Figure 21. Spatial distribution of average temperature, suitable for seed germination of safflower - Germination period: October

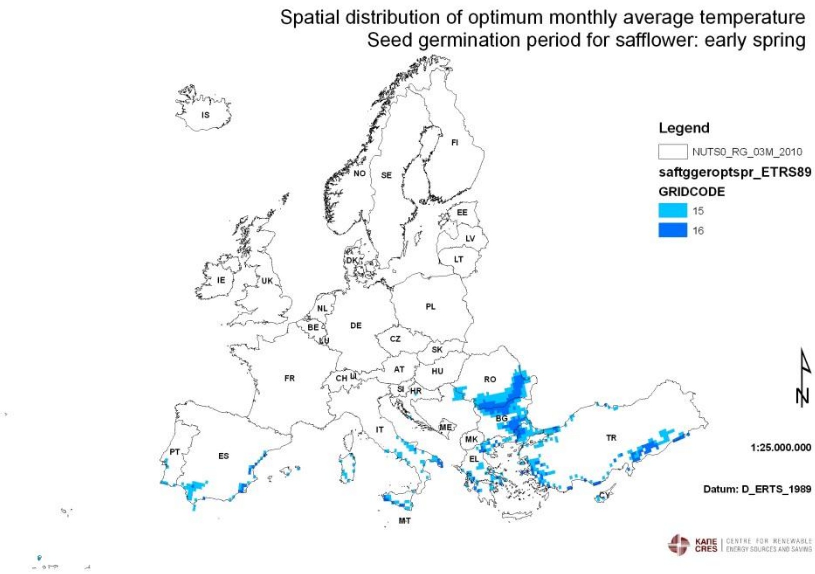

Figure 22. Spatial distribution of average temperature, suitable for seed germination of safflower - Germination period: April

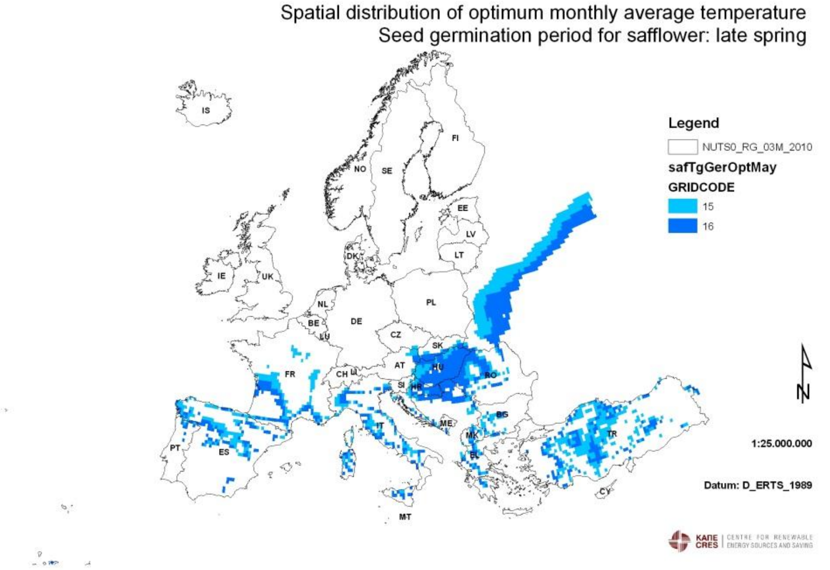

Figure 23. Arable Spatial distribution of average temperature, suitable for seed germination of safflower - Germination period: early May

