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Biomass based energy intermediates boosting biofuel production

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Deliverable

The feedstock potential assessment for EU-27 + Switzerland in NUTS-3

Appendix 1

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Introduction

Estimates of the technical biomass potential published as Deliverable 1.2 of BioBoost were modelled based on scenarios concentrated on available statistical and spatial data. In the case of disaggregation of statistical data (which are already loaded are some errors) in using spatial data (for the generalisation corresponding scale map) the overall calculation error can propagated. In addition, models and algorithms were created according to their universal application across Europe. For this reason, in certain regions, the technical potential estimates may not correspond to the actual real situation. In addition, the authors are aware of regional and / or national specific conditions, which affect the possibility of obtaining biomass. These are mainly: the structure of agricultural production, centralisation or decentralisation of agri-food industry and wood processing and microclimate.

All these factors have an effect on the value of the estimates for individual potentials in the regions; but because of the data availability, it could not always be taken into account (especially in the overall modelling resources). For this reason, the adopted algorithms tried to formulate so that the results remain rather underestimated than overestimated and that in the case of more detailed studies enable a re-calculation.

The appendix 1 to report Deliverable 1.2 shows some of the methods that can be used to validate the models. In selected areas, the test also shows the specificity of regions characteristic, which may affect the obtained results.

The first section of the appendix the risk, uncertainty and location analysis presents an assessment of the entire model for all NUTS-3 regions. In the next chapter, the occurrence of hypothetical regions with self-sufficient energy. In chapter 3 is indicated by regions in which it can be assumed that the current resource base is the most optimal for the processing in one of the three preferred project BioBoost methods (FP, CP, HTC). Then a comparison of the BioBoost model with the biomass potential assessed and based on high resolution satellite images (in two regions of Europe) was done. The final two chapters present the validation of the types of waste biomass, which can be made only on the basis of statistical data. This applies to biomass from industrial and biomass alternative.

The authors of this paper are aware that it is not complete. For it to be completed a comprehensive analysis of mainly regional capabilities of biomass waste from the food industry would need to performed. However, due to a lack of this type of data, these estimates are currently impossible to carry out. The project was established to develop a BioBoost model that can be universal accepted in Europe, and this requires a homogeneity statistical database. It seems that it can only guarantee the expansion of Eurostat data structures - especially on data for the NUTS-3 regions.

The risk, uncertainty and location analysis

The study on the technical potential of biomass gives the possibility in estimating all chosen types of biomass residues for NUTS-3 territorial units. Through cluster analysis new spatial units were obtained that were more homogeneous in terms of the structure of biomass. In most of the NUTS regions one can find resources sufficient to locate power plant or intermediate plants

On the map (Figure 1) it can be seen that in most regions the biomass potential is higher than 120 kt (based on the objectives of the BioBoost project), which indicates highly favourable locations for the processing of biomass for energy production. Smaller potentials occur only in single regions with a small area (indicated by arrows), but often they are regions with a high relative potential (spatial density of biomass). Therefore, for practical reasons, it is appropriate to perform a risk assessment of errors in previously conducted modelling and demonstrate the potential of biomass for energy purposes, assuming the greatest care in the estimates.

On these grounds, the following topics were conducted: 1) risk analysis into the possibilities of revaluation of highest potentials, 2) an analysis into the uncertainty of estimates for individual clusters and 3) an analysis of the power plants' location.

The risk analysis

As a result of sources, database modelling and analysing of their clusters data sets were obtained, which are characterised with a large right-sided skewness of distribution. The correctness of this is shown earlier in the summary of results for the modelling of the technical potential of biomass, where the asymmetry of distributions was characterised with a set of descriptive statistics (Table 1).

Table 1. Technical potential in NUTS-3 (kt). Summary statistic

Measure	b.1.1*	b.1.2	b.1.3	b.1.4	b.2.0	b.3.1	b.3.2	b.4.1	b.4.2	b.4.3	Total
Average	16.3	109.5	5.3	11.7	79.5	0.9	2.4	58.8	10.9	4.3	300.8
Median	0.0	28.5	0.0	0.1	35.3	0.4	1.7	33.2	0.0	1.6	165.9
SD	121.2	201.9	39.7	39.2	170.6	1.5	2.3	95.7	48.7	11.6	354.4
Min.	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	4.8
Max.	1711.9	1449.1	1012.6	631.7	3022.2	13.8	20.0	1683.1	960.4	210.6	3263.5
Range	1711.9	1449.1	1012.6	631.7	3022.2	13.8	20.0	1683.1	960.4	210.6	3258.7
Lower quartile	0.0	3.2	0.0	0.0	8.4	0.1	0.8	13.6	0.0	0.4	74.6
Upper quartile	0.0	107.6	0.0	4.1	89.2	0.9	3.1	64.9	1.4	4.1	403.0
Interquartile range	0.0	104.4	0.0	4.1	80.8	0.8	2.3	51.2	1.4	3.7	328.4

The clusters extraction has shown the presence in each class of specific regions of disproportionately large values (Deliverable 1.2-Fig 54-59). Therefore, the risk analysis is aimed at defining the upper value and the results should be verified with independent data (Hertz and Thomas 1983, Sienkiewicz 2005).

This is particularly justified for the practical use of the obtained results, because the regions with a very high value of potential at certain class are the most attractive prospect to invest in for infrastructure development of the energy industry.

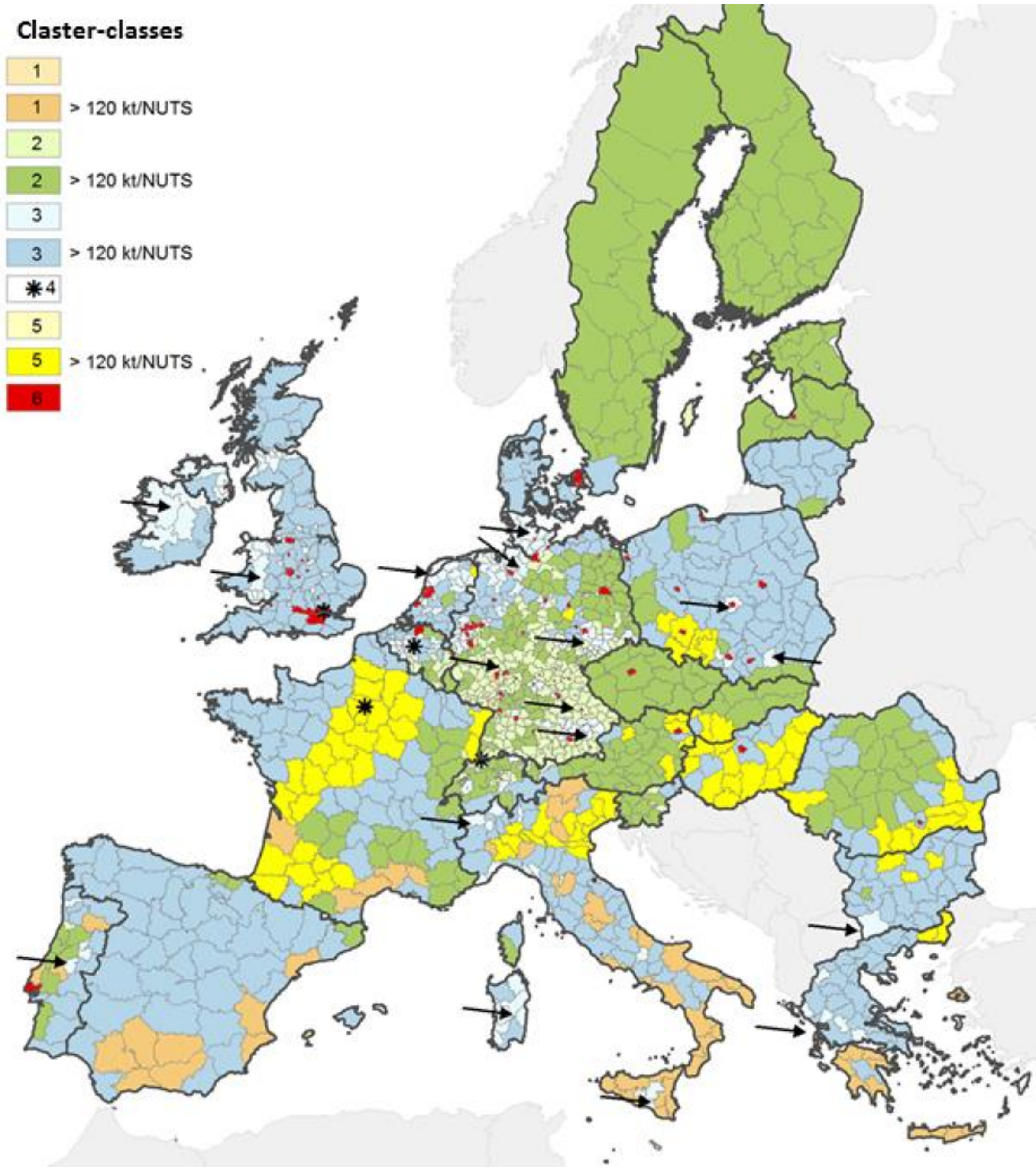

Figure 1. NUTS breakdown detailing the class of individuals with the potential of more than 120 kt

Due to the large differences in the areas of the NUTS-3 regions, the result of analyses were standardised by the polygon area and expressed as biomass in kt per km^2. Two types of analyses were performed.

In the first case, a search was done for the best statistical distributions for each of the classes (D'Agostino and Stephens 1986, Walpole et al. 1993). The upper value above, where there is possibility that the result may be loaded with an error, was assumed as a 95% percentile. The results of the analysis are summarised in Table 2, where the first column contains a list of six classes separated in cluster analysis and the second column - specified number of NUTS-3, in each cluster. Column 3 shows the values of the upper decile in each of the sets. The limit values for the risk analysis are contained in column 4, and the percentage of the subset of risk-listed is in the last column.

Table 2. Risk analysis of overestimating the technical potential in modelling the biomass spatial density according to the best of statistical distributions for each class

Cluster	n	Upper decile (10%)	Risk boundary	%
1	68	194	200	12.3
2	434	137	165	6.3
3	607	374	396	2.7
4	8	3626	3626	2.6
5	89	365	441	5.2
6	107	821	867	6.8
All set	1313	252	515	2.1

The second case, risk analysis was carried out using Monte-Carlo for 10,000 iterations (n). For sampling, the "Latin Hypercube" technology was used, the upper level was set, from where the risk of the assessed potentials was in the estimates (Rubinstein 1981, Fishman 1996). This is of 5% level of the largest value in each class (Table 3).

Table 3. Risk analysis of overestimating the technical potential in modelling biomass spatial density performed using Monte-Carlo

Cluster	n	Upper decile (10%)	Risk boundary	%
1	10,000	212	257	5
2	10,000	148	174	5
3	10,000	216	300	5
4	10,000	2601	3120	5
5	10,000	345	448	5
6	10,000	720	1000	5
All set	10,000	254	350	5

The determination of NUTS by distributions is less restrictive for classes 3 (the most numerous) and 4. This means that a lower number of such units will be classified as having an extremely high spatial density. This NUTS risk analysis must be subjected to additional tests to find out whether the high potential of a particular attribute is a result of imperfect data or algorithms. NUTS 3 regions with potentials larger than the critical value given by distributions should be treated as those in which the estimated potentials have a high statistical uncertainty. That is, to reduce the uncertainty in the estimation, NUTS case studies should be fully performed. These regions are highlighted on the map of risk (Figure 2).

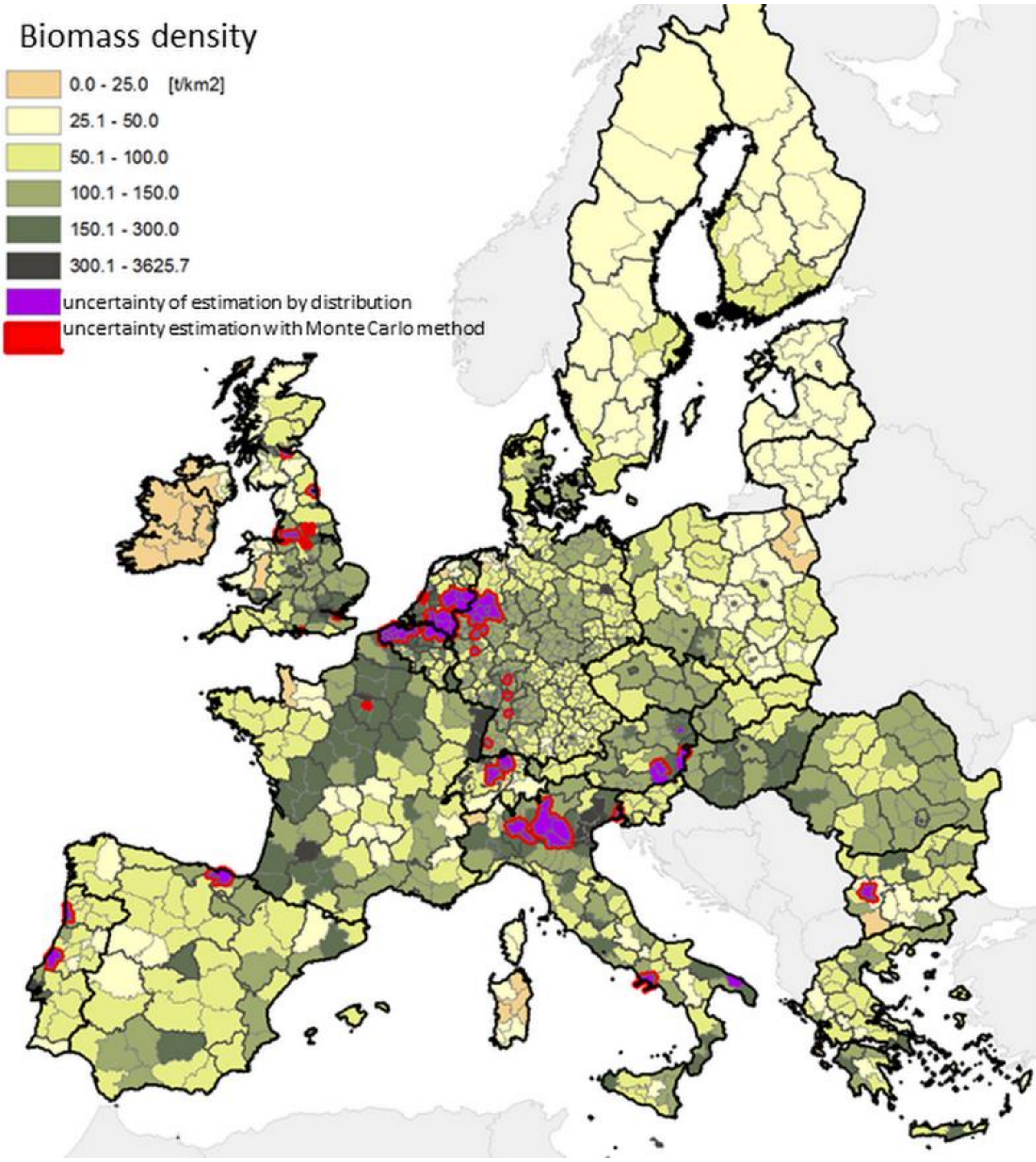

Figure 2. NUTS-3 at the risk of overestimating

Analysis of uncertainty in NUTS-3

The research and literature studies show that biomass production is regionally diverse as well as being unevenly distributed spatially (Bossard et al., 2000). This diversity depends mainly on the changing conditions of production, and was homogenised to a certain extent by the cluster analysis which delineated regions with similar potentials of biomass. However, the results of this analysis cannot lead to a fully homogeneous regionalisation. Hence, when these estimates are used, it must be assumed that the modelled regional potentials are contained within certain ranges of values (Morgan and Henrion 1990, Frey and Burmaster 1999). The substantial part of the variability in these ranges is due to objective conditions of production. However, some of this variability may be due to the fact that in the estimates of the biomass potential, statistical and geographical data were used, which are loaded with some uncertainty. This results from the different types of errors, for example: measurement errors (mass, area), the errors associated with sample representativeness of the data, not enough precision or unrepresentative values of factors were taken into account in the algorithms for estimating biomass. These errors create uncertainty that by definition is a lack of knowledge about the true value of the estimated potential. Consequently, this results in the estimates that cannot be considered or treated as accurate. However, analytically it can be assumed that the true but unknown value of the biomass potential is contained in a range of replicated estimates. If from those estimates the mean will be computed (for example for the clusters), then the difference between this mean and the unknown value of the true potential would be a systematic error of the estimation. If this error is known, it can be used for individual biomass estimates made for the NUTS -3 regions, contained in a given cluster, in order to obtain more accurate estimates of the true, but unknown, potential of biomass. The uncertainty calculated by the applied procedure is defined as following range:

$x_m - U \leq x\ true \leq x_m + U$

The true value is assumed to belong to the above interval.

The uncertainty for the average biomass potential (kt) and density of biomass ($t \cdot km^{-2}$) in biomass potential clusters was estimated with the critical value method t (t-factor), which includes t-distribution (Castrup 2010).

The estimated uncertainty in this way has two important properties. The first one shows that the average uncertainty for cluster is less than the uncertainty in the single estimate for a cluster). The second one is that, if there are more estimates in cluster, the average becomes a better estimate of the true value of the potential in this cluster.

The results of the uncertainty analysis are shown in Table 4 for biomass (kt) and Table 5 for the density ($t \cdot km^{-2}$) within the specified six classes of clusters (C1 .. C6) of biomass potentials.

Table 4. Uncertainty of estimates of biomass in six separate clusters of its potential

Statistics for biomass (kt)	Cluster					
	C1	C2	C3	C4	C5	C6
Mean	270	293	274	256	863	86,6
Standard deviation	261	385	284	113	454	102
Quantity of data	68	434	607	8	89	107
Uncertainty at 95% CI*	65	35	22	95	95	20
% Uncertainty	24	12	8	37	11	23

* - confidence intervals

Table 5. Uncertainty of estimates of biomass spatial density in six separate clusters of its potential

Statistics for biomass density ($t \cdot km^{-2}$)	Cluster					
	C1	C2	C3	C4	C5	C6
Mean	141	99.6	128	1716	220	377
Standard deviation	78.3	57.8	175	887	148	258
Quantity of data	68	434	607	8	89	107
Uncertainty at 95% CI*	20	5	14	738	31	49
% Uncertainty	14	5	11	43	14	13

* - confidence intervals

Estimated uncertainties were taken into account in the mapping of potential sites for biomass pre-treatment plants or bioenergy facilities. The basis for the location was the declared demand for biomass and the existing potential of biomass, taking into account the uncertainty. In this way, the risk of not meeting the demand for biomass was minimised. For example, if one energy plant was to meet the demand for biomass in region C1, it then needed a spatial density of biomass 60 $t \cdot km^{-2}$, the density was increased by the amount of uncertainty, which was 14%.

