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MEASURING THE ENERGY POTENTIAL OF BIOMASS FOR FIRING PURPOSES BY STATISTICAL AND GEOGRAPHICAL METHODS IN THE CASE OF A HUNGARIAN SETTLEMENT

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ABSTRACT. – Measuring the Energy Potential of Biomass for Firing Purposes by Statistical and Geographical Methods in the Case of a Hungarian Settlement. During our research we developed a method allowing to survey easily and quickly the herbaceous and woody biomass potential of any settlement in Hungary based on statistical and geographical data. Derived from the data, which can obtained from the Hungarian Central Statistical Office, it could be easy to calculate the assumable energy requirements of a given settlement. On the grounds of the method, one can recognize the settlements in a short period of time which may be suitable for the establishment of sustainable biomass-based cogeneration units on the long-term. The method can be applied in other countries as well, if the relevant national statistical database is available. During the research the town of Ibrány, which is lying in the north-eastern part of Hungary (fig. 1), was analysed in detail from multiple aspects. Furthermore, the suitability of Ibrány was analysed in order to find out whether potential bio-energy investments could be implemented in the town or not. In pursuance of the research, based on the Hungarian literature, Ibrány was found to be capable of the implementation of a bio-energy investment.

Keywords: *biomass, bioenergy, agriculture, rural development.*

1. INTRODUCTION

The Ibrány-Nagyhalász statistical micro-region is located in the north-western corner of Szabolcs-Szatmár-Bereg County in Hungary. The micro-region consists of 17 settlements. Having an area of 521 km^2, the micro-region makes up

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8.7% of the county. The centre of the micro-region is Ibrány (fig. 1), onto which the research focuses.

Based on preliminary research results the town has favourable social and economic features compared to other settlements of the micro-region. However, these settlements have a disadvantaged status, their populations are continuously declining and most of them live in extreme poverty.

All over Europe there are hundreds of heating plants using biomass which are able to cover 100% of the energy needs for a given settlement (Schmuck *et al.,* 2013). These village heating systems play an important role in the development of settlements which are lagging behind since both raw material production and consumption offer job opportunities for the local population (Johannes, 2013). Another important aspect is that the huge amount of the money spent on energy supply does not flow to foreign energy producing companies, but remain in the region since the energy is produced by energy sources of the local environment.

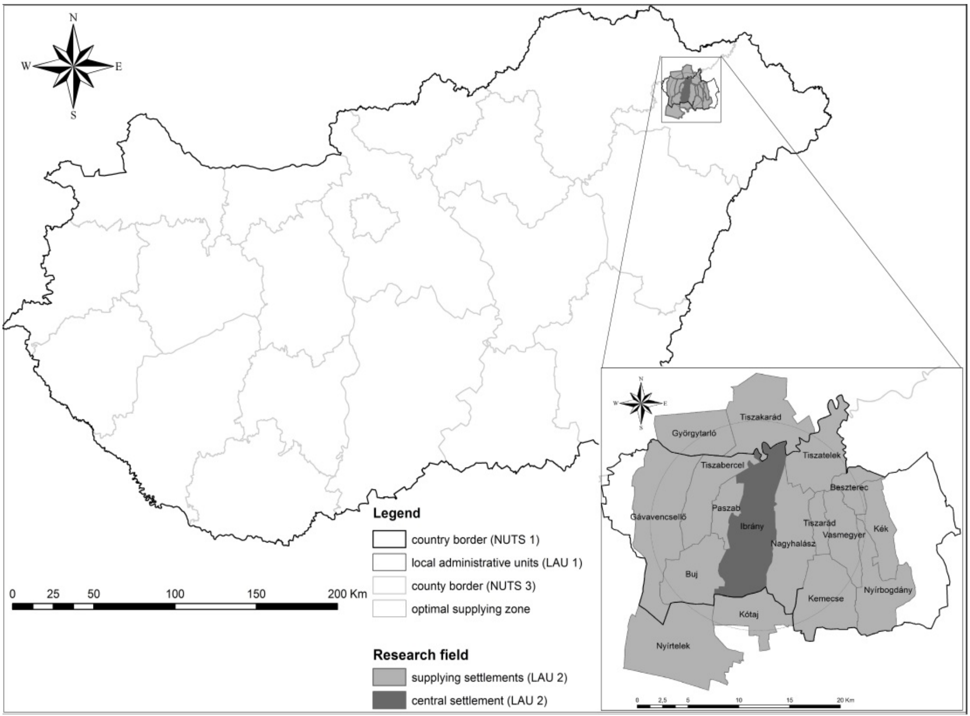

Fig. 1. The geographical location of the town of Ibrány

The study is divided into four parts:

- First, using statistical and geographical methods, a suitable supply zone was delimited, in which the biomass fuels can be produced for the town.
- Second, the energy potential of the agricultural by-products and the woody biomass in the delimited area was measured.
- Third, the annual energy needs of the town were estimated.
- Finally, the question of whether the environment of the settlement is suitable to serve the energy needs on the long-term was answered.

2. MATERIALS AND METHODS

The research results of Pintér (2012), further own calculations and estimates were used in order to delimit the suitable area fulfilling the biomass fuel needs of the studied settlement. Additionally, the impoundment of the suitable supply zone was created by using ArcGIS software.

The delimited area was studied from the aspects of land cover and spatial distribution of biomass on the basis of CLC (Corine Land Cover) 2006 raster data and seamless vector data. The smallest surfaces mapped (minimum mapping units) correspond to 25 hectares. Linear features less than 100 m in width (e.g. road, river) are not considered. The scale of the output product was fixed at 1:100,000. Thus, the location precision of the CLC database is 100 m, so it is not suitable for exact measurements. However, it illustrates the real geographical distribution of the biomass based on numeric data resources used in the research. CLC has 44 classes organised hierarchically in three levels, from which the areas with energy potentials and with other utilization potentials were separated into an individual class. The results were mapped using ArcGIS software.

Measuring the biomass potential based on agricultural by-products of the area delimited around Ibrány (r = 10.58 km) was derived from the MR-STAR 2013 (Regional statistical database system) and the ÁMÖ 2010 (Agricultural census) of the Hungarian Central Statistical Office.

