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AGRICULTURAL FEEDSTOCK FOR SOLID AND LIQUID BIOFUEL PRODUCTION IN UKRAINE: CLUSTER ANALYSIS*

Valerii Havrysh[1], Antonina Kalinichenko[2], Olha Minkova[3], Serhii Lyashenko[4]**

[1]Mykolayiv National Agrarian University, Department of Tractors and Agricultural Machinery, Operating and Maintenance, 9, Georgiy Gongadze Str., Mykolayiv, 54020, Ukraine
[2]University of Opole, Institute of Technical Science, ul. Dmowskiego 7-9, Opole, 45-365, Poland
[3]Poltava State Agricultural Academy, Department of Information Systems and Technologies, 1/3 Skovoroda str., Poltava, 36003, Ukraine
[4]Poltava State Agricultural Academy, Engineering and Technological Department, 1/3 Skovoroda str., Poltava, 36003, Ukraine

Abstract

This study is focused on the cluster analysis of biofuel feedstock in Ukraine. In recent years, Ukraine has been facing energy issues. There was a drop in fossil fuel production. On other hand, there has been a rise in crop production. Therefore, one of Ukraine's priorities is to develop energy application using agricultural feedstocks. The cluster analysis was used to distinguish regions by their feedstock potential. Feedstocks for solid biofuel, bioethanol, and biodiesel were investigated. Promising groups of regions for biofuel production were identified. The results can be used to create autonomous power supply systems based on agricultural by-products (straw and husk). The corn belt selected showed promising bioethanol production.

Keywords: agriculture, cluster analysis, energy, renewable

1. Introduction

Energy is the basis of the world economy. In 2017 the total Ukrainian consumption of

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** Corresponding author: e-mail: akalinichenko@uni.opole.pl

primary energy totaled up to 106.5 million tons of coal equivalent (State Statistics Service of Ukraine, 2017a). Fossil fuel reserves are distributed unevenly. Ukraine does not have enough fossil fuel reserves, so it is an energy-importer. There has been a decrease in production of Ukrainian energy resources (Fig. 1). Whereas, crop production is increasing (Fig. 2). Therefore, renewable energy is the sole indigenous resource, which can improve national energy security.

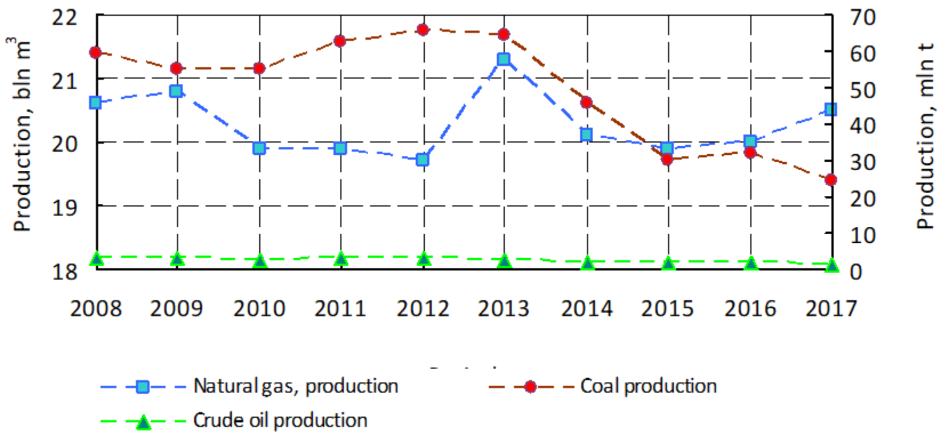

Fig. 1. Natural gas, crude oil and coal production and consumption in Ukraine (adapted from equivalent (State Statistics Service of Ukraine, 2013, 2017[2]).

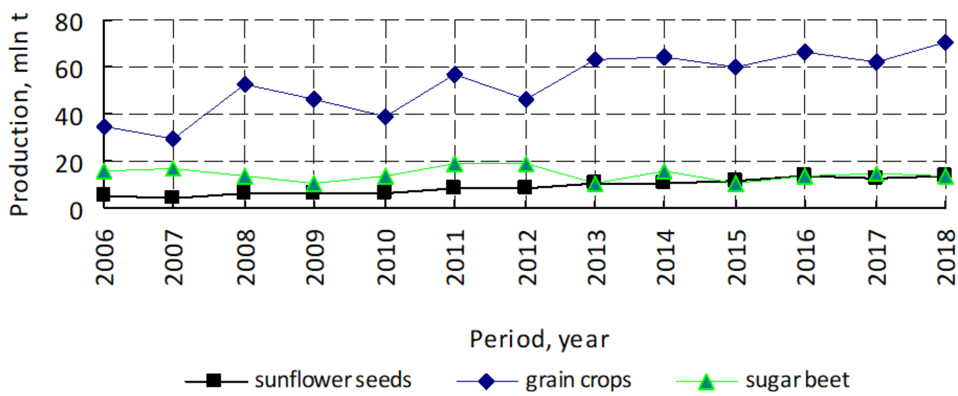

Fig. 2. Sunflower seed production history
(adapted from State Statistics Service of Ukraine, 2013, 2018)

