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Waste-free biofuel production technologies as a way to the European Green Deal

Abstract: This article analyzes the perspective of implementing target indicators in the green transition of the agro-industrial complex of Ukraine. It is established that soil degradation has acquired a global dimension, and it has become a serious problem of a socio-economic nature due to the military actions in Ukraine. Analysis of the state of agricultural land was performed based on the following indicators: humus content in the soil, volume of application of organic and mineral fertilizers, pesticides, land area under organic production, etc. The purpose of the study is to assess the impact of implementing waste-free biofuel production technologies at the enterprises of the agro-industrial complex to achieve eco-goals of the European Green Deal. The article outlines target guidelines for achieving eco-goals of the European Green Deal. Further steps necessary to overcome current problems in compliance with the norms of the EU legislation on environmental protection at agricultural enterprises for the sale of agricultural products to European markets are proposed. It has been scientifically proven that the agro-industrial complex of Ukraine has an untapped potential for reducing greenhouse gas emissions through ecological modernization and implementing waste-free production technologies. It is suggested to use biogas plants as a promising means of solving the problems of waste disposal, improving the ecological situation,

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reducing energy dependence, and increasing soil fertility. The effectiveness of applying organic fertilizer, namely digestate, a by-product of methane fermentation, as biofertilizers at agricultural enterprises has been proven. Recommendations are provided regarding soil regeneration measures in Ukraine in the future.

Keywords: agro-industrial complex, soil degradation, digestate, bioenergy recycling, biogas

Introduction

The agro-industrial complex of Ukraine is the main budget-generating industry. European integration of Ukraine and the fulfillment of international obligations depend on the greening of the agro-industrial complex. Today, our state has to form a unified agricultural policy and coordinate work with international partners for the implementation of the European Green Deal. For this purpose, it is necessary to form new food production chains based on organic production, ensure certification of product safety and labeling, and create joint incentive programs for producers and consumers to switch to the use of alternative energy sources, all of which will create a favorable external environment for the Ukrainian producer of agricultural products. One of the methods of greening agricultural production and reducing the carbon footprint is the introduction of waste-free technologies for the production of biofuels, which are capable of the ecological disposing of waste.

The introduction of biogas plants at enterprises of the agro-industrial complex can both ensure energy independence due to the production and use of biogas and improve soil fertility because a by-product of the anaerobic fermentation process in biogas reactors is organic fertilizer, i.e. digestate. Such a by-product of biogas production, given the significant increase in the prices of mineral fertilizers in Ukraine, is an additional source of income for agricultural producers.

1. Literature review

Czekała et al. (2022) and Ariunbaatar et al. (2014) investigated the properties of digestate as a fertilizer and the dependence of its composition and productivity on the raw materials used for biogas production.

Häfner et al. (2022) characterized the types of digestate and proved that their composition is related to the value of nitrogen fertilizers and the ability to decompose organic matter. The research results show that usual differences in the digestate composition have little effect on its productivity after its application into the soil.

Lamolinara et al. (2021) also proved that raw materials, processing technology, and working conditions of the anaerobic fermentation process significantly affect digestate characteristics. The results of the authors' research proved that the application of digestate ensures the return of important nutrients to the soil, such as nitrogen and phosphorus, which can also help compensate for soil erosion and increase its fertility.

Angouria-Tsorochidou and Thomsen (2021a) evaluated different scenarios of digestate use: the direct application to the soil of raw and treated digestate in liquid and solid form.

Lohosha et al. (2023) and Angouria-Tsorochidou et al. (2022b) proposed a digestate application system that improves soil properties and fertility indicators, especially with regard to increasing the absorption capacity and buffering capacity of the soil. As a result of all these processes, the nutritional conditions of agricultural crops are optimized.

Research by Kaletnik et al. (2020), Pryshliak et al. (2022), Tokarchuk et al. (2021), Honcharuk et al. (2023) and Tsytsiura (2023) are dedicated to the study of bioenergy recycling of waste at enterprises of the agro-industrial complex of Ukraine. The potential of biofuel production by the agro-industrial complex of Ukraine is calculated, which is able to ensure both the energy independence of the complex from fossil energy sources and the country as a whole.