According to the Agricultural census, the spatial distributions of forests, orchards, arable lands and vineyards of the delimited area's settlements were defined separately. In Hungary there is no such database that would made possible to estimate precisely the yields of agricultural products and by-products at municipal level, therefore the annually produced amount of herbaceous biomass in the region was estimated by a unique method in this paper. While estimating the potential, the agricultural land structure of the settlements was revealed by using the data of MR-STAR (2013) on Szabolcs-Szatmár-Bereg County. However, these data do not give an accurate description of the studied area since considering soil and weather conditions in the different parts of the county, the agricultural land structure may differ significantly from year to year. Nonetheless, due to the absence of municipal level data, only the above mentioned unique method could provide an accurate report on the agriculture land structure of the settlements.

After determining the agricultural land structure of the delimited area, the estimations of the specific yields per hectare of the agricultural by-products were based on the average values of the Hungarian Research Institute of Agricultural Economics (AKI) and the Hungarian literature. Of course, it was not possible to calculate with standard data from year to year since the weather, the genus of the cultivated plant and the cultivation techniques are changing constantly in each year. Therefore, the calculations were made by applying the average yields of the past five years, which were determined by AKI and the Hungarian literature.

To estimate the woody biomass potential of the settlement, the data of WWF Hungary and NÉBIH (Hungarian National Food Chain Safety Office – formerly the Hungarian Central Agricultural Office) were used.

In order to estimate the heat and electricity needs of the settlement and to separate the needs of the households, the industrial users and the local government, the five-year average data of T-STAR 2013 (Settlement statistical database system) of the Hungarian Central Statistical Office were analysed. The database manages separately the amount of gas and electricity used for heating in the given year by the households and the total amount of gas supplied. The energy needs of the industrial facilities and the buildings operated by the local government can be calculated only in one way, if the amount provided to households is subtracted from the total demand for gas and electricity. This step makes possible to manage separately the residential, the industrial and the municipal energy needs. For further breakdown, the energy consumption data of the local government is essential. Unfortunately, due to the absence of cooperation with the local government this process could not be made. Therefore, the energy calculations and estimates were based on the expert opinion of SINERGY Energy Service, Investment and Consulting Ltd.

3. RESULTS AND DISCUSSIONS

3.1 The Impoundment of the Supply Zone Suitable for Producing Biomass Fuels

As both the international and the Hungarian literature emphasizes, **while planning biomass-based cogeneration units it is important to consider whether the possible investment location – from the aspect of procurable and producible biomass fuels – is capable to provide sustainable operation.**

Efforts should be made to carry out the production and the procurement as near as possible to the location of the consumption (Bai, 2012; Dobos *et al.,* 2006; Pintér *et al.,* 2009). The transportation of biomass fuels can be economical within a certain distance, so it is important during the planning process to delimit the radius in which the energy producing units can be supplied.

The economic transportation distance depends on many factors such as the cost of fuel, the amount of raw materials delivered, their quantity and price, the toll rate and the means and methods of transportation. Changes in the above mentioned factors may modify the area suitable to supply on a monthly or even on a weekly basis. Therefore, to make a precise and permanent definition is a must.

Despite the fact that the geographical and infrastructure capabilities of Ibrány (fig. 2) make possible river, rail and road transportation, during the research only the road transportation was considered since on the section of the Tisza River near the settlement there is no such cargo port which offers the possibility of water transportation and shipment. To build a cargo port in the framework of a potential bioenergy project would obviously make impossible to reach a reasonable return on investment in the foreseeable future. The town has also rail connection, but it is not an option since the town does not have a freight yard.

Pintér (2012) took economic aspects into consideration in his PhD dissertation and determined on which distance it is optimal to transport biomass fuels for energy producing purposes on public roads in Hungary. According to his calculation, the economic radius of transportation is 14.3 km in the case of herbaceous biomass and 43.38 km in the case of woody biomass since it has a higher density. It is evident that the straight line distance between two geographical locations is not equal to the distance on public road. Pintér (2012) found that 1 km distance on public road is equivalent to 0.74 km distance in straight line on the average in Hungary. It means that 1 km distance in straight line is equal to 1.3514 km on public road. **Consequently, the supply of herbaceous biomass can be economical within 10.58 km, while in the case of woody biomass the distance is 32.1 km in Hungary.**

In this paper the areas capable to produce firing raw materials were delimited by considering and applying the results of Pintér (2012) and cartographic data. By ArcGIS software two zones were delimited. One with a 10.58 km radius and one wth 32.1 km radius, in the centre of which the municipal building of Ibrány is in both cases (fig. 2). Hereafter, the potential of agricultural by-products within the 10.58 km zone is presented, since considering economic aspects these areas can be suitable to provide enough raw materials to the town.

