GREECO

Territorial Potentials for a Greener Economy

Applied Research 2013/1/20

(Draft) Final Report | Version 22/11/2013

Scientific Report

Vol. 2.3. Bioenergy potentials from residues from Agriculture and Forestry

EUROPEAN UNION
Part-financed by the European Regional Development Fund
INVESTING IN YOUR FUTURE

This report presents the draft final results of an Applied Research Project conducted within the framework of the ESPON 2013 Programme, partly financed by the European Regional Development Fund.

The partnership behind the ESPON Programme consists of the EU Commission and the Member States of the EU27, plus Iceland, Liechtenstein, Norway and Switzerland. Each partner is represented in the ESPON Monitoring Committee.

This report does not necessarily reflect the opinion of the members of the Monitoring Committee.

Information on the ESPON Programme and projects can be found on www.espon.eu

The web site provides the possibility to download and examine the most recent documents produced by finalised and ongoing ESPON projects.

This basic report exists only in an electronic version.

List of authors

Eberswalde University for Sustainable Development (Germany)

Prof. Dr. Hans-Peter Piorr

Sybille Brozio

Dr. Caroline Schleier

List of Content

List of Tables

List of figures

1. Explanatory notes

This draft contains the description of the methodological approach and results of:

- bioenergy potentials from agricultural residues: crop residues and manure
- bioenergy potentials from forest residues: direct and indirect residues

Potentials from grassland are not included due to the fact that the use of grassland does not remain residues as part of the plants like it is in the crops from arable land. Nevertheless, there is a share of grassland that is not needed anymore for agricultural use because the numbers of animals, the feeding of which is partly based on grassland, decreased in the last years. Thus, this share of area could be used for energy purposes. But this share is a variable value and depends very much on the intensity of the grassland use. The more intensive grassland utilization, the higher is the share of “currently remaining” grassland area. Therefore, these analyses have to be done very carefully on a comprehensive data basis, in particular if one wants to avoid running into a sustainability conflict.

Furthermore, residues from horticulture were not taken into account because it is unusual to use them for energy purposes. The dry matter content is very low, the collection of the biomass is effortful and - mainly – dirt adheres to the biomass.

2. Bioenergy potentials from agricultural residues

Methodological approach

The assessment of bioenergy potentials from agricultural residues are based on the EUROSTAT statistical data. The yields of the following crops and crop categories are reported:

- cotton
- flax
- barley
- green maize
- pulses
- potatoes
- corn (maize)
- fruit trees (olives and citrus fruit excluded)
- olives
- oil seeds
- swede rape and turnip rape
- vine
- rice
- rye
- soy beans
- sunflowers
- soft fruits
- tobacco
- wheat
- sugar beet

The crops and crop categories were divided into two residue categories: wood-based (pruning residues of olives, fruit trees, soft fruits, vine) and crop-based (cotton, pulses, potatoes, corn (maize), oil seeds, swede rape and turnip rape, rice, rye, soy beans, sunflowers, tobacco, wheat, sugar beet).

Mean yields for the period 2000-2010 were calculated. For each crop harvest index, crop/residue ratio or average yields of residues in t/ha were defined on the basis of literature data and if necessary transformed into a crop/ residue index (Kaltschmitt et al. 2009, Esteban et al. 2008, Panoutsou et al. 2009, Diamantidis & Koukios 2000, Elbersen et al. 2012, Kim & Dale 2004, Shelton et al. 1991 (cited in Andrews 2006)).

Likewise, the share of the residues that is harvestable and available was defined. According to Panoutsou et al. (2009) the conservative assumption that 30% of the crop-based residues are available was chosen. Due to the fact that the wood-based residues - in contrary to the crop-based residues - are not needed to that far extent to be left on the field, it was assumed that 60% of which are available. Some crops were not taken into account because there are usually no residues remaining. Flax and green maize i.e. are harvested in the whole. The residues of pulses were defined as not available because they usually are left on the field. Concerning soy beans, there was just few European data found, main references were from outside Europe. According to pulses, it was assumed that the residues of soy beans are usually left on the fields and are therefore not available (Shelton et al., 1991 (cited in Andrews, 2001)). Residues from tobacco were excluded due to the serious health problems that can be caused by tobacco consumption.

Figure 1 gives an overview about the calculations.

