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ESTIMATION OF THE DOMESTIC AGRICULTURAL SECTOR POTENTIAL FOR THE GROWTH OF ENERGY CULTURES FOR BIOENERGY FUEL PRODUCTION

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ABSTRACT

The article presents discussion on the state and prospects of bioenergy development in the context of rationalization of energy crops application as resource potential of Ukraine. Along with the development of society and increase of life intensity, the needs of mankind with regard to energy resources are increasing. The reduction rates of traditional types of energy resources are progressively growing, and their shortage is increasing. In addition, Ukraine belongs to import-dependent countries in the energy sector. At the expense of its own sources, our country provides only about half of the energy needs, while domestic national economy is one of the most energy-intensive industries in the world. In this regard, there is an urgent need to search for new, alternative sources of energy. Taking into account the potential present in Ukraine, the biomass use for energy production is the most attractive option. However, along with this, there is a problem of purposeful use of the agricultural land and a competitive struggle between agricultural products for nutrition and energy purposes. At the same time, many problems arise, which concerdevelopment of an appropriate legislative framework, methodological approaches to the economic, environmental and social efficiency of production and use of biological types of energy.

Introduction

The study focuses on the justification of the bioenergy development in Ukraine, need for biological fuels, formation of the legislative and normative basis of Ukraine for production and use of biological fuels, solving the problems of high energy intensity of modern production, and reducing the import dependence of Ukraine from external energy supplies (Heletukha and Zheliezna, 2014).

With regard to assessment of biofuel production opportunities in Ukraine with the aim of finding an optimal solution to the energy problem, considering a possibility of solving the existing contradiction between production of food products and biofuels, the paper proposes an economic model of an algorithm for comparison of the effectiveness of different options of agricultural raw materials application to obtain biofuels, as opposed to traditional fuels (Galchynska et al., 2015).

Availability of the raw material base is a foundation for bioenergy development. The recent years have marked anaccelerated bioenergy development of Ukraine which needs to investigate its biomass resource base for production of solid fuels. Therefore, it is necessary to have clear data on the annual volume of production of crop by-products, as well as of that part which is available for energy use. Biomass is one of the most promising renewable energy sources, but its use in Ukraine is limited, despite the positive trend in recent years (Kozina et al., 2018).

Vegetable waste is the main component of the potential of crop-based solid biomass. To produce energy, it is necessary that collection of suitable waste is ensured. The bioenergy sector in Ukraine has the greatest potential for development. This is due to the climate peculiarities, agrarian sector potential, and availability of the necessary labor force. Such types of biomass as agricultural crops have the greatest energy potential. Biomass is one of the most promising renewable energy sources, but its use in Ukraine is limited, despite apositive trend in recent years (Mudryk et al., 2019).

Ukraine has a great potential for agricultural waste which is a cheap and affordable raw material for energy production. However, most of the crop production by-products remain in the fields or are burned without bringing any benefits. Technologies of energy use from agricultural biomass are in Ukraine at the initial stage of development, but, with appropriate conditions, they can be implemented in the coming years (Kucher and Prokopchuk, 2020).

The issues of the efficient use of the traditional energy sources in Ukraine are even more acute than in other countries. The main reasons include obsolete technologies, reduction of natural resources for production of electricity and heat, as well as significant amounts of harmful emissions. In addition, there are large losses during transportation, distribution and use of electricity and heat. The monopoly dependence on energy imports is worsening the situation on the domestic energy markets. The problem of energy security, reduction of dependence on the imported energy, particularly on natural gas, is becoming increasingly important. Significant changes have recently taken place in the energy sector of the country. Projects concerning the energy solid biofuels use and replacement of natural gas have been widely implemented (Kucher and Prokopchuk, 2018).

The power industry of any state is the foundation and an important part of the national economy, which is primarily connected with the production and maintenance of the society's demand for electric and thermal energy. Undeniably, at the present stage of human development, electricity is the basis and an integral part of not only modern industrial production, agriculture, and science, but also a habitual and integral part of our everyday life. Today, the energy policy of Ukraine aims at energy saving and development of renewable energy sources. One of the priority tasks and directions of the implementation of the energy strategy is the development of the energy legislation of Ukraine. Any economic, institutional, and other transformations in the energy sector as well as construction of the domestic and foreign policy in this area should be based exclusively on the provisions of the laws of Ukraine (Misiuk et al., 2020).

