Sustainable Bioenergy
Solutions for Tomorrow

RESEARCH REPORT
NO D1.4.2
HELSINKI 2016

Petri Latva-Käyrä (Arbonaut)
Karthikeyan Natarajan (UEF)
Anas Zyadin (UEF)

BEST task 1.4.2 – Case Poland: Biomass resource assessment

Solution Architect for Global
Bioeconomy & Cleantech Opportunities

CLIC INNOVATION OY
ETELÄRANTA 10
P.O. BOX 10
FI-00131 HELSINKI,
FINLAND
CLICINNOVATION.FI

ISBN 978-952-5947-91-5

CLIC Innovation
Research report no D1.4.2

Petri Latva-Käyrä (Arbonaut)
Karthikeyan Natarajan (UEF)
Anas Zyadin (UEF)

BEST task 1.4.2 – Case Poland: Biomass resource assessment

Name of the report: BEST task 1.4.2 – Case Poland: Biomass resource assessment

Key words: Biomass, residues, mapping, land use, Poland

Key Findings:

- On both provinces the two main land use classes, agriculture and forest, cover more than 80 % of the areas, and those are the classes of interest also in this study.

- In both provinces wheat is the most important crop for residue biomass production, even though corn has the highest total residue production in Torun region and also in Upper Silesia one of the highest. The surplus residue from all crops is in Torun region and in Upper Silesia, 0.60 and 0.59 tons/ha during one year, respectively.

- The forest biomass in Kujawsko-Pomorskie is limited mainly to the areas along the Wisla and Brda rivers, which flow through the province. In Silesia, however, there are several large areas on all sides of the province where there are quite large forest biomass coverage.

- Farmers use biomass mainly for livestock feed and bedding

Helsinki, March 2016

Contents

1 Introduction

Poland is the 9th largest country in Europe located in Central Europe with a population of 38.5 million people. Poland uses renewable energy for around 12 % (2013) of their gross final energy consumption of which around 90 % is from biofuels (GUS 2015a). Primary source of energy is coal with 61 % of total energy consumption, followed by lignite (18.2 %), natural gas (5.5 %) and crude oil (1.4 %), which totals to 86.1 % (GUS 2015b). Even though the amount of renewable energy is still fairly low, the reserves of different biomass which could be used for bioenergy production are large. It has been estimated that Poland has from 60 to 150 PJ (4 to 11 Mtons) bioenergy potential from agriculture straw, and 20-30 PJ from forest residues (Nilsson et al. 2004). Bioenergy potential estimates have been, however, uncertain due to lacking data on the topic. On top of good data in general, without good maps of the distribution of the biomass, planning of biomass utilization for energy production will be difficult. With decent maps, the areas of interest can be identified and further studies can be allocated to those regions.

The whole BEST case Poland project task 1.4 was divided into five different subtasks: subtask 1.4.1 the social processes and influences are studied concentrating on the social acceptance and willingness to supply biomass, and on people's attitudes and perception towards biomass based bioenergy production. Subtask 1.4.2 concentrates on the biomass availability side by mapping the surplus agriculture biomass and forest biomass for two pilot areas. Subtask 1.4.3 covers supply chain logistics simulation and testing of new mobile biomass reporting application. Subtask 1.4.4 studies bioenergy generation optimization covering the economical, the supply and the socio-cultural sides of the bioenergy production to provide new business dimensions. The final subtask, 1.4.6, tries to strengthen the research cooperation and to develop new research methodologies. The subtask 1.4.5 is the only one which is done outside Poland, and it concentrates in the ASEAN (Association of Southeast Asian Nations) countries and to research biomass fuel quality and properties.

Subtask 1.4.2 aim was to map the available existing biomass resources for bioenergy utilization. This mapping was done using multi-source information gathered from field studies, available literature, and best available land use/land cover (LULC) maps and other GIS data. The study was done in two different pilot provinces (voivodeships), the Silesia and Kujawsko-Pomorskie (Kuyavia-Pomerania) provinces. The mapping was done on grid-level for a grid with 1 km x 1 km cell size.

2 Materials

2.1 Study area

The study area was narrowed down to two provinces of interest. The selected provinces were Silesia, in Southern Poland, and Kujawsko-Pomorskie (Kuyavia-Pomerania) in Central Poland. The province of Kujawsko-Pomorskie is about 18 000 km^2 and the province of Silesia about 12 000 km^2 in area. The study area covers two out of 16 provinces in Poland. From the two selected provinces the main locations are the city of Torun and the surrounding areas in Kujawsko-Pomorskie, and Upper Silesia in Silesia.

Torun represents a region of high renewable energy potentials whilst Upper Silesia represents a region with high coal potentials. Therefore, the two contrasting regions will be compared in terms of biomass availability, degree of use, and how social processes and farmers' willingness can influence biomass supply for energy production purposes.

