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EVALUATION OF BIOMASS AVAILABILITY FOR BIOGAS PRODUCTION AT REGIONAL LEVEL

BIOMASAS PIEEJAMĪBAS IZVĒRTĒJUMS BIOGĀZES RAŽOŠANAI REĢIONĀLĀ LĪMENĪ

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Introduction

Considering the actual state of global needs for all forms of energy, assessing the potential of organic wastes that could be processed to obtain biogas, is one of the main tasks for a region's successful socio-economical development.

The availability and assessment of natural resources, renewable or non-renewable, is a complex issue and the assessment of biomass for energy production is no exception. A plethora of studies have been carried out in order to evaluate the biomass potential for energy use [1,2,3,4].

The use of currently available data in integrated deterministic modelling approach allows the assessment of total biomass availability. Results obtained depend on the different aims of the studies and are affected by the different assumptions made. This study is not an exception: it has a series of assumptions, and a series of limitations.

The conceptual approach of combining the benefits of relational database and Geographical Information Systems (GIS) modelling was tested in two eastern European countries – in Latvia and Romania.

This methodology was applied for biomass potential studies in the framework of the European Commission Intelligent Energy Europe program project "BiG>East", assessing the theoretical biomass potential in six Southern and Eastern European countries. The existing methodology could be further developed in order to evaluate the technical feasibility of selected biomass; however, this is the task of future research and is not considered in this evaluation study.

Methods used

Based on the literature [5,6,7,8], feedback from farmers (their existing local practices) and the current use of by products, local models were developed to evaluate the use of agricultural and waste products and to calculate the feedstock availability for biogas production in each region. To evaluate the biomass potential, different sources of information were used, e.g., EUROSTAT data were used to assess land use, agricultural production yields, population and tourism potential, as well as national statistics were used for the evaluation of agricultural wastes (from primary and secondary production), sewage sludge and food-processing wastes. Finally, biomass availability was calculated at the regional level, indicating the regions with low, medium and high potential.

The overall approach of assessing biomass resources was first to estimate the quantity of material generated from municipal waste and agricultural practices in each of the research areas. In the next step, the quantity of material that could be recovered from these practices, taking into account the technical and environmental constraints associated with other site factors, was evaluated. Data sources for land management included monitoring and reporting information from national and European regional statistical institutions. The amounts of annually generated agricultural residues were calculated based on the annual average area of hectares harvested, yield values per hectare, and estimated residue generation factors [9,10]. In order to calculate the amount of biomass resulting from animal breeding practices, information on the quantity of residues per head of animal were used [11,12,13].

Municipal and sewage sludge wastes were estimated based on the locally reported values of production per inhabitant. The ecological approach of interrelated ecosystems (agro-ecosystem and human dominated systems) is generating products and wastes, and some of them potentially could be used as feedstock for biogas production. Interaction among different parts of the above- mentioned system is shown in Figure 1