Varchenko et al. (2020) investigated the tools of state and regional support tools for farms growing energy crops for biofuel production and proposed a mechanism for stimulating this type of activity through the partial reimbursement of production costs.

Bulgakov et al. (2019) and Kupchuk et al. (2022) conducted a comparative study of indicators of the productivity of the working body of tillage on the growth and yield of energy crops.

2. Materials and methods

Statistical research methods and comparative analysis were used to obtain scientific results. Trends and regularities in the development of individual processes were revealed by systematizing and analyzing statistical data,

The article uses statistical data for 2021–2022 of the research conducted by the Food and Agriculture Organization, BTU-CENTER, the National Academy of Agrarian Sciences of Ukraine, the National Scientific Center "Institute of Soil Science and Agrochemistry named after O. N. Sokolovsky", the State Service of Ukraine for Emergency Situations, the State Environmental Inspection of Ukraine and the Kyiv School of Economics regarding the loss of the land fund as a result of soil degradation and its contamination as a result of military operations conducted on the territory of Ukraine. The main indicators for 2018–2021 which characterize the state of agricultural land and organic production were also analyzed. The data of the State Statistics Service on the amount and structure of the application of organic fertilizers in crops in

Ukraine in 2018–2021 were analyzed. With the help of these methods, the influence of certain factors on the reduction of soil fertility was determined and reserves for the eco-modernization of agricultural production were identified.

The method of logical generalization was used for the theoretical justification of the tasks and clarification of the content of key concepts of the conducted research. It is based on the successful case, namely the practice of biogas production from agri-biomass and waste and the use of a by-product, i.e. digestate, during the cultivation of agricultural crops at individual agricultural enterprises of the Vinnytsia region and Ukraine, which is recommended for implementation by other agricultural enterprises.

The main chemical parameters of the organic fertilizer "LoostEco" produced by Lootdorf LLC were determined using agrochemical analysis, and a comparative analysis of the quantitative content of components with litter manure was performed.

3. Results and discussion

Soil degradation is a global problem. Around 25% of the world's land surface is degraded soil. Every year, the planet loses 24 billion tons of fertile soil. In the region of 3.2 billion people suffer annually due to depleted land resources. If this trend continues, degraded soils will occupy 95% of the earth's surface by 2050. Halting and reversing current soil degradation trends can result in getting up to €1.2 trillion per year of global economic benefits.

According to FAO estimates, almost 33% of agricultural land in Ukraine has undergone significant degradation (FAO 2021). According to the research, more than 50% of Ukrainian farmers have already felt the effects of soil degradation. Over the last century, Ukrainian lands have lost 30% of humus (BTU-CENTER 2022).

Ukraine's poverty rate is one of the highest in the world – 53.9% (Poland – 36.5%, Germany – 34.1%, USA –17.5%, China – 12%). According to estimates, economic losses from soil degradation in Ukraine before the start of the war amounted to about UAH 40 billion per year (National Academy of Agrarian Sciences of Ukraine 2021).

More than 200,000 hectares of the territory are contaminated by mines, shells, and ammunition fragments due to military operations. Only in the first 3 months of the full-scale war did the damage to the Ukrainian environment reach UAH 200 billion. As of May 2022, more than 200 eco-crimes were recorded. According to preliminary estimates, as of September 1, 2022, the amount of total damage caused to the lands and soils of Ukraine was USD 15.013 billion.

1. Losses of the land fund:

- according to the calculations of the National Scientific Center "Institute of Soil Science and Agrochemistry named after O. N. Sokolovsky", targeted costs for the reclamation of lands that were disturbed as a result of hostilities comprise UAH 171 billion (about USD 4.672 billion) (2022);

- damage caused to the owners (land users) of agricultural plots of land amount to USD 2.135 million (Kyiv School of Economics 2022);
- costs for the restoration of reclamation areas amount to UAH 120 billion (about USD 4 billion) (Recovery Plan of Ukraine 2022);
- costs for demining comprise USD 436 million (State Emergency Service of Ukraine 2022).