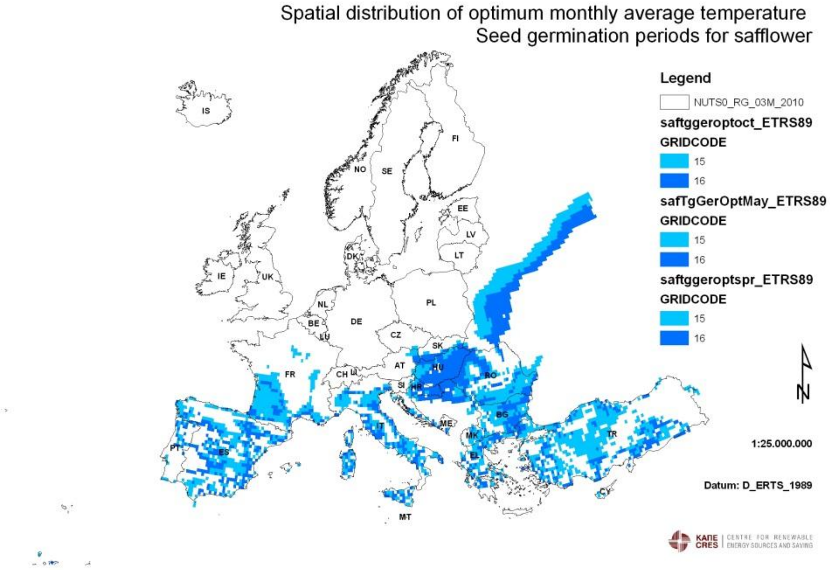

Figure 24. Spatial distribution of average temperature suitable for seed germination of safflower in three different planting dates

On the final phase of this work, previously produced geo-data were analyzed and the identification of agricultural areas suitable for the cropping of safflower was the expected result. Data used in the process were:

- The spatial distribution of arable lands in EU27+, where the precipitation level is suitable for cropping of safflower
- The spatial distribution of average temperature suitable for seed germination of safflower for three different planting dates

In that way the combination of selection parameters was activated, providing the opportunity for more detailed determination of lands for safflower cultivation.

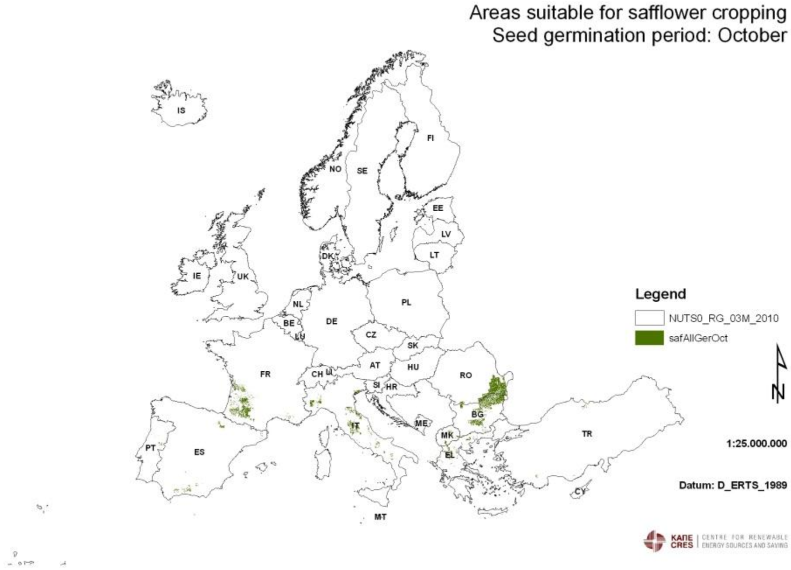

Figure 25. Arable and non- irrigated lands in EU27+, suitable for growing of safflower – Germination period: October

The first result based on intersection of previously produced data was the determination of areas suitable for safflower cropping taking into account tree different scenarios about seed germination (Figure 25, Figure 26, Figure 27)

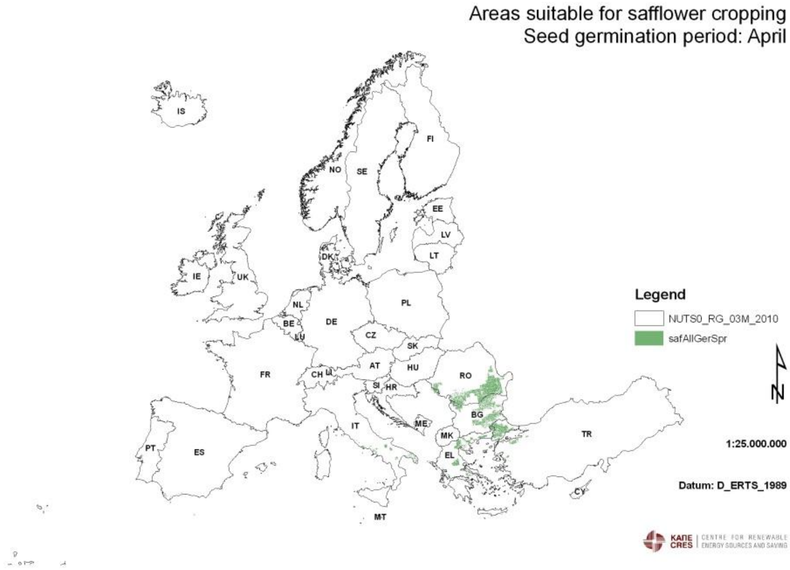

Figure 26. Arable agricultural lands in EU27+, suitable for growing of safflower – Germination period: April

