Proposal of methodology for determining of potential residual biomass for agriculture and forestry in Slovak republic

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The issue of efficient use of biomass as a renewable source of energy in the process of sustainable development of every country is a problem that is often tackled nowadays being also imposed by the legislation of the European Union. In the process of the accession to the EU, the Slovak republic incorporated the obligations as defined by the EU Directive 2001/77/EC on the promotion of electricity produced from renewable energy sources. Out of all the renewable sources of energy, biomass has the greatest economic potential to be used on the territory of Slovakia. The use of biomass for the purposes of electricity generation is the most promising alternative to generate not only thermal but also electrical energy. This paper presents the proposal of methodology developed to determine the utilization potential of residual biomass in the sectors of forestry and agriculture within a certain area of eastern Slovakia. The theoretical proposal is developed based on using Corine Land Cover. The application of Corine Land Cover and GIS tools made it possible to effectively determine residual biomass for the selected sectors of the economy.

Keywords: *Corin Land Cover, methodology, residual biomass, GIS*

Introduction

Based on the general definition of biomass, at this point it is necessary to provide a specific definition ofthe term. Since biomass as a source of energy is dealt with by a large number of qualified experts not only in Slovakia but also abroad, the following parts of the paper will focus on establishing and introducing a preliminary definition of this term. On the territory of the Slovak republic biomass is one of the several sources of clean energy with a high potential of utilization (Resch et al., 2011). According to *the Directive 2001/77/ES* the term biomass means " *the biodegradable fraction of products, waste and residues from agriculture* (including vegetal and animal substances)*, forestry and related industries as well as the biodegradable fraction of industrial and municipal waste*" (Directive 2001/77/ES). Regulation of the Government of the SR *No 246/2006 Coll.,* defines biomass in a narrower context as " *the biodegradable fraction of a product or residues of vegetal and animal substances from agriculture, forestry and related industries or the biodegradable fraction of industrial and municipal waste* " (Regulation No 246/2006 Coll.).

In light of further relevant legislation, i.e. *Act No 309/2009*, biomass means the biodegradable fraction of a product, residue from vegetal and animal substances from agriculture, forestry, the biodegradable fraction of municipal and industrial waste, including black liquor from wood processing (Act 309 of 19 June 2009). In general, biomass can be considered the most important renewable source of energy. In terms of utilization, biomass as a source of energy is suitable to produce thermal energy, electrical energy, biogas and biofuels. In terms of general definition there are two basic types of biomass: biomass of vegetable and biomass of animal origin. (Trenčianský et al., 2007). Due to its high energy efficiency, traditional biomass creates prerequisites for partial independence of society from fossil fuels (Resch et al., 2011, Pastorek, 2001).

The above-mentioned subject matter is tackled through implementation of Corine Land Cover methodology (CLC). The advantage of interconnecting several methodological techniques to deal with the above referred problem is simplification and automation of the process of determination of the residual biomass potential.

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Study area

Generally Slovakia is a landlocked Central European country with mountainous regions in the north and flat terrain in the south. Slovakia borders Poland in the north - 547 km, Ukraine in the east - 98 km, Hungary in the south - 669 km, Austria in the south-west - 106 km, and the Czech Republic in the north-west - 252 km for a total border length of 1672 km. The relief of the country is characterised by great differences (Commertial Slovakia Directory). Two main geographic regions define the Slovakian landscape:

- the Carpathian Mountains
- the Pannonian Basin.

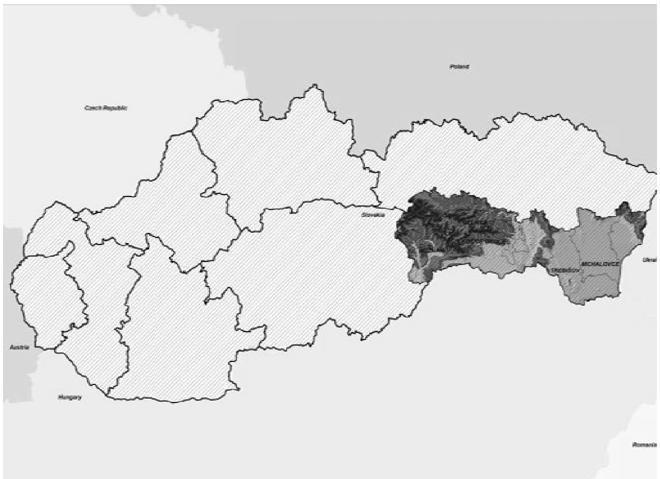

Fig. 1. Location and overview of study area.