Methodology and purpose of the study

The paper aims at presentation of the current use of biomass for energy production in Ukraine. The main attention is paid to the schemes for renewable energy production. It presents key indicators of the developed concepts for heat and power production from energy crops. It uses secondary data sources which cover the period of 2010-2017.

To present the results of the study the following were used:

Table, graphic, and calculation methods, which allowed analyzis of the dynamics of the economics potential of by-products of energy crop production in 2010-2017;

The analysis of biomass potential of energy crops volumes was carried out with the help of an in-depth statistical method taking into consideration the structure of agricultural land in Ukraine;

Complex assessment of bioenergy potential;

The economic and graphic methods used for the study of economic potential domestic energy crops.

The purpose of the present study is to assess the opportunities of the domestic agrarian sector in growing energy crops for bioenergy fuels.

Results and discussion

To determine Ukraine's potential in the production of energy crops and to avoid contradictions with the production of food crops, which may create probable threats to food security, it is necessary to assess the available land resources and the existing structure of the crop area (Table 1). This will provide an opportunity to determine the optimal share of land that may be additionally involved in the production of energy crops.

The studies show that the prevailing peculiarity of the structure of agricultural land in Ukraine, compared with other countries, is that the arable land, the size of which tends to increase, occupies the predominant part here. Cultivated areas are mostly occupied by cereals and leguminous crops. The area of arable land, grassland, perennial plantations, hayfields, and pastures decreased in the course of the studied period. Instead, the total size of the sown area has increased, however, the cross-sectoral trends are observed in the context of species, in particular, the sown area of cereals and leguminous crops, potatoes, vegetable and melon food crops has decreased, the sown area of technical crops and the unused arable land area have increased. In Figure 1 we present the proposed percentage distribution of the total area under energy crops.

Table 1.
The structure of agricultural land in Ukraine

Parameters	2010		2015		2017		2010–2017 (%)
	K (ha)	Structure (%)	K (ha)	Structure (%)	K (ha)	Structure (%)	
Agricultural land	41576	100	41512	100	41489	100	99.8
Arable land	32477	78.1	32531	78.4	32544	78.4	100.2
Grassland	310	0.7	239	0.6	229	0.6	73.9
Perennial plantations	897	2.2	893	2.2	895	2.2	99.8
Hayfields	2411	5.8	2407	5.8	2399	5.8	99.5
Pastures	5482	13.2	5441	13.1	5422	13.1	98.9
Sowing land	26952	100	26902	100	27585	100	102.3
Incl. Cereals And legumes	15090	56.0	14739	54.8	14624	53.0	96.9
Technical crops	7296	27.1	8350	31.0	9259	33.6	126.9
Potatoes, vegetable crops and melon Food crops	1967	7.3	1823	6.8	1844	6.7	93.7
Fodder crops	2599	9.6	1990	7.4	1859	6.7	71.5
Pure fallow land area	1465	-	614	-	598	-	40.8
Unoccupied arable land area	4060	-	5015	-	4361	-	107.4

Source: Author's own study based on Statistical information (2018). State Statistics Committee of Ukraine [electronic resource]. Access: www.ukrstat.gov.ua.

The largest area is occupied by corn (50%), the smallest – by poplar and Miscanthus, respectively 10 and 15%. The total area under willow plantations is 25%. It should be noted that the lack of reliable, systematic, and transparent information support is a rather problematic issue for conducting a pertinent assessment of domestic potential in bioenergy. In order to achieve the goals set by Ukraine in the field of renewable energy, information is required on the energy potential of biomass. However, the results of existing estimations of biomass resources for the same geographic area differ significantly.

The most significant reason for the difference in results is the variety of approaches to choosing a common methodology for estimating input data, methods for identifying the potential of land available for growing energy crops, coefficients and assumptions about the production and utilization of biomass.