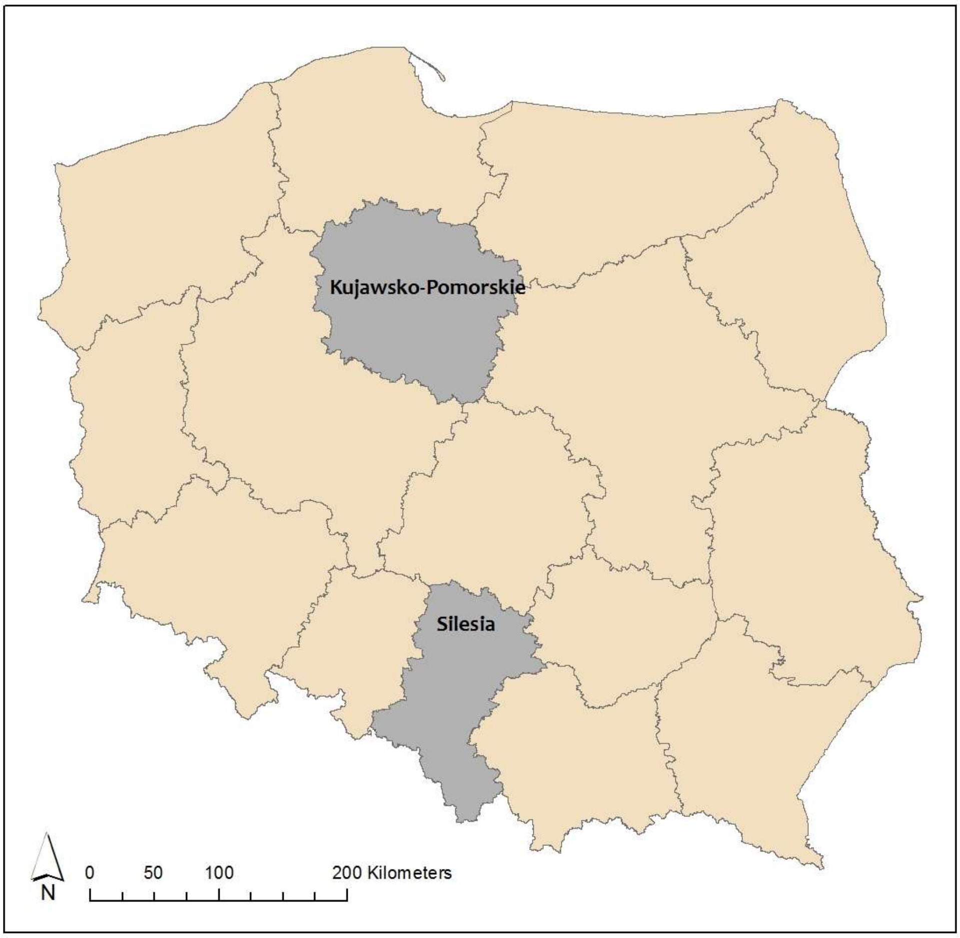

Figure 2-1: Map of provinces in Poland with two study provinces highlighted.

2.2 Biomass data

2.2.1 Field data

Field data was collected separately from both provinces. The field data was collected by doing a survey among the Polish farmers in both provinces. The survey tool was first developed by UEF team in English language and thereafter was sent to partners from Poland for translations into Polish language.

The questionnaire consisted of several sections. The first was devoted to biographical information, farm size and farming machines, sources of energy at home, uses of biomass at the farm level. The second was devoted to measure the production capacities and therefore the biomass availability. The farmers' ability and willingness to supply biomass was measured through 8 Likert-scale statements. The farmers' perceptions of the current biomass market were measured through 8 Likert-scale statements. In Upper Silesia, data collection took place within the range of 100 km from the city of Częstochowa. The sampling strategy started with the search for farmers selling their biomass (straw, corn, and rapeseed or energy willow) on the online auctions or advertisement sites. This gave the possibility to obtain phone numbers via which farmers were contacted for appointment. July was the harvesting season and it was very difficult to get appointments with farmers, therefore, the work was postponed into August and the farmers were re-contacted. Another mode of collecting data was through contacting offices of the Agricultural Advisory Centre from Częstochowa, Łódź, Opole and Kraków and leaving copies of the questionnaires in their offices. The method proved successful as about 50 farmers filled in the questionnaire. In Torun and the surrounding areas, the sampling strategy was simply by contacting the farmers from a database which was already made by the Polish partner Bartlomiej Iglinski from Nicolaus Copernicus University in his previous research. Questionnaires were also mailed to the farmers.

In total, 200 surveys were collected from both sites; about 100 surveys from each. The field data was processed from field sheets into table format either after field data collections by field team (Upper Silesia) or before analysis by authors (Torun). After tabulating the data, the data was processed in the statistical software R. The data was processed by calculating average crop and residue biomass production values for agriculture in total and for different crop types. By combining the residue production and average national residue use of 85 %, the amount of available residue biomass was calculated. The values were calculated for both areas separately and all results were in tons per hectare.

2.2.2 Other sources

The field survey only included farmers with agriculture as their main occupation and, thus, the forestry data from the survey was incomplete. Furthermore, the forests are mainly owned by the state in Poland. For the purpose of mapping forest biomass, the average forest values were acquired from literature. The statistical yearbook of Slaskie voivodship for the year 2014 (Statistical Office in

Katowice, 2014) was used for Silesia province and the statistical yearbook of Kujawsko-Pomorskie voivodship for the year 2014 (Statistical Office in Bydgoszcz, 2014). The statistical yearbooks have the total volume of growing stock and area of different forest classes (coniferous/mixed/deciduous). Based on these values the average growing stock volume per hectare on different forest classes was calculated.

The forest growing stock volume is not the volume which would be commonly used for bioenergy production; more often it would be the non-stem aboveground volume. To get the non-stem biomass, the aboveground biomass of tree species was calculated based on IPCC Good Practice Guidance (IPCC, 2003) default values of biomass expansion factors and wood densities for European coniferous and deciduous tree species. The non-stem biomass was calculated by subtracting the stem biomass from the aboveground biomass. The original values for volume and the parameters and results can be seen in tables 2-1 and 2-2. This gives an estimation of how much wood is left after extracting the growing stock. Because there was no reliable wood consumption values the existing consumption was not considered. Furthermore, the belowground biomass or biomass which should be left to the forest to ensure that the soil does not impoverish in nutrients were not considered.

Table 2-1. Average tree species volume (Statistical Office in Bydgoszcz, 2014), and biomass values and density and biomass expansion factor parameters (IPCC 2003) for Kujawsko-Pomorskie province.

Tree species	***Volume, m^3/ha***	***Density, t/m^3***	***BEF***	***AGB, t/ha***	**Non-stem biomass, t/ha**
Coniferous trees	273.6	0.42	1.3	149.3	34.5
Broadleaved trees	195.0	0.53	1.4	144.8	41.3
Mixed conifer	262.2	0.43	1.31	149.7	33.8

Table 2-2. Average tree species volume (Statistical Office in Katowice, 2014), and biomass values and density and biomass expansion factor parameters (IPCC 2003) for Silesia province.

Tree species	*Volume, m^3/ha*	*Density, t/m^3*	*BEF*	*AGB, t/ha*	**Non-stem biomass, t/ha**
Coniferous trees	268.1	0.42	1.3	144.8	33.8
Broadleaved trees	248.7	0.54	1.4	189.1	53.7
Mixed conifer	262.1	0.45	1.33	158.4	38.9

2.3 Land use/land cover maps

The CORINE Land Cover 2012 (CLC2012) land use/land cover map was used as the land use reference in this project. CLC is the land cover inventory done by the Copernicus Land Monitoring Services and European Environmental Agency (EEA) working under the European Commission. CLC inventory has been done four times now with reference years 1990, 2000, 2006 and now 2012. The CLC2012 has been done during 2013 – 2015, and it has the temporal coverage of 2011 – 2012. However, the CLC2012 does not have yet a full European coverage and has, thus, not been validated. The land cover map does, however, cover Poland fully. CLC2012 has been done using IRS (Indian Remote Sensing), SPOT (Satellite Pour l'Observation de la Terre) and RapidEye dual coverage satellite imagery, orthophotos, topographic maps.

CLC2012 has minimum mapping unit of 25 ha, minimum mapping with of 100m, and has been reported to have thematic accuracy of more than 85 %. The accuracy figure is, however, valid only on the whole map extent scale; therefore, it is not directly valid on local scale.

The land cover classes in CLC2012 are done in three different levels, with 5, 15, and 44 different classes, respectively from level 1 to 3 (Table 2-3). The level 3 classes of agricultural areas, and forests and semi-natural areas were used for the biomass mapping. Other areas were considered as non-productive areas, when agriculture or forest biomass is concerned.