2. Damage caused to land resources and soils (State Environmental Inspection of Ukraine 2022):

- damage caused to soils and land plots as a result of soil pollution and the littering of land plots amounts to UAH 138 billion (about USD 3.770 billion).

In the EU countries and Ukraine, the main program document that sets targets and benchmarks for the green transition in the agricultural sector of the economy is the European Green Course, which is summarized in Table 1.

Currently, the domestic agro-industrial complex must make the transition to environmentally friendly production of agricultural and food products, as exporters of products to the EU agricultural market are forced to comply with the relevant environmental norms of the European agricultural policy legislation. This contributes to reducing the impact on the natural environment of agriculture and the agro-industrial complex as a whole.

Having analyzed the state of the key indicators of the program documents of the European Green Deal (Table 2), a negative tendency towards the reduction of humus content by 0.09% in the soils of agricultural lands in 2020, compared to 2015, was observed. The reduction of agricultural lands under organic farming did not contribute to the restoration of soil fertility as well, which was 39.7 thousand ha less in 2021, compared to 2020. The area and volume of application of mineral fertilizers are increasing (the share of areas treated with mineral fertilizers to the total area of agricultural land is 61.7%), which is the opposite of the goals of achieving the greening of agriculture, By contrast, the share of agricultural land treated with organic fertilizers remains insignificantly small (3.4%). The negative tendency is also seen in the dynamics of the increase in the amount of the usage of external pesticides for the harvest of the reporting year from 2018 to 2022, although their use should decrease in accordance with the stated goals. However, in 2022, a slight reduction of 5,905.2 kg in the amount of pesticide application is seen compared to 2018.

When diagnosing soil condition, one of the indicators showing its degradation is a decrease in the content of organic carbon (humus) in the soil. To restore soil fertility, it is necessary to increase the amount of organic fertilizers, while reducing the amount of mineral fertilizers and pesticides.

Some of the most common organic fertilizers are litter manure of farm animals, poultry droppings, peat and its substrates, post-harvest residues, green manure (siderates), etc., which contain organic carbon, nitrogen, potassium, phosphorus, magnesium, calcium, and other trace elements.

In 1990, when the number of farm animals in Ukraine was almost ten times higher than today, manure has the largest share among organic fertilizers applied in the soil of agricultural lands. Due to the system of fertilization with manure, farms met up to 50% of plant nutritional needs. However, during 2018–2022, there was a decrease in the amount of manure from farm animals by 979.4 thousand tons under the crop (Table 3). That was caused by a decrease in the number

Table 1. Key directions and target orientations of the eco-goals of the program documents of the European Green Deal

Tabela 1. Kluczowe kierunki i docelowe orientacje ekocelów dokumentów programowych Europejskiego Zielonego Ładu