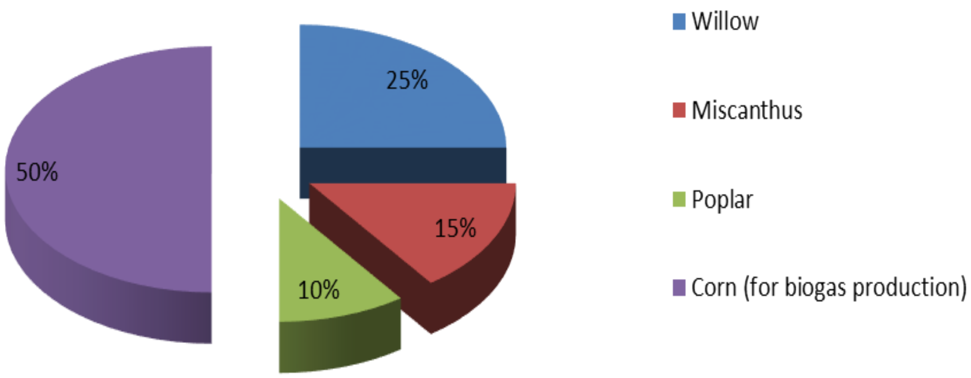

Figure 1. Distribution of total area under energy crops,(%)

Source: Authors' own study based on Bondar and Fursa (2015)

Dependence for calculation of the economic potential of biomass is determined by the following formula:

$$Pe = \sum_{i=1}^{n} Sec \cdot Kasb_i \cdot Csb_i \cdot Kt - sb_i \cdot Koe - sb_i \qquad (1)$$

where:
is the area of free agricultural land; calculated as follows using the statistical data: /arable land area/ - /sown area/ - /area of clean fallow land/, $Kasb_i$ is a coefficient that determines which part of free agricultural land can be used for planting of the *i* species energy crop in order to obtain solid biomass (to calculate the theoretical potential). This coefficient is determined taking into account local conditions.

The estimated value:
Kasb = 0.25 for the entire "set" of energy crops intended for solid biomass production;
Csb_i – productivity of energy crop of the *i* species, in tons of dry matter (dm)/(ha^{-year});
$Kt\text{-}sb_i$ = 0.9 – the coefficient of technical availability of biomass (for calculation of technical potential, which in this case coincides with the economic potential);
$Koe\text{-}sb_i$ – the coefficient of conversion of biomass potential into oil equivalent: calorific value of biomass of energy crop / calorific value of the oil equivalent (Shpychak, Bodnar & Pashko 2019).

Typical values of the yield of certain energy crops suitable for Ukraine (Csb), and the value of the coefficient for calculating the biomass potential in the oil equivalent (Koe) are shown in Table 2.

Table 2.
The ratio of the biomass potential to the oil equivalent

Type of energy crops	Csb_i t dm·(ha/year)$^{-1}$		$Koe-sb_i$
	Sufficient rainfall	Tack of rainfall	
Poplar	12	8	0.442
Willow	10	8	0.430
Miscanthus	12	10	0.406

Source: Formed by authors based on Klius (2012) and Iankovska (2017)

Taking into account the technological possibilities of using green mass as the raw material for biogas production, the potential of synthesis of biogas production and its use as a fuel can be considered considerably larger.

Dependence on the calculation of the economic potential of biogas:

$$Pe = Sec \cdot Kabg \cdot Cbg \cdot g_{ec}^{bg} \cdot Kt - bg \cdot Koe - bg \tag{2}$$

where:

is the area of free agricultural land; it should be calculated as described in the explanations to the dependence.

$Kabg$ ·= 0.25 (estimated value) is the coefficient that determines which part of free agricultural land can be used to grow energy crops for production of biogas (to calculate the theoretical potential of biomass). This coefficient should be adjusted to take into account local conditions;

Cbg – yield of energy crop for biogas, tons/(ha·year^{-1}). In Ukraine, such a culture may be corn for silage; The average yield of corn for silage is 30 tons·(ha·year^{-1})$^{-1}$.

g_{ec}^{bg} – expected specific output of biogas from energy crop, m^3·t^{-1}. For corn silage the default value is 185 m^3·t^{-1};

$Kt-bg$ – the coefficient of technical availability of biomass (for calculation of technical potential, which in this case coincides with the economic potential). For corn silage the default value is 0.7;

$Koe-bg$ – the coefficient of conversion of biomass potential into oil equivalent: calorific value of biomass of energy crop / calorific value of the oil equivalent. For corn silage the default value of the net calorific value is 20 MJ·m^{-3}. Accordingly = 0.478.