Location analysis in NUTS-3

Uncertainty analysis and biomass density map were used for the optimisation of the results obtained so far, in terms of location capabilities of biomass pre-treatment plants or bioenergy facilities. This analysis assumes the designation of such an NUTS-3 regions in which one can obtain sufficient, for technological reasons, amounts of biomass in the most favourable, in terms of logistical reasons, radius. Technical potential size ranges were adopted on the basis of assumptions from the BioBoost project whose main goal is to develop practical technology to convert waste and excess biomass into intermediates of energy carriers. Based on these assumptions, specified interval demand for biomass (10, 60, 120 and 200 kt) were defined. In the optimisation of raw material bases, a very important issue is the area from which biomass is harvested. This is because of the fact that the carriage at a distance of 80-100 km energy consumption for transport equals energy value of transported biomass (Sokhansanj and Fenton 2006, Castillo et al. 2010, Strašil et al. 2010, Kowalczyk-Jusko 2012). However, the most rational radius transport of biomass should not exceed 20 km (Börjesson 1996).

For these reasons, it was assumed that the NUTS -3 will be divided into four classes, where the created biomass demand ranges are possible to achieve within a radius of 20 km. The potential availability of biomass in the regions was calculated as the average of the total technical potential of biomass resources in a circle with a radius of 20 km, taking into account any amendments to the uncertainty. The calculation uses the spatial density map and a cluster map. The result of the analysis is the map of the optimal location of biomass-based power plants (Figure 3). Given the scale of the work, the basic unit on the map is NUTS -3, and the situation shows the average values that result from the use of biomass potential density maps. Therefore, the actual locations are based on studies for a local variation of biomass resources per unit that will lead to even better choice of locating power plants, i.e. those that are in close proximity to biomass sources selected for conversion. Based on the map, you can say that in Europe there are two regions particularly suitable for the production of bio-energy. Those are contiguous clusters of NUTS -3 in the Netherlands, Belgium, Germany and northern Italy. It should be noted however, that these regions are also at high risk of overestimation of the technical potential biomass availability (Figure 2). The European regions with the least favourable locations include Scandinavia, Baltic States and north-eastern Poland.

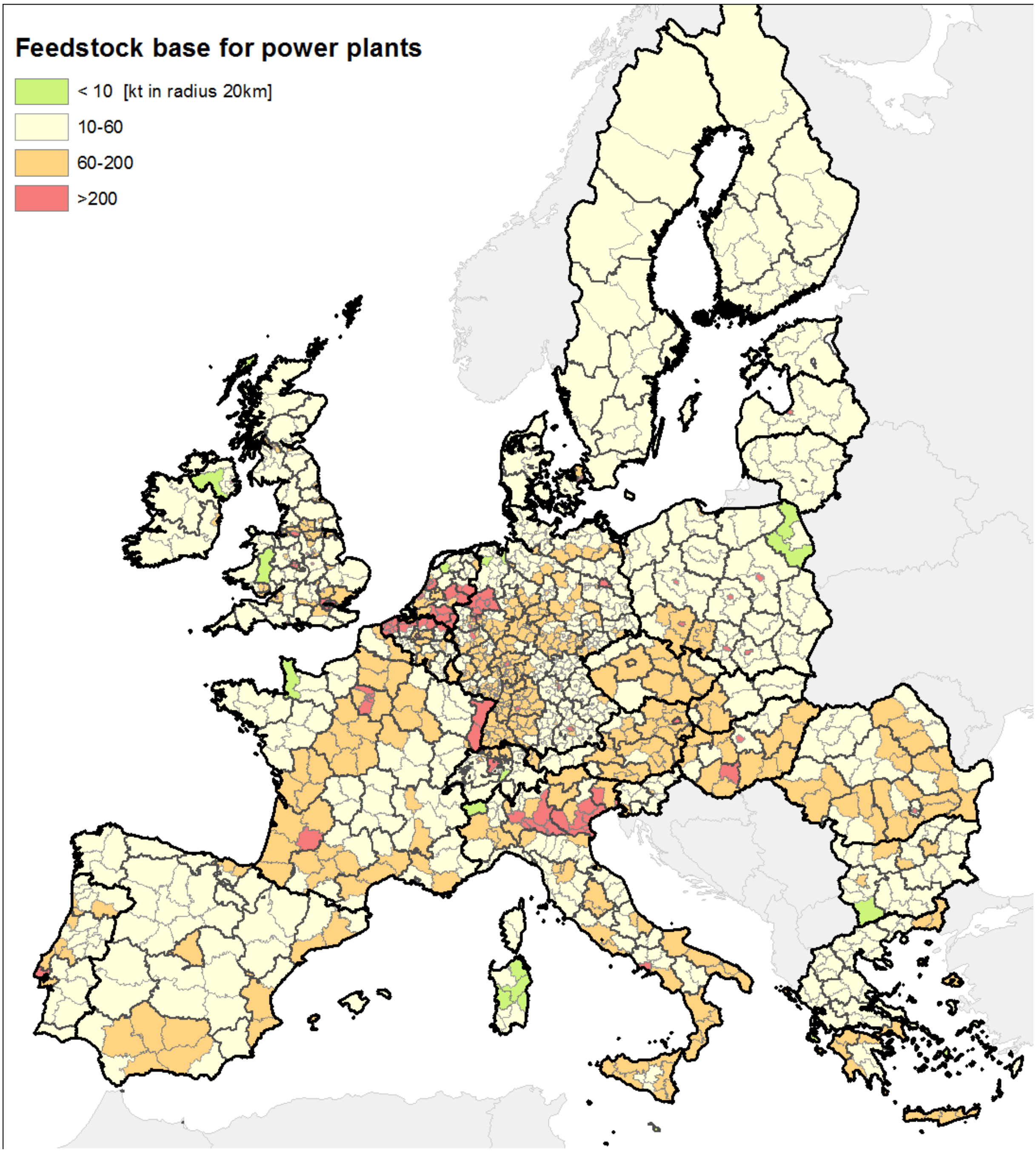

Figure 3. Optimal location for biomass-based power plants

Materials and methods

The aim of present research was to identify the best localisations for straw biomass processing plants in European regions that were combination of NUTS 3 and NUTS 2 regions. Such a combination was applied in order to obtain regions with relatively similar areas. NUTS 3 in Germany, Netherlands, Belgium and the UK are smaller than respective NUTS 3 regions in the rest of the European countries. In these countries, data of NUTS 2 were applied which provided more homogenous spatial structure to a European scale. In the analysis, each of regions was considered as independent of its neighbours. Such assumptions were made to remove possible interactions between regions and competition for straw between them. Competition between regions for straw would bring additional complexity to the research (e.g. regional policy measures should be considered in that case).

The starting point of analysis was a raster layer of straw biomass potential obtained in an earlier research. For each region a part of the raster layer was selected which corresponded to particular region. Such a fragment of biomass raster was smoothed by summing values in moving the window of 40km radius. Then a point was selected for which a maximum was attained. This point was assumed as the best localisation of potential biomass processing facility in the region. The procedure was iterated over all of the regions.

A precise formulation of the algorithm is as follows. The cell of the raster is a square with length of the side equal to 10km. Let A be a set of pairs of integers corresponding to the dimensions of biomass potential raster (m rows and n columns). That is

$$A = \{(i,j): i = 1,..,m; j = 1,..,n\}.$$

The subset $N_k \subset A$ is a raster representation of k-th region

Subsequently denote the values of the raster (which can be seen as a function from A to $\mathbb{R}_+ \cup \{0\}$) as f

A ball with centre in $x \in A$ and radius r is given by formula

$$B_{x,r} = \{y \in A: \|x - y\| \le r\},$$

where $\|\cdot\|$ is an Euclidean metric.

Assuming $r = 4$, let $\hat{B}_{k,x}$

$$\hat{B}_{k,x} = B_{x,4} \cap N_k = \{y \in N_k: \|x - y\| \le 4\}.$$

Application of moving window can be defined as:

$$S_k(x) = \sum_{y \in \hat{B}_{k,x}} f(y)$$

Then point of optimal possible location in k-th region is:

$$\hat{x}_k = \arg\max_{x \in N_k} S_k(x)$$

Results

The general overview for the application of the algorithm described in the preceding sections can be seen in Figure 1. It shows the best locations for potential straw processing facilities in each region apart from regions where the best location would not yield more than 20,000 tonnes of straw. Three kinds of green dots represents the potentials in spots of different regions, a bigger dot means a higher straw potential and red dots show places with very high potential of straw and it may suggest favourable conditions for a potential straw processing facility.

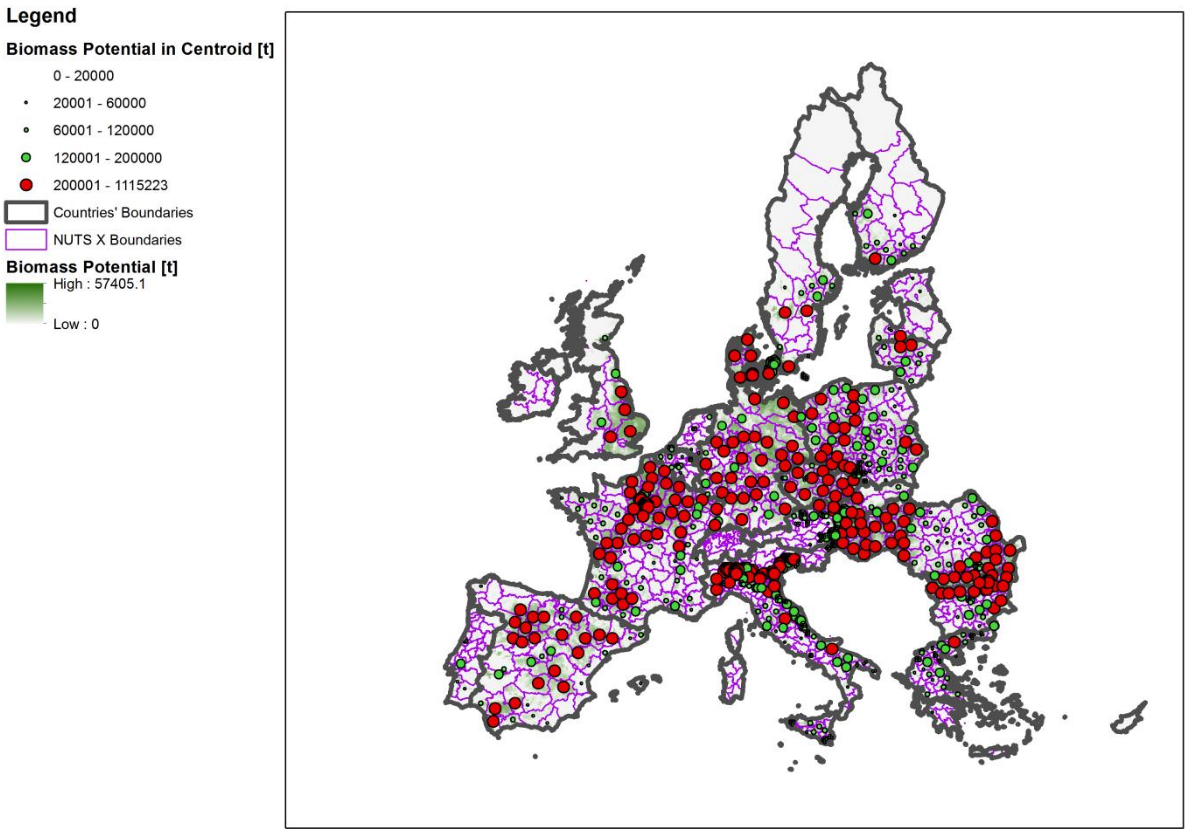

Figure 4. Biomass potentials in optimal locations for straw processing plants within NUTS regions.

Figures (Figure 4 to Figure 12) show results in greater detail. Figure 13 and Figure 14 show how the assumption of regions' independence works in practice. It can be seen that selected NUTS (with light blue boundary) take into account only the straw potential contained within their interior. If this were not the case, optimal spots would be placed near the borders with regions with a higher potential. In such a situation, a problem of competition for straw would occur which would make the model far more complex and complicated.

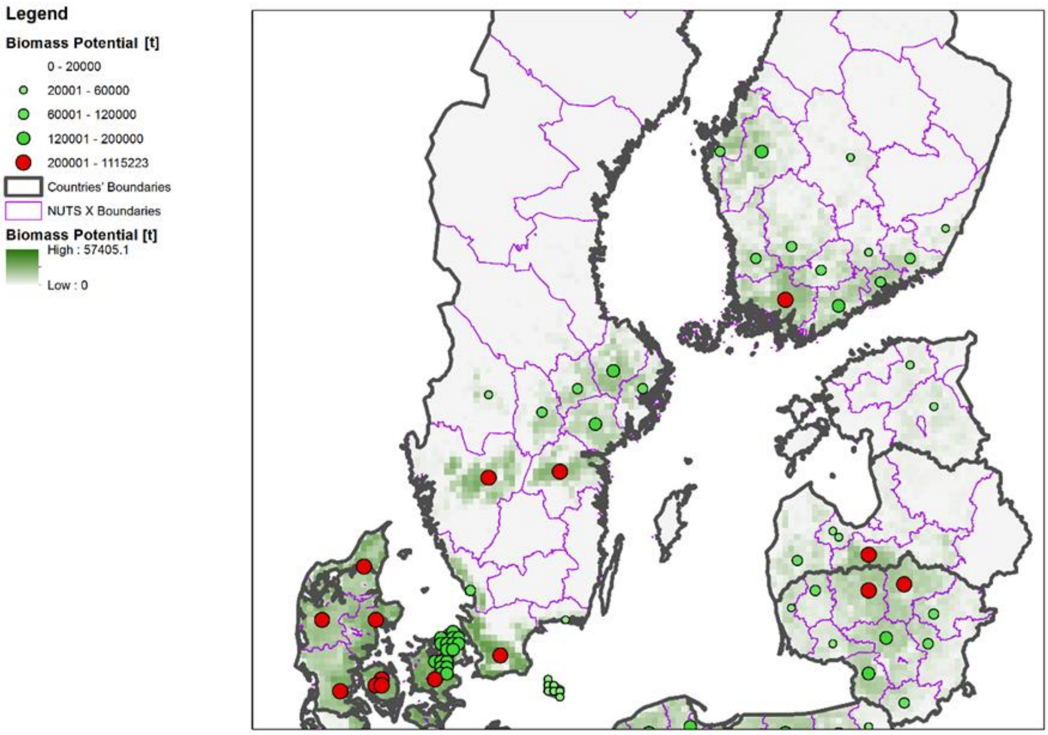

Figure 5. Optimal spots for straw processing facilities in Denmark, Sweden, Finland, Estonia, Latvia and Lithuania.

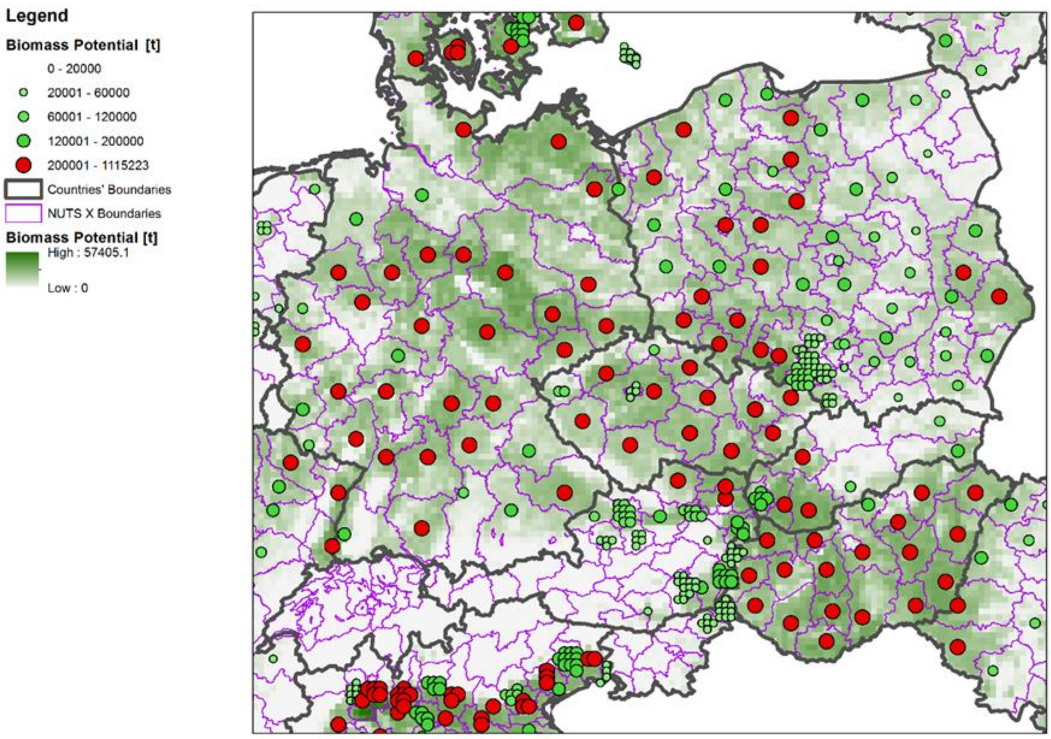

Figure 6. Optimal spots for straw processing facilities in Germany, Poland, the Czech Republic, Slovakia, Hungary and Austria.