Table 2-3: CORINE Land Cover 2012 original land use class levels.

LEVEL 1	LEVEL 2	LEVEL 3
1. ARTIFICIAL SURFACES	1.1. Urban fabric	1.1.1. Continuous urban fabric
		1.1.2. Discontinuous urban fabric
	1.2. Industrial, commercial and transport units	1.2.1. Industrial or commercial units
		1.2.2. Road and rail networks and associated land
		1.2.3. Port areas
		1.2.4. Airports
	1.3. Mine, dump and construction sites	1.3.1. Mineral extraction sites
		1.3.2. Dump sites
		1.3.3. Construction sites
	1.4. Artificial, non-agricultural vegetated areas	1.4.1. Green urban areas
		1.4.2. Sport and leisure facilities
2. AGRICULTURAL AREAS	2.1. Arable land	2.1.1. Non-irrigated arable land
		2.1.2. Permanently irrigated land
		2.1.3. Rice fields
	2.2. Permanent crops	2.2.1. Vineyards
		2.2.2. Fruit trees and berry plantations
		2.2.3. Olive groves
	2.3. Pastures	2.3.1. Pastures
	2.4. Heterogeneous agricultural areas	2.4.1. Annual crops associated with permanent crops
		2.4.2. Complex cultivation patterns
		2.4.3. Land principally occupied by agriculture, with significant areas of natural vegetation
		2.4.4. Agro-forestry areas
3. FOREST AND SEMI-NATURAL AREAS	3.1. Forests	3.1.1. Broad-leaved forest
		3.1.2. Coniferous forest
		3.1.3. Mixed forest
	3.2. Scrub and/or herbaceous associations	3.2.1. Natural grassland
		3.2.2. Moors and heathland
		3.2.3. Sclerophyllous vegetation
		3.2.4. Transitional woodland-scrub
	3.3. Open spaces with little or no vegetation	3.3.1. Beaches, dunes, sands
		3.3.2. Bare rocks
		3.3.3. Sparsely vegetated areas
		3.3.4. Burnt areas
		3.3.5. Glaciers and perpetual snow
4. WETLANDS	4.1.Inland wetlands	4.1.1. Inland marshes
		4.1.2. Peat bogs
	4.2.Marine wetlands	4.2.1. Salt marshes
		4.2.2. Salines
		4.2.3. Intertidal flats
5. WATER BODIES	5.1. Inland waters	5.1.1. Water courses
		5.1.2. Water bodies
	5.2. Marine waters	5.2.1. Coastal lagoons
		5.2.2. Estuaries
		5.2.3. Sea and ocean

2.4 Land cover validation data

CORINE land cover map was validated using visually assessed plots. The creation and classification of the accuracy assessment plots were based on methodology created for EU funded project, ReCover (Sirro et al. 2013, Häme et al. 2013). About 100 sample plots were generated for both areas. The sample plots were sampled systematically using 11 km plot distance in Silesia and 14 km plot distance in Kujawsko-Pomorskie. This totaled to 99 plots in Silesia and 94 plots in Kujawsko-Pomorskie. The plots were square plots and each the reference plot coincided with a cell in the in the CLC2012 map, i.e. the sample plots were 100 m * 100 m squares with exactly one CLC2012 reference cell. This ensured that there were no mixed pixels. Each plot was classified into the classes based on majority rule meaning largest class in total area was selected. The classification was done based on Google Earth high-resolution imagery, where majority of the images were from the years 2014-2015.

The sample plots were visually assessed for land use using the level 1 classification (Table 2). Only the level 1 classification was used and not a more detailed level, because the accuracy of visual assessment of level 2 or level 3 classes would have been too difficult and would have resulted with high probability in inaccurate data.

3 Methods

3.1 Biomass mapping

After acquiring the biomass values for different agriculture and forest land use classes and acquiring the best possible LULC classification map, the biomass distribution maps were possible to create by using these two datasets. The biomass mapping was done for a result grid with 1 km x 1 km result units. The surplus biomass of agricultural residue was calculated for the result grid cells. The residue surplus was calculated as total surplus residue from agriculture, as well as for main crops: wheat, corn, rapeseed, rye, triticale, barley, and grass. Forest biomass was calculated as the biomass of non-stem biomass (see chapter 2.2.2).

The agriculture land use classes were evaluated for mapping, that which biomass values could be connected to which class. For example, orchards-class were given only the orchard biomass, and class 2.4.3. (Land principally occupied by agriculture, with significant areas of natural vegetation) was assumed to have 50 % of mixed agriculture, therefore getting 50 % of the total surplus biomass. Also, forest land use were given only the biomass of the corresponding forest types, i.e. coniferous forest -class was given an average non-stem biomass of coniferous trees.

The mapping was done principally in two main stages. First, the land use map was combined with the result grid, resulting in a polygon with different land uses within each result unit. After the area of each land use class was known, the area could be used to calculate the amount of biomass. This was done by multiplying the area of each land use within a cell by the corresponding biomass value of that land use class. This resulted on the initial biomass distribution map.

Because the LULC classification and the biomass values incorporate error, it is important take that into consideration in the map. Because good accuracy assessment was done for the LULC classification (see section 3.2.2), it was possible to take that into consideration in the biomass maps. A level of reliability was calculated for each land use class in the accuracy assessment. It can be reasoned that if a class has for example an error-level of 50 %, then in the biomass map result unit that specific class can have in reality 50 % less area. In that case, also total biomass of that class within the result unit would be 50 % smaller when assuming an even distribution of biomass within the class. Based on this premise, a conservative biomass estimate (CBE) was calculated for each class. The CBE was calculated simply by multiplying the initial biomass with the classification accuracy of the corresponding class. This methodology does not, however, take into consideration the fact that in the case of misclassification the class would be in reality some other class. Therefore, the CBE values are not summable between classes, meaning that a total CBE cannot be calculated.

3.2 Accuracy assessment

There are two main sources of error in the biomass mapping, the LULC classification and the biomass values. The LULC classification can have misclassifications and with high probability these misclassifications are not random, meaning that the misclassifcations are usually into some certain direction, e.g. agriculture is more often misclassified as forest than settlement. The biomass values themselves can have multiple sources of error depending on the way the values have been generated. In the survey data the most prominent errors arise from the fact that most of the farmers are estimating the crop and residue production. Other main source is of course the fact the farmers are not selected in a statistically sound manner.

3.2.1 Biomass values

The accuracy of the biomass data cannot be fully assessed, because there is no validation data to compare it to. The farmer survey was conducted on a fairly small area in their respective provinces. However, when comparing the province total available biomass values to earlier studies done in Poland (Faber 2012), the values coincide very well with results in this study. Faber (2012) reported the amount of straw available for energy production 212 thousand tons and 67 thousand tons for Kujawsko-Pomorskie and Silesia, respectively. They assumed that 30 % of available straw could be used for energy production due to technical and other constraints. With that assumption, Kujawsko-Pomorskie and Silesia had in our results 178 and 57 thousand tons available, which is reasonably close to the figures reported by Faber (2012).