In accordance with the presented methodology, the structure of the domestic potential of energy crops is calculated (Table 3).

It is proved that energy crops should be grown only on unproductive, degraded, technogenically polluted, broken areas and wetlands. Degraded areas include land occupied by landslides, rocky places, ravines. Unprofitable areas include lawn arable land and arable land on slopes of more than 7. Based on the information of the State Service of Ukraine on geodesy, cartography, and cadastre regarding the number of such lands, Figure 2 and Table 3 presents the domestic potential of energy crops structured by regions.

Table 3.
Structure of the potential of energy crops from 2010 to 2017, K tons o.e.·year^{-1}

Indicators	2010	2011	2012	2013	2014	2015	2016	2017	2017-2010 (%)
Willow	908	805	772	718	997	1122	1100	1778	8.7
Miscanthus	607	538	516	480	667	750	735	1189	5.8
Poplar	371	328	315	293	407	458	449	726	3.6
Corn (for biogas)	942	835	801	745	1034	1164	1141	1816	8.7
Total	2829	2506	2404	2236	3106	3495	3425	5508	26.8

Source: Formed by authors based on Tkachenko (2018)

Figure 1. Distribution of total area under energy crops,(%)

Source: formed by the author

It is established that the greatest potential for growing energy crops is in Volyn, Rivne, Zhytomyr, Chernihiv, Odessa, Poltava, and Sumy regions. This will allow not only to obtain bioenergy fuels, but also to prevent soil erosion and to improve the condition of natural environment.

Ukraine has three natural and climatic zones (Steppe, Forest-steppe, Polissya and Carpathians), so it is most advisable to grow energy willow in the wetlands of all these zones.

However, this approach is suggested according to the ratio of rainfall to the amount of accumulated heat. Today, with the change in the average annual temperature and the amount of accumulated heat, these agroclimatic zones are shifted. According to the data provided by weather forecasters, they gradually migrate to the north. The increase in temperature by 1°C shifts the boundary of agroclimatic zones by an average of 100 km to the north, and if the temperature increases by 2°C, the boundary of climatic zones is shifted by as much as 200 km, which means that the conditions for cultivating conventional agricultural crops considerably deteriorate. Studies demonstrate that in the steppe zone it is economically efficient to plant about half of the area of inappropriate land with miscanthus. For the climatic conditions of the forest-steppe zone, poplar and alder are more adapted, which are also recommended for planting on unsuitable lands. For Polissya and Carpathians, 75% of unsuitable land is expedient to plant poplar and alder, and 25% to plant miscanthus. It should be noted that the miscanthus is one of the perennials that can provide both the energy component (biofuels for sale) and the extremely important additional processing products – cellulose, paper, raw materials for production of construction materials and MDFs.

Table 4.
Theoretical potential of energy crops by regions of Ukraine for 2017

	Ukraine	Vinnytsya	Volyn	Dnipro	Donetsk	Zhytomyr	Zakarpattia	Zaporizhia	Ivano-Frankivsk	Kyiv	Kirovohrad	Luhansk	Lviv	Mykolajiv	Odesa	Poltava	Rivne	Sumy	Ternopil	Kharkiv	Kherson	Khmelnytsky	Cherkasy	Chernivtsi	Chernihiv
Crops by area, K (ha)																									
Willow	497	9	32	20	40	41	21	18	7	14	6	8	6	18	46	32	31	33	7	10	26	16	13	8	35
Miscanthus	298	5	19	12	24	25	13	11	4	8	4	5	4	11	28	19	19	20	4	6	15	9	8	5	21
Poplar	199	3	13	8	16	16	8	7	3	5	3	3	3	7	18	13	13	13	3	4	10	6	5	3	14
Corn (for biogas)	993	17	65	39	79	82	42	36	14	27	13	17	13	37	92	64	63	66	13	19	51	32	26	16	71
Total	1986	35	129	78	159	165	84	71	28	55	25	34	26	74	183	128	125	132	27	39	102	63	52	32	141
Yield of corn for silage, $t \cdot ha^{-1}$	23	28	37	17	16	26	15	16	33	25	16	11	30	11	13	22	36	31	35	14	22	34	24	24	30
Structure of the potential of energy crops, K (tons o.e.$\cdot year^{-1}$)																									
willow	1778	31	116	70	142	147	75	64	25	49	23	30	23	66	164	115	112	118	24	35	92	57	46	28	126
Miscanthus	1189	21	77	47	95	98	50	43	17	33	15	20	15	44	110	77	75	79	16	23	61	38	31	19	84
poplar	726	13	47	29	58	60	31	26	10	20	9	12	9	27	67	47	46	48	10	14	37	23	19	12	52
corn (for biogas)	1816	38	190	51	103	171	51	45	37	54	16	15	31	33	97	110	179	160	38	21	88	86	50	31	168
Total	5508	102	430	197	398	477	208	178	89	155	63	77	79	169	438	348	413	405	88	93	278	204	146	89	430