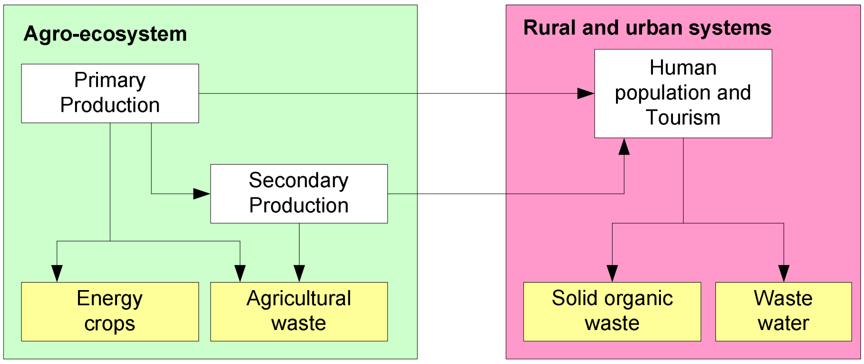

Fig.1. Interaction among systems for estimation of available biomass resources

For each of the assessed countries, energy crops that can be used for co-digestion have been defined. Project “BiG>East” consortium has defined suitable energy crops and their specific yields. One of the basic assumptions made in this study is that biogas potential is proportional to the total biomass potential in each target area. From the total potential (seen as total biomass), certain classes of biomass are more suitable for biogas production than others, and also different biomass classes are with different *availability* (in terms of quantity) and with different *technical availability* (in terms of real accessibility to this biomass resource to use it as feedstock for biogas production). In this study, any reference to *energy crops* is used to refer to the *total biomass produced on agricultural lands*, and not to crops cultivated for energy production. Basically, all the biomass produced in agricultural areas is virtually an energy crop, meaning that it could be theoretically used as feedstock for biogas production. That does not mean that it will be definitely used as, or become, a feedstock for biogas production.

As a conceptual background, an adapted form of the proposed approach [14] is given in Figure 2 and the questionnaire for data collection is summarized in Table 1.

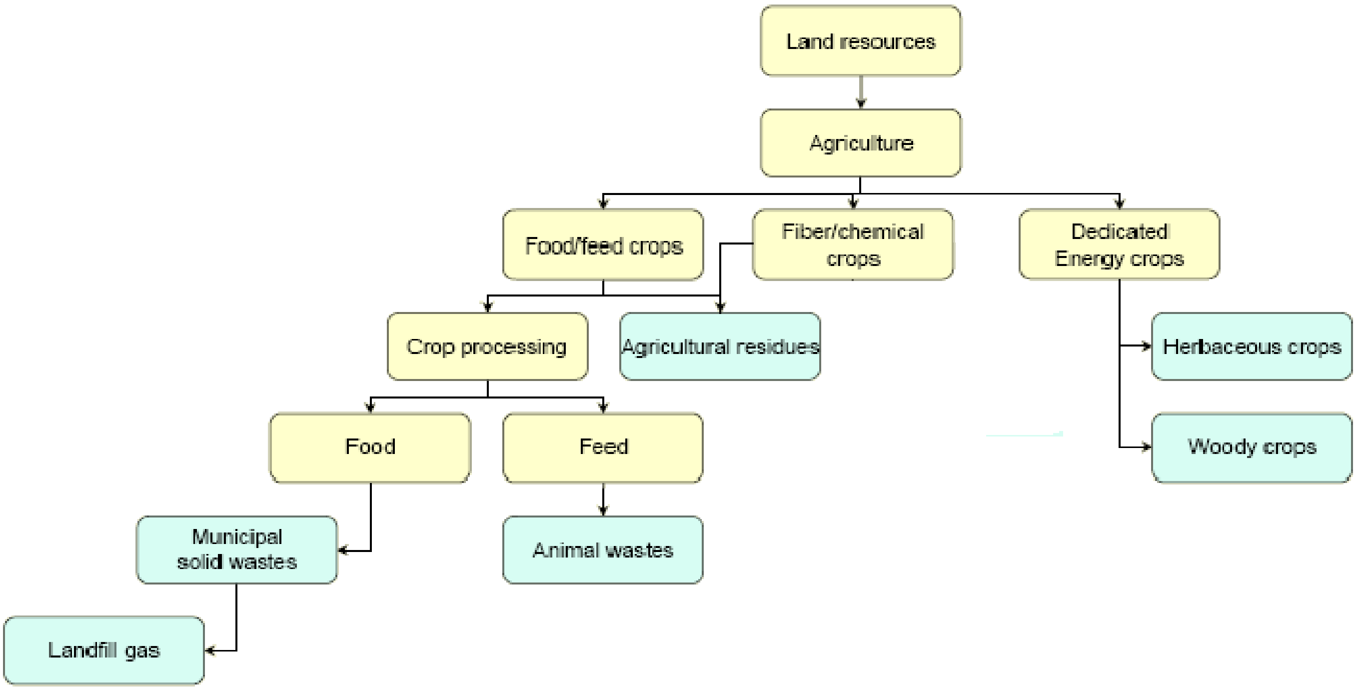

Fig.2. Assessment chains of energy crops, agricultural residues, animal wastes and solid municipal wastes [14]

Table 1.