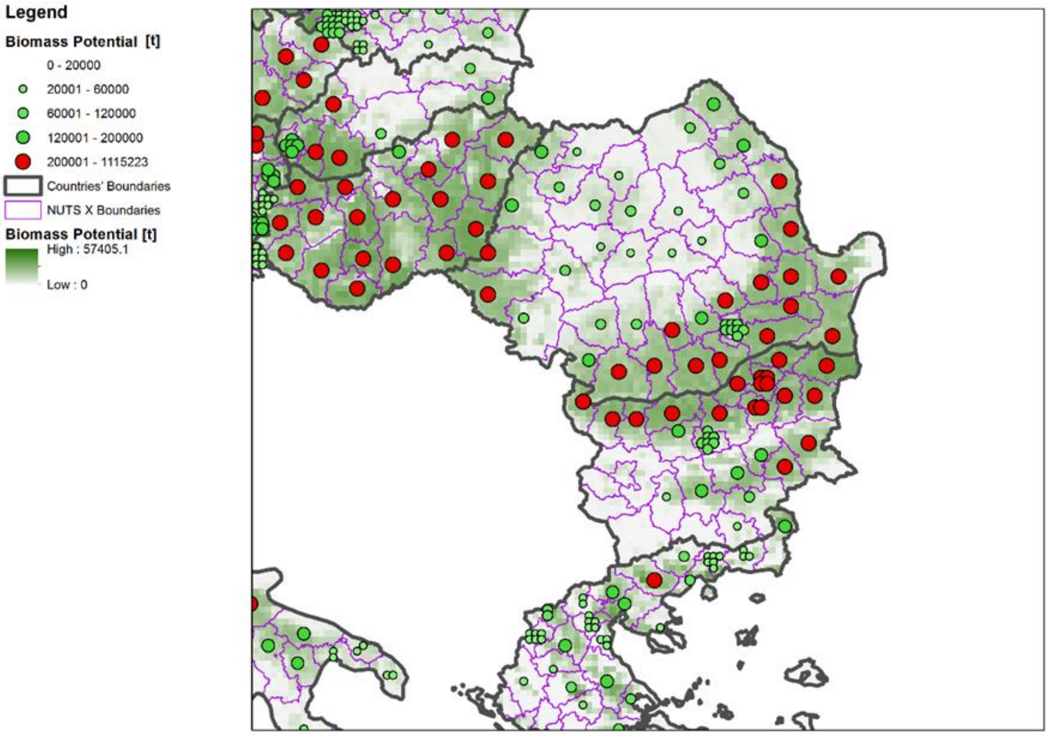

Figure 7. Optimal spots for straw processing facilities in Romania and Bulgaria.

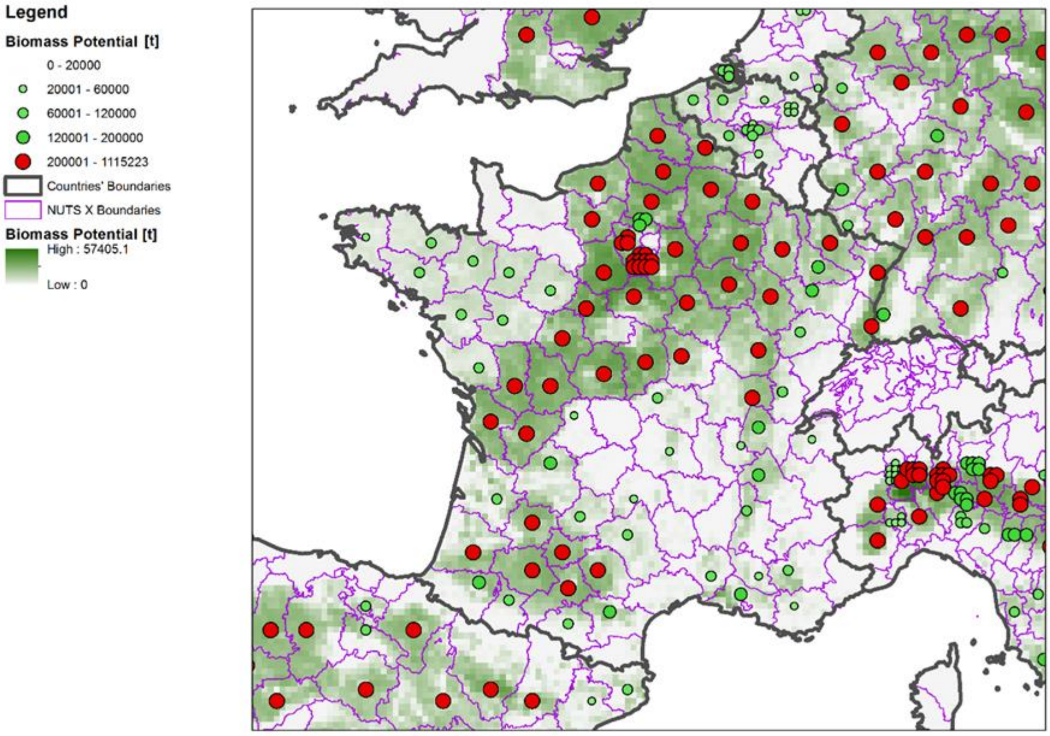

Figure 8. Optimal spots for straw processing facilities in France.

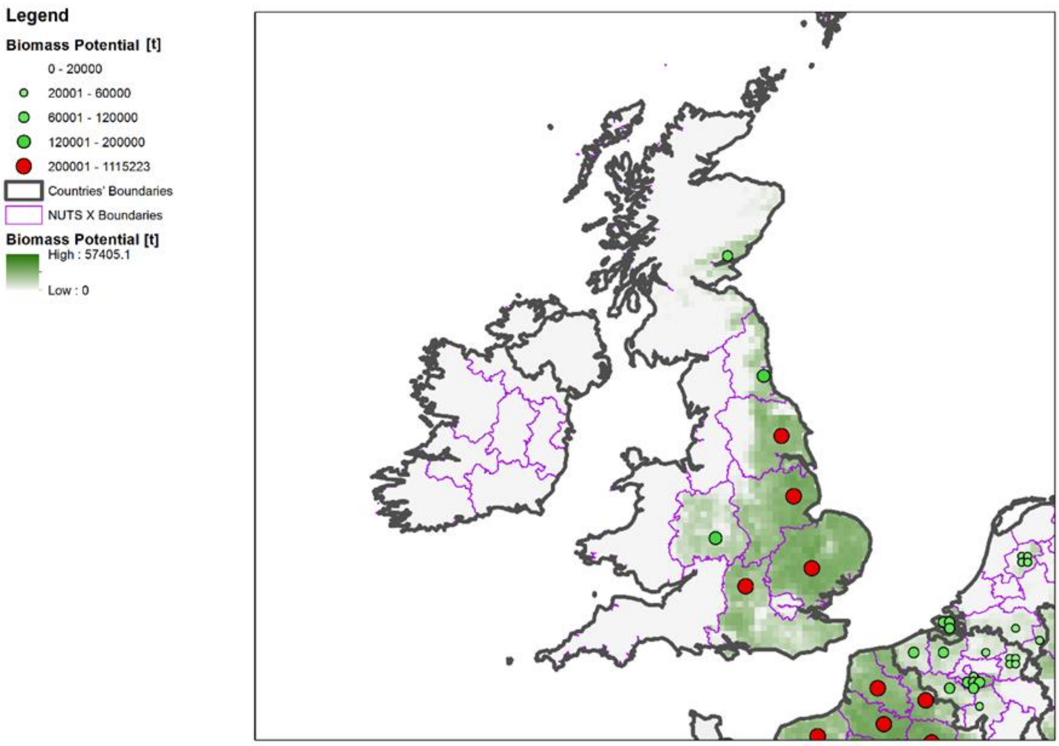

Figure 9. Optimal spots for straw processing facilities in the United Kingdom and Ireland.

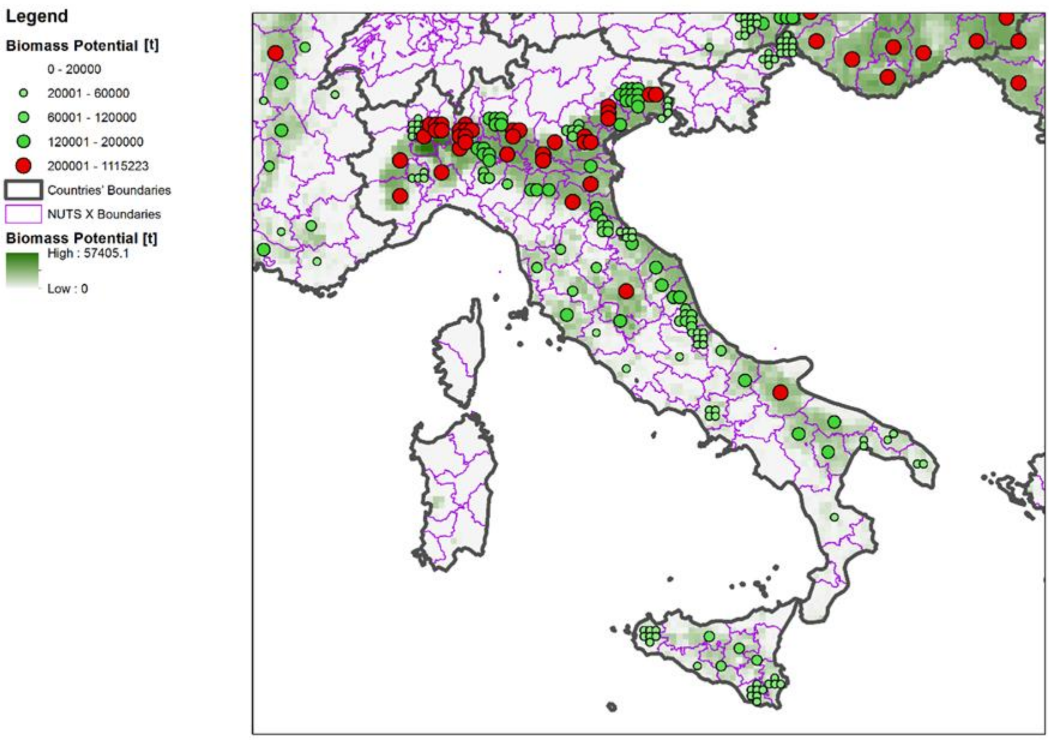

Figure 10. Optimal spots for straw processing facilities in Italy.

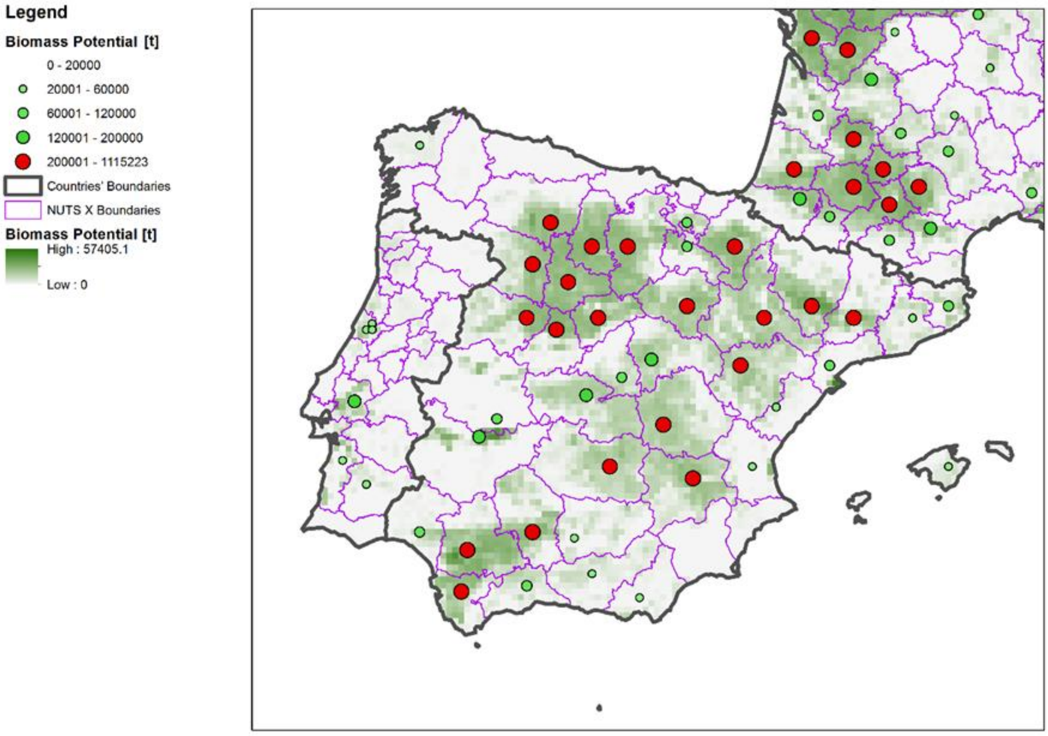

Figure 11. Optimal spots for straw processing facilities in Spain and Portugal.

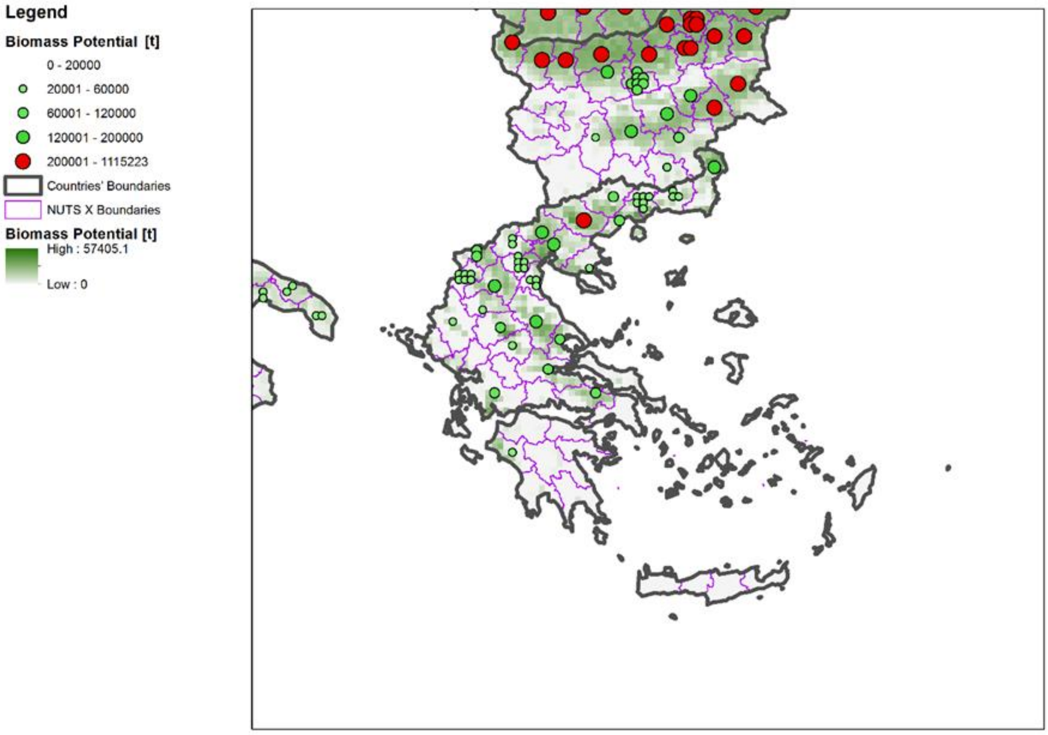

Figure 12. Optimal spots for straw processing facilities in Greece.

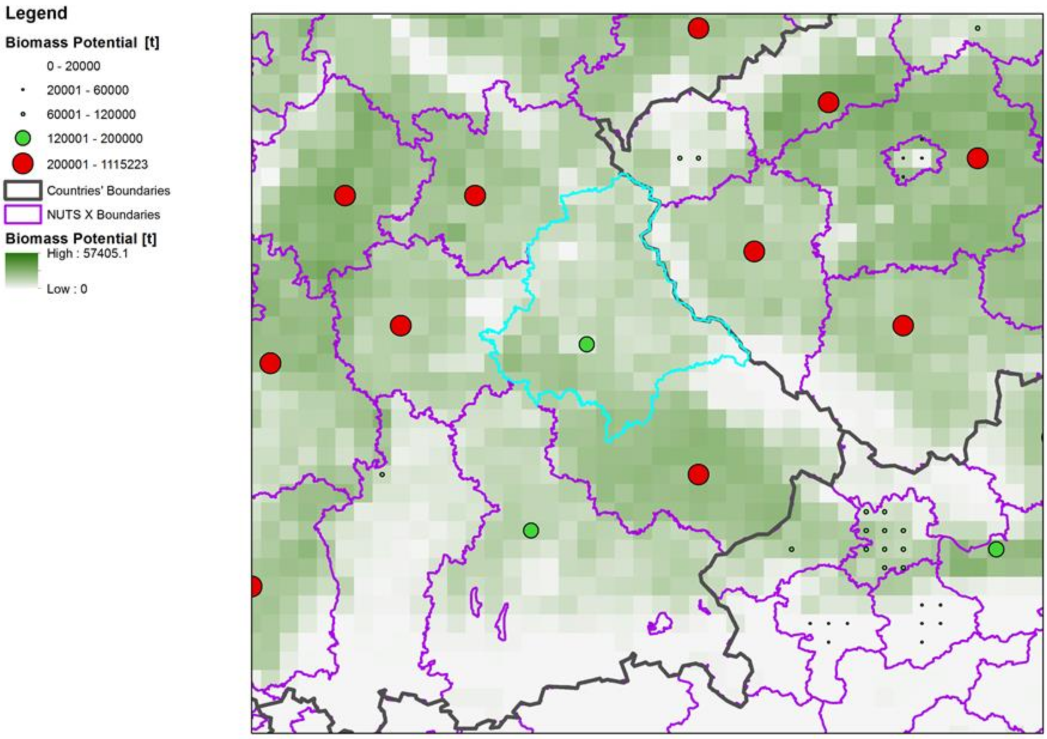

Figure 13. First example showing that the algorithm does not take into account straw from neighbouring regions.