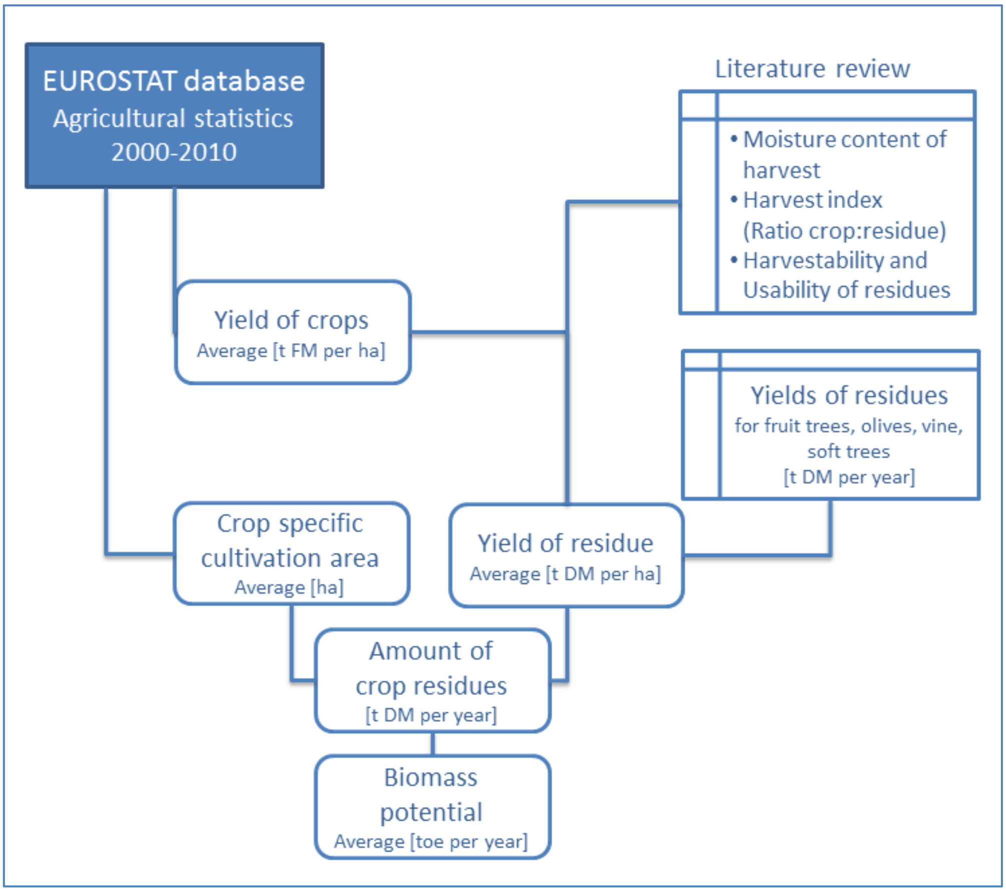

Figure 1 Overview about the data and calculations

The calculation of ton of oil equivalent (toe) from the amounts of crop residues were made according to Panoutsou et al. (2009), assuming that the residues have an energy content of 18 GJ/oven dry tons and that 1 toe corresponds to 41,868 MJ.

Table 1 shows the crops and crop categories which were taken into account, the crop/residue ratio respectively the residues yields per area, the available share of the residues, type of residue and the sources of the data. In some cases the crop/residue ratio was divided by geographical large regions: Central, Northern and Southern Europe. These regions were assigned to the ESRI classification.

Table 1 Overview about crops/crop categories

Crop/crop categories	Crop/Residue ratio	Availability [%]	Type of biomass	source
cotton	1:2,0	30	„straw“	Esteban et al. 2008
barley	0,5 (Central / Northern EU) 0,9 (Southern EU)	30	straw	Panoutsou et al. 2009
corn (maize)	0,7	30	straw	Panoutsou et al. 2009
fruit trees (olives and citrus fruit excluded)	2,15 t dm /ha	60	wooden material	Elbersen et al. 2012
olives	0,3 t dm /ha	60	wooden material	Panoutsou et al. 2009
oil seeds	1,6	30	straw	Panoutsou et al. 2009
swede rape/ turnip rape	1,6	30	straw	Panoutsou et al. 2009
vine	1,5 t dm/ha	30	Holz	Panoutsou et al. 2009
rice	0,7143 (1,4:1)	30	straw	Kim & Dale 2004
rye	0,5 (Central / Northern EU) 0,9 (Southern EU)	30	straw	Panoutsou et al. 2009
sunflowers	3,3	30	straw	Panoutsou et al. 2009
soft fruits	2,15 t dm/ha	60	wooden material	Elbersen et al. 2012
Wheat	0,5 (Central / Northern EU) 0,9 (Southern EU)	30	straw	Panoutsou et al. 2009
sugar beet	4,1 (Central EU) dm t/ha 3,7 (Southern EU) dm t/ha	30	crop-based	Diamantidis & Koukios 2000

EFTA-Countries

For Switzerland, Norway, Iceland and Liechtenstein different data bases had to be chosen. Several adjustment steps had to be done.

Switzerland

The national statistics of Switzerland comprised regional data on NUTS2-level for the area of grains, vineyards and fruit trees. Residues for vineyards and fruit trees were calculated according to EU27 countries. Yields for grains were available just on national level. An average grain yield in t/ha was calculated and distributed over the regions on the basis of the regional grain area. Corn (maize) is included in the grain category and therefore calculated with the crop/residue ratio of grains (0,5 instead 0,7).

Liechtenstein

The national statistics of Liechtenstein comprised regional data on NUTS2-level for the area of grains, vineyards and fruit trees. Residues for vineyards and fruit trees were calculated according to EU27 countries. Yields for grains were not available at all. At current state, the grain yield of the neighbouring NUTS2 region AT34 was taken assuming that the yield is comparable. Due to the fact that the yields for the other neighbouring NUTS2 region in Switzerland had to be deduced from national data, this data was not taken into account.

Norway

For Norway there were regional data for grain yields just available for the years 2000-2006, for the remaining years there were national data available. On this basis, average yields were calculated. Pruning residues were calculated on the basis of areas of fruit trees according to EU 27.

Iceland

National statistics of Iceland delivered production of cereal grains for the years 2000-2010. The agricultural area had to be taken from 2009.