Ukrainian agriculture has huge renewable energy potential. Using by-products of crops and energy crops can supply consumers with heat, electricity, and alternative vehicle fuels. It is of great importance, especially for the countryside. A number of scientists studied agricultural bioenergy potential in Ukraine. Fedorchenko (2014) and Melnychenko (2018) used cluster analysis of bioenergy potential in their research. Burdenyuk et al. (2017) simulated an optimal location for biofuel production. The novelty of this study is an analysis that considers the main components of energy feedstock, which are available in agriculture. It is then possible to determine the difference of individual regions.

This study is based on previous works of some authors (Brzozowska et al., 2017; Goncharuk et al., 2018; Havrysh et al., 2019; Kalinichenko et al., 2016; Kalinichenko and Havrysh, 2019).

The main objective of this study is to evaluate the allocation of homogeneous groups which have enough feedstock for energy application and are most suitable for biofuels or bioenergy production. In this context, zones which have feedstock for solid fuel, bioethanol and biodiesel production were studied.

This work is divided in three main parts:

- selection of agricultural feedstocks for energy application;
- cluster analysis of feedstock potential for solid fuel;
- cluster analysis of feedstock potential for bioethanol and biodiesel production;
- analysis of results, drawing conclusion and formulation of recommendations for decision makers in renewable energy.

2. Materials and methods

The analyzed data was collected from the State Statistical Service of Ukraine (State Statistics Service of Ukraine, 2013, 2017a, b, 2018). The above data included information about grain crop, sunflower seeds, and rapeseed production. The data of straw and husk production is presented in PJ (1 PJ = 10^{15} J = 23884.6 tons of oil equivalent), bioethanol production potential is expressed in million cubic meters, and biodiesel production is expressed in million tons.

For sets of data the cluster analysis was applied. Clustering of regions was done using the Statistica program. Dendrograms were cut off at 24 regions. The regions were grouped into clusters. Average, sum, minimum and maximum values of energy potential for each cluster were calculated.

3. Results and discussion

3.1. Agriculture as a source of renewable energy

In 2017 Ukraine consumed: total energy – 106.5 mln t of coal equivalent; liquid biofuel (for transport) – 45 thousand tons of oil equivalent; solid biofuels – 1794 thousand tons of oil equivalent (biofuel represent 2.5 %) (State Statistics Service of Ukraine, 2017b).

Agriculture has different kinds of feedstocks for energy application: straw, sunflower husk, energy crops, manure etc. Feedstocks for solid and liquid biofuels are the subjects of this study. Nowadays Ukraine has experience in using biomass for heat, electricity and cogeneration plants (Geletukha et al., 2015), which should be developed. Moreover, to improve biomass burning efficiency, scientists are developing composite fuels (Mikhailov et al., 2017) and new technologies (Panchuk et al., 2019).

Liquid biofuels (bioethanol and biodiesel) are prospects for Ukraine. Despite the fact that they are not used widely, the country has enough feedstock to produce them. Biogas is not a subject of this study.

3.2. Feedstock potential for solid fuel

Straw and sunflower seed husk productions were the initial data for the cluster analysis. The above feedstock are used to produce pellets or are burnt in boilers. Around 48% of sunflower husk volume is currently used to cover the energy requirements of sunflower oil mills. The rest may be used for energy generation too.

The annual straw potential volume depends on a number of factors: species, yield, weather, technology, etc. The available straw weight is determined by applying straw to grain mass ratios. After the analysis of technological charts, the ratio of 1.1 was taken. To calculate the net weight of straw, some additional factors have been taken into consideration: straw is retained for soil conservations and as organic fertilizer; technological losses of combine harvesters; mulching; losses through transport and storage. In this study, we assumed: soil conservation – 0.75 t per hectare; the harvest loss – 30% (Hamelinck et al., 2005; Liu, 2008; Perlack and Turhollow, 2002); the storage and transportation loss – 15% (Hamelinck et al., 2005; Liu, 2008).