3.2.2 Land use/land cover map

The level of accuracy of the CLC2012 map in the two project provinces was assessed by doing a cell-level accuracy assessment using an independent reference plot data. The plot data was created to cover all of the pilot areas and to cover all common land use classes to get an unbiased estimate for the accuracy. The reference plots were visually assessed to mark every plot with a reference class, which were compared to the classified classes by creating a confusion matrix. Naive accuracy statistics and Cohen's kappa statistic were calculated using the confusion matrix.

Multinomial accuracy tests can be used to assess errors of individual classes in a thematic map. Such tests show the error frequencies by thematic class. Multinomial tests are based on a confusion matrix which shows the number of observations (reference data) against the mapped (classified) data. The confusion matrix is the most commonly applied method for the accuracy assessment of thematic maps (Foody 2002). The columns of the matrix represent the observations and the rows the mapped classes. The matrix diagonal contains the number of correctly classified observations, while off-diagonal cells represent miss-classification. Based on such matrix, it is possible to derive the user’s accuracy and producer’s reliability, and overall accuracy. These statistics are commonly called naive statistics, as they do not take into consideration the difference in class size or take into consideration the effect of change. The user’s accuracy of a thematic class is the portion of observations for that class that have been mapped (classified) correctly. In other words, if the user goes into some particular location on the map, the user’s accuracy gives the probability that the land use is correct in the map. The producer’s reliability is, on the other hand, the portion of the mapped samples in a class that are correctly classified. So, this gives the producer of the map the probability of a class to be correctly classified. The overall accuracy is the amount of correctly classified cells. The overall accuracy can be derived by considering all off-diagonal cells in the matrix as misclassifications (Olofsson et al. 2013).

The Cohen's kappa index of agreement (Cohen 1960) can be used as a measure of classification accuracy. It is derived from the confusion matrix. The kappa index compensates for the effect of differences in class sizes in the sampled data (observations). The usual form of the kappa index (unweighted kappa) considers all errors as equally important. The kappa index can be calculated as described by Rossiter (2004). Kappa index gives a value between -1 and 1. If kappa is more than zero, the classification is considered to be better than mere change. Landis and Koch (1977) have created a way to interpret the Cohen's kappa coefficient values (Table 3.1). It should be remembered, however, that this kind of interpretations and especially the class limits are always subjective.

Table 3-1: Cohen's kappa coefficient interpretation based on Landis and Koch (1977).

Cohen's kappa coefficient	Strength of agreement
<0.00	Poor
0.00-0.20	Slight
0.21-0.40	Fair
0.41-0.60	Moderate
0.61-0.80	Substantial
0.81-1.00	Almost perfect

4 Results and discussion

4.1 Land use/land cover mapping

The land cover map was done by the Copernicus Land Monitoring Services working under the European Commission. The land cover classification was for the year 2012, and it was the best available classification for the areas of interest in Poland. While the original classification has 44 different classes only five was used for this study. Moreover, only those five were classified for the land cover validation data. A preliminary validation of accuracy has been conducted in the European Environmental Agency (EEA) for the CLC2012 product (EEA 2015), which covered majority of the map area (80 %), including Poland. The thematic accuracy of the map was reported as 83.3 % for the entire European area. The accuracy for Poland's major bio-geographic region (Continental) was 84.1 %. Small part of southern Silesia is in the Alpine bio-geographic region where the accuracy was 83.8 %. Copernicus Land Monitoring Services will be doing a more detailed validation for the full 44 classes in the near future. It was assumed that the validation accuracy of the aggregated 5 classes would be better than accuracy for 44 classes, but at the same time the CLC2012 validation is valid only on European and bio-geographic region scale, which is considerably larger than the scale we conducted our validation, province scale.

The project areas were both validated separately using about 100 sample plots. The results of those validations can be seen from table 4.3. The overall thematic accuracy on both areas was about 79 %, which is slightly lower than the EEA accuracy, but on the same level, which was expected. Overall the accuracy is good, and makes the use of the CLC2012 data justified. The Cohen's kappa value was 0.648 for Silesia and 0.56 for Kujawsko-Pomorskie. Both kappa coefficients are both good, Kujawsko-Pomorskie kappa value being moderate and Silesia kappa value substantial, according to Landis and Koch (1977). The reason, why Kujawsko-Pomorskie has slightly lower kappa value even though the overall accuracies of the two areas are the same, is most likely due to the more varied landscape in Kujawsko-Pomorskie. There are more forested areas in Kujawsko-Pomorskie which results into more varied landscape and ultimately into more difficult area to classify.

On both provinces the two main classes, agriculture and forest, cover more than 80 % of the areas, and those are the classes of interest also in this study. In Silesia the user's accuracy is for agriculture and forestry, 70 % and 100 %, respectively, and the producer's reliability, 94 % and 73 %, respectively. In Kujawsko-Pomorskie, user's accuracy is for agriculture and forestry, 85 % and 64 %, respectively, and the producer's reliability is 87 % and 70 % respectively. The forest areas are easier to classify in Silesia where they are more frequent and most likely more clearly separated from the other classes. In Kujawsko-Pomorskie the forest areas are not as common and agriculture areas are more often than in Silesia a mosaic of forest and agriculture, which makes it more difficult to separate the two. The misclassifications are for forest mainly with agriculture, and for agriculture they are along with forests also with settlement class. The three other classes on top of agriculture and forest, settlement, wetlands, and water, have very small portions in the classification and, thus, there are not that many validation plots which hit those classes. Therefore, there is not much that can be concluded for those classes.

4.2 Biomass mapping

The field survey, which was conducted in Torun region in Kujawsko-Pomorskie province and Upper Silesia region in Silesia province, resulted in farmer data about their current year production of crops and residue, and use of that residue. This data was further analyzed and the result for both areas can be found from tables 4-1 and 4-2. The result tables show the average biomass residue, which is the residue after farmers' own use, average residue without reductions, and average crop yield. In both provinces wheat is the most important crop for residue biomass production, even though corn has the highest total residue production in Torun region and also in Upper Silesia has one of the highest productions of residue. In Torun corn has a very high residue production, but zero available residue. According to farmers' answers corn is used heavily as animal fodder. However, many farmers did answer that corn residue is available for selling or are selling corn residue already, but due to insufficient data the amount of residue could not be quantified. It can be outlined that some corn residue most likely is available also in Torun region for selling. Wheat, however, is the most important crop having the most area in both regions, 27.3 % in Torun region and 29.6 % Upper Silesia region. Wheat also has decent surplus residue in both regions, during one year the surplus residue is 1.12 tons/ha in Torun region and 0.59 tons/ha in Upper Silesia. Wheat produces about half of the surplus residue in Torun region and about one third in Upper Silesia of the total. The surplus residue from all crops is in Torun region and in Upper Silesia is on average 0.60 and 0.59 tons/ha during one year, respectively.