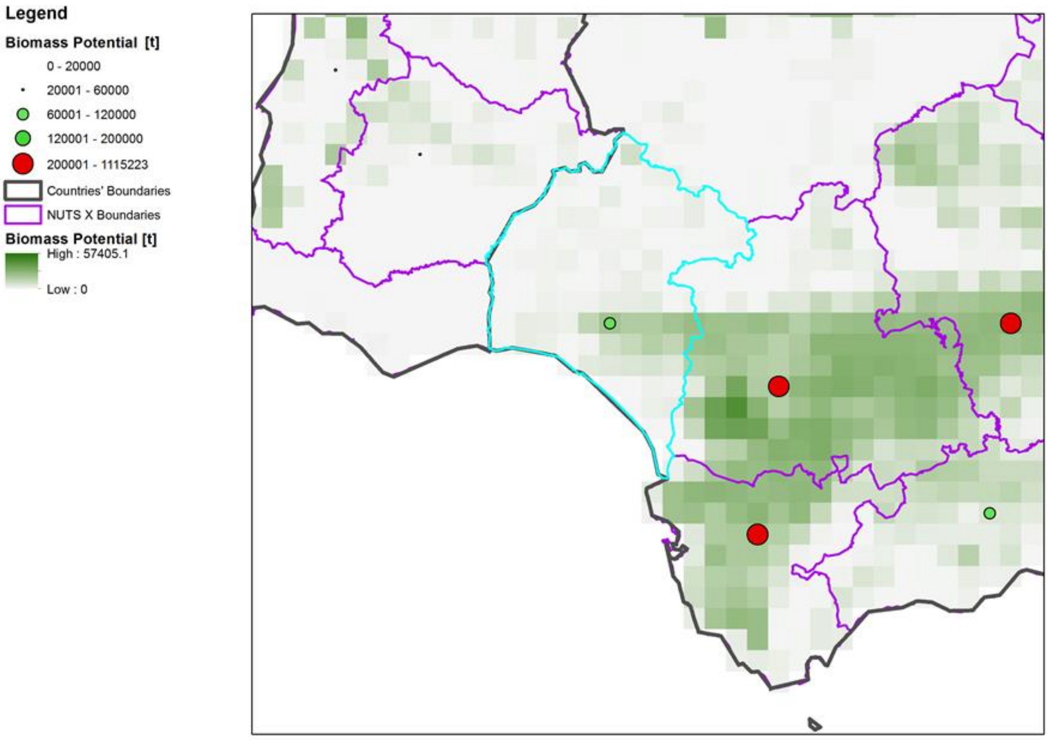

Figure 14. Second example showing that the algorithm does not take into account straw from neighbouring regions.

Autarkic regions

In an attempt to delineate potential autarkic regions in terms of energy demand from households and supply with straw biomass, the ASECO tool was used. This is an optimisation tool, which is based on GAMS (General Algebraic Modelling System) language. The task of finding autarkic regions is formulated as a linear programming problem, where objective function to be minimised is a total cost of transporting biomass and constraints are set to reflect the need of satisfying demand for energy. ASECO works on spatial data in a raster form. It needs to be provided with a balance raster and cost raster. A balance raster is obtained by subtracting the raster layer of demand for energy from the raster layer of supply of energy. In the case of the presented study, a layer of supply was obtained from an earlier layer of straw potential with a 10 km resolution]. The layer of demand was created by the transfer of Eurostat household consumption data for NUTS 2 and NUTS 3 into a spatial layer. The combination of NUTS 2 and NUTS 3 was applied in order to gain a homogeneity in the size of regions. Partition based on NUTS 2 was used in Germany, Belgium, the Netherlands and the UK and a NUTS 3 based partition in the rest of the EU countries. After obtaining such a region layer for Europe, a centroid of each region was calculated and a certain fraction of demand for energy (depending on scenario – explained below) in corresponding NUTS was assigned to it. In further steps, the layer was converted to a raster and subtracted from the supply layer. A cost layer was set to take two values: unit value at land and very high value which is excluding the transportation possibility on water bodies (sea, large lakes). Such an approach is implied by the assumption that in a spatial resolution being considered (10 km), in almost every raster cell a good quality road can be found. In considering other forms of transport, straw transported by sea for example is very unlikely.

Two scenarios were considered in the analysis. In the first one, it was assumed that 2.5 per cent of household energy demand would be satisfied by straw biomass, and in the second, the share of energy demand satisfied by straw equals 5 per cent.

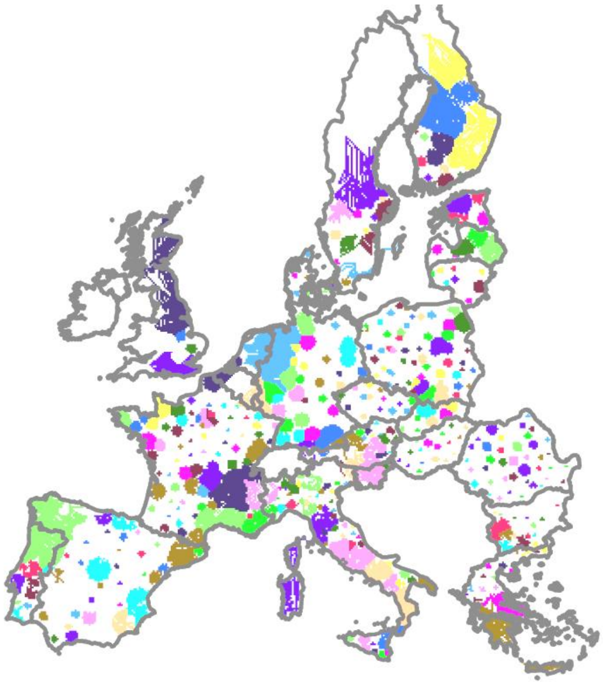

Figure 15. Autarkic regions in first scenario (2.5 per cent of household energy satisfied by straw biomass).

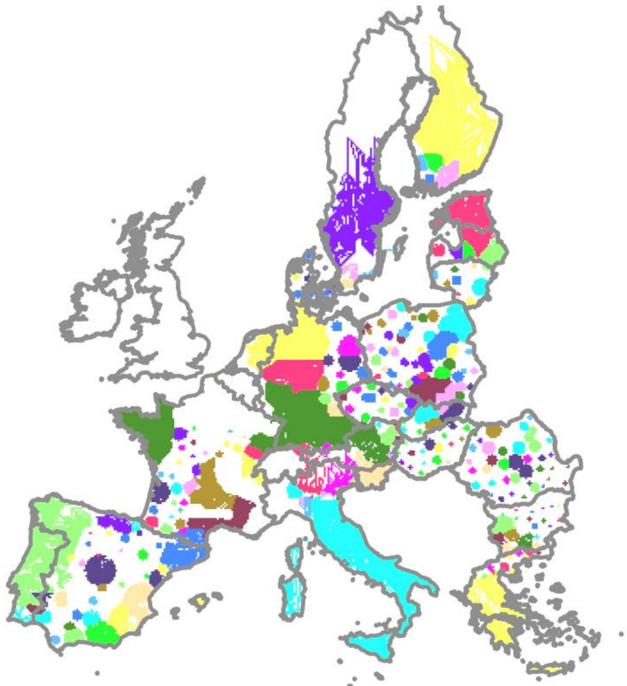

Figure 16. Autarkic regions in second scenario (5 per cent of household energy satisfied by straw biomass).

Preferred process type for NUTS 3 regions

For each technology, different types of biomass have been chosen as feedstock for energy carrier production by fast pyrolysis (FP), catalytic pyrolysis (CP) and hydrothermal carbonisation (HTC). The detailed description of these types of biomass can be found in Deliverable 2.1 Feedstock selection, Characterisation and Preparation.

These are the biomasses according to technologies:

FP (fast pyrolysis):

- Middle fraction (residues from flour production)
- Miscanthus
- Scrap wood (industrial residue wood)
- Wheat straw

CP (catalytic pyrolysis):

- Beechwood (commercial wood biomass under the brand name Lignocel)
- Miscanthus
- Wheat straw

HTC (hydrothermal carbonisation):

- Organic municipal waste
- Spent grains from breweries
- Wheat straw

In the following analysis, each of the NUTS 3 regions was assessed in terms of biomass types that are adequate as substrates for three processing technologies: fast pyrolysis (FP), catalytic pyrolysis (CP) and hydrothermal carbonisation (HTC). The analysis resulted in the attribution of a preferred processing technology for each NUTS 3 region. The idea of the preference assignment was based on comparing processing requirements for substrates with a combination of biomass potentials in regions. A rough description of the algorithm is as follows: for a region under consideration, one takes such a processing type, for which the substrates are in abundance in the region. The algorithm also takes into account (to some extent) levels of preference for substrates by the biomass processing types. In the below section a precise and formal description of an algorithm that was used is presented.

Let:

I – the set of NUTS3 indexes,

$P_{M,i}$ – technical potential of Miscanthus in region $i \in I$,

$P_{W,i}$ – sum of technical potentials of forest (2.0*) and wood_industry (5.3*) in region $i \in I$,

$P_{OMW,i}$ – technical potential of biodegradable municipal waste (5.1*) in region $i \in I$

HTC – hydrothermal carbonisation,

FP – fast pyrolysis,

CP – catalytic pyrolysis,

PP_i – Preferred processing type in region $i \in I$; $PP_i \in \{HTC, FP, CP, Other\}$.

*- reference to chapters of the Deliverable 1.2

Straw, which is an important type of biomass in each of types of processing under consideration, is omitted because it occupies the same place in the preference list of these processes. So a distinction between the two types of pyrolysis and hydrothermal carbonisation is made by the use of the technical potential value of Miscanthus, biodegradable municipal waste and the sum of forest residues as well as wood Industry residues. A formal expression that describes determination of processes in regions is given below.

For $i \in I$

$$PP_i = \begin{cases} HTC, & \text{if } P_{OMW,i} \geq P_{M,i} + P_{W,i} \\ FP, & \text{if } (P_{OMW,i} < P_{M,i} + P_{W,i}) \wedge (P_{M,i} > P_{W,i}) \\ CP, & \text{if } (P_{OMW,i} < P_{M,i} + P_{W,i}) \wedge (P_{M,i} < P_{W,i}) \\ Other, & \text{if } P_{OMW,i} = P_{M,i} = P_{W,i} = 0 \end{cases}$$

The case $(P_{OMW,i} < P_{M,i} + P_{W,i}) \wedge (P_{M,i} = P_{W,i})$ does not occur for any $i \in I$, so it was omitted in order to avoid complication of the equation above.

The result of computing the above equation is depicted in Figure 17. The map shows that fast and catalytic pyrolysis are most likely for application. Processing HC can be used effectively only in a few regions in Europe, mainly in Great Britain, Belgium. Netherlands and Switzerland.

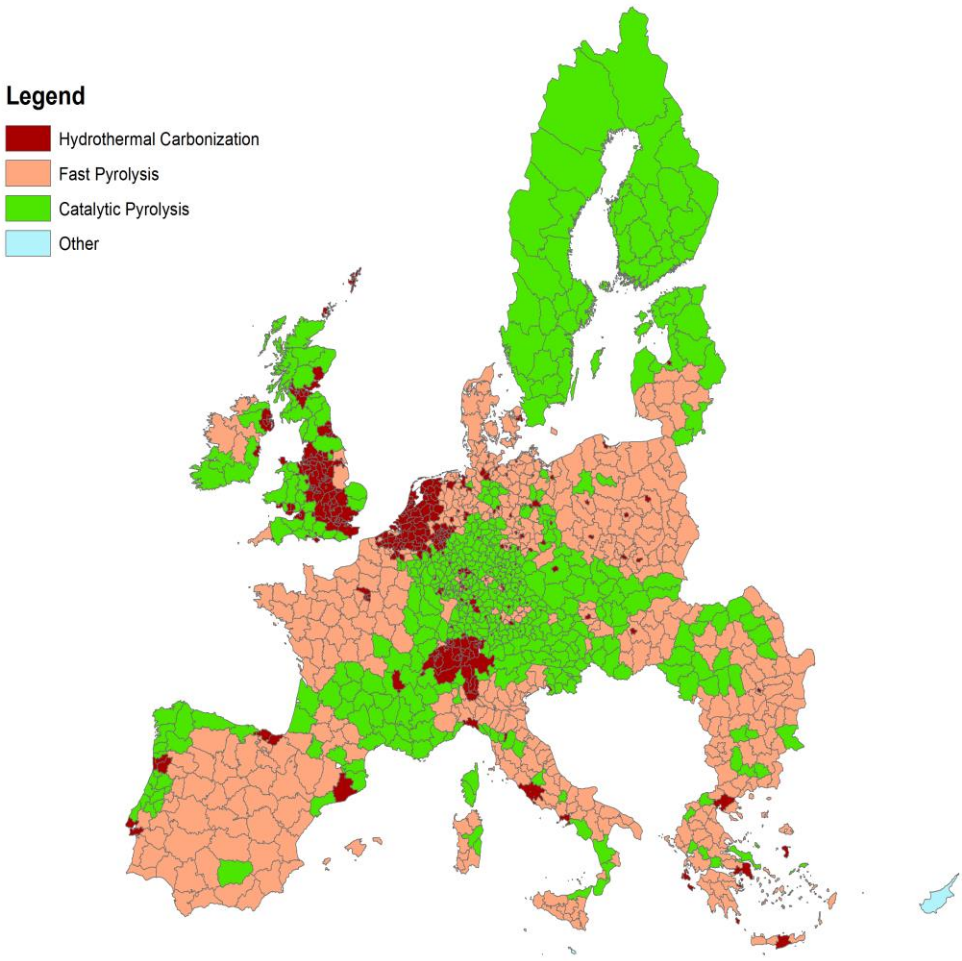

Figure 17. Preferred process type for NUTS 3 regions.

Biomass model vs. Satellite imagines, five case studies

The validation of waste and excess of biomass potential, which were estimated using the spatial methods with Corine Land Use map, was carried out in five European regions (Figure 18). The use of satellite images with a high resolution enables more accurate land cover mapping and study of local spatial variability within a larger, seemingly homogeneous complexes. The study used the available archival images obtained from satellite SPOT, in terms corresponding to the climax vegetation (May-June).

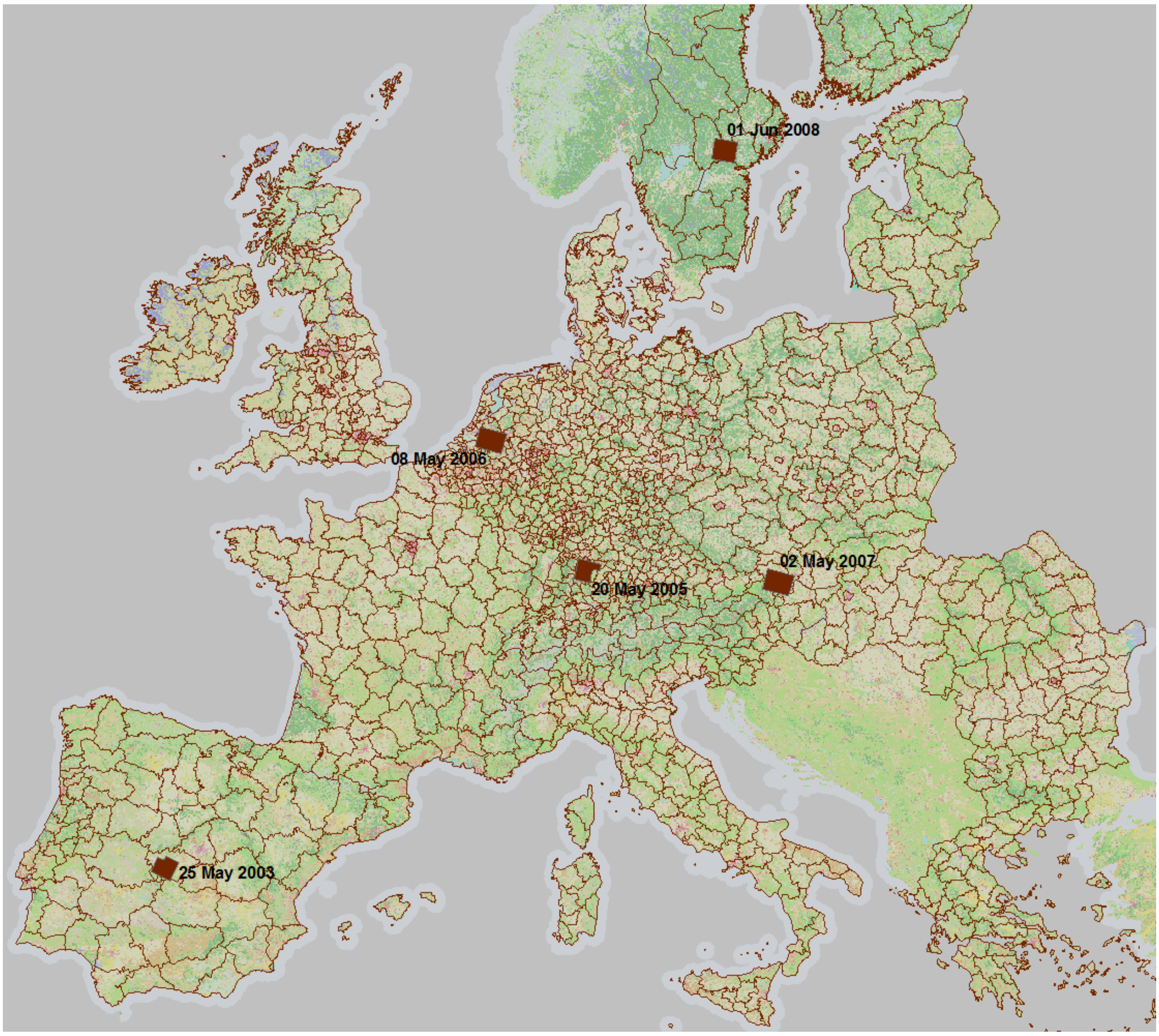

Figure 18. Case studies area and the date when the picture was taken.

AUSTRIA: No. 5070252070502102109 2V9, 02 May 2007

http://www.geodatawork.net/core/SceneDetails/Default.aspx?ApplicationId=DDWC&SceneUid=50702520705021021092V9::5c2cfd7b-ddb2-482f-bbee-093bb2ea3790::DR&ProductUid=5c2cfd7b-ddb2-482f-bbee-093bb2ea3790

Picture covers totally or partly following NUTS-3: AT: 112, 122, 126, 127, 130.

THE NETHERLANDS: No. 50422450605081026061V1, 08 May 2006

http://www.geodatawork.net/core/SceneDetails/Default.aspx?ApplicationId=DDWC&SceneUid=50422450605081026061V1::5c2cfd7b-ddb2-482f-bbee-093bb2ea3790::DR&ProductUid=5c2cfd7b-ddb2-482f-bbee-093bb2ea3790

Picture covers totally or partly following NUTS-3: SW: 122, 123, 124, 125).