The Kosice self-governing region is one of eight self-governing regions in Slovakia. The area of the region is 6751.9 km^2 which means it is the fourth largest in Slovakia. It is divided into 11 districts (*see Fig.1*). It is geographically various and diverse. The territory of the Kosice region comprises East-Slovakian plain, the Zemplin hills, part of the Kosice Basin, the Bodvianska Heights, the Slanske and Vihorlatske hills. The Slanske hills stretch along the central part of the region.

According to the geomorphological division of Slovakia (Mazúr et al., 1986) the area in question is located in the northern part of the Kosice Basin and Toryska pahorkatina hills (Petro, Polaščinová, 1992). The territory of the region is located 231 – 275 m above the sea level and lies in the moderately warm climate zone T-1 (Quitt, 1971) characterized by long summers, warm, dry and very short transition period with a warm or moderately warm spring and autumn, winters are moderately warm, dry even very dry with short duration of snow (50-80 days).

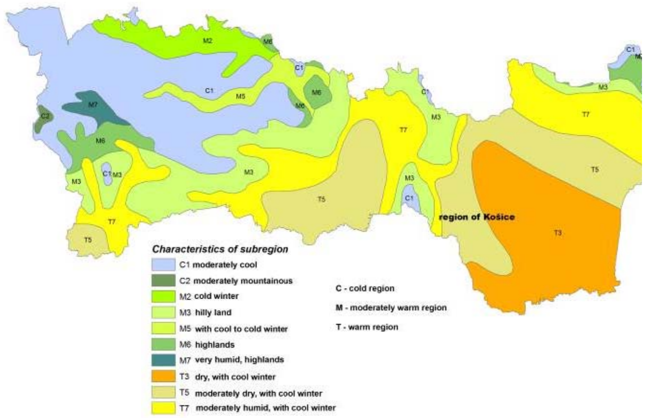

Fig. 2. Location and overview of climatic region.

The agricultural land has an area of 336 942 hectares and occupies 39,52 % of the region's territory. The southern and south-eastern parts of the plain account for the higher share of the region's total area. In the East-Slovakian plain as well as in non-flood prone areas of the Kosice Basin, there can be found black earth, brown and illimerised soils (Albic Luvisols) which are less fertile. In the river alluvial plains, alluvial soils are Fluvisols and flood-plain soils are Phaeozems. Silicate rocks of the mountains are covered by brown forest soils Cambisols, on limestone and dolomites there developed rendzina.

The forest land has an area of 266 929 hectares and occupies 39, 52 % of the region's territory (RegDat regional statistics database). These forests are found in the mountains and foothills in the northern and south-western part of the region (the Slovak Ore Mountains, the Slovak Paradise, the Slovak Karst) with prevailing deciduous forests (oak, hornbeam) or mixed forests of the moderate zone (beech, fir). The south-eastern part of the region is covered with riparian forests.

Geographical location, climate conditions, pedological potential are accompanying factors for production of biomass in the Kosice region. In terms of the high energy utilization potential of biomass, this part of Slovakia is one of the regions having *great potential according* to the evaluative report of the Kosice self-governing region.

Methodology

Tab. 1. Basic characteristics of CLC.

Corin Land Cover	
Minimum mapping unit	25 ha
Location accuracy	100 m
Area covered	> 3 million km^2
Nomenclature	3 levels, 44 classes

The methodology is based on the bottom-up approach and considers the really used land: data come from Corin Land Cover (CLC), country-to-country basis. The methodology is applied to Nuts-3 region level. In generally the CLC approach classifies the different types of land cover into a limited number of standard European classes. As a result, CLC data are comparable across Europe. The mapping scale of CLC is 1:100 000 and the smallest mapping unit is *25 ha*. The updated plan will be based on a list of CLC changes, kept by satellite images. CLC is so used as Geo-referential data base in order to map the biomass potential typologies on the basis of the real land use. The European nomenclature of CLC distinguishes *44 different types* of land use cover; in some cases, this classification has been integrated with a more detailed level (EEA, 2000, Gallego, 2011).