Table 4-1: Field survey results for selected crops in Torun region, in Kujawsko-Pomorskie province.

crop	Relative Area	AVG surplus residue, tons/ha	AVG residue, tons/ha	AVG yield, kg/ha
corn	18.3%	0.00	8.91	7350
wheat	27.3%	1.12	4.64	9700
rye	5.3%	1.21	4.94	4100
barley	5.7%	0.38	3.49	4800
rapeseed	6.7%	0.05	1.54	3700
triticale	6.5%	0.72	5.56	5700
grass	9.2%	1.50	3.20	3200
all crops		0.60	4.64	

Table 4-2: Field survey results for selected crops in Upper Silesia region, in Silesia province.

crop	Relative Area	AVG surplus residue, tons/ha	AVG residue, tons/ha	AVG yield, kg/ha
corn	12.3%	1.43	7.69	19350
wheat	29.6%	0.59	3.73	4800
rye	9.7%	0.78	2.66	4150
barley	19.7%	0.34	3.54	4950
rapeseed	10.2%	0.49	3.49	3750
triticale	7.6%	0.42	2.98	3950
grass	0.6%	0.00	5.00	11750
all crops		0.59	3.88	

The figures 4-2 and 4-4 show the results for agriculture biomass surplus mapping for Silesia and Kujawsko-Pomorskie, respectively. Values represent the Conservative Biomass Estimate (CBE) for each 1 km x 1 km cell. Based on the mapping it is clear that Kujawsko-Pomorskie has much more agriculture surplus biomass than Silesia. Majority of Kujawsko-Pomorskie area has around 40-60 tons of biomass surplus per year per 1 km^2 pixel. In Silesia the biomass surplus varies between no biomass surplus and decent biomass surplus depending on the land use distribution. The areas of no agriculture biomass are mainly those which have dense forest cover. Figures 4-3 and 4-5 show the forest nonstem aboveground biomass coverage in Silesia and Kujawsko-Pomorskie provinces, respectively. The forest biomass in Kujawsko-Pomorskie is limited mainly to the areas along the Wisla and Brda rivers, which flow through the province. In Silesia, however, there are several large areas on all sides of the province where there are quite large forest biomass coverage.

The biomass result maps can also be downloaded from the Arbonaut ftp-server in ESRI shapefile format:

Host: ftp.arbonaut.com (ftp://BEST@ftp.arbonaut.com if you are using Windows Explorer or a browser)
Username: BEST
Password: DUn5qHZ8
The results for Poland can be found under BEST_Poland –folder.

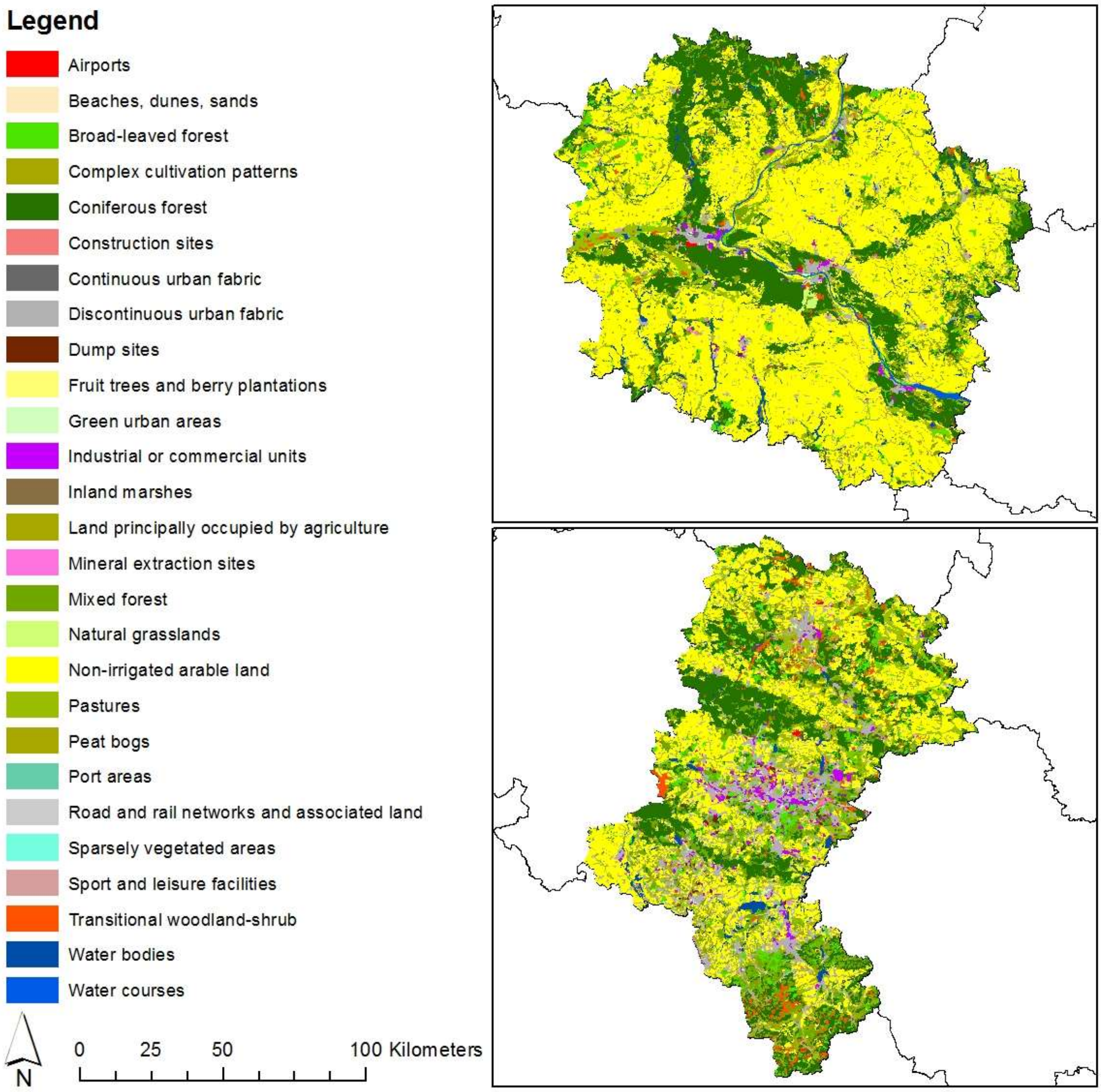

Figure 4-1: CORINE 2012 land cover map for Kujawsko-Pomorskie (above) and Silesia (below) provinces.