SPAIN: No. 50322700305251124462V, 25 May 2003

http://www.geodatawork.net/core/SceneDetails/Default.aspx?ApplicationId=DDWC&SceneUid=50322700305251124462V::5c2cfd7b-ddb2-482f-bbee-093bb2ea3790::DR&ProductUid=5c2cfd7b-ddb2-482f-bbee-093bb2ea3790

Picture covers totally or partly following NUTS-3: 33A, 224, 226, 310, 411, 412, 413, 414).

GERMANY: No. 50542510505201017322V9, 20 May 2005

http://www.geodatawork.net/core/SceneDetails/Default.aspx?ApplicationId=DDWC&SceneUid=50542510505201017322V9::5c2cfd7b-ddb2-482f-bbee-093bb2ea3790::DR&ProductUid=5c2cfd7b-ddb2-482f-bbee-093bb2ea3790

Picture covers totally or partly following NUTS-3: DE: 113,114, 141, 142, 143

SWEDEN: No.50572290806010958022V1, 01 Jun 2008

http://www.geodatawork.net/core/SceneDetails/Default.aspx?ApplicationId=DDWC&SceneUid=50572290806010958022V1::5c2cfd7b-ddb2-482f-bbee-093bb2ea3790::DR&ProductUid=5c2cfd7b-ddb2-482f-bbee-093bb2ea3790

Picture covers totally or partly following NUTS-3: 425

Images with a spatial resolution of 2.5 m, showing the test area in the spectral resolution of light green, red and near-infrared were reclassified to map of Normalised Difference Vegetation Index (NDVI). The following ranges of index values were adopted for differentiation of biomass potential:

-1.0 – 0.1: 0%

0.1-0.2: 20%

0.2-0.3: 50%

> 0.3: 100%

The main aim of the study is to assess the diversity of actual vegetation (biomass) in different regions of Europe, on the corresponding classes of land cover. The study used analysis of the CLC classification which directly has been used for modelling or downscaling NUTS-2 and

NUTS-3 (Deliverable 1.2). This analysis was designed to validate the modelling assumptions on the scale of NUTS-3.

Analyses were performed for selected biomass potentials: Straw (1.1), Residuals of pruning (1.2), Green urban areas (3.1) – which have been described in the report (Deliverable 1.2).

Straw (1.1)

Due to the rotation of crops and different harvesting dates, the validation of biomass straw potential with remote sensing methods is particularly difficult. Therefore, this analysis was restricted only to an assessment of the local spatial variability of the production space and for identification of regional differences in the structure of fields. The selection of terms for the satellite images (May - June) allowed registering the maximum greenness of cereal crops.

Estimating the spatial variability also aims at the characteristics of the occurrence of borders (natural or artificial) within agricultural areas. This is particularly important because the size of the fields, their shape, the presence of natural barriers such as drainage channels, midfield afforestation, field margins, roads, etc., affect the sourcing and straw logistics, which is intended for energy purposes. Analyses were performed at the same scale (1:50 000), so that surfaces and shapes shown in the satellite images are comparable (Figure 19 - Figure 24).

Austria. The area is typically rural. Fields have regular rectangular shapes. There is a large proportion (approximately 20%) of fields with a large surface area (> 5 ha) and its shape is similar to a square and very large fields with an area > 50 ha. Due to the logistics of biomass, these are most appropriate areas. However, despite the most favourable structure of cultivation, there are also small fields (<1 ha), which are not suitable for industrial straw sourcing (<10%).

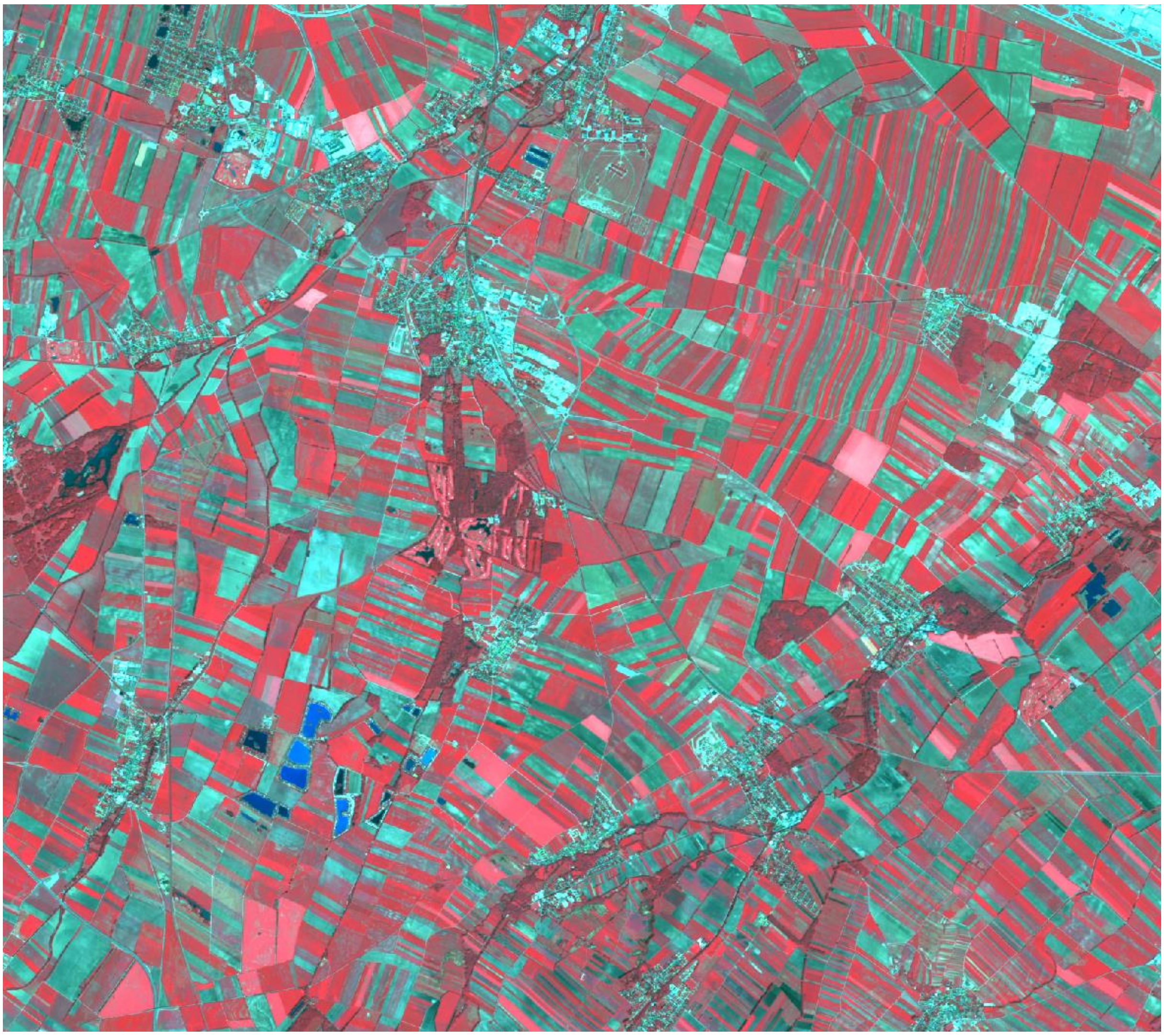

Figure 19. Austria. A fragment of a satellite photo SPOT. Scale 1: 50 000.

Germany. The regions are made up with a large share of forest areas and natural vegetation. Arable land occurs in local clusters, surrounded by forests or adjacent to built-up areas. Most of the fields are of a similar shape with an area in the range of 3-10 ha. This structure promotes location of the storage of biomass, which for logistical reasons should be in the centroid of cluster fields and/or the passageways.

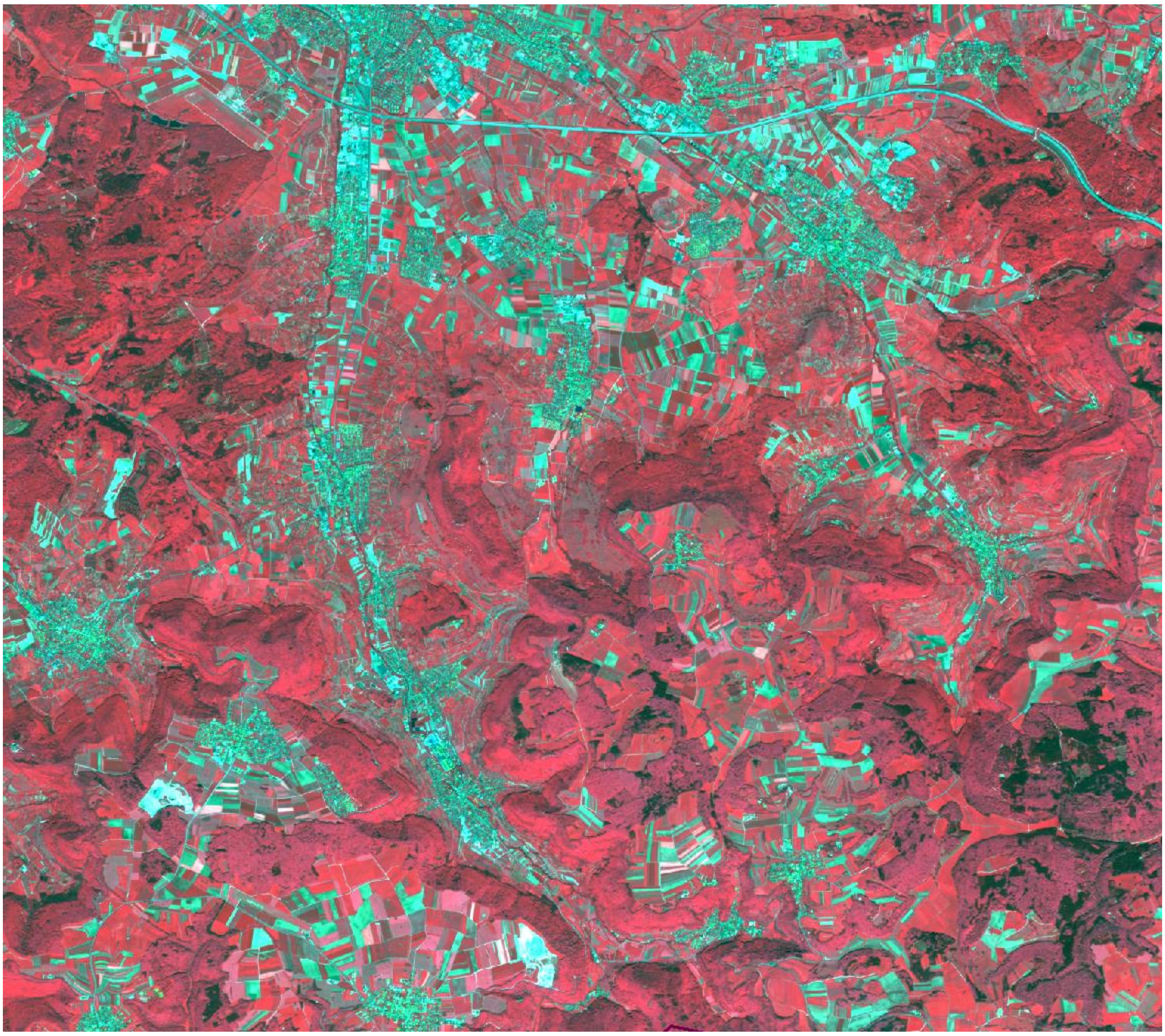

Figure 20. Germany. A fragment of a satellite photo SPOT. Scale 1: 50 000.

<u>The Netherlands</u> The area is typically rural, about 80% of the area is arable land, and the rest consists mostly of built-up areas and infrastructure industries. Fields are made up with regular rectangular shapes with similar area surfaces of 3-10 ha. Visible regional differences are in the shape of fields in the south-east part of the image where the fields are larger and similar in shape to a square; in the north-west they are smaller and more elongated. For logistics reasons in obtaining the straw, the field structure seems to be one of the most optimal across Europe. One of the major problems in collecting straw directly from the adjacent fields is a vast drainage-irrigation system (Figure 21), which imposes longer routes for machines.

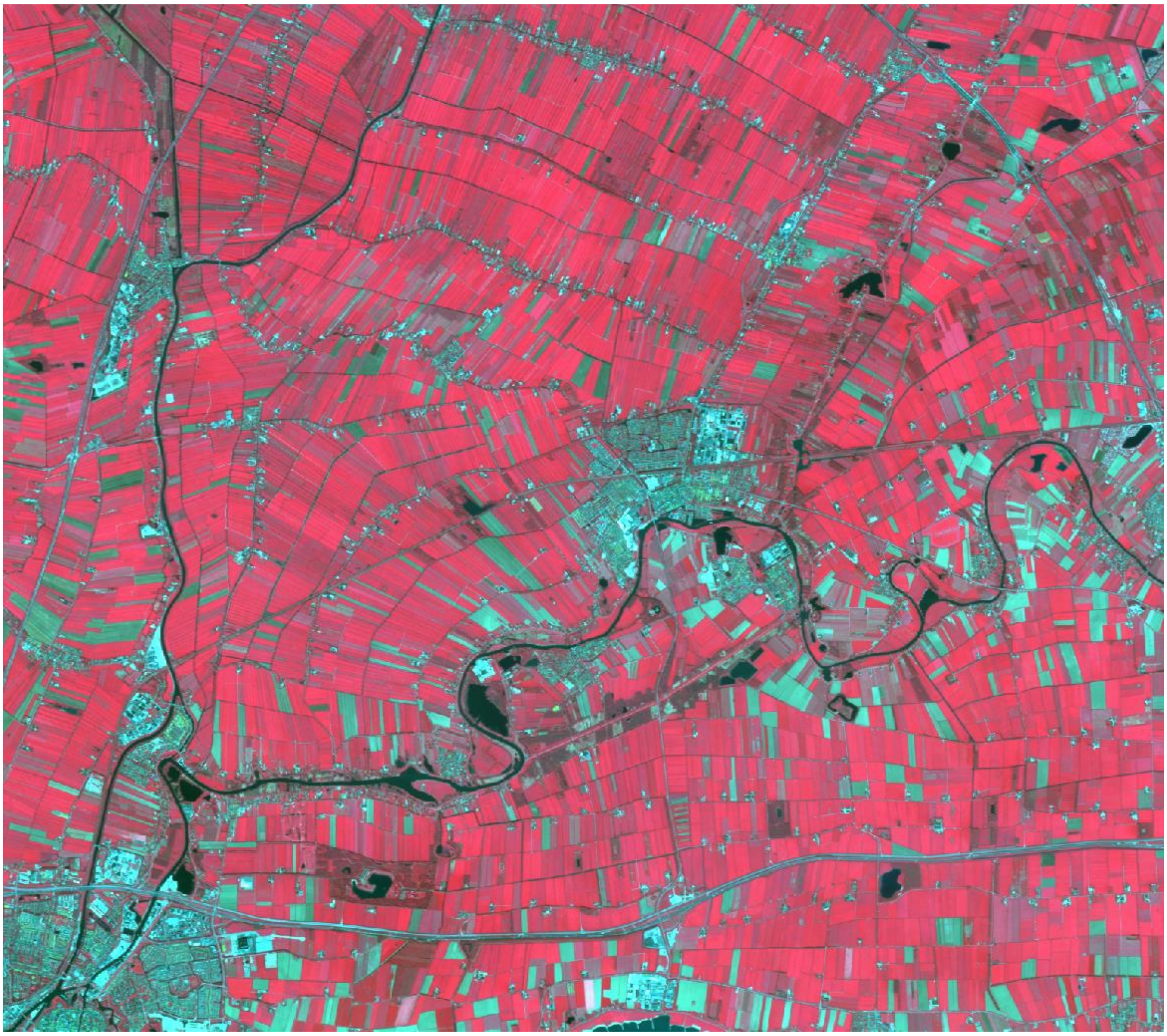

Figure 21. The Netherlands. A fragment of a satellite photo SPOT. Scale 1: 50 000.

Spain Intensive agricultural cultivations on arable land occur only on irrigated areas. Other agricultural areas are characterised by low and very low indices of vegetation, which substantiates the impossibility of efficient biomass harvesting in these areas. Irrigated areas are located in the river valley. Water availability determines the location of the fields and their shape. Visible characteristic circles are fields with an area of 30-40 hectares with pivot irrigation system. The compact nature of the structure of the fields and the area provides opportunities for effective sourcing of straw for energy purposes. In contrast, the primary limitation is the relatively small proportion of irrigated land in the total area of the region.