In Košice area the CLC nomenclature includes *26 different types* of soil utilization given in the following *Fig. 3* Graphical illustration of CLC by area and method of utilization which was elaborated using GIS tools. The applied CLC color range was not stochastic, but it was strictly prescribed by a particular RGB for each type of the nomenclature in the assessed region.

Graphical representation of CLC under developed area and usage has been processed by using the GIS environment. CLC color scale used is not accidental, but exactly been prescribed a specific RGB value for each type of nomenclature of Košice area. Illustrates *Fig. 3.*

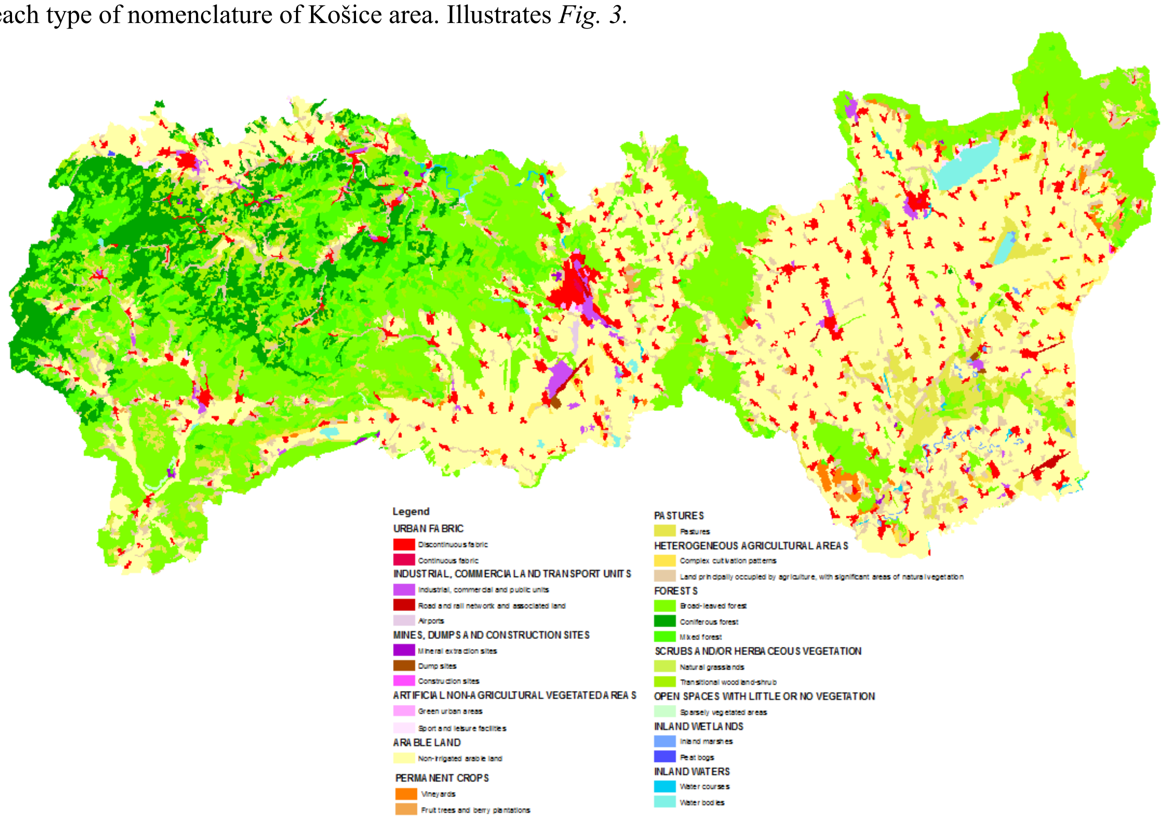

Fig. 3. CLC of Košice region.