Manure potentials

The calculation of potentials from manure was footed on EUROSTAT life stock data at NUTS2-level, for Germany just on NUTS1-level. **As the data had to be reported on NUTS2-level, the results of NUTS1 regions were downscaled on the basis of the NUTS region's area. Due to the fact, that there is no spatial distribution of live-stock available, this adjustments as basis for interpretation has to be treated very carefully! Therefore, the results for German NUTS regions differ strongly from the other regions – with a much lower quality.**

The NUTS2 data set comprises numbers of animals in 2010. According to Burton & Taylor (2010), average amounts of produced manure for dairy and beef cows of different age classes, pigs and hens/broilers were taken into account (Tab 2). It was assumed that dairy cows are 180 days of the year in the stables, chicken and pigs 365 days. In order to differentiate solid and liquid manure, the shares of both at national data (Leip et al., 2010) were applied at regional level. It was assumed that just the liquid manure of the dairy cows and pigs and 50% of the chicken manure are available. The energy potentials were calculated on the basis of high calorific values (Panoutsou et al. 2009) on dry basis for wet manure (9 GJ/oven dry ton) and dry manure (14,5 GJ/oven dry ton).

Table 2 Overview about manure production (Burton & Taylor 2010)

Animal	Body weight (kg)	Manure produced per animal over 6 months (m3)	Dry matter content of manure (kg DM/m3)
Dairy cow	550	9,70	100
Beef cattle >2 years	500	5,80	100
Beef cattle 1-2 years	400	4,80	100
Beef cattle 0.5-1 year	180	2,40	100
Sow plus litter	200	2,00	60
Pig (dry ratio)	35-105	0,80	100
100 Laying hens	220	2,10	300
100 Broilers	220	1,10	600

EFTA-Countries

Data for Norway and Switzerland were included in the EUROSTAT dataset. Life stock data from Iceland and Liechtenstein were found in the national statistical reports. For Liechtenstein cattle numbers were reported in the categories dairy cows and other cows differentiated into male and female animals in different age categories. For Iceland, cattle numbers were reported for the categories: cows, beef cows, heifers, steers and calves. Just the calves were assigned to cattle younger than one year. Heifers and steers were assigned to the category of cattle older than 2 years. Numbers for pigs and chicken were not divided into further categories in both states. All pigs were assigned to the category “Pig (dry ratio)” and all chicken to the category “broilers” in order to avoid overestimations.

Transformation from NUTS2-2006 to NUTS 2010

The biomass potential data that was reported in January was mainly on the basis of NUTS-2006 datasets. As it was necessary to transform the data to NUTS 2010 data, four different adjustment categories had to be done:

1. Renaming: some regions just got new names and/or new codes. They were renamed
2. Merging: some regions were merged. The results of which were summed up
3. Split up: some regions were split up into two parts. In this case, the biomass potentials were distributed among the parts on the basis of the NUTS region’s area. That corresponds to the assumption that the biomass potential is eventl distributed over the region and leads to a lower quality of data
4. New borders: In some regions the border between two regions was newly defined. In this case, a factor was calculated that describes the percentual distribution of the total area amongst the both regions. The factor of the reduced region (x; <1) was taken as factor to reduce the biomass potential. For the enlarged region, the biomass potential was calculated as a sum of the originally biomass of the region and the enlarged part`s biomass potential multiplied the factor 1-x.

Results

Figure 2 and 3 show the spatial distribution of the technical bioenergy potentials from crop residues and manure.

The bioenergy potentials from agriculture depend to a large extent from the land use management system. Moreover, the land use management has a strong impact on the environmental perspective of sustainability. Thus, a high potential for bioenergy from agriculture, that was calculated on the basis of the current statistics and therefore on the basis of the current use, could be in conflict to the idea of green economy, if the high potentials are based on an unsustainable way of production. As one indicator the diversity of cultivated crops was analysed: Figure 4 shows the share that the dominant crop in each

NUTS region holds. In some NUTS 2 regions, the dominant crop holds a share of more than 50%. Additionally, the IRENA-Indicator 13: Cropping/livestock patterns was calculated.