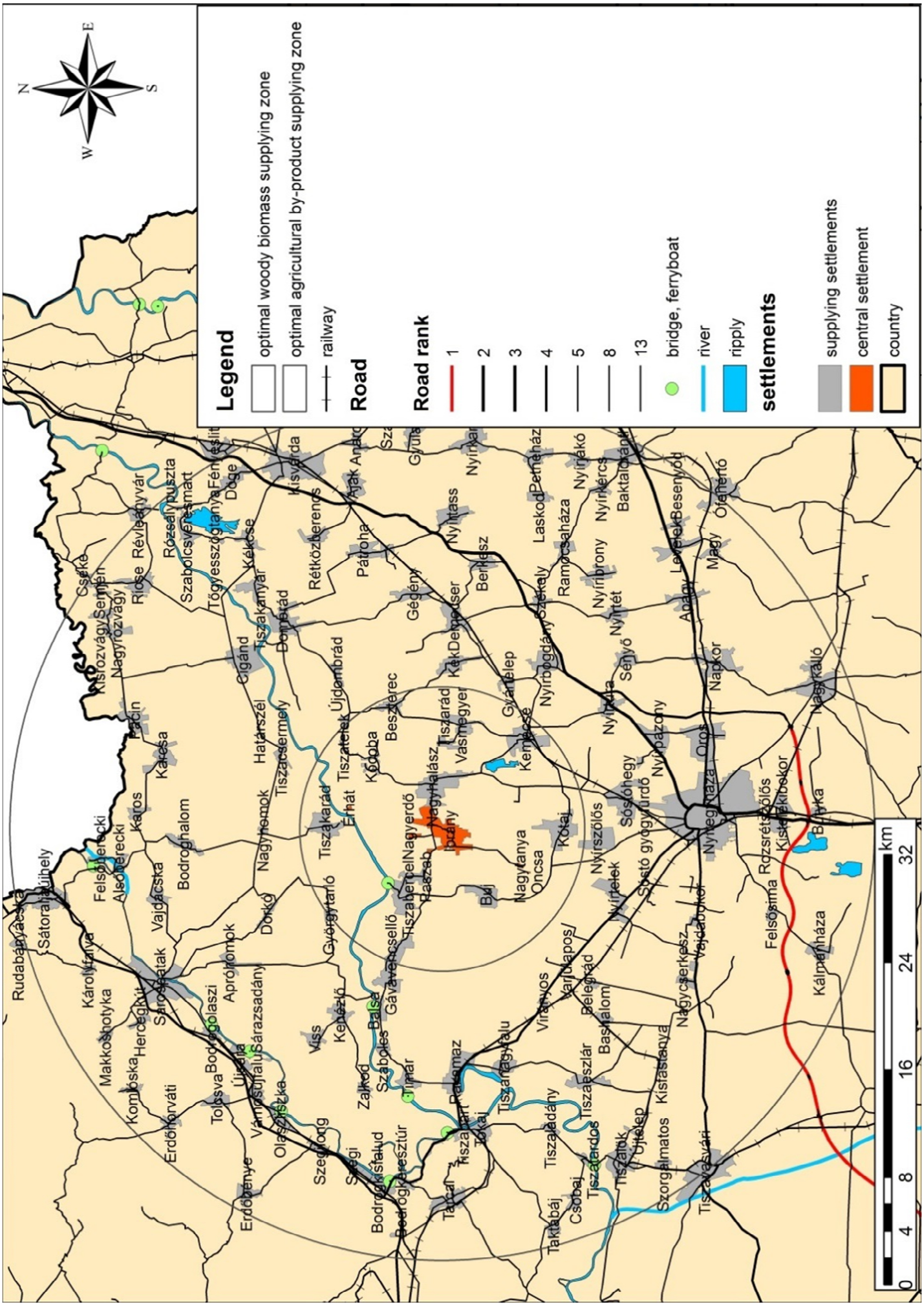

Fig 2. Transport infrastructure of the studied area (Edited by the Authors)

3.2. Evaluating the Transport Infrastructure of the Town

Following the delimitation of the area the evaluation of the transport infrastructure was done. Regarding the road network capabilities of the town (fig. 2) it can be stated in terms of supply that the capabilities cannot be considered as ideal ones since the town has no direct motorway connection and lies in the periphery in this respect. For this reason the long distance transportation can be carried out economically just in a few cases.

From the northern areas of the supply zone Ibrány can be reached on road after a long detour. This is caused by the fact that there are only 2 bridges and 3 ferry crossings on the nearby section of the Tisza River. Therefore, it is not economically efficient to supply from the settlements of Bodrogköz, Taktaköz and Hegyalja due to the long detours. Although, there is no need for a major detour if the ferry crossings are used, but trucks having gross vehicle weight over 5 tons are expected to pay 3.2 euros for every crossing. Depending on the type, quantity, quality and on the price of the transported material, the economic transportation distance may vary. Therefore, to avoid the miscalculation of the economically transportable biomass potential, settlements lying north from the Tisza River were not considered in the analysis.

In Hungary there is no database that would made possible to estimate precisely the yields of agricultural products and by-products at municipal level, therefore during the research, the annually produced amount of herbaceous biomass in the region was estimated by a unique method.

3.3. Estimating the Energy Potential of Agricultural By-Products Produced in the Studied Area

While doing the potential estimation, the agricultural land structure of the settlements was concluded from the Hungarian Central Statistical Office's Regional statistical database system (MR-STAR 2013) on Szabolcs-Szatmár-Bereg County. Still, these data do not give an accurate description on the studied area since considering soil and weather conditions in the different parts of the county, the agricultural land structure may differ significantly from year-to-year. Nevertheless, due to the missing data on every single settlement, only the above mentioned unique method may provide an accurate picture on the settlement's agriculture structure. The distribution varies from year to year as a result of the changing crop rotation, climatic conditions and crop prices, so it is obvious that calculating with the values of a single year is not enough. In consequence, the agricultural land structure's model in delimited area was made on the basis of the averages of 2009-2013 (fig. 3).

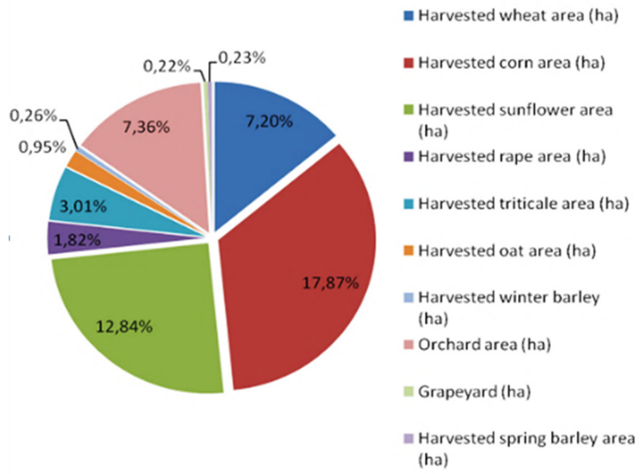

Fig. 3. General agricultural land structure of Szabolcs-Szatmár-Bereg County between 2009 and 2013 (Calculated by the authors based on KSH-MRSTAR 2013)

Following the determination of the agricultural land structure in the delimited area, estimations were made on the specific yields per hectare of the agricultural by-products on the basis of the average values demonstrated by the Hungarian Research Institute of Agricultural Economics (AKI) and the Hungarian literature (table 1). However it is important to mention that it was not possible to calculate with standard data from year to year, because the weather, the genus of the cultivated plant and the cultivation techniques are changing constantly in every year. Therefore, the calculations were made by involving the past five years' values on average yields, which were detected by the above mentioned sources (table 1).