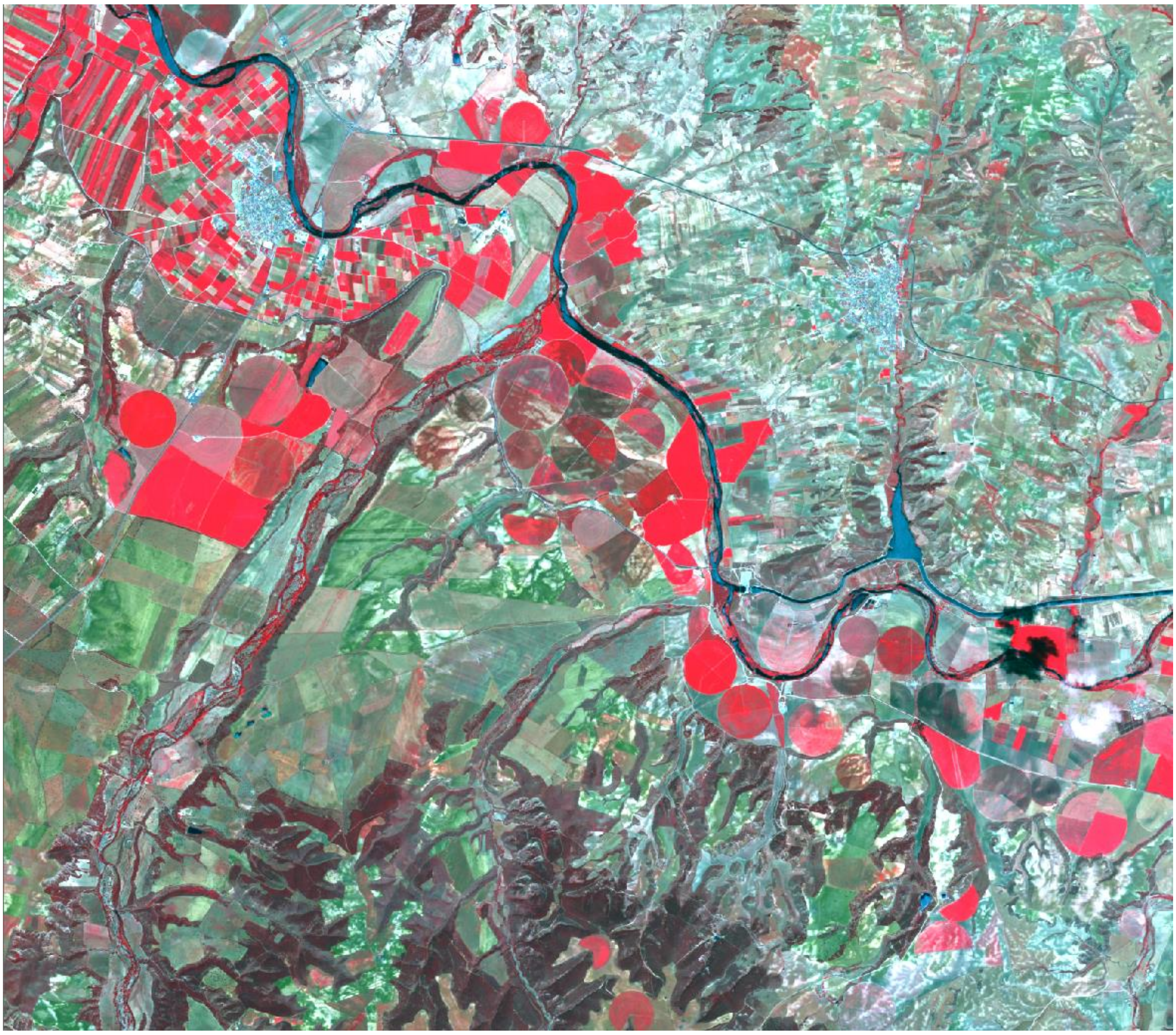

Figure 22. Spain. A fragment of a satellite photo SPOT. Scale 1: 50 000.

Sweden. Agricultural areas in the region are located in large, shallow valleys, surrounded by forests and lakes. The structure of fields is not as regular as in the previous examples. However, the fields are large (most of the area.> 5 ha) and most of them are adapted to a comprehensive sourcing of surplus straw. Similar to example in the region in Germany, isolated clusters are determined by the location of intermediate field biomass storage points.

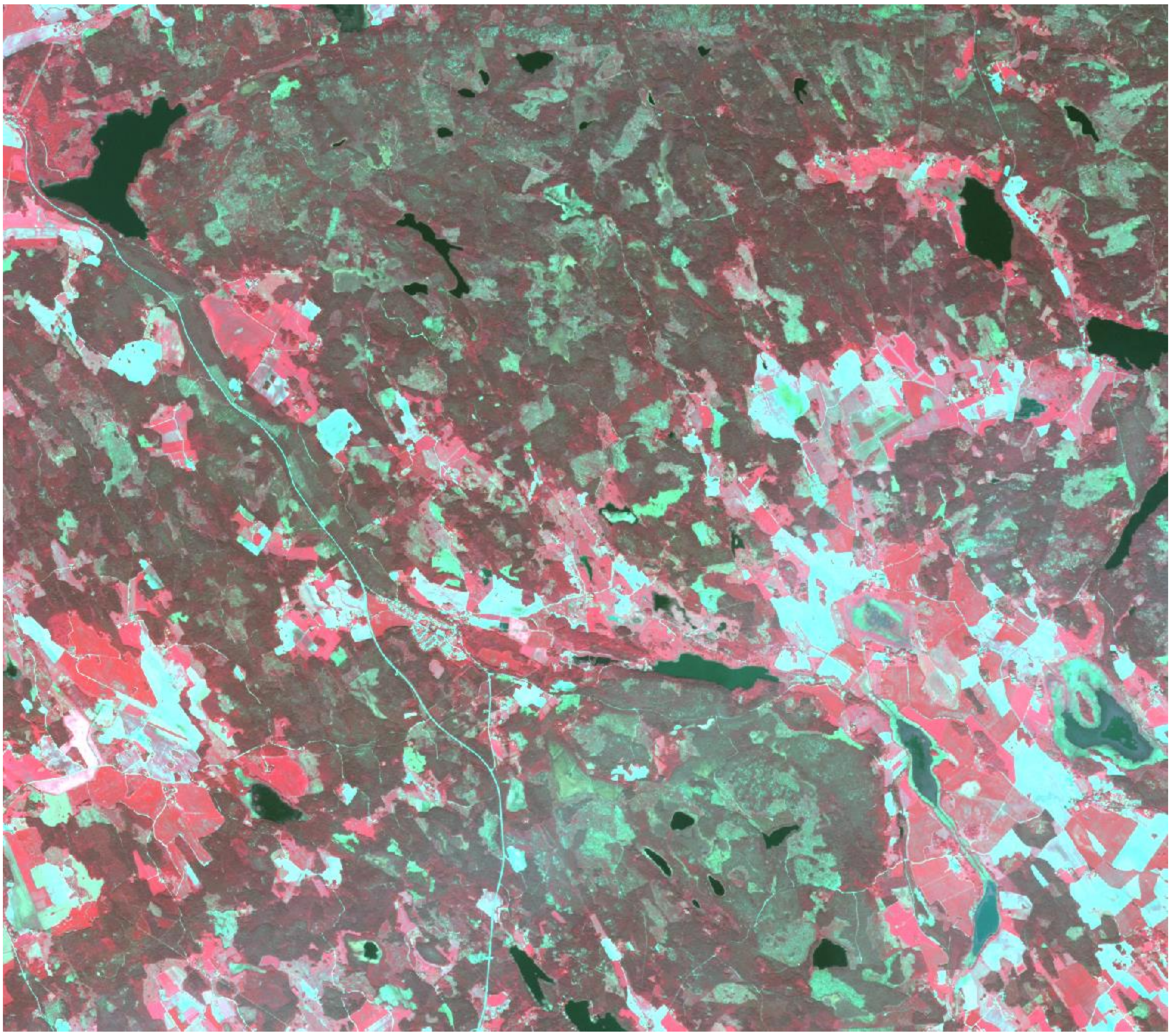

Figure 23. Sweden. A fragment of a satellite photo SPOT. Scale 1: 50 000.

Summary

The analysed regions are examples of a good use of habitat conditions for agricultural production. The structure of the fields in most cases, should not adversely affect the ability to raise surplus straw for energy purposes. The size of objects and their compactness enables the optimisation of sourcing raw materials both from the fields as well as with a general agreement between owners of neighbouring farms.

In Europe, however, there are regions where the logistics of straw may be impossible. An example would be south-eastern Poland, where, despite decent habitat conditions, and the dominant share of arable land, the fragmentation of fields and their shape makes it virtually impossible to be economically viable for the acquisition of this material (Figure 24).

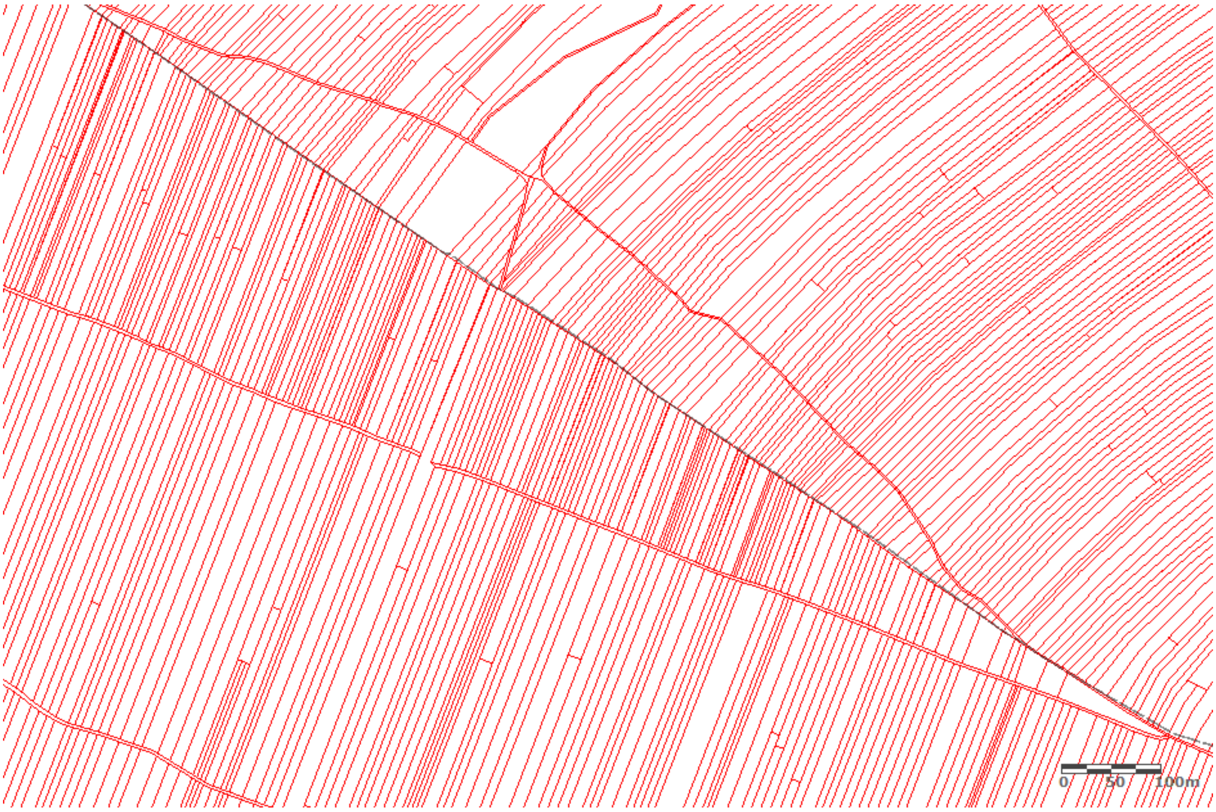

Figure 24. The boundaries of land parcels (arable land). Poland, NUTS 5. Gmina Janów Lubelski. Scale 1:5 000. sources: http://mapy.geoportal.gov.pl/

Residuals of pruning (1.2)

The main objective of the analysis is to compare the intensity of vegetation with the yield of biomass which were modelled as a residuals from perennial plants. NDVI maps of an adopted resolution allow for the separation of land directly under the cultivation of non-agricultural use, in most cases devoid of vegetation.

Austria. The analysed area of the perennial crops represent about 7% of the agricultural land. The image analysis does not show however, the presence of trees or larger shrubs, indicating only the production of berry crops. In addition, in the areas classified under CLC, there is a great diversity of use (different values of NDVI on adjacent fields). This suggests that there is a diversity of crops, including the presence of non-perennial crops (cereals, vegetables). Part of the area, Class 16, is also occupied by a neglected land and natural vegetation (Figure 25).

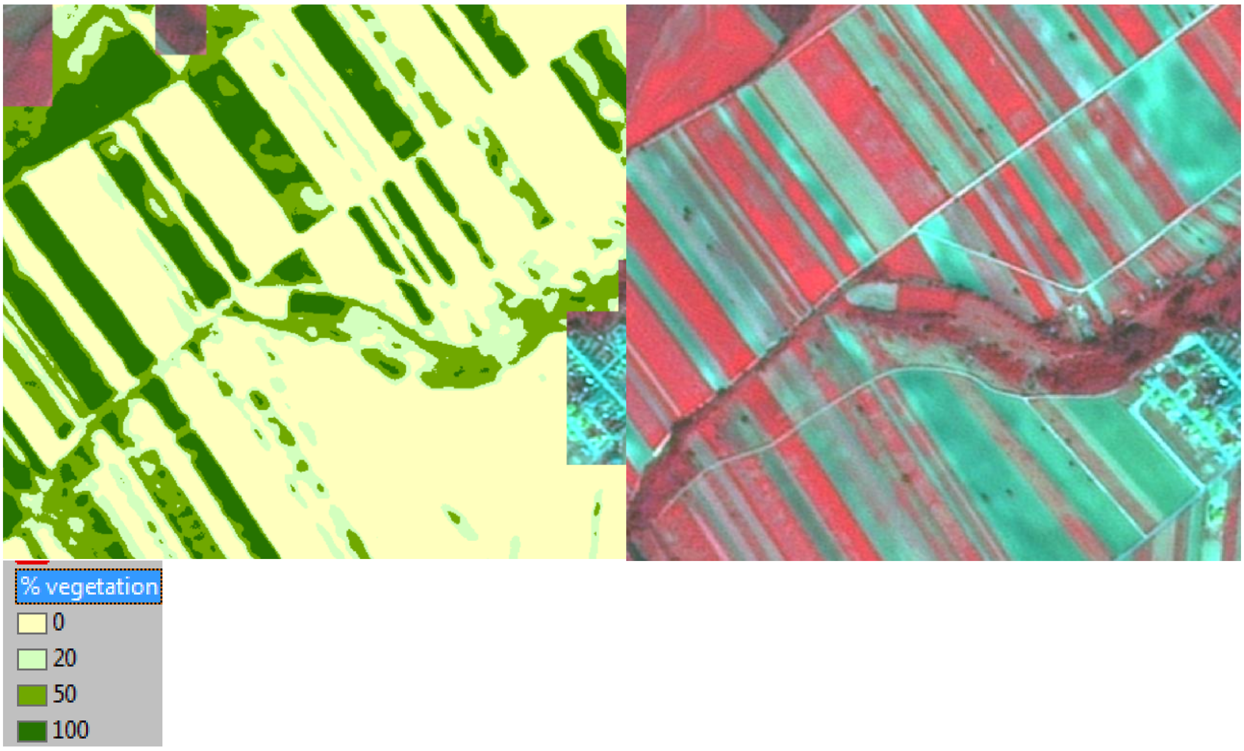

Figure 25. Intensity of vegetation (left) with comparison to source data (SPOT image, right)

Germany. Fruit trees and berry plantations represent about 15% of the agricultural land in the area of research. They are dominated by orchards, which are clearly distinguishable on satellite images by individual trees on a grass background. Among all test areas, the crops in Germany have the highest biomass potential. This is connected with a known maximum intensity of vegetation (more than 40% of the vegetation is dense, less than 30% are areas with a lack of vegetation). This gives the basis for a calculation into the high potential of woody biomass (commas) as well as extraction from mowing grass and small shrubs.

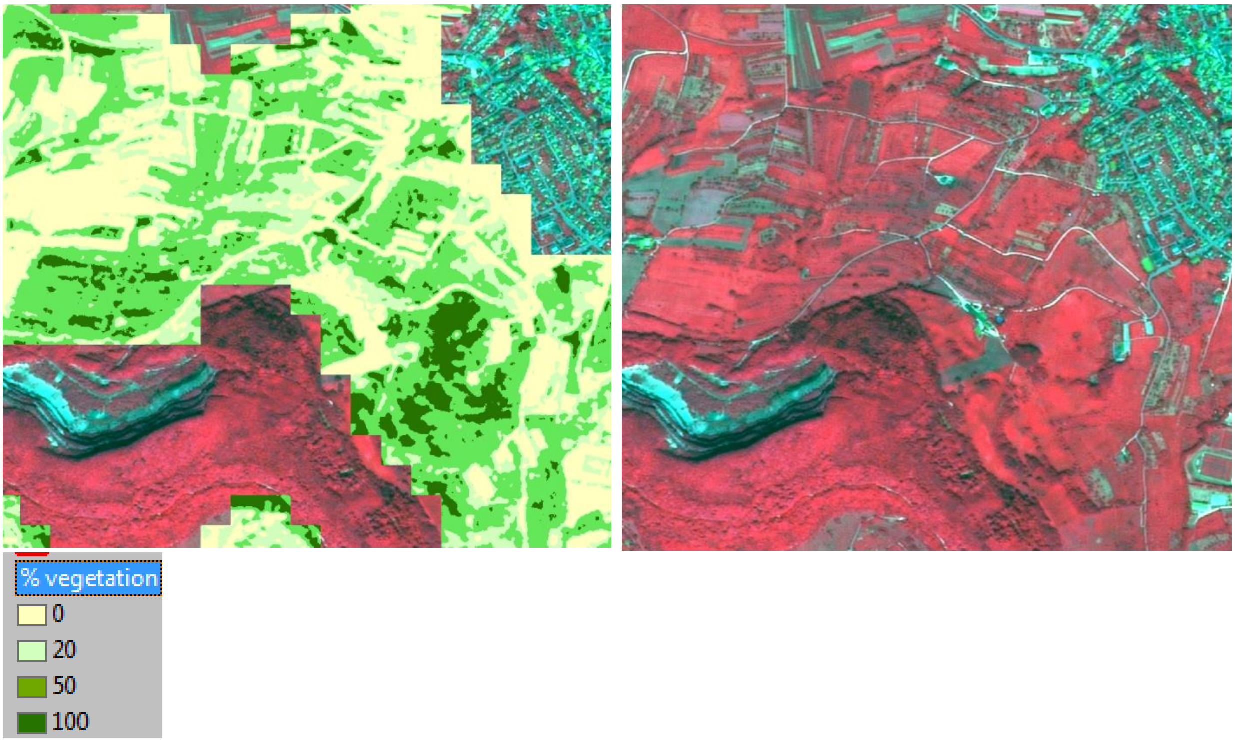

Figure 26. Intensity of vegetation (left) with comparison to source data (SPOT image, right)

<u>The Netherlands</u>. Fruit trees and berry plantations represent a small proportion (less than 1%) of agricultural land in the research area. The separated area in the image was found to be characterised with a very low intensity of vegetation (more than 70% of the surface is not covered with extensive vegetation, including half of this land without vegetation). Similarly, to the image presenting the region in Austria, the analysis does not show a presence of trees, shrubs or strip structure, which shows that there are grown low plants or berry. In addition, on the areas classified under CLC there is a great diversity of land use (different values of NDVI on adjacent fields). This suggests the diversity of crops, including the presence of non-perennial crops (cereals, vegetables).