Table 4-3: Accuracy assessment results of CORINE land cover map for 2012 at province-level. Accuracy results are presented by province with overall, user's and producer's accuracy, confidence intervals of the accuracies, as well as Cohen's kappa statistics.

SILESIA

Map \ Reference	Settlement	Agriculture	Forest	Wetlands	Water		User's accuracy	CI lower limit	CI upper limit
Settlement	6	2	5	0	0	13	46%	15%	77%
Agriculture	4	32	10	0	0	46	70%	55%	84%
Forest	0	0	40	0	0	40	100%	99%	101%
Wetlands	0	0	0	0	0	0	NA	NA	NA
Water	0	0	0	0	0	0	NA	NA	NA
	10	34	55	0	0	99			
Producer's reliability	60%	94%	73%	NA	NA				
CI lower limit	25%	85%	60%	NA	NA				
CI upper limit	95%	103%	85%	NA	NA				
Overall accuracy	79%	**Cohen's Kappa**							
CI lower limit	70%	0.648							
CI upper limit	87%								

KUJAWSKO-POMORSKIE

Map \ Reference	Settlement	Agriculture	Forest	Wetlands	Water		User's accuracy	CI lower limit	CI upper limit
Settlement	3	0	0	0	0	3	100%	83%	117%
Agriculture	2	55	6	0	2	65	85%	75%	94%
Forest	0	7	14	0	1	22	64%	41%	86%
Wetlands	0	1	0	0	0	1	0%	-50%	50%
Water	0	0	0	1	2	3	67%	-3%	137%
	5	63	20	1	5	94			
Producer's reliability	60%	87%	70%	0%	40%				
CI lower limit	7%	78%	47%	-50%	-13%				
CI upper limit	113%	96%	93%	50%	93%				
Overall accuracy	79%	**Cohen's Kappa**							
CI lower limit	70%	0.560							
CI upper limit	88%								

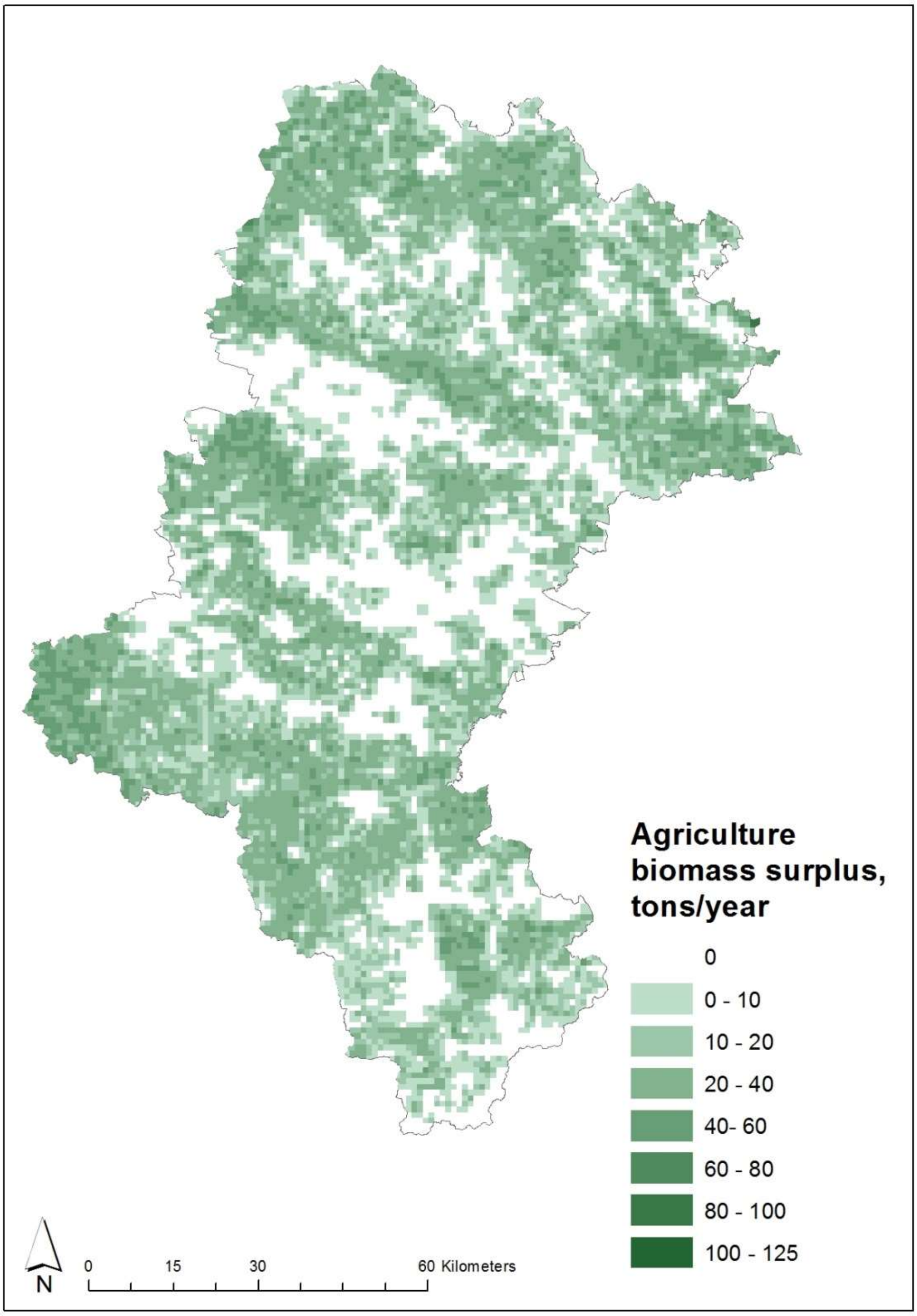

Figure 4-2: Silesia agriculture biomass surplus estimate in tons per year.