Table 1.

Key features of the by-products taken into account

Type of agricultural by-product	Harvestable volume (t/ha/year)	Heating value (at 20% moisture content) (GJ/t)
Straw (wheat, triticale, barley, oat)	3	12
Rape straw	2.5	13
Corn stalk and cob	5.5	11
Sunflower stalk and husk	2	13
Vine-branch	2.5	14
Fruit-tree loppings	1.5	14

(Source: edited by the authors based on Bai, 1998; Marosvölgyi, 2002; Juhász, 2006; Barkóczy and Ivelics, 2008; Fábián, 2008; Popp, 2011; Pintér, 2012; Torben, 2011; Bai, 2016.)

In accordance with the average yields and heating value of agricultural by-products, moreover considering the agricultural land structure of the delimited areas, our estimates show that the agricultural by-products produced annually in the countryside of Ibrány have approximately 643,591.83 GJ energy content (table 2).

Table 2.

The annual yield of agricultural by-products generated around Ibrány

Type of agricultural by-product	Potential herbaceous plant crop lands based on the county average	Potential herbaceous biomass based on the county average	Inferential energy content of the potential herbaceous biomass
	(ha/year)	(t/year)	(GJ/year)
Straw (wheat, triticale, barley, oat)	3,687.16	10,499.90	125,998.77
Rape straw	574.49	1,436.22	18,670.88
Corn stalk and cob	5,652.41	31,088.24	341,970.65
Sunflower stalk and husk	4,063.03	8,126.06	105,638.77
Vine-branch	69.78	174.46	2,442.46
Fruit-tree loppings	2,327.16	3,490.73	48,870.29
Total	16,374.03	54,815.62	***643,591.83***
Could be mechanized/transported			155,896.34
The amount can be used for energy purposes			***115,805.50***

(Source: calculated by the authors)

However, the spatial distribution of theoretical potential originating in agricultural by-products is far from equipartition. As reported by Agricultural census 2010 (ÁMÖ) of the Hungarian Central Statistical Office there are significant differences in the total crop lands and the land use of the settlements. Gávavencsellő (4451 ha), Nagyhalász (3891 ha), Tiszakarád (3605 ha) and Ibrány (3311 ha) have the largest crop lands in the bounded zone. 48.23% of the crop lands are related to the above mentioned settlements (table 3).

Table 3.

Crop lands of the bounded zone by settlements

Györgytarló	*0.26%*	**Vasmegyer**	*3.44%*	**Kótaj**	*9.50%*
Beszterec	*0.56%*	**Buj**	*5.13%*	**Ibrány**	*10.47%*
Tiszarád	*0.64%*	**Tiszabercel**	*5.61%*	**Tiszakarád**	*11.40%*
Paszab	*0.78%*	**Nyírbogdány**	*6.81%*	**Nagyhalász**	*12.30%*
Tiszatelek	*1.84%*	**Kemecse**	*7.19%*	**Gávavencsellő**	*14.07%*
Kék	*2.71%*	**Nyírtelek**	*7.30%*	***TOTAL:***	***31 636 ha***

(Source: calculated by the authors)

If the spatial distribution of crop lands, the land use and the yields of agricultural by-products are compared (fig. 4), one may found that Ibrány has a favourable potential regarding the potentials of agricultural by-products, since the majority of herbaceous biomass for firing purposes is concentrated in the core areas of the favourable supply zone.

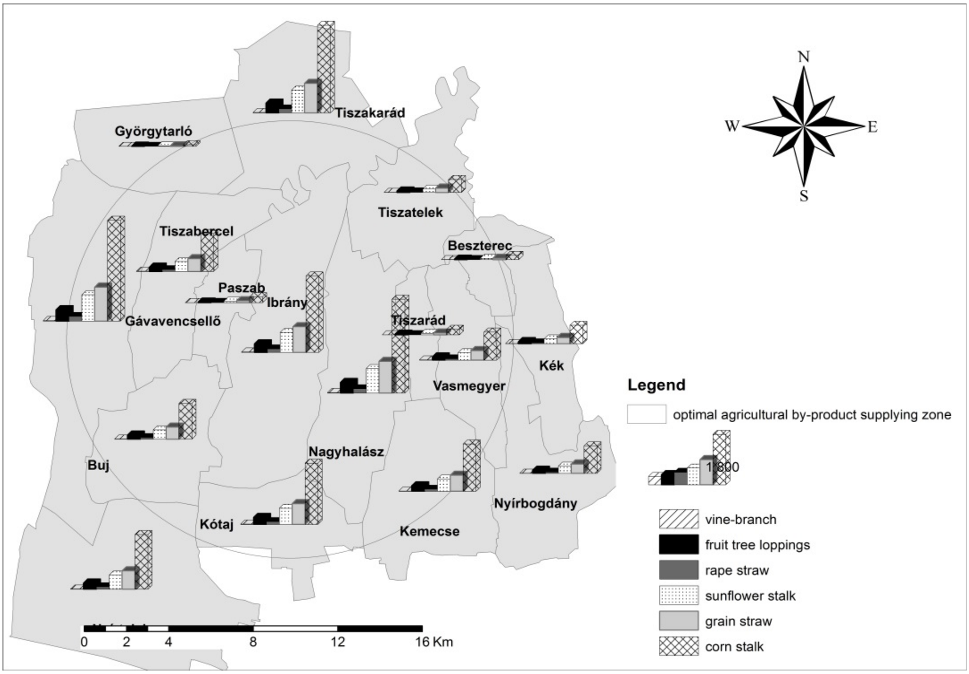

Fig. 4. Quantitative distribution of the annually produced potential agricultural by-products by settlements (t)

(Source: edited by the authors based on KSH-MRSTAR 2013; KSH ÁMÖ 2010; AKI 2013)

Although the amount of the herbaceous biomass's theoretical potential is enormous, its energetic utilization is more limited than in the case of woody biomass. Because the agricultural products basically have nutritional and feeding purposes, while the by-products are mainly used for soil nutrient replenishment and they are partly used for animal husbandry (as bedding) (Bai, 1998; Juhász, 2006; Pintér, 2012). So it is important to estimate the actual amount of agricultural by-products which can be used for energy purposes apart from determining theoretical biomass potential.