In the calculation it was necessary to take into account the proportion of individual types of land utilization for the purposes of its further application in the sector of forestry and agriculture. Spatial tools of geographical information systems were used for the demarcation of land areas. The results of these measurements are shown in *Fig.4* characterizing the respective area in relation to the unit of acreage (ha - hectare).

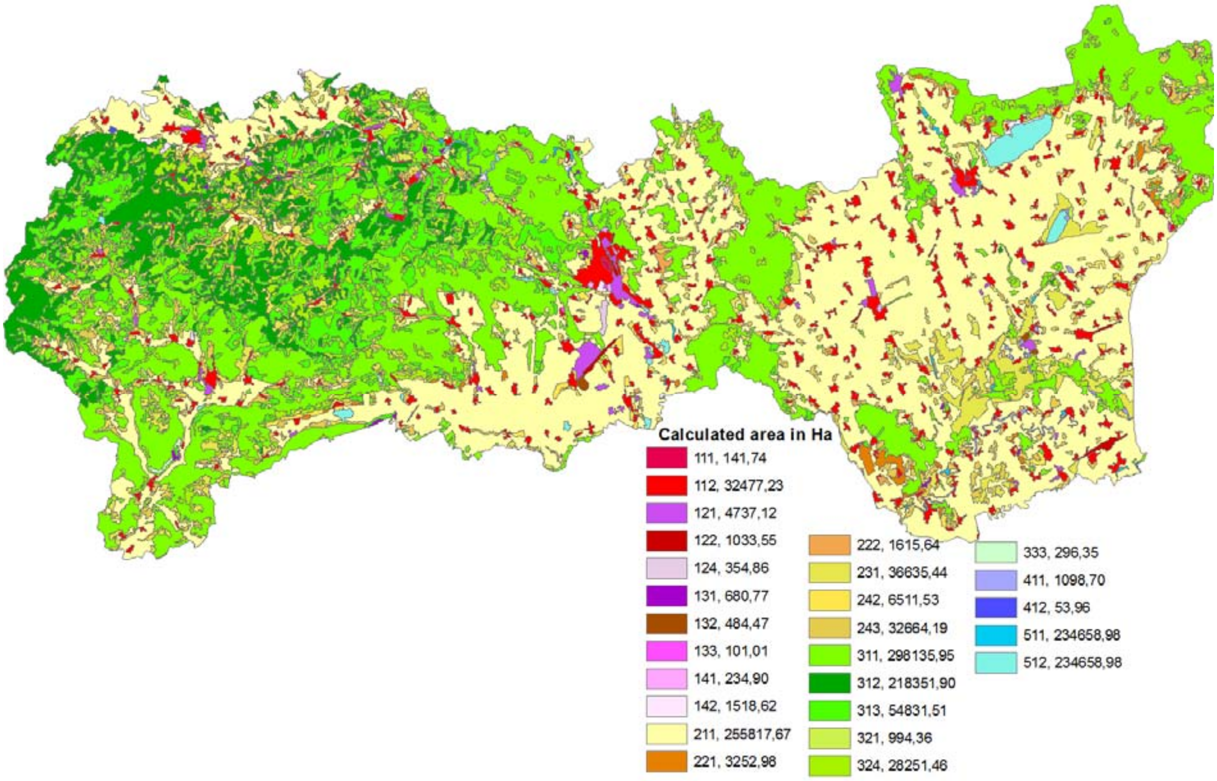

Fig. 4. Calculated area in Ha.

The calculated values for each type of land use with the specified frequency in a transparent level are shown in *Tab.2*.

Tab. 2. Summarizing the calculated area units with a frequency of occurrence for selected types of CLC.

CLC code	Frequency	Total are of code in Ha	CLC code	Frequency	Total are of code in Ha
111	2	141,7421	231	369	36635,44
112	409	32477,23	242	97	6511,531
121	41	4737,116	243	468	32664,2
122	9	1033,551	311	242	298135,9
124	1	354,8559	312	168	218351,9
131	16	680,7742	313	320	54831,51
132	7	484,4682	321	11	994,3556
133	3	101,0095	324	366	28251,46
141	5	234,8977	333	3	296,3467
142	24	1518,619	411	23	1098,701
211	165	255817,7	412	1	53,95715
221	41	3252,977	511	23	234659
222	22	1615,641	512	17	4862,143

Biomass analysis for the selected area

Two main biomass analyses for selected area were assumed:

1. potential forest residues,
2. potential agricultural residues.