Questionnaire for partitioning of product and their use (adapted from Perlack, 2004 [14])

Land use	Resources and crops	**Corn (C_1)**	**Wheat (C_2)**	**Soybean (C_3)**	**Pulse (C_n)**
	Land base	**agri**	**agri**	**agri**	**agri**
Average crop characteristics	Gross yield (dt/ac)				
	Hectares in production				
	Grain yield ($t*year^{-1}Ha^{-1}$)				
	Energy content (MBtu/dt)				
	Bd ft/ac				
Use of crop	% dry wt food & fiber				
	% dry wt fiber & timber				
	% dry wt energy				
	% dry wt chemical				
	% dry wt sustainability requirements				
Total vision	Million dry tons (15 MBtu/dt)				

The main intention was to use biomass from primary (vegetal production) and secondary (animal products) production having agro-ecosystems as the main source of biomass. However, the human population are also considered within this study as the third stage anthropogenic activities.

To establish a common approach of data analysis and to handle the heterogeneity in agricultural practices in both countries addressed in this investigation, an integrated information system (BIOEast) was developed to support data collection.

To assess the structure and functionality of complex systems, the GIS were used. This approach made it possible to reflect spatial distribution and ensured the accurate identification of administrative units with low to high biomass potential. Based on data availability, an integrated analysis on the national level divided by territorial unit (NUTS) level 3 was performed. Input data for analysis was represented by the following data taken from EUROSTAT databases:

- Agriculture
  - Crops
  - Production level
  - Cultivated surface
  - Animals grow and animal wastes
- Demography (urban+ rural anthropogenic systems)
  - Human population
  - Tourism potential
- Waste disposal/treatment
  - Solid waste
  - Water waste (liquid waste).

Primary production wastes. Wastes of primary production were assessed using an aggregate function of crops and their spatial extent at NUTS level 3. In order to identify the biomass quantities with and without market values, production covering vegetal structure was assessed (see Formulas 1 and 2).

$$EC = \sum_{i=1} C_i S_i (\sum_{j=1} P_{ij})$$
$$PPW = \sum_{i=1} \sum_{j=1} C_i S_i P_{ij} f_{ij}, \qquad (1;2)$$

Where:

EC – Energy crop potential (tonnes);

PPW – Wastes from primary production (tonnes);

C_i – yield of crop type i (tonnes/ha);

S_i – surface cultivated with crop type i(ha);

P_{ij} – quantity of product j from crop i (tonnes);

f_{ij} – factor of product j from crop type i which can become a feedstock for biogas production.

Secondary production (animal) wastes

Wastes of secondary production include liquid manure from pig and cattle breeding, chicken litter, food and kitchen waste. The next step of this study was to assess the secondary production based on national statistical data giving the number of animals per NUTS level 3 units (see Formula 3).

$$SPW = \sum_{p=1} \sum_{k=1} H_p P_{pk} f_{pk}, \qquad (3)$$

Where:

SPW – wastes from secondary production (tonnes);

H_p –heads of animals of type p;

P_{pk} – quantity of product k from one animal p (tonnes);

f_{pk} – factor of product k from crop type p which can be used as feedstock for biogas production.

Socio-economic systems. Biomass from socio-economic systems considered in this study includes biological wastes, old cooking oil, flotation sludge, glycerine, and waste from animal slaughter houses. This waste category includes organic waste material from solid municipal waste management systems and food processing industry residues. The amount of biomass from this category is calculated using Formulas 4 and 5.

$$\begin{aligned} OSW &= Pop * r_{osw} + TourPot * r_{tosw} \\ WW &= Pop * r_{ww} + TourPot * r_{tww} \end{aligned} \quad (4;5)$$

Where:
OSW – organic solid waste (tonnes);
WW – dry matter of waste water (tonnes);
Pop – population (number of inhabitants);
TourPot – tourism potential (number of beds);
r_{osw} – rate of organic solid waste generation (tonnes/year);
r_{tosw} – rate of organic solid waste generation per tourist place (tonnes/year);
r_{ww} – rate of waste water generation (tonnes/year);
r_{tosw} – rate of waste water generation per tourist place (tonnes/year);

Results

In this study two countries for further analysis were selected. One of the selected countries – Latvia has the structure of a homogenous boreal biogeographically region. The second one is Romania with a different, very heterogeneous structure. There are five from a total of eleven bio-geographical regions (alpine, continental, Black sea, steppic, pannonial) represented in Romania (see Figure 3). A comparative analysis of the territories represented in Latvia and Romania reflects the heterogenic structure of Eastern European countries and provides an opportunity to test the developed methodology at different levels of complexity regarding environmental and ecological structures.
Since Latvia has the same extent of NUTS level 0 to NUTS level 2, it was decided that in order to compare the results from both countries, the analysis will be done at NUTS level 3.