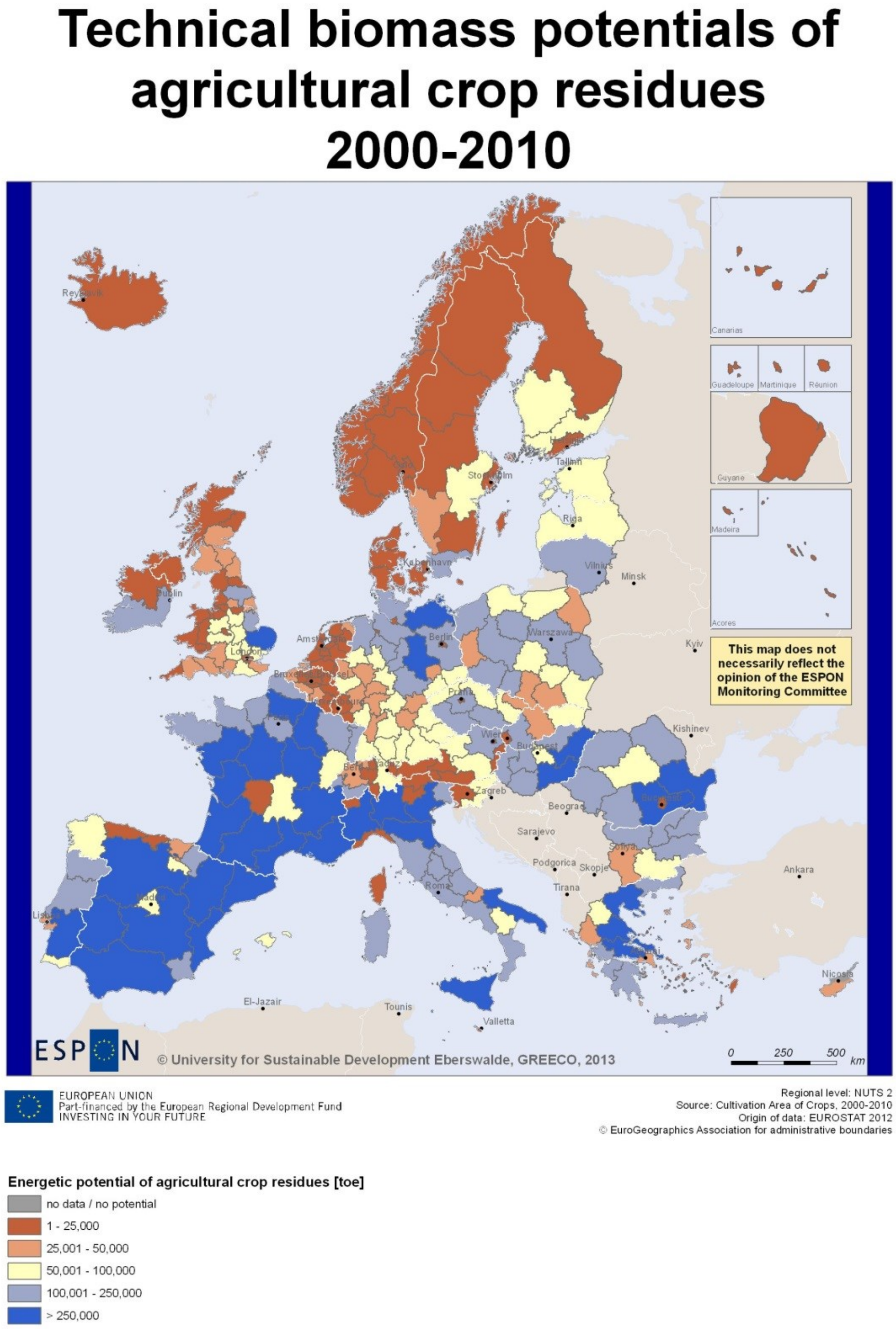

Figure 2 Technical bioenergy potential from agricultural residues – crop residues