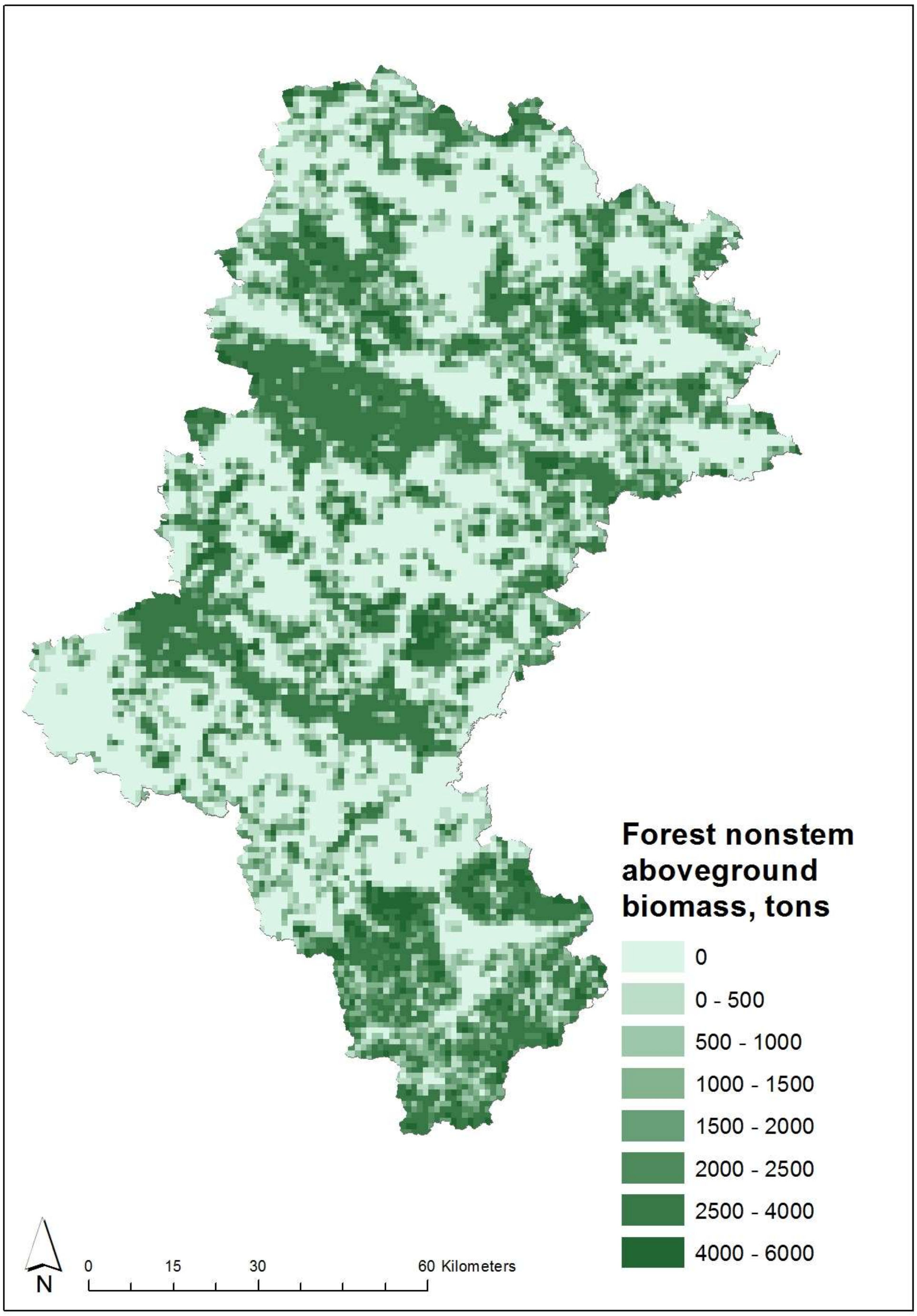

Figure 4-3: Silesia forest nonstem aboveground biomass in tons.

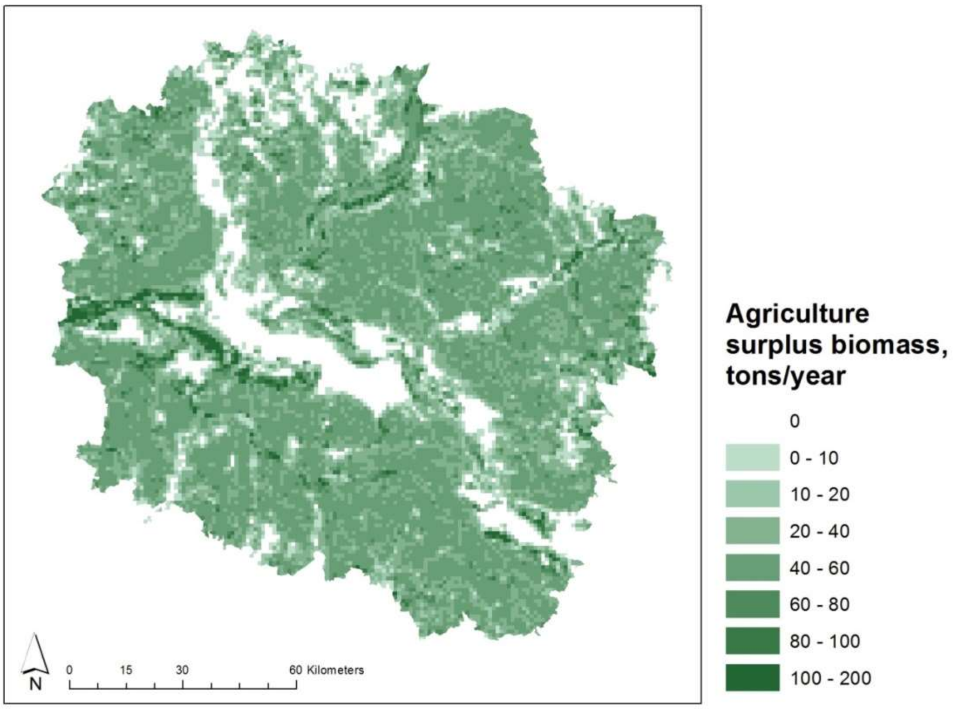

Figure 4-4: Kujawsko-Pomorskie agriculture biomass surplus estimate in tons per year.