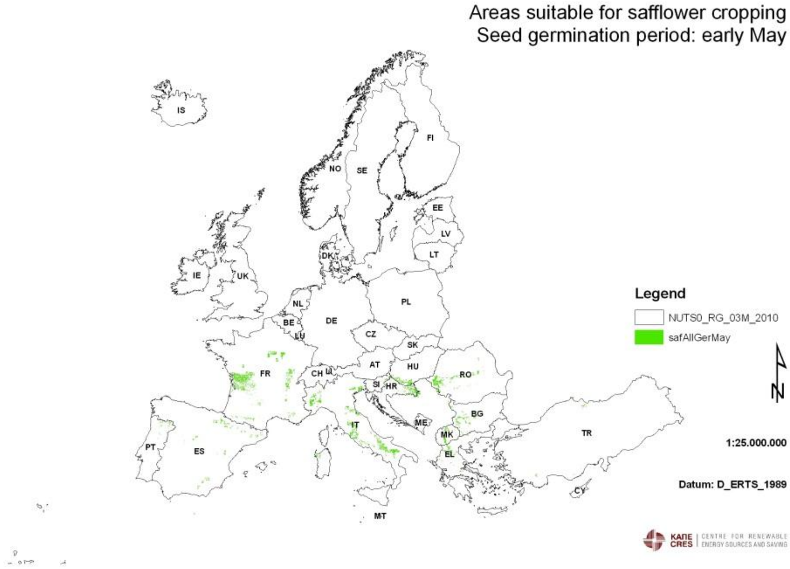

Figure 27. Arable agricultural lands in EU27+, suitable for growing of safflower – Germination period: early May

Figure 28 presents arable agricultural lands in EU27+ suitable for safflower cropping, taking into account climatic and topographic parameters, as well as, possible scenarios about germination period targeting a more successful cultivation and efficient production for safflower.