While corn and sunflower stalks are produced in the biggest amount in the studied area, yet energy utilization is a question, because there is no appropriate technology available to transport them from the crop lands and to store them. Therefore these by-products were not included into further calculations.

In the case of cereal straw it is difficult to define the amount of agricultural by-products which can be used in energy production. Weiser *et al.,* (2013) found for Germany that 24% of the harvestable cereal straw production is used for livestock husbandry and insignificant amounts used for energy purposes. On the European Union level, Scarlat *et al.* (2010) found that between 1/5 to 1/3 of harvestable crop residues are used for livestock and little for energy. Similar assumptions (1/3 of harvestable residues used for livestock) were made by Ericsson *et al.*, (2006). Denmark is one of few exceptions considering the use of agricultural residues in advanced energy supply (Scarlat *et al.,* 2010, Ericsson *et al.*, 2006), with 20-40% of the crop residues from cereal production used for energy. Still, only up to 60% of the total residue production is harvested and used for livestock or energy purposes (Denmark statistik, 2012). For the US, the 'Billion ton annual supply study' (Perlack *et al.,* 2005) and its update (Perlack *et al.,* 2011) report an annual crop residue production of 550 million metric tons dry matter; a more recent study report the annual production to 518 Tg (Ľ million metric tons) dry matter (Chatterjee, 2013). 5.6 million metric tons corn stover is used for energy corresponding to 1% of the total production. The amount used for other purposes is not reported but the 'billion ton annual supply study' indicates use rates well below 20% of the total agricultural residue production Bentsen *et al.,* 2014).

A number of studies estimated the potential of different biomass residues available for energy conversion, some for the EU as a whole and some looking at individual Member States. The technical potential of straw is in the range of 50 and 110 million tonnes of straw dry matter per year (or between 674 to 1,829 PJ) (Kretschmer *et al.,* 2012).

The straw yield is typically about three tons per hectare, but it depends on course rotation, yield level and weather (Torben, 2011).

According to the Hungarian literature, 20-50% of cereal straw is rotated to the soil during ploughing, while the other 30-50% is used for animal bedding (Bai *et al.,* 2016). As far as we are concerned, the latter (approximately 40%)

cannot be considered for energy purposes since it is essential for livestock production systems and animal husbandry. Therefore approx. 40% of the straw (wheat, triticale, barley and oat) which can used for livestock purposes was subtracted before making further calculations.

Our calculations show that after subtracting corn and sunflower stalks and straw used by livestock from the total amount, the agricultural by-products produced in the 10.58 km radius around Ibrány have **approximately 135,850 GJ/year** energy content which could be used for producing energy by firing (fig. 5).

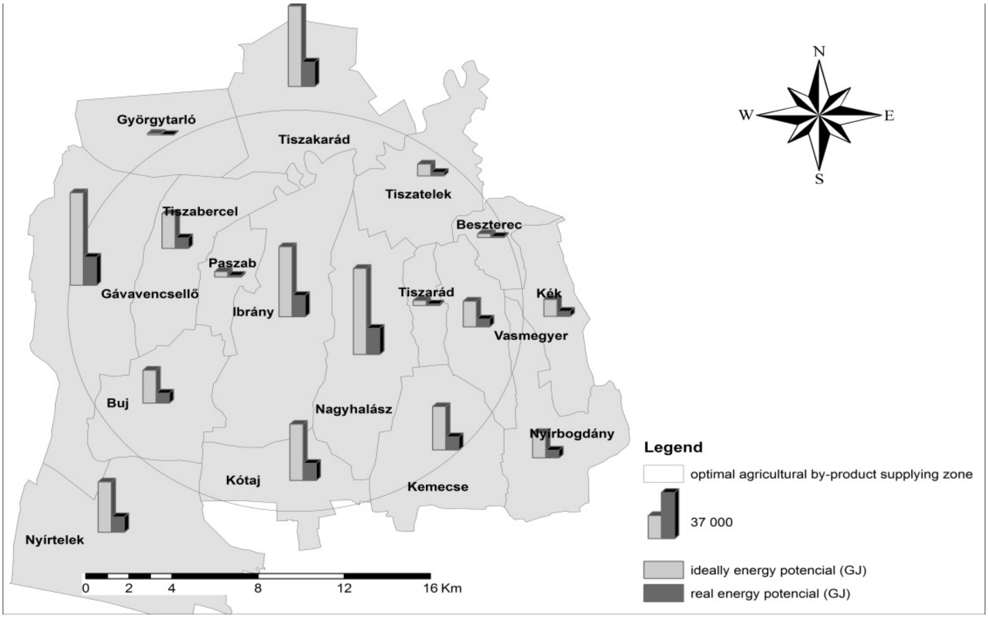

Fig. 5. Theoretical and real energy potential of agricultural by-products by settlements

3.4. Estimating the Energy Potential of Woody Biomass Produced in the Studied Area

During the second step of measuring the biomass potential of the bounded area, the estimation of the amount of woody biomass, which can be used for producing energy, was put through. The necessary data was gained from the database of WWF Hungary, which is concerned with the forest biomass potential of Hungary at micro-regional-level.

Regarding the evaluation of the transport infrastructure of Ibrány (see Section 3.2), it can be stated that the woody biomass potential can be reached entirely in the micro-regions of Ibrány-Nagyhalász and Nyíregyháza, and partially in

Baktalórántháza, Kisvárda and Tiszavasvári micro-regions with respect to the favourable supply zone. Based on the micro-regional-level database prepared by WWF Hungary (table 4), the public and private sector may produce 105,045 t_{atro} (1174 TJ/year) forest biomass in these micro-regions during the forest cycle of 2015-2019.

Table 4.