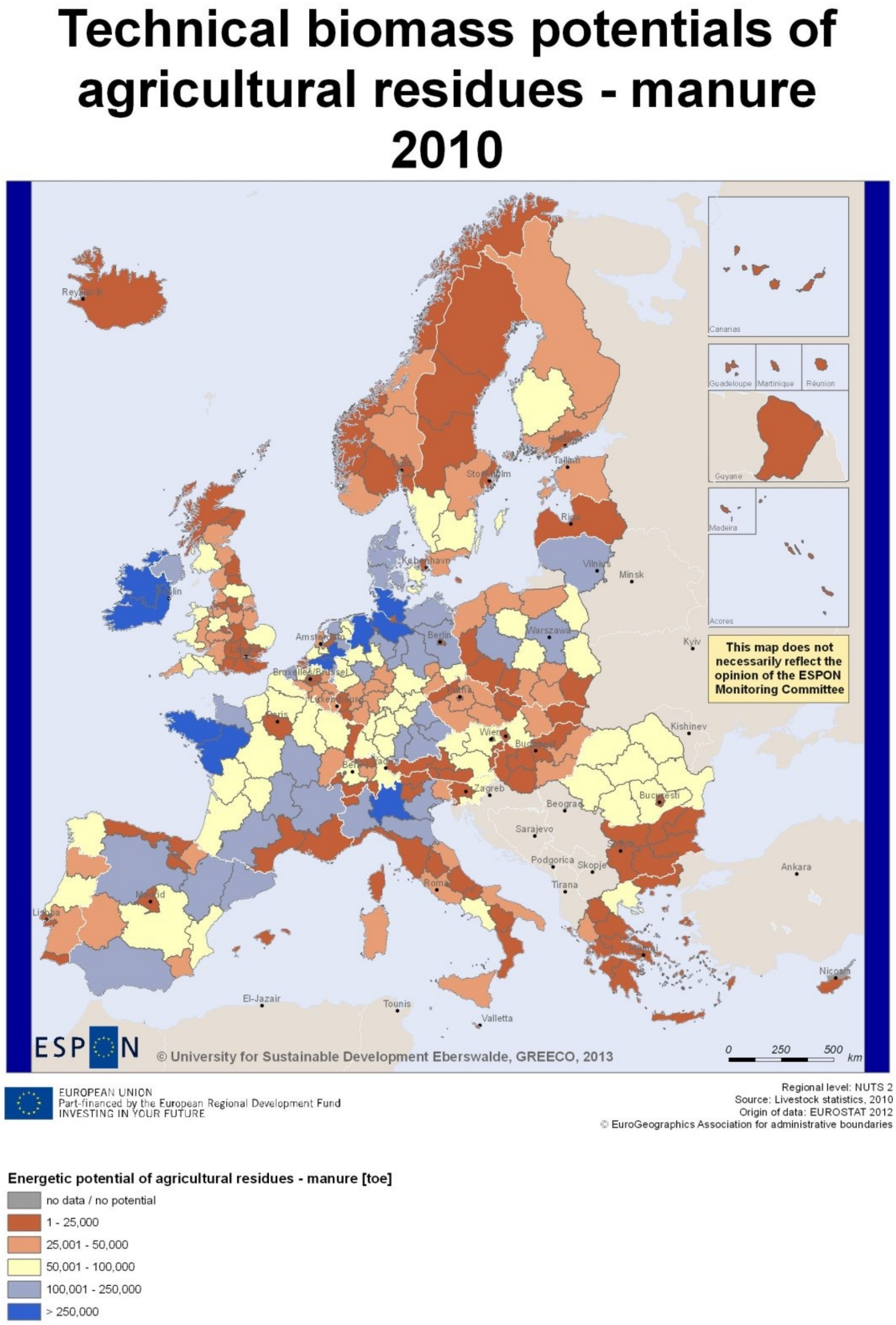

Figure 3 Technical bioenergy potential from agricultural residues – manure

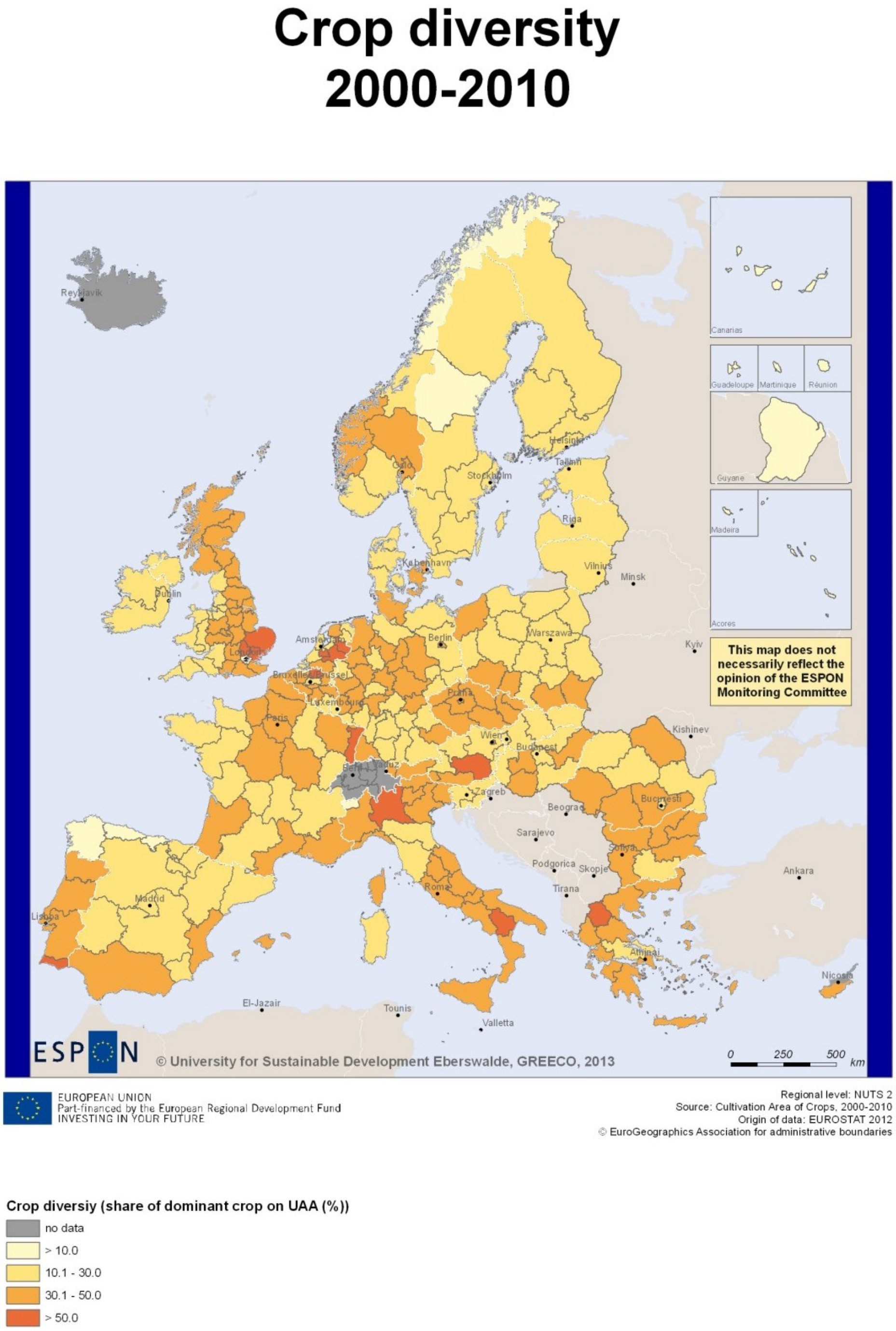

Figure 4 Diversity of cultivated crops expressed as share of dominant crop on arable land