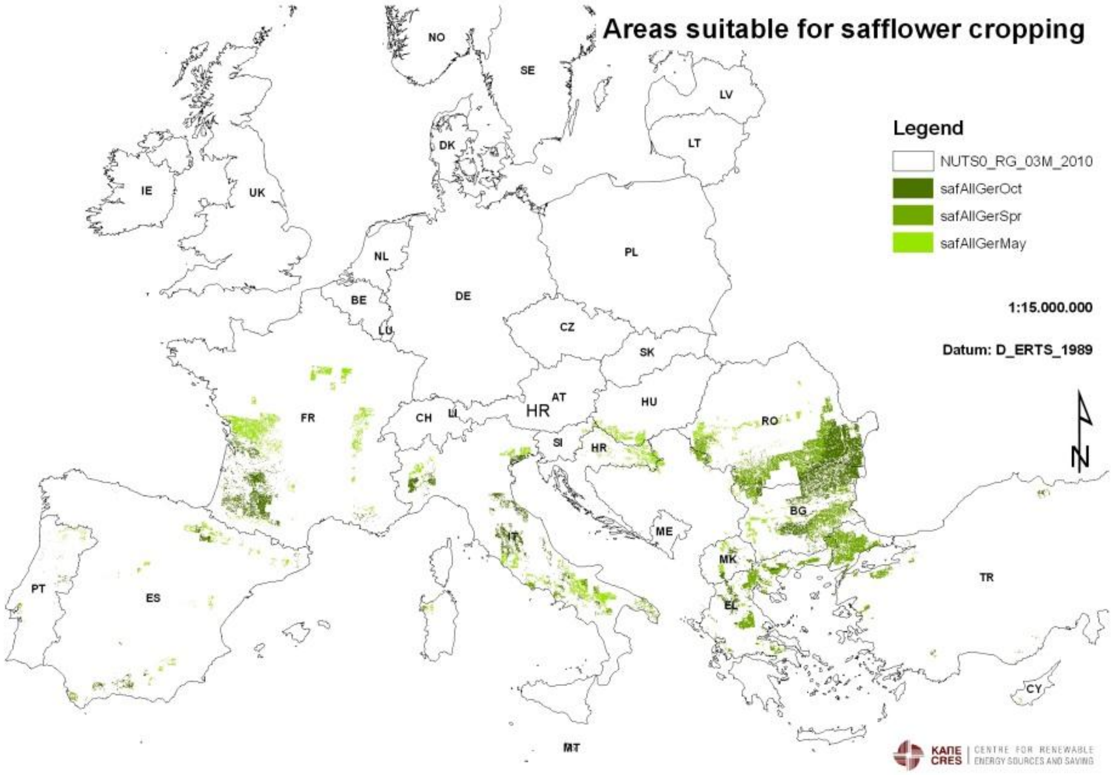

Figure 28. Arable agricultural lands in EU27+, suitable for growing of safflower

The arable agricultural lands suitable for safflower cropping in relation to the planting dates were estimated for every country, separately. Results are presented in Table 3.

Table 3. Areas in Europe suitable for safflower cropping in relation to different planting dates

	Area (ha)		
	Germination period		
Country	October	April	early May
Bulgaria	1.843.089	2.271.908	284.872
Romania	1.820.802	3.614.373	621.080
France	1.381.751		1.824.314
Italy	1.014.430	389.882	1.609.729
Greece	341.142	1.072.323	222.279
Spain	249.559	46.294	348.004
FYROM	163.150	18.327	209.631
Turkey	65.823	1.276.196	62.202
Portugal	33.629	26.582	61.507
Bosnia Herzegovina	7.383	9.013	475.000
Hungary			312.652
Total	6.920.803	8.732.463	6.072.254

Conclusions

The current available area for the cultivation of non-food crops as estimated in the 4Fcrops project (www.4fcrops.eu) was the sum of the current fallow land and the area that is being cultivated with energy crops. In order to estimate the available land in 2020 and 2030 three parameters were taken under consideration: a) current fallow land, b) current land area that is being cultivated with energy crops and c) the surplus land released from food and fodder crops.

The total available land is estimated at around 13.2 Mha, while in 2020 it is expected to increase up to 20.5 Mha. The projections for 2030 are even higher, reaching 26.2 Mha. The majority of the land available for non-food crops at present and for 2020 was recorded in Spain (3,600 ha), while in 2030 Poland will take the lead (4,100 ha). The top five countries in all timeframes are: Spain, Germany, Poland, France and Romania. These countries together with Italy, Bulgaria and Hungary are the eight European countries that at present can assure the 80.9 % of the total available land for non-food crops, the 81.7% in 2020 and in 2030 they could contribute the 84.5%.

The suitability of the crops for each environmental zone was mainly based on the climate requirements of each crop as they are defined by the crop ecology (areas of origin), biology (tolerance in abiotic stresses, etc.) and physiology (nutrients and soil requirements, growing season, radiation use efficiency, water and nutrients use efficiency, etc.)

- Cardoon is perennial oleaginous crop with Mediterranean origin and thus adapted in the drought conditions of the Mediterranean South Zone. There is no indication for growing this crop in northern zones.

- Miscanthus, a rhizomatous C4 perennial grass, has a broad genetic base and many varieties and hybrids are cultivated successfully in all environmental zones of Europe, except from the Nemoral, where the crop has no resistance to extreme cold at the transplanting year and Mediterranean South, where the crop has no resistance to extreme drought.

- Switchgrass is a perennial C4 grass that can be established by seeds. Like miscanthus, there are lots of varieties adapted in a wide range of climate conditions because the crop was grown for decades as pasture. It has higher tolerance to drought than miscanthus. It can grow in Atlantic Central and South zones, however it could also be grown in almost all zones.

- ❖ Giant reed is a lignocellulosic rhizomatous C3 perennial crop well adapted to warm-temperate or subtropical climates, but it is also able to survive short periods of frost; it prefers soils with abundant. It can grow in Mediterranean zone, where it originates from although there are indications that it can grow even in northern climates.

- ❖ Willow is grown mainly in the Continental climate zone as well as Nemoral, since it has a relatively high resistance to frost, however it has a high water requirement, and often water availability is a limiting factor for its production

- ❖ Safflower is an annual oilseed crop grown throughout the semiarid region of the temperate climates in many areas of the world. Based on its climate requirements, it can be grown mostly in Bulgaria, Romania, France, Italy, Greece and Spain.