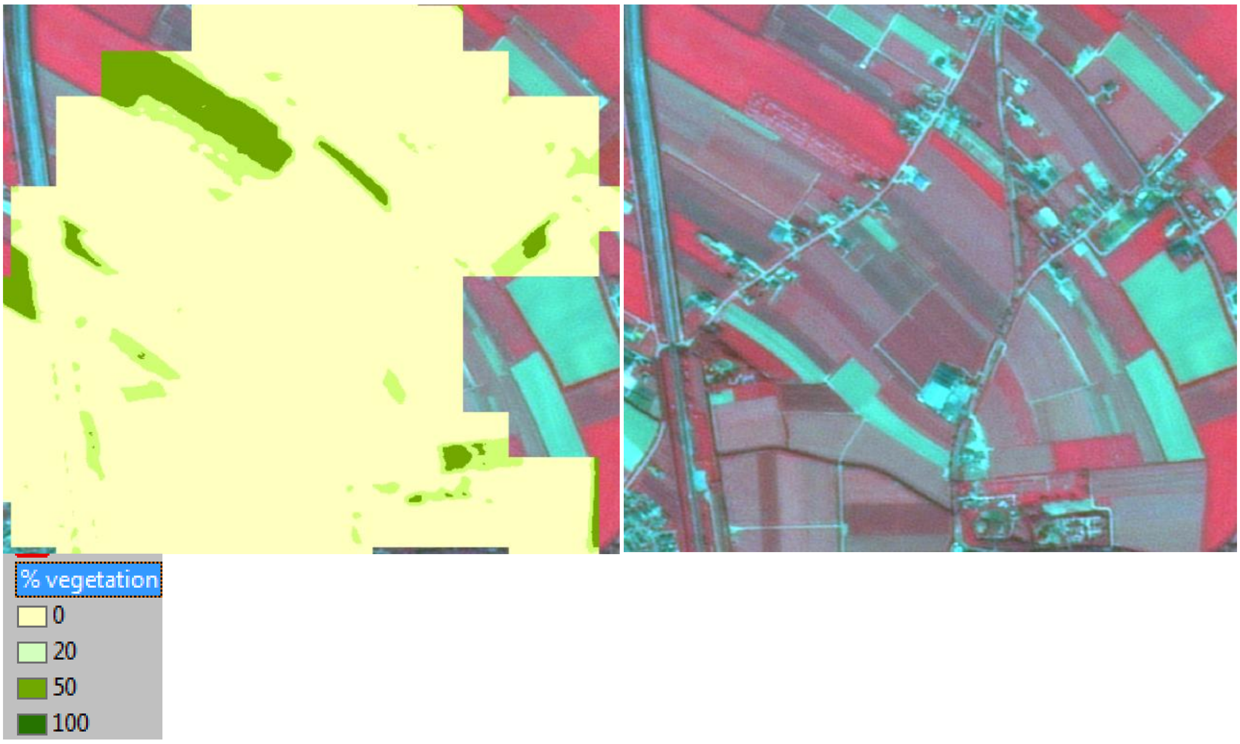

Figure 27. Intensity of vegetation (left) with a comparison to source data (SPOT image, right)

Spain. In the region presented in the image, olive plantations are grown as long-term plantations. Due to the climatic conditions (drought) in the period when the satellite image was acquired, the greenness index for the crop is not a sufficient criterion for describing the biomass potential. On the picture, olive trees are distinguishable as growing in fields with no vegetation in the form of grass or shrubs. Therefore, it can be said that during this period the only biomass possible to obtain in this areas of perennial crops are olive branches with no signs of intense vegetation. Comparing the areas under perennial crops (zero values of vegetation indices) with irrigated arable land, it can be concluded that from non-irrigated areas, even those where agricultural production is carried out; one cannot expect to obtain significant amounts of biomass.

Figure 28. Perennial plants vs. Irrigated arable areas. Intensive vegetation (red). Perennial plantations (top left corner of the photo)

Sweden – lack of perennial crops in the analysed image.

Discussion

An analysis of the vegetation intensity in the test areas has shown a large variation in vegetation cover on areas classified as perennial crops, including an observed great proportion of areas with no or poor vegetation. This is due to the varied climate, the dominant crops in the regions and the method of cultivation. Perennial crops, mainly olive trees and vines, established in the Mediterranean climate, were characterised with very low indices of vegetation.

Interrows are mostly devoid of vegetation in general, and the plants were watered directly. The situation is well illustrated by comparing the values of NDVI with a map of the Net Primary Productivity (NPP) (Figure 29). Biomass from these crops comes from branches of trees and shrubs after the pruning. Luxuriant vegetation is characteristic of fruit trees in the orchards of central and northern European countries. A comparison of the NDVI, for the areas corresponding to the classes 15, 16 and 17 CLC of countries where case studies were performed, shows the highest values of the vegetation index for fruit crops in Germany (Table 6). It suggests the possibility of obtaining biomass not only from the pruning but also from interrows. However, in each case, these indexes have much lower values than for other types of use for agricultural land (arable, pasture) or compared to the forests and natural vegetation.

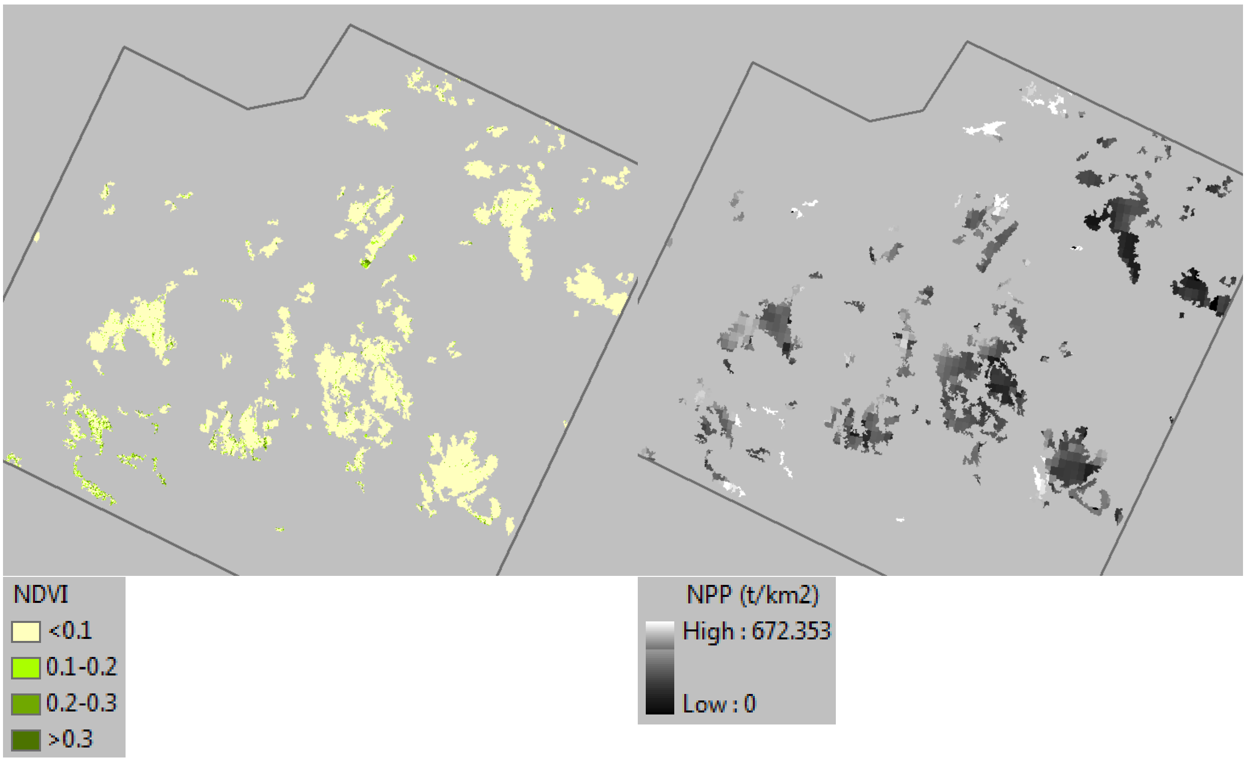

Figure 29. Case study in Spain. NDVI vs. NPP (Perennial crops).

Table 6. Case studies. NDVI vs. NPP (Perennial crops)

COUNTRY	NDVI	SD of NDVI	NPP	SD of NPP
AU	**-0.06**	0.19	**224**	101
DE	**0.13**	0.15	**205**	56
NL	**-0.01**	0.16	**148**	57
ES	**-0.05**	0.09	**196**	62

Green urban areas (3.1)

The modelling of the biomass potential from the maintenance of green areas has adopted two classes of maps CLC, which clearly state the presence in their area of vegetation: green urban areas (class 10) and Port and leisure facilities (class 11). However, these areas are not completely covered with vegetation as shares of them also have infrastructures. It is therefore assumed for the estimation of the potential biomass ratio of 0.5 [1](on a scale modelling NUTS-3). Another element of uncertain value has become the NPP value. In the World Data Centre for Remote Sensing of the Atmosphere (WDC), natural productivity of built-up areas is masked out. Therefore, the average for NUTS value was adopted.

The performed validation for this type of biomass is designed to determine the differences in the vegetation in the area of selected classes of CLC (10 and 11) and an estimate of the remaining biomass that can be obtained from a built up area (classes 1-9). For logistical reasons, this problem is quite important, usually because whole green urban areas are under care and the biomass is removed. In addition, the use of satellite imagery in these analyses is very useful because of the fact that urban greenery is particularly easy to identify in the background of buildings.

The analysis was performed for the five selected test areas. In the first stage, the coverage of the vegetation areas defined as class 10 and 11 on the CLC map was assessed. As in previous studies, the differentiation of the biomass potential for the following values ranges index: 0.1-0.2: 20% 0.2-0.3: 50%; > 0.3 100%. was adopted. The structure of the vegetation cover is shown for each of the areas in the pie chart (Figure 30- Figure 38). In addition, the share of biomass / energy for the accepted gross calorific value was assessed.

In the second step, the diversity of vegetation and its potential for the whole surface of the built-up area was analysed. The main aim of the study was to compare current estimates of the biomass potential in Urban Green areas with the potential of biomass that is theoretically possible to raise in the rest of the built-up areas (classes 1-9 on the CLC map). The biomass of classes 1-9 was characterised by the same methods as biomass classes 10 and 11. As a result, the total intensity of the shares covered by greenery for grades 1-9 and 10-11 (according to the methodology) - Figure 30 -Figure 38 was estimated. As in the first step, the determination of the biomass / energy share, which may be obtained in each of the compartments for each group of classes, was completed. Areas with lush vegetation were identified as areas of NDVI> 0.2 (> 50% of the biomass potential).

[1] See Deliverable 1.2, chapter 3.1

Results

Austria. Recreational areas (vegetated) were found to have a high proportion of lush vegetation (about 54%). In these areas, one can acquire more than 80% of the biomass waste during the care and maintenance of these areas. A comparison of biomass potential between classes 10-11 and 1-9 shows that urban green areas can obtain about 81% of the total biomass from active maintenance of municipal green areas. In addition, this case study highlights a strong possibility of obtaining efficient biomass from built-up areas. More than 2/3 of the areas covered by vegetation belong to a land with lush vegetation; so that you can obtain about 90% of the biomass found in this group (class 1-9 CLC).

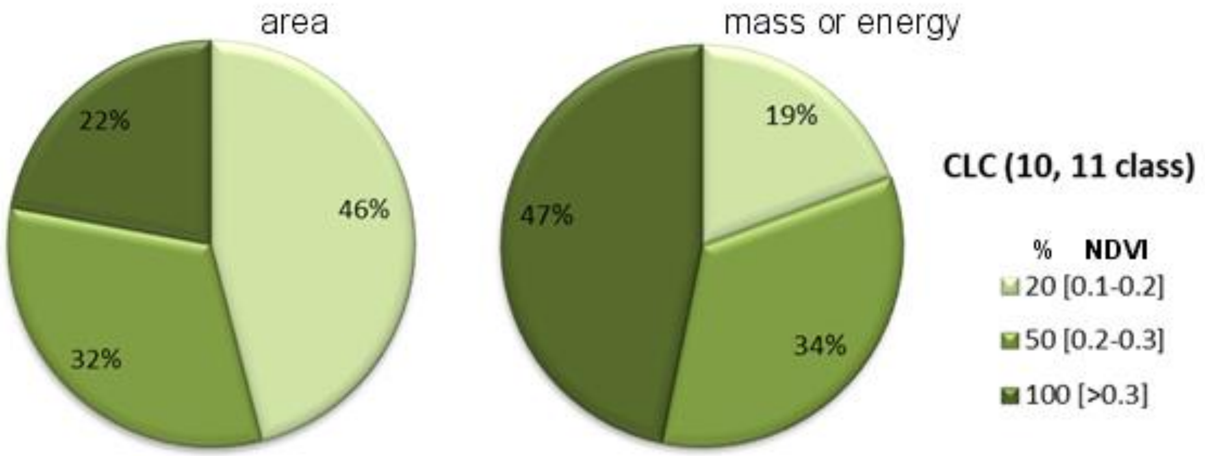

Figure 30. Austria case study. Structure of vegetation based on NDVI (10, 11 class of the CLC).

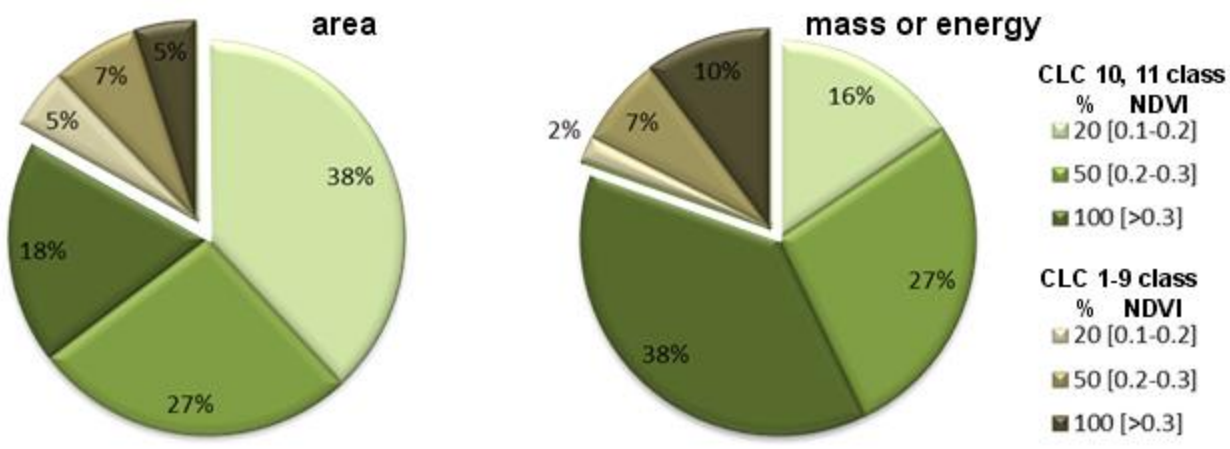

Figure 31. Austria case study. Structure of vegetation based on NDVI (1-11 classes of the CLC).

Germany. The areas covered with vegetation for urban green areas and recreational facilities are not particularly rich in vegetation. This involves inter alia, the presence of sport infrastructures (e.g. football pitches). In addition, green urban built-up areas should not be of a particularly intensity. The overall structure of the possibility of obtaining municipal biomass can be estimated so that the biomass can make up about 10-12%.

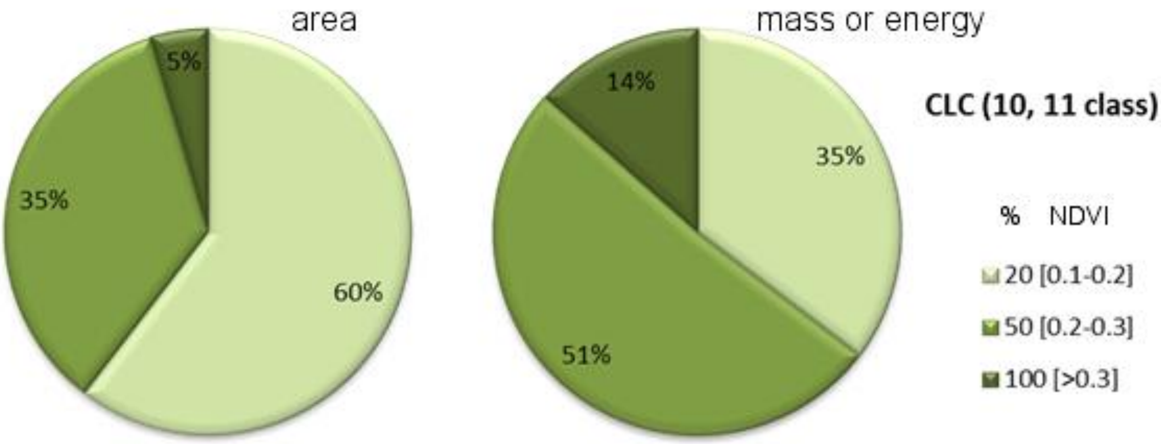

Figure 32. Germany case study. Structure of vegetation based on NDVI (10, 11 class of the CLC)

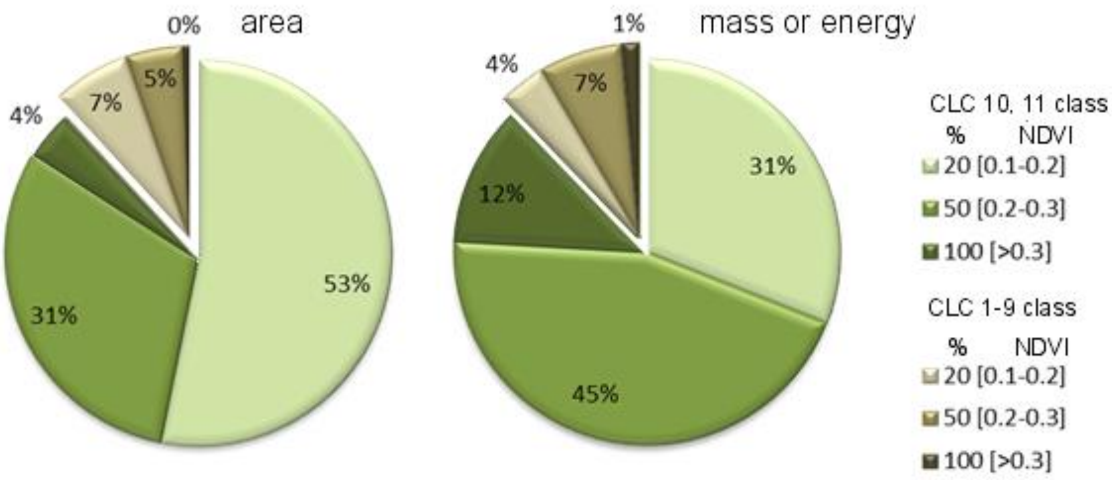

Figure 33. Germany case study. Structure of vegetation based on NDVI (1-11 classes of the CLC)

The Netherlands. The structure of the intensity of greenness in the areas covered by vegetation within class 10 and 11 CLC is similar to the test region of Germany, and from the point of view of obtaining biomass it is even less favourable. A much better possible suggestion in compensating the biomass is through its acquisition from more built-up area (classes 1-9), but also a surface covered with vegetation does not show significant greenness index values (0.1-0.2).