Total woody biomass potential of the micro-regions of the favourable supply zones in each forest cycles (tons/years/cycle)

		Public and private sector			
	Values: Tonnes (per year / per cycle)	**2010-2014**	**2015-2019**	**2010-2014**	**2015-2019**
Ibrány-Nagyhalász micro-region	**Hardwood**	12,958	17,092	2,592	3,418
	Softwood	27,966	63,601	5,593	12,720
	Pine	1,110	832	222	166
	Total:	42,034	81,525	8,407	16,304
Nyíregyháza micro-region	**Hardwood**	39,763	42,223	7,953	8,445
	Softwood	8,051	27,846	1,610	5,569
	Pine	3,200	3,135	640	627
	Total:	51,014	73,204	10,203	14,641
	TOTAL:	**93,048**	**154,729**	**18,610**	**30,945**
Baktalórántháza micro-region	**Hardwood**	90,634	146,247	18,127	29,249
	Softwood	22,249	64,441	4,450	12,888
	Pine	10,920	11,702	2,184	2,340
	Total:	**123,803**	**222,390**	**24,761**	**44,477**
Kisvárda micro-region	**Hardwood**	34,728	55,138	6,946	11,028
	Softwood	30,216	50,713	6,043	10,143
	Pine	2,832	2,618	566	524
	Total:	**67,776**	**108,469**	**13,555**	**21,695**
Tiszavasvári micro-region	**Hardwood**	11,699	13,784	2,340	2,757
	Softwood	20,655	25,638	4,131	5,128
	Pine	274	214	55	43
	Total:	**32,628**	**39,636**	**6,526**	**7,928**
	TOTAL:	**224,207**	**370,495**	**44,842**	**74,100**
	Available total potential:	**317,255**	**525,224**	**63,452**	**105,045**

(Source: calculated by the authors based on the data of WWF on Hungary)

However, one has to take into consideration the fact that three of the concerned micro-regions have only certain parts within the area, which was bounded using an economic viewpoint. Therefore, it was defined by using ArcGIS 10 software, what are the certain areas of the partially concerned micro-regions, from which the raw materials could be supplied economically. The results show that in the case of Ibrány-Nagyhalász and Nyíregyháza micro-regions 100% of the total area can be taken into account, while the values of Baktalórántháza, Kisvárda and Tiszavasvári are 87%, 76% and 69% respectively (fig. 7). Despite the fact that the delineating stripe affects the micro-regions of Nagykálló and Hajdúböszörmény, these areas were not involved into the analysis since CLC maps show that they do not significant amount of woody biomass.

Considering the WWF database on woody biomass potential of micro-regions and cartographic analyses, one can state that bounded zone around Ibrány has **~91 599 t_{atro}/year (~1024 TJ/year)** woody biomass potential for the 2015-2019 forest cycle.

During the micro-regional level analysis, misleading results may occur in relation to the areas, where only partial potential was included into the calculations. It may take place that the favourable areas are lying outside the zone, which causes overestimation. Conversely, there is a risk for underestimation. So it is important to plan the biomass-based cogeneration units with regard to a scenario, in which the amount of biomass fuels is underestimated, in order to secure supply.

For the sake of studying the spatial distribution of woody biomass and agricultural by-products, a map was made based on the database of Corine Land Cover (CLC) 2006, on which the land cover features and road network of the bonded area are presented[3] (fig. 6).

Based on the map, results show that essentially cultivated lands can be found in the close proximity of the town, while areas not suitable for forest and agricultural cultivation (built-up areas, natural grasslands and pastures) are also common.

The majority of woody vegetation is located in the peripheral regions, especially in the south-eastern and north-western parts of the area. A significant amount of biomass is expected to be found in the floodplain of Tisza. However, the majority of it is a nature conservation area, as can be seen on figure 6.

[3] **Green colour**: areas covered by deciduous forests, woody coppice,
Yellowish colour: cultivated lands,
Shades of grey: areas not suitable to produce bioenergy (built-up areas, natural grasslands, pastures and marshlands)