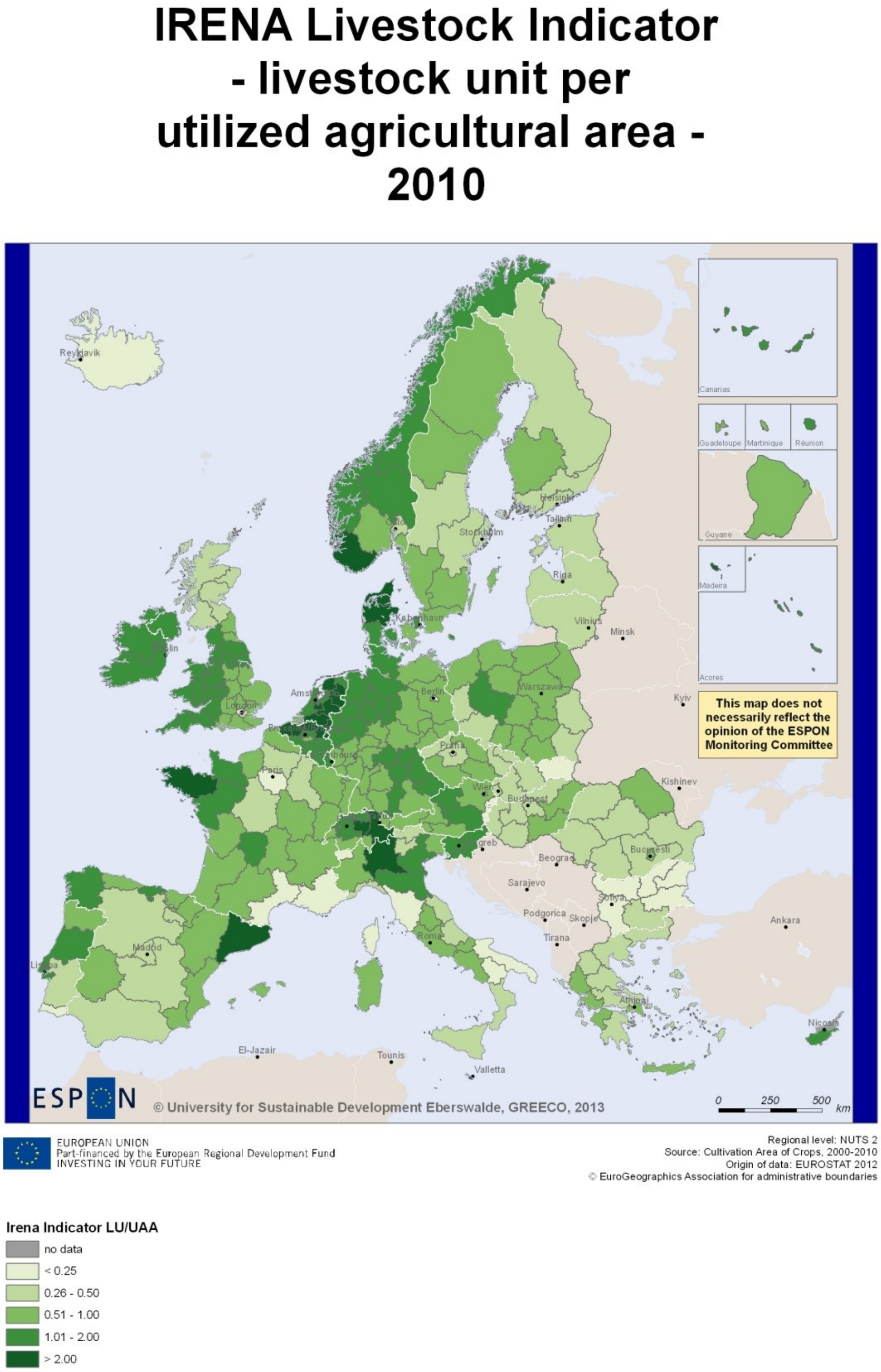

Figure 5 IRENA Livestock Indicator – livestock unit per utilized agricultural area

5. Bioenergy potentials from forestry residues

The calculations of bioenergy potentials from forestry residues are based on the results of the EUwood project (Mantau et al. 2010a, 2010b). EUwood delivered a framework tool that helps to develop a databasis which present – instead of the traditional statistics - not only partly information about supply and demand of raw materials but the whole entity of sectors and their interactions. Wood resource market is divided into forestry resources, other woody biomass, material uses and energy uses. The primary forest biomass was calculated by the EFISCEN model (Schelhaas et al, 2007), differentiated into stemwood from conifers and non-conifers, bark and forest resisdues. Industrial residues were differentiated into sawmill by-products. The cascade use of wood causes some problems during the calculations of bioenergy potentials from these data, because the sawmill by-products serve as input material for further processes such as the panel, pulp and fuel industry.

The potential biomass supply was calculated firstly as theoretical potential and afterwards – taking multiple environmental, technical, social and economic constraints into account – as realizable potential. Comprehensive description of the methodological approach is to be found in the methodological report (Mantau et al. 2010b). EFISCEN delivered biomass potentials from broadleaved and coniferous species: stemwood, logging residues (stem, tops. branches and needles), stumps and early thinnings. The integrated environmental constraints comprise Soil and water protection (nutritional impact of biomass extraction, soil erosion protection, protection of watersheds, soil compaction), Biodiversity protection, technical recovery rates, soil bearing capacitie and ownership structure.