Residual biomass from forest sector

For the forest category, potential biomass deriving from broad-leaved forest cultivation, coniferous forest and biomass residues from mixed forest are selected. The amount of biomass from each forest type is calculated by multiplying the available land (by its CLC code) by the corresponding residue productivity index. Indexes of residue production are summarized in *Tab. 3*.

Tab. 3. Index of residual production by the forest sector (Biomass Handout, 2011).

Forestal wood categories	Type of Biomass	Biomass production[2] $[t_{dm}/ha]$	Harvest moisture [%]	Lower Heating Value $[MJ/kg_{dm}]$
Hardwood Forest	tops and branches	2 – 4	25 – 60, 40	18.5 – 19.2
Coniferous Forest	tops and branches	2 – 4	25 – 60, 40	18.8 – 19.8
Wood from river bank	Tops and branches	0.8 – 1.6 [3]	40 – 60	16 -18

[1] Range and Average value
[2] Range value is referred to "wet tons per 100 m linear meter"

Residual biomass from agricultural sector

The calculation is done for each class of agricultural sector; the classes selected from CLC available codes are: vineyard, fruit tree plantations, non irrigated arable land used for cereal cultivations. The harvest indexes of their residues are considered and multiplied by the respective areas. In calculation for the selected CLC parts, for example, for the areas utilized for farming purposes it is necessary to consider some parameters. In particular, the following parameters apply to crop growing in the agricultural sector:

- type of biomass - residue
- residual Ratio - main product/residue
- biomass production $[t_{dm}/ha]$
- harvest moisture [%]
- lower Heating Value $[MJ/Kg_{dm}]$

The harvest indexes of residues are calculated on the basis of several references, collected in bibliography and described in the Biomass Handouts: short summary of them is shown in *Tab*. 4. Provides an overview of information is processed on the conditions of the Slovak Republic.

Calculation of Potential Biomass

When evaluating the "available biomass" the model must include the different environmental, social and economic restrictions that may decrease the potential sources. Generally, the amount of the biomass residues from each above mentioned biomass class is determined as shown before. An example of a matrix with equations for biomass estimation is reported in Tab. 5.

A matrix calculation of the biomass for each territory can often contain thousands of polygons for each CLC code on the basis of the specific land use. Therefore, the different estimated biomass, linked to specific polygons, could contain more than some hundreds thousands of output data. These matrixes make possible the elaboration of the different biomass maps. To produce output biomass maps is appropriate to apply GIS tools, which currently represent a sort of standard use in different spheres of social life.

[2] *Range and average value*
[3] *Range value is referred to "wet tons per 100 m linear meter"*

Tab. 4. Residual values of Agricultural Crops .

Agricultural crops	Type of Biomass *(residue)*	Straw cultivation (Main product/residue)				Residual Ratio (Main product/residue)	Biomass production *(t_{dm}/ha)*	Harvest moisture *(%)*	Lower Heating Value *(MJ/Kg_{dm})*	References
			[3]	[4]	[5]					
Residual amount of agricultural crops										
Cereals	**Straw**	grain : straw	-	-	1: 0.8	0.8	-	-	-	[4]EkoWATT, The Renewable and Energy Efficiency Center, 2000 [5]www.tzb-info.cz [6] Decree-Law No. 2005-338 SR
Wheat	**Straw**	grain : straw	1: 1.85	1:0.85	-	1.85	-	-	-	
Rye	**Straw**	grain : straw	1:1.7	1:1.7	-	1.7	-	-	-	
Barley	**Straw**	grain : straw	1:0.8	1:0.8	-	0.8	-	-	-	
Oat	**Straw**	grain : straw	1:1.4	1:1.4	-	1.4	-	-	-	
Corn for grain	**Straw**	grain : straw	1:1.2	1:1.2	1:1.2	1.2	-	-	-	
Oil rape	**Straw**	grain : straw	1:1.2 -1.8	1:1.2 -1.8	1:2.0 - 3.2	1.2 - 1.8	-	-	-	
Legumes	**Straw**	grain : straw	-	-	1:1.1					
Sunflower	**Straw**	grain: straw	-	-	1:3.1					
Sugar beets	**Beets tops**	ball: tops	-	-	1:0.7					
Vineyards	**Leaves quantity**	the amount of grapes: the amount of leaves	-	-	1:1.5					
Hops	**The amount of green tops**		-	-	1:1.5					