Energy crop potential. Since in Latvia there are only a few biomass plants using specially grown energy crops like cereal straw, maize silage, grass silage and rape, in calculation of energy crop potential all kinds of crops that could be used as energy crops are included (as well as those currently used for human food and animal feeding). Crops included in the calculation of energy crops potential are different kind of cereals, potatoes, pulses, rape, flax, sugar beets and others traditionally grown in Latvia.
Data on the sown area for each kind of crop and yield of agricultural crops were obtained from the Central Statistical Bureau of Latvia [15], as well as from online statistical databases to evaluate the spatial distribution of crops by NUTS 3 regions in Latvia. The average figures from the data collected in 2001-2006 were used. The spatial distribution of energy crop potential in the territory of Latvia is given in Figure 4. The highest energy crop potential is identified in the Zemgale region (LV009).
Romania has significant potential for primary production (including energy crops). There are several areas well suited for large production, especially in the south-eastern part of the country with an average (for the entire region) of over 17 million tonnes (see Figure 5). Other areas could also contribute significantly to the overall production, and for some crops the potential is even greater.

Agricultural waste. The amount of agricultural waste products from primary production (incl. cereal straw, waste from grain drying and processing, potatoes stalks, beet leafs, rape seed processing residues etc.) was calculated based on the average figures of statistical data [15] in 2000 – 2006. The set of assumptions were made to define the percentage of waste that could be collected and used for biogas production. Wastes from primary production are also to be found in the same area (LV009) as this is also the main primary production area for the country. Quantities of over 400 thousand tonnes of waste in the past years are typical in this area (Figure 6).