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ANNEX 2. Land cover classification according to CLC programme (source: www.eea.europa.eu)

GRID_CODE	CLC_CODE	LABEL_1	LABEL_2	LABEL_3	RGB
1	111	Artificial surfaces	Urban fabric	Continuous urban fabric	230-000-077
2	112	Artificial surfaces	Urban fabric	Discontinuous urban fabric	255-000-000
3	121	Artificial surfaces	Industrial commercial and transport units	Industrial or commercial units	204-077-242
4	122	Artificial surfaces	Industrial commercial and transport units	Road and rail networks and associated land	204-000-000
5	123	Artificial surfaces	Industrial commercial and transport units	Port areas	230-204-204
6	124	Artificial surfaces	Industrial commercial and transport units	Airports	230-204-230
7	131	Artificial surfaces	Mine dump and construction sites	Mineral extraction sites	166-000-204
8	132	Artificial surfaces	Mine dump and construction sites	Dump sites	166-077-000
9	133	Artificial surfaces	Mine dump and construction sites	Construction sites	255-077-255
10	141	Artificial surfaces	Artificial non-agricultural vegetated areas	Green urban areas	255-166-255
11	142	Artificial surfaces	Artificial non-agricultural vegetated areas	Sport and leisure facilities	255-230-255
12	211	Agricultural areas	Arable land	Non-irrigated arable land	255-255-168
13	212	Agricultural areas	Arable land	Permanently irrigated land	255-255-000
14	213	Agricultural areas	Arable land	Rice fields	230-230-000
15	221	Agricultural areas	Permanent crops	Vineyards	230-128-000
16	222	Agricultural areas	Permanent crops	Fruit trees and berry plantations	242-166-077
17	223	Agricultural areas	Permanent crops	Olive groves	230-166-000
18	231	Agricultural areas	Pastures	Pastures	230-230-077
19	241	Agricultural areas	Heterogeneous agricultural areas	Annual crops associated with permanent crops	255-230-166

20	242	Agricultural areas	Heterogeneous agricultural areas	Complex cultivation patterns	255-230-077
21	243	Agricultural areas	Heterogeneous agricultural areas	Land principally occupied by agriculture with significant areas of natural vegetation	230-204-077
22	244	Agricultural areas	Heterogeneous agricultural areas	Agro-forestry areas	242-204-166
23	311	Forest and semi natural areas	Forests	Broad-leaved forest	128-255-000
24	312	Forest and semi natural areas	Forests	Coniferous forest	000-166-000
25	313	Forest and semi natural areas	Forests	Mixed forest	077-255-000
26	321	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Natural grasslands	204-242-077
27	322	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Moors and heathland	166-255-128
28	323	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Sclerophyllous vegetation	166-230-077
29	324	Forest and semi natural areas	Scrub and/or herbaceous vegetation associations	Transitional woodland-shrub	166-242-000
30	331	Forest and semi natural areas	Open spaces with little or no vegetation	Beaches dunes sands	230-230-230
31	332	Forest and semi natural areas	Open spaces with little or no vegetation	Bare rocks	204-204-204
32	333	Forest and semi natural areas	Open spaces with little or no vegetation	Sparsely vegetated areas	204-255-204
33	334	Forest and semi natural areas	Open spaces with little or no vegetation	Burnt areas	000-000-000

34	335	Forest and semi natural areas	Open spaces with little or no vegetation	Glaciers and perpetual snow	166-230-204
35	411	Wetlands	Inland wetlands	Inland marshes	166-166-255
36	412	Wetlands	Inland wetlands	Peat bogs	077-077-255
37	421	Wetlands	Maritime wetlands	Salt marshes	204-204-255
38	422	Wetlands	Maritime wetlands	Salines	230-230-255
39	423	Wetlands	Maritime wetlands	Intertidal flats	166-166-230
40	511	Water bodies	Inland waters	Water courses	000-204-242
41	512	Water bodies	Inland waters	Water bodies	128-242-230
42	521	Water bodies	Marine waters	Coastal lagoons	000-255-166
43	522	Water bodies	Marine waters	Estuaries	166-255-230
44	523	Water bodies	Marine waters	Sea and ocean	230-242-255