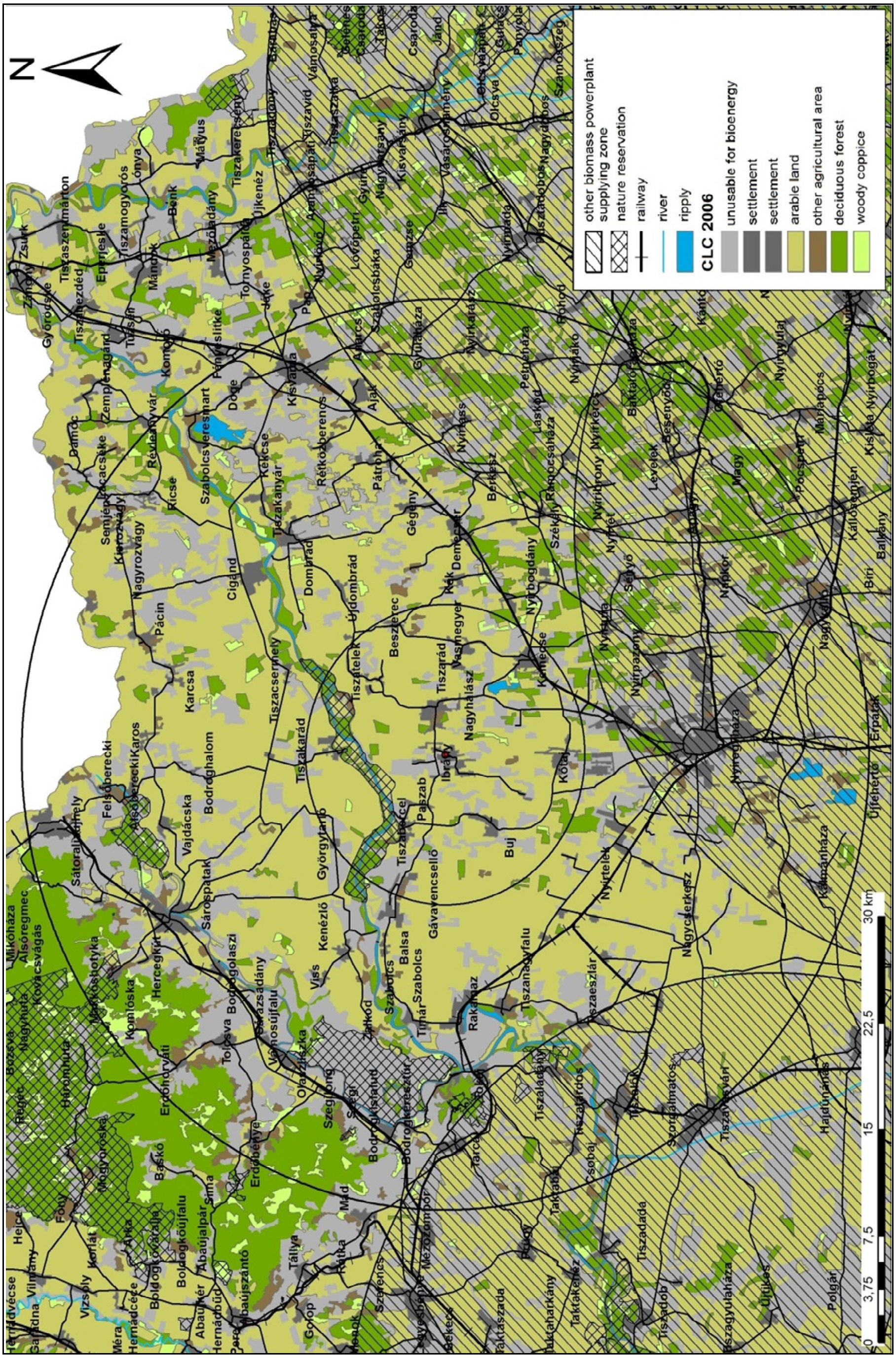

Fig 6. The studied area's land cover (CLC 2006), road network and the hypothetical optimum supplying zones of the surrounding biomass power plants (Source: Edited by the Authors based on EEA, Institute of Geodesy, Cartography and Remote Sensing (FÖMI), Hungarian Ministry of Rural Development (KvVM) 2009)

3.5. Spatial Analysis of the Bounded Zone Concerning Biomass Potential

Hungary has currently three regularly operating (in Mátészalka, Tiszaújváros) or periodically operating (in Szakoly) woody biomass applying cogeneration units, which may affect the supply security of the settlement studied in the paper. The annual woody biomass need for the heating plant in Mátészalka is 6,000 tons per year. The heating plant of Szakoly has a need for 180,000 tons per year. In Tiszaújváros a 500 kWth fluidised bed heating plant was opened in 2013, the specific parameters of which are still unknown. The optimal supply zones of the three facilities partially overlap the raw material base of Ibrány (see the hatched areas on Figure 7). The supply zones of the above mentioned bioenergy producing facilities affect the southern, south-eastern and eastern parts of studied area. According to the analysis of the CLC land cover map and micro-regional database of WWF (fig. 7) it can be concluded that a significant proportion of Ibrány's woody biomass potential is concentrated in the same zone.

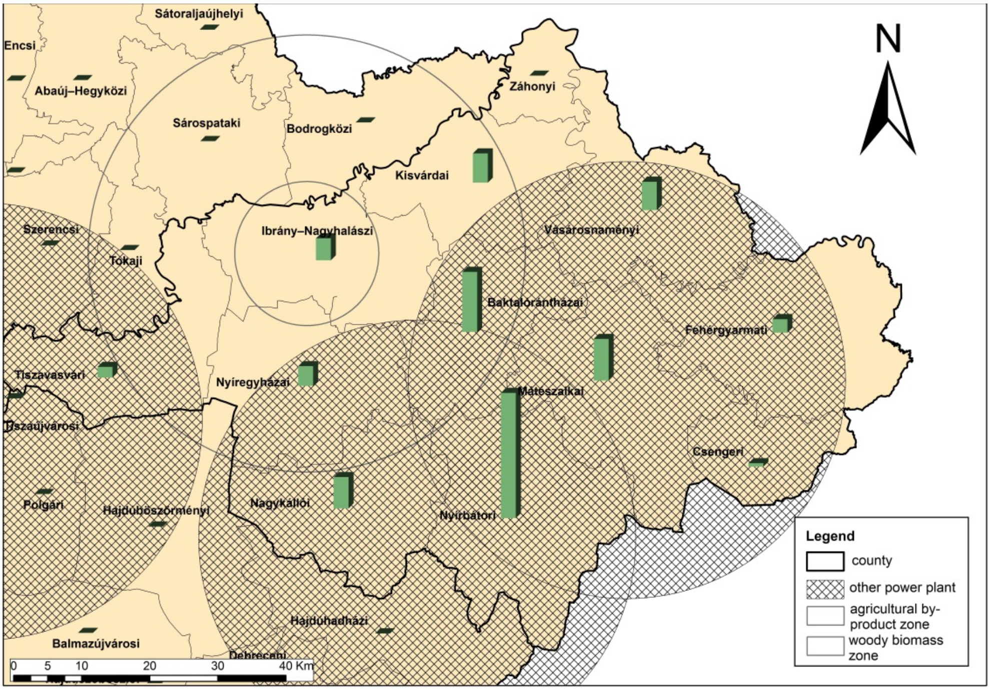

Fig. 7. The results map of the potential woody biomass survey at micro-region-level performed by WWF Hungary (t). The figured is concerned with the results related to Szabolcs-Szatmár-Bereg County (edited by the authors based on WWF database)

Cartographic analyses show that a significant amount of the woody biomass potential can be found far from the place of consumption or it is rather located in a natural reserve in the studied area. There is a considerable amount of potential which is located in the sphere of interest of other energy producers. This fact can lead to the increase of demand for firewood in the overlapping zones. For these reasons it would be important to study the potential of cultivating short rotation woody energy crops (SRWCs).

3.6. Surveying the Heat Energy Needs of the Town of Ibrány

In order to estimate the heat and electricity needs of the households, the industrial users and the local government, calculations were made with data of the period 2010-2013 based on the Settlement statistical database system of the Hungarian Central Statistical Office (T-STAR 2013). Due to the absence of worthy cooperation with the local government, the energy needs of buildings operated by the local government were calculated on the basis of estimates made by experts and literature.