The implementation of different recommendations that are supposed to help avoiding the above mentioned constraints were defined in three mobilization scenarios: high, medium and low mobilisation. The scenarios project different degrees of success of how the recommendations will be implemented. The reported data is based on the “medium mobilization scenario”:

> *The* ***medium mobilisation scenario*** *builds on the idea that recommendations are not all fully implemented or do not have the desired effect. New forest owner associations or co-operations are established throughout Europe, but this does not lead to significant changes in the availability of wood from private forest owners. Biomass harvesting guidelines that have been developed in several countries are considered adequate and similar guidelines are implemented in other countries through improved information exchange. Mechanisation of harvesting is taking place, leading to a further shift of motormanual harvesting to mechanised harvesting. To protect biodiversity forests are being protected, but with medium impacts on the harvests that can take place. Application of fertilizer is permitted to limited extent to limit detrimental effects of logging residue and stump extraction on the soil.*

The medium mobilization scenarios comprise for maximum extraction rates for extracting:

- Stem biomass during early thinnings: 0% on slopes over 35%; 0% in protected forest areas and recovery rate of 95%;
- Crown biomass during early thinnings: 0% on poor soils, 70% on other soils; 0% on slopes over 35%; 0% on Redzina, Lithosol, Ranker, Histosols, Fluvisols, Gleysols and Andosols; 35% on peatlands, 0% on soils with very high compaction risk, 25% on soils with high compaction risk; 0% in protected forest areas and recovery rate of 80%;
- Logging residues from final fellings: 0% on slopes over 35% unless cable-crane systems are used; 0% on slopes over 35%; 0% on Redzina, Lithosol, Ranker, Histosols, Fluvisols, Gleysols and Andosols; 35% on peatlands, 0% on soils with very high compaction risk, 25% on soils with high compaction risk; 0% in protected forest areas and recovery rate of 67% on slopes up to 35%, 0% on slopes over 35%, but 67% of cable-crane systems are used;
- Logging residues from thinnings: 0% on poor soils, 70% on other soils; 0% on slopes over 35% unless cable-crane systems are used; 0% on Redzina, Lithosol, Ranker, Histosols, Fluvisols, Gleysols and Andosols; 0% on peatlands, 0% on soils with very high compaction risk, 25% on soils with high compaction risk; 0% in protected forest areas and recovery rate of 67% on slopes up to 35%, 0% on slopes over 35%, but 47% of cable-crane systems are used;Additionally, environmental and technical as well as social constraints are included.
- Stumps from final fellings (Finland, Sweden, UK): Conifers, 15% on poor soils, 33% on other soils, 0% on slopes over 20%, 0% on peatlands, 0% on soils < 40 cm (including Rendzina, Lithosol and Ranker), 33% on soils >40 cm; 0% on soils with very high compaction risk, 25% on soils with high compaction risk; 0% in protected forest areas; 0% on Histosols, Fluvisols, Gleysols and Andosols.
- Stumps from thinnings: 0% at all.

Until the end of January, the regional data was not available, the regionalization of the potentials had to be done on the basis of the forest area of the NUTS 2 level as it is comprised in the CORINE landcover data. For the countries Slowenia, Latvia, Ireland and Spain, forest area from the LUCAS survey had to be taken as basis for the calculation of the shares of area. For UK, the forest area was taken from the PELCOM data set. This methodological approach raised the problem that it has to be assumed that the production is the same all over one country and therefore has to be assessed as of relatively low quality. In some regions as the Nordic countries i.e., the potentials are probably overestimated in the northern regions.

The calculation of energy potentials was based on conversion factors as they were used in EUwood:

1 M m3 => 0,21 toe

As indirect residues from forestry the sawmill by-products were taken into account. It comprises wood residues that originate from the production of sawnwood (wood chips, sawdust, particels, sawmill rejects, slabs, edgings and trimmings). The sawmill by-products serve as input material for panel industry, pulp industry and wood fuel industry. For the greeco study just the demand for the wood fuel industry were taken into account.

¡Error! No se encuentra el origen de la referencia.

Figure 6 show the results of the bioenergy potentials forestry residues. For the EFTA countries, an average of residues/area for the EU regions West and North as reported in the EUwood report were calculated and assigned to the forest area in the EFTA countries. Due to the fact that the result of this first step seemed to be too high, another adjustment step was done for Norway and Switzerland. The proportion of roundwood removals from Norway in comparison to the EU North region was taken as basis for an adjustment factor. As the Switzerland is mainly characterized by the Alpine region, another basis for an adjustement factor was chosen here. The results of the neighboring NUTS2-levels were taken as basis for the calculation of an average residue/area factor that has been afterwards applied to the forest area of Switzerland.