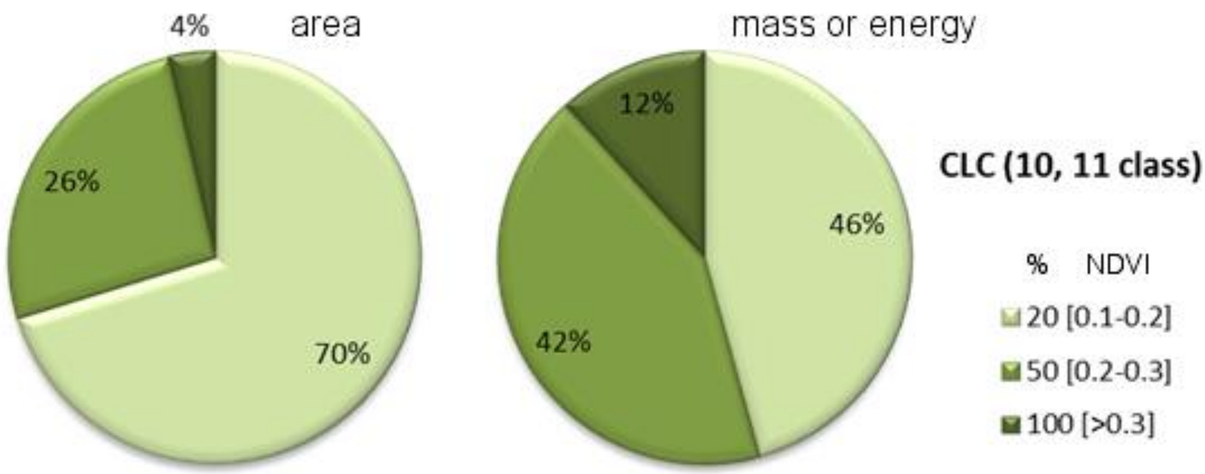

Figure 34. The Netherlands case study. Structure of vegetation based on NDVI (10, 11 class of the CLC).

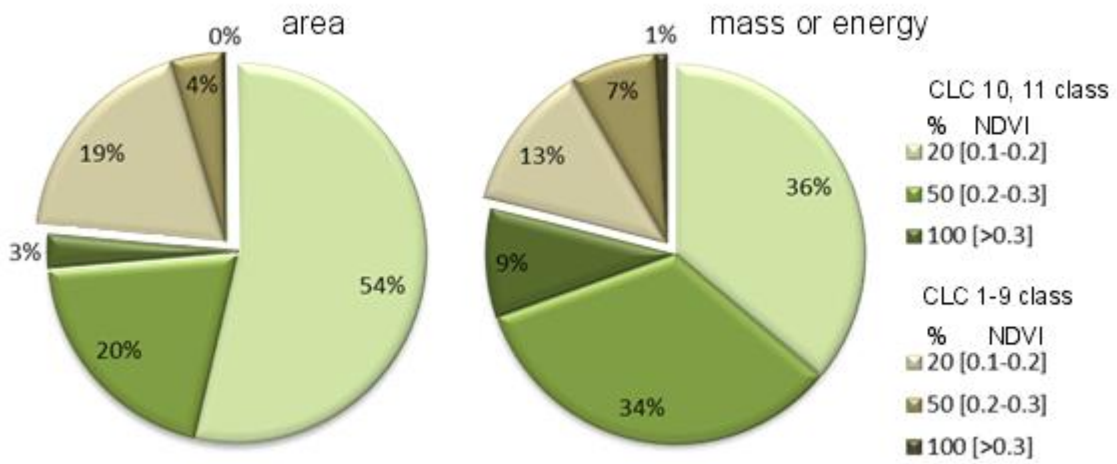

Figure 35. The Netherlands case study. Structure of vegetation based on NDVI (1-11 classes of the CLC)

Spain

In the test area, there was no presence of urban green areas or recreational areas. On the other built-up areas, lush vegetation made up about 33% of the total surface covered with vegetation in areas of urban green areas and recreational areas. The absence of grade 10 and 11 CLC, in this case, prevents a validation of the estimated potential for this region.

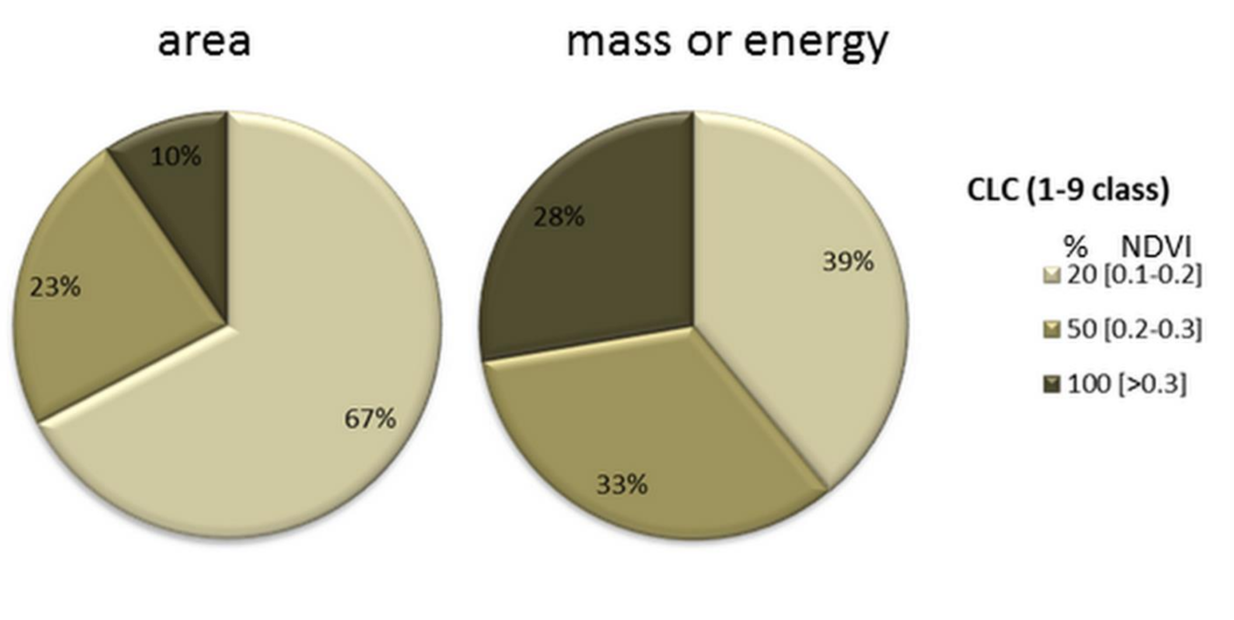

Figure 36. The Spain case study. Structure of vegetation based on NDVI (1-9 classes of the CLC)

Sweden The area of research in the Swedish case study observed the largest share of land covered with lush vegetation in urban green areas and recreational areas. These areas can obtain 80% of the biomass in relation to the total amount of biomass from urban landscape maintenance.

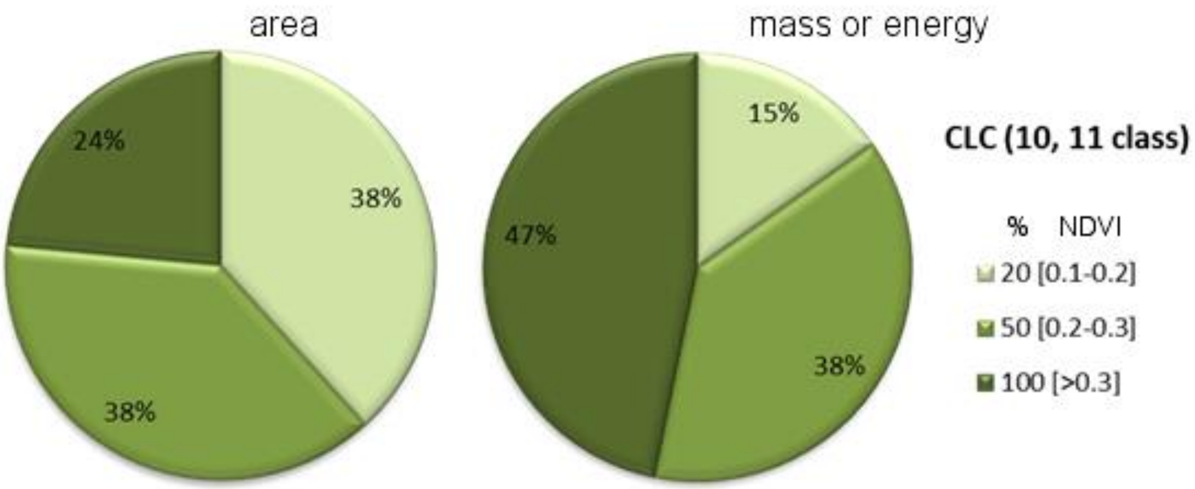

Figure 37. The Sweden case study. . Austria case study. Structure of vegetation based on NDVI (10, 11 class of the CLC).

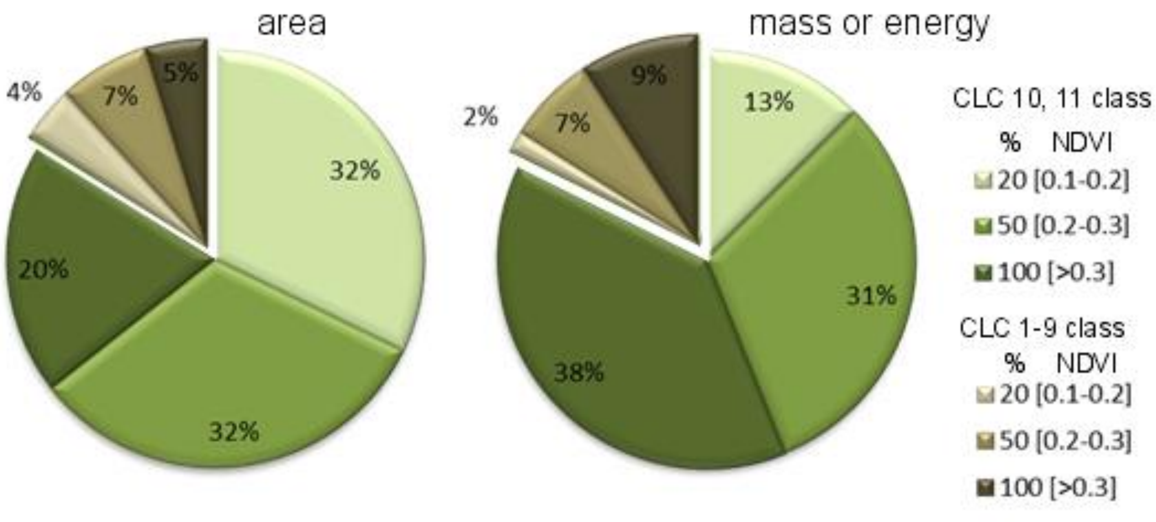

Figure 38. The Sweden case study. Structure of vegetation based on NDVI (1-11 classes of the CLC).

Discussion

The presented case studies show that it is possible to increase the estimated potential of biomass derived from the care of green areas to 25%. However, in individual regions there may be some differences between the proportions of biomass from urban green areas and built-up areas. The analysis also showed a large variation in the intensity of the vegetative areas. This applies to both study types alike (green and building areas). In both cases, none-intensive vegetation prevails, and is characterised with NDVI indices in the range 0.1-0.2. In analysing all the regions, demonstrated the legitimacy of introducing coefficients to reduce the estimates of the biomass potential from municipal green maintenance (Formula 11, Deliverable 1.2). However, it appears that the same value of this factor should be regionally determined and based on more data.

Livestock waste distribution in NUTS-5, case study of the Netherlands

The Netherlands is a country with an area of about 3.5 Mha of which about 2 Mha is agricultural land. The Netherlands is specific in terms of animal production. The production of livestock has several impacts on the environment. Most of these effects are related to the emissions of nitrogen and phosphorus from manures to the environment. An improvement in the management of manure is a major option in decreasing environmental nitrogen and phosphorus emissions. Moreover, manure processing could help Member States of the European Union in controlling manure surpluses, and may help in better implementation of the Nitrates Directive. The high manure production results from intensive livestock production.

Table 7. The structure of livestock production

	2011	**2012**	**2013***
Cattle	4,068,709	3,879,252	3,999,221
Sheep	1,304,567	1,042,758	1,033,566
Goats	178,571	396,725	412,545
Equidae	117,490	132,411	130,540

Sources: Statistics of Netherlands

The specific location of agricultural land in the polders, and other depressed areas with low capture of the groundwater, possibly vulnerable to flooding, limits this kind of cultivation method. For this reason, manure becomes a burdensome waste, which can be used for energy purposes. The large volume and dispersion of the local production allows the use of this product in the needs of the local biogas plant. The Netherlands has about 130 biogas plants and 13 biomethane plants in operation. The country has gained rich experience with biogas upgrading from different sources such as landfill gas (4 projects), sewage gas (2 projects), gas derived from biowaste and industrial waste (7 projects), and from agricultural biomass. All these biomethane plants are connected to the natural gas grid and inject the produced biomethane.

Six percent of manure is being processed. Mandatory manure processing will start from 1 January 2014. To create enough processing capacity, every farmer becomes responsible for processing part of the surplus on the farm. This gives the opportunity to use the surplus in line with the Bioboost project.

Livestock waste distribution in NUTS-5, Case study of Poland

A surplus of livestock production has a negligible contribution to the estimated technical potential of biomass. However, because of the high theoretical potential of this material (> 1.2 Gt) some attention should be devoted to this type of biomass. In the performed analysis, we assumed the use of manure in agriculture, in accordance with the requirements of the Nitrates Directive (2010). The literature review can lead to the conclusion that such specific criteria are the most restrictive (Fischer and Schrattenholtzer 2001, Nikolaou et al. 2003, de Noord et al. 2004, Vis et al. 2010).

Compared to the current analyses performed for the NUTS-2 regions, within the Biomass Future project (Elbersen et al. 2012); the results correspond to the relative regional volatility. However, for some regions the potential seems to be overestimated. In order to explain these differences, additional analyses were carried out for Polish agricultural production. The statistical data from CSO (2002) was used and on the basis of information about livestock, arable land and grassland, the amount of manure attributable to the agricultural NUTS-3 area was therefore estimated.

An analysis confirmed the lack of manure surplus for non-agricultural purposes, assuming its intensive use in the fertilisation of arable land and grassland (fertiliser use to 170 or 100 kg N ha^{-1} arable land). Despite the existing situation, biomass from animal-core is considered as a bio-energy, mainly due to the advantageous properties in the production of biogas.

Biogas plants located near large farms focusing on livestock production for economic reasons and logistics, more effectively than others do, use the manure surplus. In addition, energy policy guidelines promote this direction of agricultural biomass development, resulting in a mechanism of subsidies and EU funding of local energy infrastructure. An example might be an idea to implement the construction of the 2020 biogas plants.

Analyses conducted at the regional NUTS-3, due to the lack of more detailed data; do not allow modelling that takes into account the point location of the animal production. For this reason, one cannot exclude point clusters of biomass potential that can be effectively used to produce bioenergy. This applies for example to biogas plants at poultry farms, so that one can at spot and utilise the produced energy to heat buildings for livestock. In this case, the utilisation of post-fermentation residues are significantly less problematic than fresh matter disposal as waste digestive are better absorbed by plants, emit less ammonia and are not so onerous in odour (Igras 2012). In addition, these wastes are still of a high value as fertiliser (Jadczyszyn 2011).

The point character of livestock production clusters is evidenced by the comparison of modelling results for the NUTS-3 and for the NUTS-5 in Poland (Figure 39).

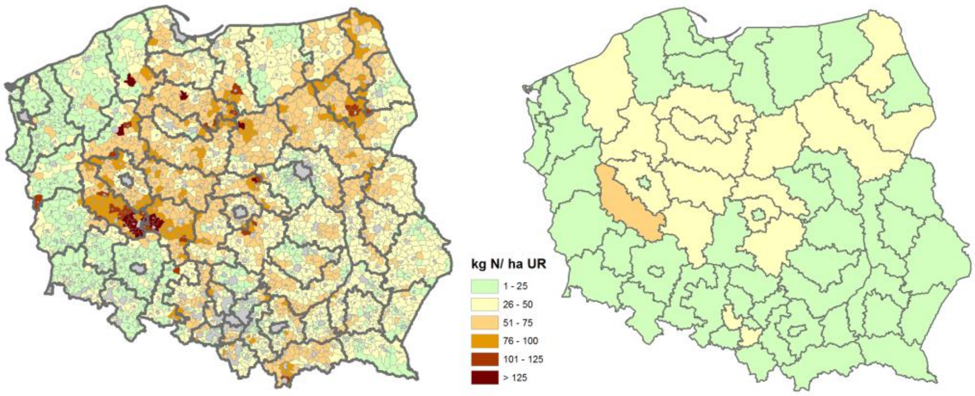

Figure 39. Comparison of the results for technical potential modelling of natural fertilisers for NUTS-3 and local district in Poland

The natural fertilisers used as an energy resource, is also rational in regions with hazardous water pollution by nitrates and phosphates (Nitrates Directive 91/676/EEC). In these zones, it should be also provided with suitable storage conditions for natural fertilisers (especially with the consistency of liquid).

For these reasons, the availability of natural fertilisers, in practice can be much higher than in results from the analyses. In these regions, bio-energy obtained from this type of material may have regional significance.

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