The output of sunflower seed husk ranges from 15.94 to 18.88% (SEIA, 2009). An output of 17 % was assumed in this study. By cutting off the tree diagram for 2017, four clusters re-emerged (Fig. 3). Regions belonging to individual groups and average values in these groups are listed in Tables 1, 2. Straw and husk contain 437.87 PJ. It is 14.03 % of the national total energy consumption.

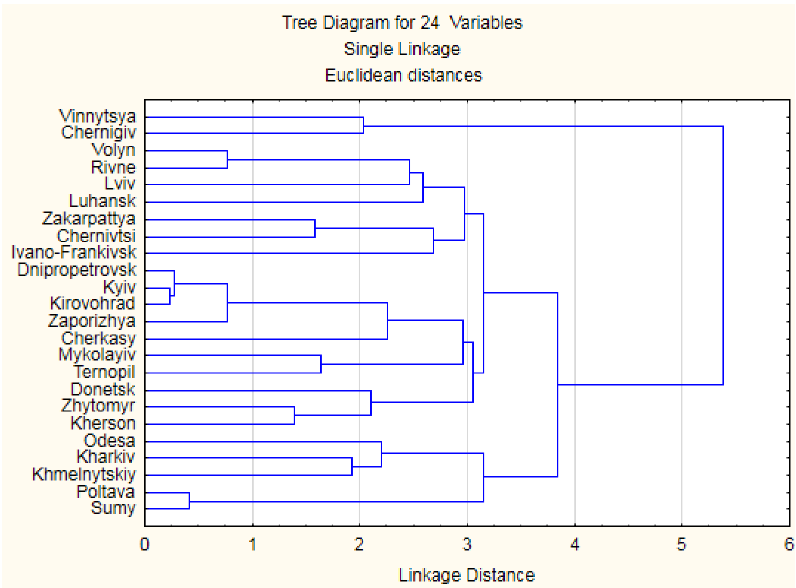

Fig. 3. Tree diagram for grain crop straw and sunflower husk Energy Potential, 2017 (developed by authors)

The A and D clusters are characterized by the value of the energy potential above the national average. Therefore, in these regions (Vinnitsa, Chernigiv, Odesa, Kharkiv, Poltava, Sumy, and Khmelnitskiy) it is advisable to produce and use solid biofuels. A promising area for the production of solid biofuels is in the adjacent regions: Kharkiv, Poltava, Sumy, and Chernigiv. These clusters have been plotted on a map of Ukraine (Fig. 4).

3.3. Feedstock potential for liquid biofuel production

Ukrainian farmers annually produce more than 25 million tons of corn and around 10-15 million tons of sugar beets (Fig. 5). The above products may be used to produce bioethanol. Ethanol yields are: corn – 400 l/t; sugar beets – 100 l/t (GREENFACTS, 2019). All regions may be divided into 4 clusters (Fig. 6). Regions belonging to individual groups and average values in these groups are listed in Tables 3, 4.

Table 1. Clusters*

Nr	*Group*			
	A	***B***	***C***	***D***
1.	Vinnytsya	Volyn	Dnipropetrovsk	Odesa
2.	Chernigiv	Rivne	Kyiv	Kharkiv
3.		Lviv	Kirovohrad	Khmelnytskiy
4.		Luhansk	Zaporizhya	Poltava
5.		Zakarpattya	Cherkasy	Sumy
6.		Chernivtsi	Mykolayiv	
7.		Ivano-Frankivsk	Ternopil	
8.			Donetsk	
9.			Zhytomyr	
10.			Kherson	

* developed by authors

Table 2. Group average energy potential*, PJ

Group	*Average*	*Sum*	*Minimum*	*Maximum*
A	35.62	71.24	34.90	36.34
B	5.62	39.31	1.11	10.34
C	18.42	184.17	14.06	22.95
D	28.63	143.16	25.66	31.10
Total	18.24	437.87	1.11	36.34

* developed by authors

Fig. 4. Visual presentation of the groups (developed by authors)

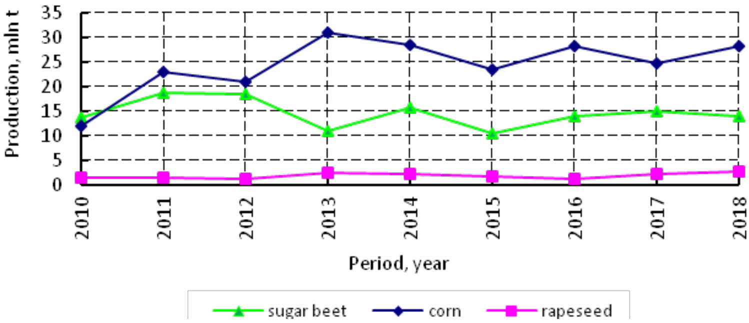

Fig. 5. Corn, rapeseed and sugar beet production history
(adapted from State Statistics Service of Ukraine, 2017a, 2018)