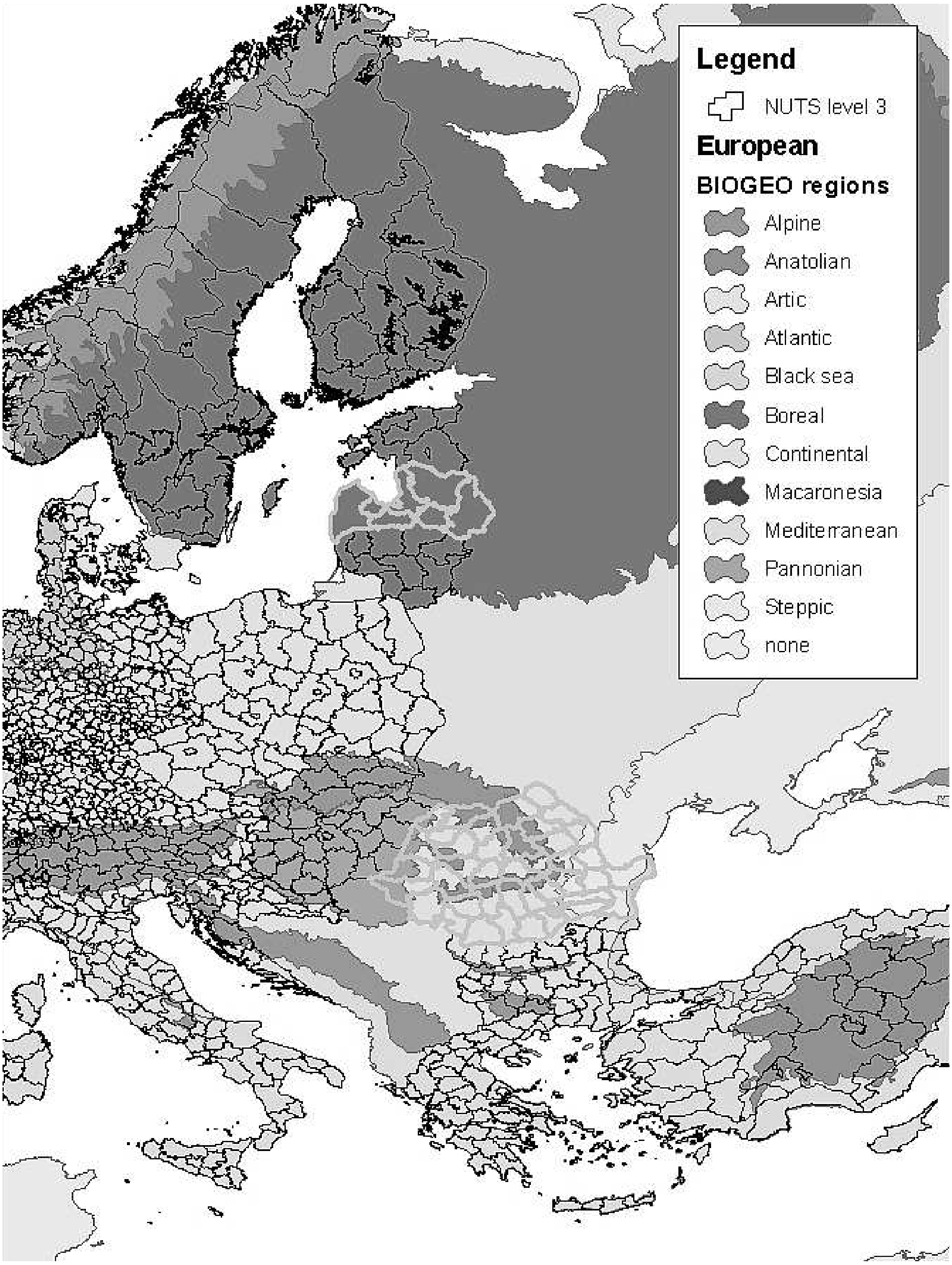

Fig.3. Distribution of assessed NUTS in the East European territory

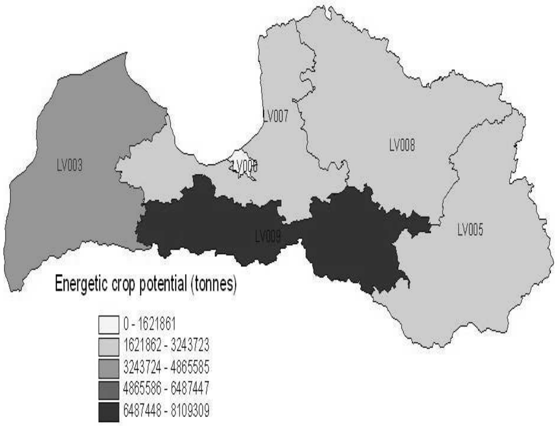

Fig.4. Energy crop potential in Latvia

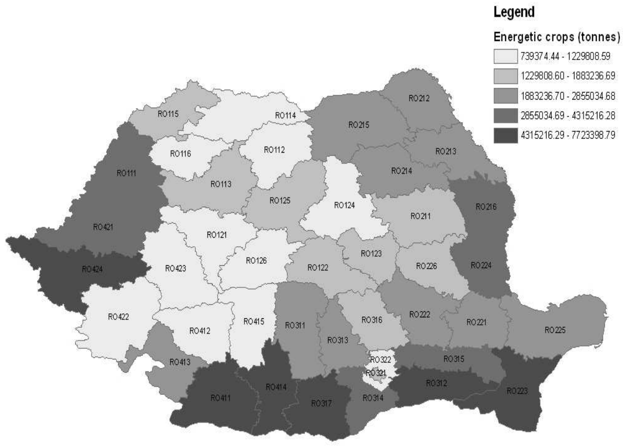

Fig.5. Energy crop potential in Romania

Secondary agricultural wastes in Latvia include manure and organic waste from animal slaughtering. Secondary agricultural waste amounts were calculated based on the annual number of livestock (including cattle, pigs, sheep, goats, horses and poultry). The number of livestock in each NUTS 3 region was obtained from the State agency Agricultural Data Centre [16]. The amount of by-products from each type of animal was calculated based on waste factors obtained from the Latvian Meat Producers Association and according to information collected from different animal breeding associations and farmers. Secondary agricultural waste is based in 3 different areas (LV003, LV005 and LV008). Waste of up to 46 164 tonnes (an average over several years) is found in all of these regions, making these regions potentially-attractive for the development of biogas facilities (Figure 7).