[4] *For energy purposes can be used about 10-20 % of cereal straw*
[5] *For energy purposes, it is common to use about 70 to 90 % rape straw*
[6] *Decree-Law No. 2005-338 SR*

Tab. 5. Matrix for biomass calculation by using Corin Land Cover codes.

CLC Code	Polygon Area [ha]	Hardwood Forest Residues [$t_{d.m.}$/y]	Coniferous Forest Residues [td.m./y]	Mixed Forest Residues [td.m./y]	Vineyard Residues (woody) [td.m./y]	Fruit Trees Residues (woody) [td.m./y]	Straw Residues [td.m./y]
211	n_1	**0**	**0**	**0**	**0**	**0**	$I_{S1} = n_1 \times i_S$
211	n_2	**0**	**0**	**0**	**0**	**0**	$I_{S2} = n_2 \times i_S$
211	n_3	**0**	**0**	**0**	**0**	**0**	$I_{S3} = n_3 \times i_S$
213	n_1	**0**	**0**	**0**	**0**	**0**	**0**
213	n_2	**0**	**0**	**0**	**0**	**0**	**0**
213	n_3	**0**	**0**	**0**	**0**	**0**	**0**
221	n_1	**0**	**0**	**0**	$I_{V1} = n_1 \times i_V$	**0**	**0**
222	n_1	**0**	**0**	**0**	**0**	$I_{f1} = n_1 \times i_f$	**0**
311	n_1	$I_{h1} = n_1 \times i_h$	**0**	**0**	**0**	**0**	**0**
312	n_1	**0**	$I_{c1} = n_1 \times i_c$	**0**	**0**	**0**	**0**
313	n_1	**0**	**0**	$I_{m1} = n_1 \times i_m$	**0**	**0**	**0**
Total		$\sum I_{hn}$	$\sum I_{cn}$	$\sum I_{mn}$	$\sum I_{vn}$	$\sum I_{fn}$	$\sum I_{sn}$

The different indexes of the matrix are listed below:

Legend:

n_1, n_2, n_3 = Area of each polygon linked to different Corin Land Cover.
i_h = residues production index related to Hardwood forest species.
i_c = residues production index related to Coniferous forest species.
i_m = residues production index related to Mixed forest species.
i_v = residues production index related to Vineyard cultivation.
i_f = residues production index related to Fruit Trees cultivations.
i_s = residues production index related to Straw cultivation.

$\sum I_{hn}$ = Sum of the Biomass production by Hardwood residues of each polygon

$\sum I_{cn}$ = Sum of the Biomass production by Coniferous residues of each

$\sum I_{mn}$ = Sum of the Biomass production by Mix forest residues of each polygon belonging

$\sum I_{vn}$ =Sum of the Biomass production by Vineyard residues of each polygon

$\sum I_{fn}$ = Sum of the Biomass production by Fruit Tree residues of each polygon

$\sum I_{sn}$ = Sum of the Biomass production by Straw residues of each polygon

Conclusion

The aim of the article is to point at the problematics of the determining of potential residual biomass. The presented method of calculation of residual biomass is a theoretical proposal of calculation for agricultural sector and forest industry. The analysis of the residual biomass potential was performed using a matrix. The proposed calculation takes CLC into account and in Slovakian condition applies from residues production index related to hardwood forest species, coniferous forest species, mixed forest species, vineyard cultivation, fruit trees cultivations and straw cultivation. GIS tools made it possible to perform the real calculation of the land area for residual biomass.

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