The total heat energy need of the total was calculated from the quantitative data of piped gas provided. In this case the result equals to the total heat energy produced from gas, which means that the amount of gas used for heating and the amount of gas used for e.g. cooking or other purposes are not separated from each other. But this calculation provides a good approximation regarding the total demand for heat energy of the town. The total electricity demand of the town was based on the data provided by the Hungarian Central Statistical Office.

Between 2010 and 2013 (table 5), the town used 2,828,200 m^3 gas on average, which corresponds to about 154,742 GJ actual demand for **heat energy**, if the boiler efficiency is considered to be 80% on average. The town's heat energy demand was the highest in 2010, when the total demand may have been approximately 154,742 GJ. The **total electric power** consumption of the town is regarded as balanced since minimum disparities can be found amongst the data of the given years.

The data of the Hungarian Central Statistical Office is not split to different levels regarding the households, the industrial users and the local government. Just the total amount of consumption and the consumption of the households are differed. Therefore in order to estimate the energy needs of the industrial users and the local government, the amount of energy provided to the households was subtracted from the total amount. In pursuance of further breakdown, to differ the energy consumption of the industrial users and the local government, energy calculations and estimates were based on the expert opinion since there is no cooperation with the local government.

Table 5.

The amount of gas and electricity provided to the settlement between 2010 and 2013

Year	The total amount of piped gas provided (1000 m^3)	The total amount of piped gas provided (GJ)	Presumed energy demand (at 80% boiler efficiency) (GJ)	The total amount of electricity provided (1000 kWh)
2010	3,792.70	128,951.80	154,742.16	10,939.00
2011	2,646.90	89,994.60	107,993.52	11,633.00
2012	2,432.50	82,705.00	99,246.00	10,637.00
2013	2,440.70	82,983.80	99,580.56	10,407.00
AVERAGE	***2,828.20***	***96,158.80***	***115,390.56***	***10,904.00***

(Source: Edited by the Authors based on KSH-TSTAR 2010-2013)

After separating the energy consumption regarding the households, the industrial users and the local government (table 6), it can be stated that the householders are considered to be the largest consumers, since they consume 58.45% of the heat energy and 61.33% of the electricity.

Table 6.

The quantitative distribution among the consumers of the amount of gas and electricity provided to the settlement between 2010 and 2013

Year	The amount of electricity provided to households (1000 kWh)	Presumed thermal energy need of households (at 80% boiler efficiency) (GJ)	The amount of electricity provided to industrial users and local government (1000 kWh)	Presumed energy need of industrial users and local govern-ment (at 80% boiler efficiency) (GJ)
2010	6,645.00	80,832.96	4,294.00	73,909.20
2011	6,719.00	74,366.16	4,914.00	33,627.36
2012	6,163.00	62,391.36	4,474.00	36,854.64
2013	5,970.00	65,508.48	4,437.00	34,072.08
AVERAGE	***6,374.25***	***70,774.74***	***4,529.75***	***44,615.82***
RATIO	***58.46%***	***61.33%***	***41.54%***	***38.67%***

(Source: edited by the authors based on KSH-TSTAR 2010-2013)

In terms of the electricity needs in each year, it can be assessed that there are no significant fluctuations in the electric power consumption of the different users. However, meaningful changes can be observed considering the annual heat energy demand. In the case of households, it is caused by the seasonal changes in temperature.

More significant fluctuations can be experienced in the case of the industrial users and the local government than in the case of the households. On the other hand this is caused by the changing heating needs of the offices and it can also be explained by the changing capacities from year to year, which are more responsible for the fluctuations. The biggest changes may occur due to the working intensity changes of the crop drying plant located in the town, because its utilization and so the energy needs of the plant are determined by the annual crop yields and by the moisture content at the time of the harvest. The end of the winter and the springtime in 2010 were extremely wet. As a result the farmers were able to sow the spring-sown crops just with a lag. This event led to high harvest moisture content. Presumably, this is why the industrial and the municipal gas consumptions were exceptionally high in 2010.

Based on the analysis of the three-year data set it can be concluded that the estimated yields of the annual biomass potential, **135,850 GJ/year from agricultural by-products and 998,000 GJ/year from woody biomass**, can fully cover the total electricity and heat energy needs of the town even in the most energy-intensive years.

However, the electric energy consumption of Ibrány (1,245 kWh/h) fails to reach the minimum production volume (approx. 2,500 kWh/h), at which the electricity production could be economically efficient. Therefore, the idea to invest in a biomass-based energy producing unit has to be rejected.

A heating plant serving the heating needs of the residents, the industrial users and the local government could be an economically profitable investment. The length of gas pipeline network in Ibrány is 57.55 km suggesting that if all the households will be connected to district-heating network then approximately the same length of district-heating pipes should be installed. This would increase the costs of the investment to the extent that even in the case of having 90% aid intensity, the investment would not be cost-effective. In addition, it may happen that a significant proportion of the households will not join the district-heating network, which would further increase the losses of the investment.

Concerning the industrial users and the local government a joint heating plant would be beneficial. However, due to the extreme capacity needs of the industry (see the year 2010), a boiler with more horsepower should be installed which is not worthwhile. Not to mention that an approximately 1 km long heating pipe is needed to be built between the buildings operated by the government and the industrial park of the town, which would increase the costs of the investment as it can be seen in the case of the households, therefore to make an investment like that is not profitable.

So in the case of Ibrány, an investment aiming to construct district-heating for the households, the industrial users and the local government would be possible, if the construction of the projected district-heating infrastructure will be supported by EU funds.

As far as we are concerned, it would be an economical investment for the local government to build a district-heating plant fulfilling the energy needs of the buildings operated by the local government. In our future research economic analyses will be made to support the idea.

4. CONCLUSION

The paper aimed to present the method in the case of Ibrány, which allows to survey easily and quickly the herbaceous and woody biomass potential of any settlement in Hungary based on statistical and geographical data. Derived from the data of the Hungarian Central Statistical Office, the energy needs of the given settlement were calculated.

By using the above mentioned method, one can recognize in a short period of time the settlements which may be suitable for the establishment of sustainable biomass-based cogeneration units on the long-term.

The method can be applied not just in Hungary, but also in other countries, if the relevant national statistical database is available.

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