It is obvious that the Romanian areas that are involved in the total primary energy production are characterized by significant agricultural waste production amounts, giving the maximum outcome of around six million tonnes per year (Figure 8). The agricultural waste from secondary production is the highest in the Northern part of Romania (Figure 9). The highest potential is in the region RO215 with a total of around 300000 tonnes per year.

Comparative analysis

A comparative analysis of regions was performed using the cluster analysis methodology. Cluster analysis is commonly used to organize observed data into meaningful structures; however, in this study the main intention was to use cluster analysis to assess the results of a developed methodology and to understand how the methodology reflects the different structures and heterogeneity of selected regions.

The result of the cluster analysis is reflected in the form of a tree diagram that is provided in Figure 10. The tree diagram reflects the similarity or dissimilarity of selected cases. Cases connected on lower distances are more similar than cases connected at higher distances.

As reflected in Figure 10, the majority of the Latvian regions, except the Zemgale (LV009) and Riga regions (LV006) belongs to one package and is not similar with the Romanian regions. This is due to the difference in the bio-geographical structure of both countries, including different agricultural practices and different climate conditions.

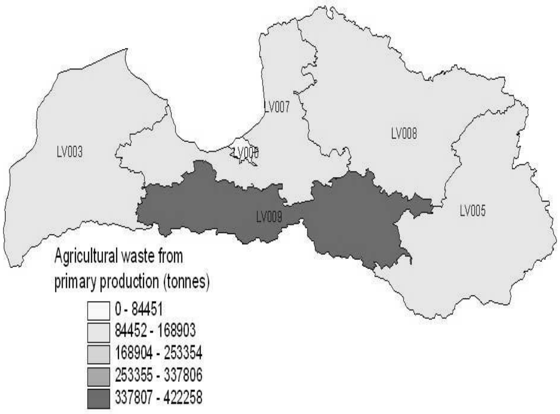

Fig.6. Agricultural waste from primary production in Latvia

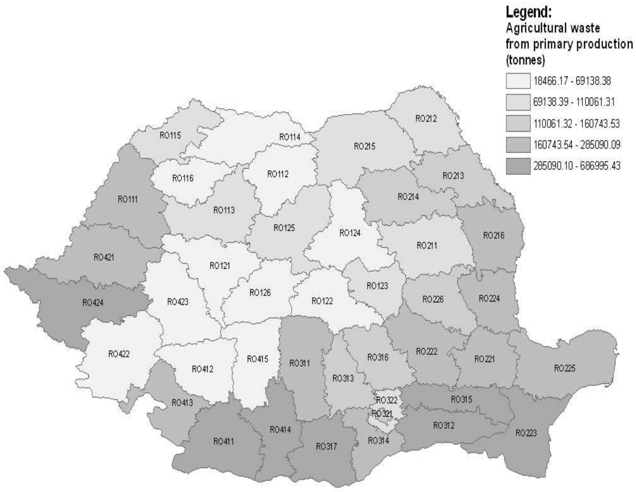

Fig.8. Agricultural waste from primary production in Romania

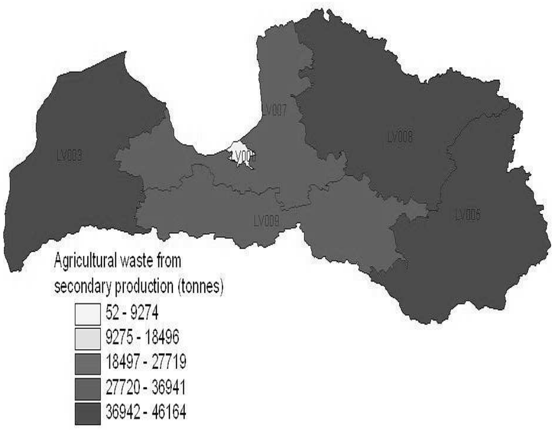

Fig.7. Agricultural waste from secondary production in Latvia

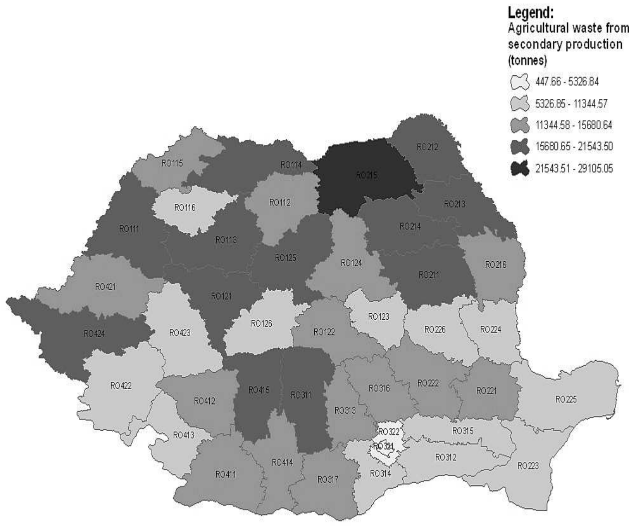

Fig.9. Agricultural waste from secondary production in Romania

Since Latvia is covered by only one type of bio-geographical division (see Figure 3), the reflection of the Latvian regions compared to Romanian regions is more homogeneous. The exception is the Zemgale region (LV009) in Latvia and the Calarasi County (RO312) in Romania which, according to the performed cluster analysis, are found to be similar. The reason for this similarity could be the fact that both regions are located in an area characterized by intensive agricultural activity which result in a high agricultural waste potential from primary production processes (see Figures 6 and 8).

The Riga region (LV006) in Latvia has less similarity to other regions due to its urban character and its more transformed structure compared to other regions in Latvia.

In comparison, the Romanian regions can be divided in four groups of similar regions. These four groups, with some exceptions, partly reflect the heterogeneous bio-geographical structure of Romania. However, to determine the exact reasons for similarities for each group of regions, an additional investigation is necessary.