Note: Author's own calculations

In Ukraine, the hybrid of the miscanthus was invented, which provides more yield and adaptability to the Ukrainian soil. This perennial plant for the 2nd year after planting already provides 3-4 tons of biomass from 1 hectare, and in the third year it is already possible to collect up to 20 tons of biomass, obtaining up to 6 kg of cellulose from 1 hectare. In the context of the cost of growing, miscanthus is the least costly culture among energy crops. Cellulose is one of the most important elements of raw materials for production of cotton and paper fabrics, plastic masses, artificial fibers, and many others. This will make it possible to increase the added value and the amount of cultivation of this culture.

Conclusions

Despite the significant import dependence of Ukraine on energy resources, currently little attention is paid to implementation of the existing potential in the production of energy crops and use of biomass for energy production. The feasibility of involvement of unsuitable lands for cultivating energy crops has been substantiated. It has been established that the benefits of these crops include no need of reduction of the area of arable land and agricultural land involved in agricultural production. Taking into account the existing areas of an unsuitable land in Ukraine, the huge potential in production of energy crops in terms of their species (willow, miscanthus, poplar) is determined, and the optimal structure of their production is proposed on the basis of domestic energy needs.

The results of the calculations show that the theoretical potential of energy crops in the regions of Ukraine in 2017 is equal to 5508 thousand tons of oil equivalent. According to the study results, the greatest potential for growing energy crops is in Volyn, Rivne, Zhytomyr, Chernihiv, Odessa, Poltava and Sumy regions. The reorientation to energy crops growing will allow these areas to create new jobs, create guaranteed and predictable sources of biofuels, replace imported energy, reduce greenhouse gas emissions, develop the local economy, restore soil fertility, and improve the trade balance of the state.

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OCENA POTENCJAŁU KRAJOWEGO SEKTORA ROLNICZEGO W ROZWOJU KULTUR ENERGETYCZNYCH W PRODUKCJI BIOPALIWA

Streszczenie. W niniejszym artykule przedstawiono rozważania na temat stanu i możliwości rozwoju bioenergii w kontekście racjonalizacji zastosowania upraw energetycznych jako potencjału zasobów Ukrainy. Potrzeby ludzkości związane ze źródłami energii wzrastają wraz z rozwojem społeczeństwa i zwiększającą się intensywnością życia. Poziomy redukcji tradycyjnych rodzajów źródeł energii stale zwiększają się a ich niedobór wzrasta. Ponadto, Ukraina należy do krajów, które polegają na imporcie w kwestii energetycznej. Bazując na swoich zasobach, nasz kraj zaspokaja jedynie około połowy zapotrzebowania na energię, podczas gdy krajowa gospodarka jest jedną z największych energochłonnych gałęzi przemysłu na świecie. Dlatego, istnieje pilna potrzeba znalezienia nowych, alternatywnych źródeł energii. Biorąc pod uwagę możliwości Ukrainy, zastosowanie biomasy do produkcji energii jest najbardziej atrakcyjną opcją. Jednak, istnieje także inny problem, a mianowicie kwestia celowego wykorzystania użytków rolnych i walka konkurencyjna pomiędzy produktami rolniczymi na żywność i na cele energetyczne. Jednocześnie, pojawia się wiele problemów dotyczących przygotowania odpowiedniej ramy legislacyjnej, podejść metodologicznych do skuteczności gospodarczej, środowiskowej i społecznej produkcji i wykorzystania biologicznych rodzajów energii.

Słowa kluczowe: bioenergia, wewnętrzna przewaga konkurencyjna, produkt zbożowy