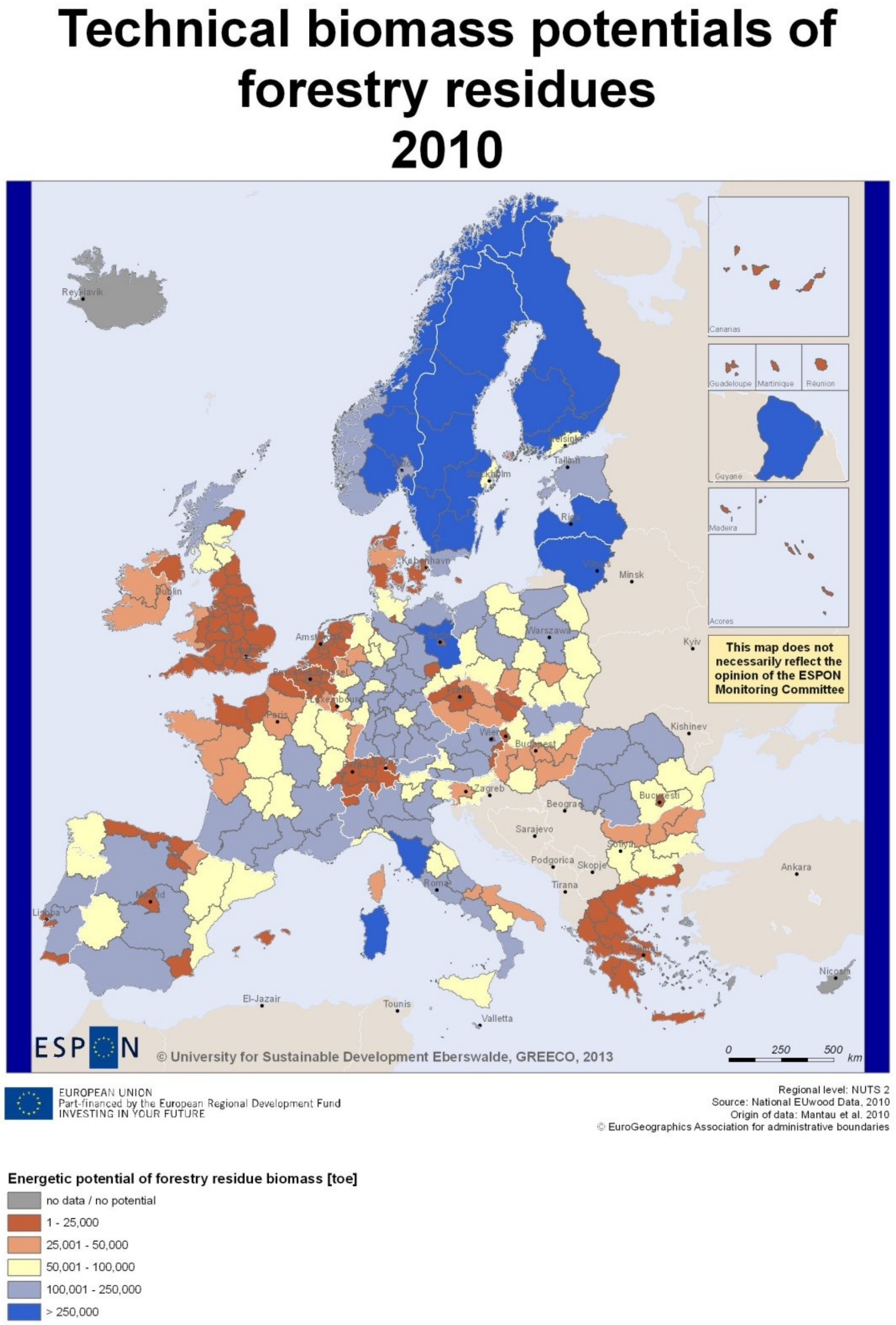

Figure 6 Technical Bioenergy potential of forestry residues

6. References

Andrews, S. 2006: Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations. White paper USDA-National Resource Conservation Service.

Burton, C.H., Turner, C. 2010: Manure Management – Treatment strategies for sustainable agriculture. 2nd edition.

Diamantidis, N.D., Koukios, E.G. 2000: Agricultural crops and residues as feedstocks for non-food products in Western Europe. Industrial Crops and Products 11: 97-106

Elbersen, B., Startisky, I., Naeff, H., Hengeveld, G., Schelhaas, M.-J., Böttcher, H. 2012 Deliverable 3.3: Spatially detailed and quantified overview of EU biomass potential taking into account the main criteria determining biomass availability from different sources. BiomassFutures.

Esteban, L.S., Ciria, P., Carrasco, J.E. 2008: An assessment of relevant methodological elements and criteria for surveying sustainable agricultural and forestry biomass byproducts for energy purposes. BioResources 3: 910-928

Kaltschmitt, M., Hartmann, H., Hofbauer, H. (eds) 2009: Energie aus Biomasse – Grundlagen, Techniken, Verfahren (Energy from Biomass – Principles, technics and processes - In German) Springer

Leip, A., Weiss, F., Wassenaar, T., Perez, I., Fellmann, T., Loudjani, P., Tubiello, F., Grandgirard, D., Monni, S., Biala, K. (2010): Evaluation of the livestock sector's contribution to the EU greenhouse gas emissions (GGELS) –final report. European Commission, Joint Research Centre.

Mantau, U. et al. 2010a: EUwood – Real potential for changes in growth and use of EU forests. Final report. Hamburg/Germany, June 2010 160p.

Mantau, U. et al. 2010b: EUwood – Real potential for changes in growth and use of EU forests. Methodology report. Hamburg/Germany

Panoutsou, C., Eleftheriadis, J., Nikolaou, A. 2009: Biomass supply in EU27 from 2010 to 2030. Energy policy 37: 5675-5686

Schellhaas et al. (2007) Model documentation for the European Forest Information Scenario Model (EFISCEN 3.1.3) Alterra report 1559 and EFI technical report 26

Shelton, D.P., Dickey, E.C. and Jasa, P.J. 1991. Crop residue management in the western Corn Belt. Crop Residue Mangement for Conservation, Lexington, KY, Soil and Water Conservation Society. Cited in: Andrews, S. 2006: Crop Residue Removal for Biomass Energy Production: Effects on Soils and Recommendations. White paper USDA-National Resource Conservation Service.

www.espon.eu

The ESPON 2013 Programme is part-financed by the European Regional Development Fund, the EU Member States and the Partner States Iceland, Liechtenstein, Norway and Switzerland. It shall support policy development in relation to the aim of territorial cohesion and a harmonious development of the European territory.

ISBN