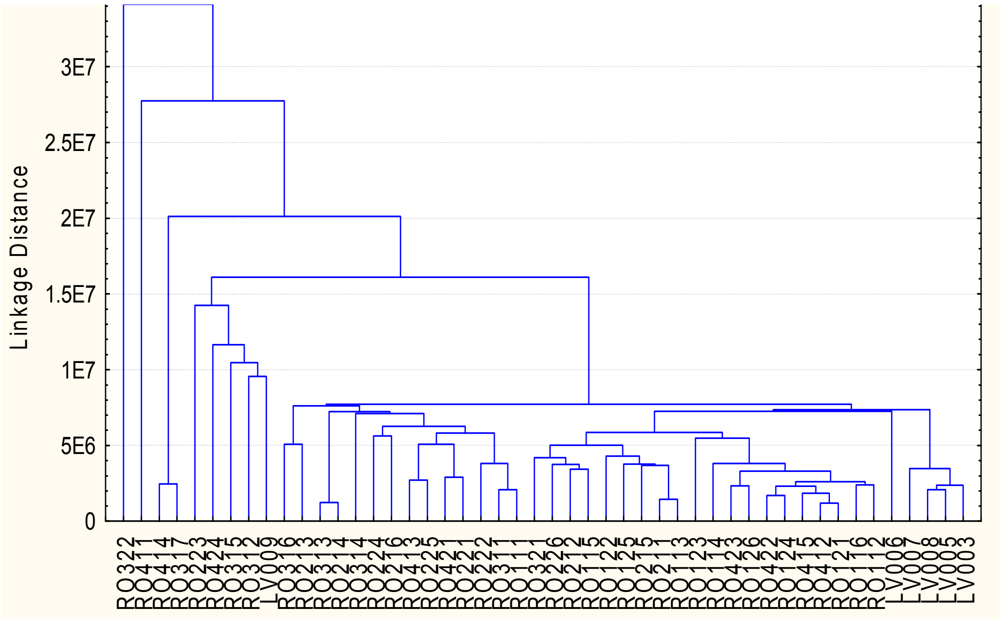

Fig.10. Tree diagram showing comparative analysis of studied regions

Conclusions

In order to handle the heterogeneity of different studied countries, an integrated information system based on a geographical information system concept was used. The developed system was tested on different bio-geographical structures presented by two European countries - Latvia and Romania - and has proven its efficiency in dealing with different levels of complexity regarding environmental and ecological structures.

Using the above mentioned system, the biomass potential that can be used as feedstock for biogas production, was assessed. Romania has significant potential for primary production (including energy crops) and there are several areas appropriate for large production amounts, especially those that are located in the south-eastern part of the country. In Latvia, the most significant energy crop and primary production organic waste potential is identified in the Zemgale region (LV009). Secondary agricultural wastes are based in three different areas (LV003, LV005 and LV008).

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Ilze Dzene, Florian Bodescu, Biomasas pieejamības izvērtējums biogāzes ražošanai reģionālā līmenī

Lai novērtētu biomasas pieejamību, tika analizēti šobrīd pieejamie dati, izmantojot integrētu determinējošu modelēšanas pieeju. Konceptuālā pieeja, kombinējot relāciju datu bāzu un ĢIS modelēšanas rīkus, tika pārbaudīta divās Eiropas valstīs – Latvijā un Rumānijā, kas abas atrodas atšķirīgās bioloģiski ģeogrāfiskajās zonās. Tika pierādīta izstrādātās sistēmas efektivitāte, analizējot neviendabīgas, dažādas sarežģītības vides un ekoloģiskās struktūras. Vispārējā pieeja biomasas resursu novērtēšanai bija vispirms noteikt to materiālu daudzumu, kas rodas no sadzīves atkritumiem un lauksaimniecības aktivitātēm katrā no izpētes apgabaliem. Pēc tam tika novērtēts tā materiāla daudzums, kuru var iegūt iepriekšminēto aktivitāšu rezultātā, ņemot vērā gan tehniskos, gan vides ierobežojumus. Izpētes rezultātā katrā valstī tika noteikti konkrēti apgabali, kuros ir augsts, vidējs vai zems biomasas potenciāls.

Ilze Dzene, Florian Bodescu, Evaluation of biomass availability at regional level

Currently available data were used in an integrated deterministic modelling approach to assess the total biomass availability. The conceptual approach of combining the benefits of relational database and GIS modelling was tested in two eastern European countries – in Latvia and Romania, both located in different bio-geographical regions. The developed system has proven its efficiency in dealing with heterogeneity in different levels of complexity regarding environmental and ecological structures. The overall approach of assessing the biomass resources was first to estimate the quantity of material generated from municipal waste and agricultural practices in each of research areas. The quantity of material that could be recovered from these practices was then taken into account and the technical and environmental constraints associated with other site factors were evaluated. As a result, the particular areas with high, medium and low potential in each country were identified.

Илзе Дзене, Флориан Бодеску, Оценка доступности биомассы дял производства биогаза на региональном уровне

Для оценки доступности биомассы был проведён анализ имеющихся на данный момент данных с использованием интегрированный детерминирующей способ моделирования. Концептуальный подход с комбинированием реляционной базы данных и инструментов моделирования географических информационных систем был апробирован в двух Европейских странах, находящихся в разных географических зонах, – в Латвии и Румынии. После анализа различных неоднородных усложнений в экологических структурах и структурах окружающей среды была доказана эффективность разработанной системы. Общий подход к оценке доступности ресурсов биомассы заключался в определении количества материала, полученного из бытовых отходов и в результате сельскохозяйственных работ в каждом их исследуемых регионов. Далее была проведена оценка количества материала, которое возможно получить в результате вышеуказанных процессов, принимая во внимание технические и экологические ограничения. В результате исследования в обеих странах были определены конкретные регионы с высоким, низким или средним потенциалом биомассы.