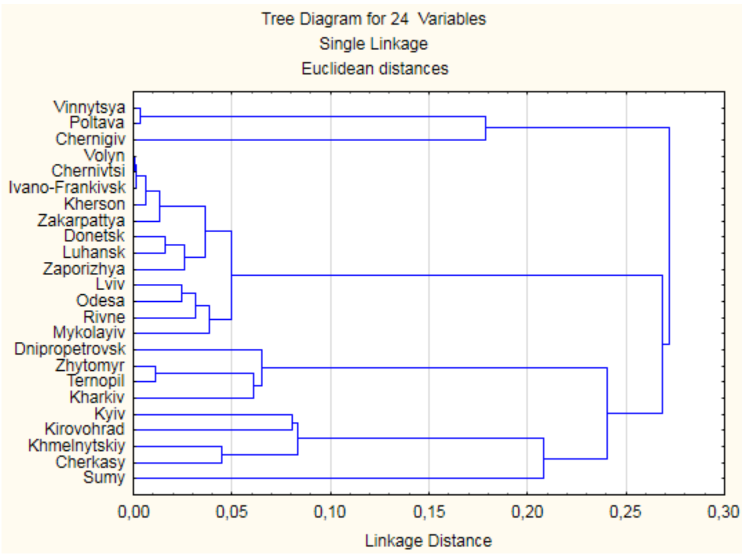

Fig. 6. Tree diagram for bioethanol production potential, 2017 (developed by authors)

Table 3. Clusters for bioethanol production*

Nr	***Group***			
	A	***B***	***C***	***D***
1.	Vinnytsya	Volyn	Dnipropetrovsk	Kyiv
2.	Poltava	Chernivtsi	Zhytomyr	Kirovohrad
3.	Chernigiv	Ivano-Frankivsk	Ternopil	Khmelnytskiy
4.		Kherson	Kharkiv	Cherkasy
5.		Zakarpattya		Sumy
6.		Donetsk		
7.		Luhansk		
8.		Zaporizhya		
9.		Lviv		
10.		Odesa		
11.		Rivne		
12.		Mykolayiv		

* developed by authors

Table 4. Group average bioethanol potential*, mln m^3

Group	*Average*	*Sum*	*Minimum*	*Maximum*
A	1.257	3.77	1.172	1.300
B	0.133	1.593	0.054	0.188
C	0.475	1.901	0.417	0.515
D	0.808	4.039	0.685	0.980
Total	0.471	11.303	0.054	1.300

* developed by authors

Group A has the highest average bioethanol potential. Group D has the second. Therefore, the promising bioethanol belt includes 8 regions. Fig. 7 shows the visual presentation of the above groups. Ukraine can produce more bioethanol than its demand in petrol. Bioethanol energy is approximately 9.7% of total national energy consumption. Therefore, investment in bioethanol production for both domestic and foreign markets may be attractive. In recent years, Ukrainian farmers annually produced around 2 million tons of rapeseed (Fig. 5). Biodiesel produced from it may cover around 40 % of national diesel fuel consumption.

Fig. 7. Bioethanol feedstock distribution by regions (developed by authors)

Ukraine can produce more bioethanol than its demand in petrol. Bioethanol energy is approximately 9.7 % of total national energy consumption. Therefore, investment in bioethanol production for both domestic and foreign markets may be attractive. n recent years, Ukrainian farmers annually produced around 2 million tons of rapeseed (Fig. 5). Biodiesel produced from it may cover around 40 % of national diesel fuel consumption. Four clusters were cut off (Fig. 8). Regions belonging to individual groups and average values in these groups are listed in Tables 5 and 6. Groups A and B are promising areas for biodiesel production. But due to higher than average feedstock potential, Cluster A is preferable. The rapeseeds belt is situated in the western part of Ukraine (Fig. 9).