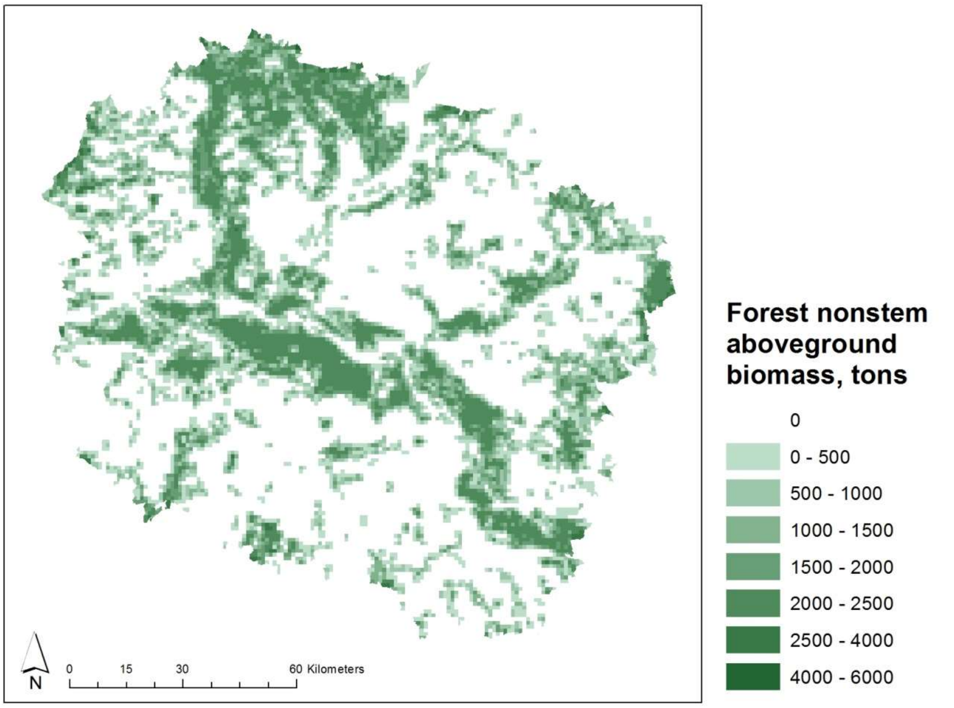

Figure 4-5: Kujawsko-Pomorskie forest nonstem aboveground biomass in tons.

5 Conclusions

The aim of this study was to map available agriculture biomass surplus for bioenergy purposes in Poland. Moreover, the forest biomass storage of nonstem aboveground biomass was mapped. This nonstem biomass means mainly the branches of the trees, the portion of the tree which would be used for bioenergy production. The mapping was done using the best possible GIS data available, literature, and a field survey conducted in Poland for farmers in both project provinces. The mapping was conducted for two provinces in Poland, Kujawsko-Pomorskie in Central Poland and Silesia in Southern Poland. Kujawsko-Pomorskie is agriculture heavy province with relatively small areas of forest, whereas Silesia has larger areas of forest cover which alternates in the landscape with areas of agriculture.

The LULC accuracy is one of the most important points when using this methodology, as the distribution of different land uses is dependent on it. The CORINE Land Cover 2012 (CLC2012) proved to be very good for the purpose with its fairly recent date, reliable source and the accuracy, which proved to be on the level that it can be used in this project, even though we were using a continent level LULC map in provincial level. The existing classification errors were taken, however, into consideration by calculating the conservative biomass estimate (CBE). This way it can be taken into consideration that due to misclassifications the biomass from agriculture residue surplus might be lower.

The result biomass maps are a good representation of the distribution of available agriculture and forest biomass which could possibly be used for bioenergy production. The mapping does not take some critical issues into consideration which will limit the actual amount of biomass which can be used. For example the road conditions or similar logistical limitation have not been taken into consideration. This mapping, however, gives an image of the overall situation and can be used as a starting point in planning of new bioenergy based power plants.

6 Acknowledgement

The work was carried out in the Sustainable Bioenergy Solutions for Tomorrow (BEST) research program coordinated by CLIC Innovation with funding from the Finnish Funding Agency for Innovation, Tekes. The authors would like to thank the following project partners from Poland for their efforts to conduct the survey data with Polish farmers: Bartlomiej Iglinski from the Nicolaus Copernicus University, Aleksandra Kaczmarek, the International Faculty of Engineering, Lodz University of Technology, and Jakub Kajdanek, the Faculty of Biology and Environmental Protection, University of Lodz.

References

Cohen, J. 1960. A coefficient of agreement for nominal scales. Educational and Psychological Measurement 20 (1): 37–46.

European Environmental Agency & Copernicus Land Monitoring Services. 2015. Validation of CORINE Land Cover Products – Summary of preliminary results. EEA/MDI/14/010. 3 p.

Faber, A. 2012. Istniejący potencjał produkcji biomasy z upraw energetycznych – czy jest szansa na rozwój plantacji energetycznych? Forum Biomasy – produkcja, kontraktowanie, logistyka. Ostroleka 22.-23. March 2012. (In Polish)

URL: http://scc.com.pl/konferencje/prezentacje/BPKL_22-23-03-2012/04 Antoni Faber.pdf

Foody, G.M. 2002. Status of land cover classification accuracy assessment. Remote Sensing of Environment 80: 185-201.

Główny Urząd Statystyczny – Central Statistics Office (GUS). 2015. Energia – Energy 2015. Production Department CSO Energy and Raw Materials Balances Section, Warsaw. 28 p.

Główny Urząd Statystyczny – Central Statistics Office (GUS). 2015. Energy Statistics in 2013 and 2014. Statistical Information and Elaborations, Warsaw. 294 p.

Intergovernmental Panel on Climate Change (IPCC). 2003. Good Practice Guidance for Land Use, Land-Use Change and Forestry. Eds. Penman, J., Gytarsky, M., Hiraishi, T., Krug, T., Kruger, D., Pipatti, R., Buendia, L., Miwa, K., Ngara, T., Tanabe, K., Wagner, F. IPCC National Greenhouse Gas Inventories Programme, Technical Support Unit. pp. 3.171 & 3.178

Häme, T., Sirro, L., Cabrera, E., Enßle, F., Haarpaintner, J., Hämäläinen, J., de Jong, B., Paz Pellat, F., Pedrazzani, D. and Reiche, J. 2013. ReCover: A Concept for Tropical Forest Assessment for REDD+. Living Planet Symposium 2013, 9. - 13. September, 2013, Edinburgh. 8 p.

Landis, J. and Koch, G. 1977. The measurement of observer agreement for categorical data. Biometrics 33: 159–174.

Nilsson, L., Pisarek, M., Buriak, J., Oniszk-Popławska, A., Bućko, P., Ericsson, K. 2004. Bioenergy Policy and Strategies for Poland. 2nd World Conference on Biomass for Energy, Industry and Climate Protection, Italy, Rome, 10-14 May.

Olofsson, P., Foody, G.M., Stehman, S.V. and Woodcock, C.E. 2013. Making better use of accuracy data in land change studies: Estimating accuracy and area and quantifying uncertainty using stratified estimation. Remote Sensing of Environment 129: 122-131.

Rossiter, D.G. 2014. Technical Note: Statistical methods for accuracy assessment of classified thematic maps. Department of Earth Systems

Analysis, International Institute for Geo-information Science & Earth Observation (ITC), Enschede, The Netherlands. URL: http://www.itc.nl/~rossiter/teach/R/R_ac.pdf

Sirro, L., Häme, T., Rauste, Y., Antropov, O., Hämäläinen, J., Latva-Käyrä, P., Paz, F. and de Jong, B. 2013. Comparison of Optical and SAR Data in Tropical Land Cover Classification for REDD+. Living Planet Symposium 2013, 9. - 13. September, 2013, Edinburgh. 7 p.

Statistical Office in Katowice. 2014. Statistical Yearbook Śląskie Voivodship 2014. 438 p.

Statistical Office in Bydgoszcz. 2015. Statistical Yearbook Kujawsko-Pomorskie Voivodship 2014. 395 p.