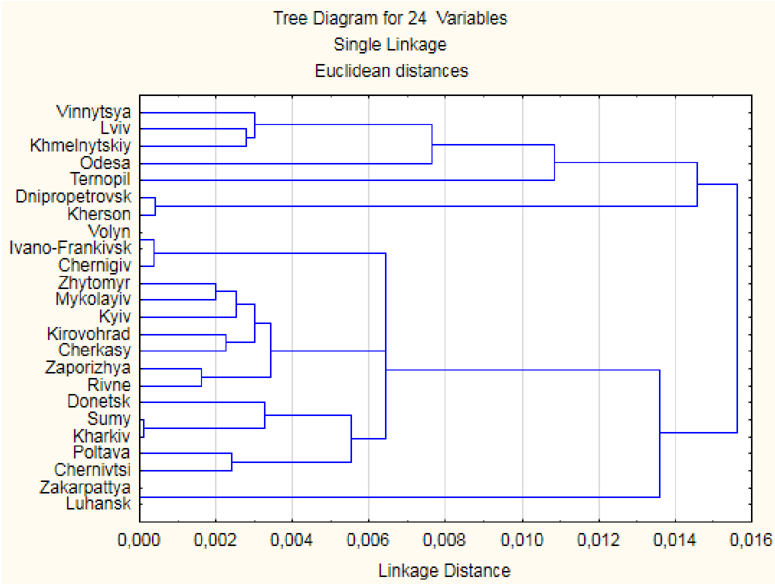

Fig. 8. Tree Diagram for Biodiesel production Potential, 2017 (developed by authors)

Table 5. Clusters for biodiesel production*

Nr	***Group***			
	A	***B***	***C***	***D***
1.	Vinnytsya	Dnipropetrovsk	Volyn	Zakarpattya
2.	Lviv	Kherson	Ivano-Frankivsk	Luhansk
3.	Khmelnytskiy		Chernigiv	
4.	Odesa		Zhytomyr	
5.	Ternopil		Mykolayiv	
6.			Kyiv	
7.			Kirovohrad	
8.			Cherkasy	
9.			Zaporizhya	
10.			Rivne	
11.			Donetsk	
12.			Sumy	
13.			Kharkiv	
14.			Poltava	
15.			Chernivtsi	

* developed by authors

Table 6. Group average biodiesel potential*, mln t

Group	*Average*	*Sum*	*Minimum*	*Maximum*
A	0.0684	0.342	0.059	0.076
B	0.0487	0.097	0.049	0.049
C	0.025	0.375	0.01	0.038
D	0	0	0	0
Total	0.0339	0.814	0	0.076

* developed by authors

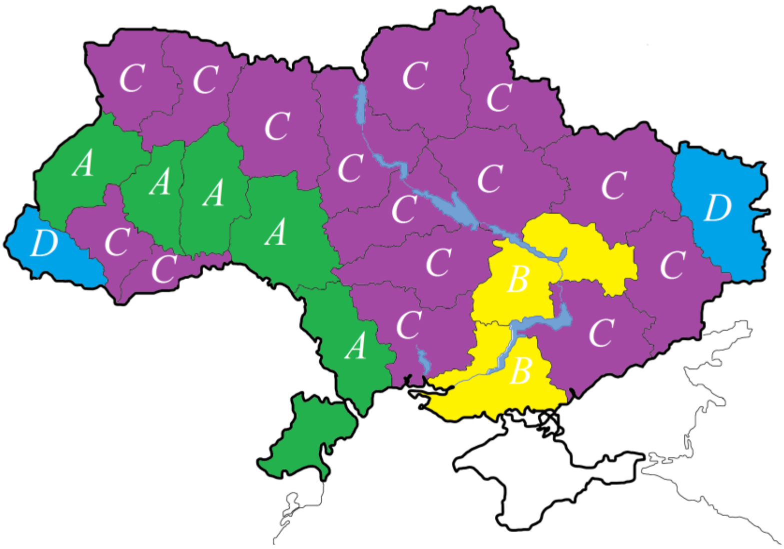

Fig. 9. Biodiesel feedstock distribution by regions (developed by authors)

4. Concluding remarks

Agriculture has feedstock potential to cover up to 24 % of total national energy consumption.

To select suitable regions for biofuels production, a cluster analysis has been made. We have selected the following promising areas for different biofuel production:

- solid biofuels – Kharkiv, Poltava, Sumy, and Chernigiv regions;
- bioethanol – Vinnitsya, Poltava, Chernigiv, Kyiv, Kirovohrad, Khmelnitskiy, Cherkasy, and Sumy regions;
- biodiesel – Vinnitsya, Lviv, Khmelnitskiy, Odesa, and Ternopil regions.

The resulting clusters can be used to create autonomous power supply systems, biofuel production, as well as to plan strategic solutions for the development of energy supply in the regions of Ukraine.

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