Key directions	Target orientations
European Green Deal	
✦ "clean" energy; ✦ ecological construction and renovation; ✦ actions aimed at climate protection; ✦ the eco-modernization of agriculture, industry, and other sectors of the economy; ✦ the preservation of biodiversity; ✦ reducing the level of environmental pollution.	✦ reducing the use of pesticides by 25% by 2030; ✦ reducing the use of fertilizers and antibiotics in agriculture by 25% by 2030; ✦ banning the import of food products from countries that do not comply with EU legislation on environmental protection.
EU Strategy "From the Farm to the Table"	
✦ reforming the EU food system on the basis of sustainability; ✦ the production of organic food, formation and provision of food security while reducing environmental pollution; ✦ the popularization of healthy food; ✦ reducing the amount of waste and encouraging recycling; ✦ control of falsification and low-quality food products.	✦ reducing the use of chemical pesticides by 50% by 2030; ✦ reducing the use of mineral fertilizers by 20% by 2030; ✦ reducing the use of antibiotics in livestock and fish farming by 50% by 2030; ✦ ensuring an increase in the areas under organic production up to 25% by 2030; ✦ halving the amount of food waste per capita at the retail and consumer levels; ✦ 100% access to high-speed broadband Internet in rural areas by 2025.
EU Soil Strategy	
✦ the introduction of norms regarding soil management on the basis of sustainability in EU countries; ✦ the implementation of the initiative "Test Your Soil for Free"; ✦ promoting the circular economy; ✦ the study of the possibility of introducing a sanitary certificate of soil health, which will be necessary for the execution of land transactions; ✦ support for the initiative of the EU countries to counter and combat desertification at the global level; ✦ the transition to organic farming considering the consequences of climate change, and the use of innovative soil cultivation technologies that reduce environmental pollution. In particular, for this purpose, it is planned to establish legally binding provisions aimed to stop the drainage of wetlands and organic soils; ✦ the mobilization of public involvement and financial resources for the popularization of scientific soil research.	✦ making proposals and developing a new legal act that will regulate soil health until 2023. This legislative act should supplement the Law on the Nature Restoration; ✦ achieving a healthy state of soils and their ecosystems in EU countries by 2050.

Source: developed by the authors based on the analysis of program documents of the European Green Deal (2022).

Table 2. Soil condition of Ukraine's agricultural lands in 2018–2022

Tabela 2. Stan gleby na ukraińskich gruntach rolnych w latach 2018–2022

Indicator	Years					Absolute deviation +/-
	2018	2019	2020	2021	2022	
The content of organic carbon (humus) in the soils of agricultural lands [%]	3.07			–	–	–
The amount of organic fertilizers applied per 1,000 t	11,648.9	11,382.5	11,414.0	11,962.9	11,043.5	-605.4
The application of organic fertilizers per unit area of agricultural land, 1,000 t	562.7	549.9	554.1	580.7	536.1	–31.1
Areas treated with organic fertilizers [million hectares]	0.8	0.8	1.0	1.0	0.7	–0.1
The total amount of mineral fertilizers applied, 1,000 tons	2,346.3	2,338.3	2,779.7	2,876.6	2,079.4	–266.9
The amount of mineral fertilizers applied per unit area of agricultural land [kg per 1 ha]	113.3	113.0	134.9	139.6	101.0	–12.3
Areas treated with mineral fertilizers [million ha]	16.1	16.4	16.4	16.8	12.7	–3.4
Areas under organic production [thousand hectares]	309.1	468	462	422.3	–	–
The total amount of pesticides applied [kg]	25,343,444	24,324,580	24,621,738	26,968,450	19,438,2	–5,905,2

Source: developed by the authors based on the data of the State Statistics Service of Ukraine (2023).

of cattle, pigs, goats, and sheep. This trend promotes the search for alternative solutions and the use of other types of organic fertilizers.

Table 3. Application of organic fertilizers in crops in Ukraine in 2018–2022 [thousand tons]

Tabela 3. Stosowanie nawozów organicznych w uprawach na Ukrainie w latach 2018–2022 [tys. ton]

Indicator	Years					Absolute deviation, +/–
	2018	2019	2020	2021	2022	
The volume of applied organic fertilizers in crops during the reporting year	10,674.7	10,429.8	10,222.9	10,745.9	9,728.2	–946.5
farm animal manure	8,478.3	8,832.8	8,345.2	8,131.6	7,498.9	–979.4
poultry droppings	1,302.6	989.2	1,158.8	1,345.7	966.3	–336.3
silt and sapropel	18.0	3.3	16.9	37.2	42.4	24.4
peat and its substrates	66.8	37.5	77.2	85.3	29.5	–37.3
other types of organic fertilizers	809.0	567.0	624.8	1,146.1	1,191.1	382.1

Source: developed by the authors based on the data of the State Statistics Service of Ukraine (2023).

Volumes of the use of organic fertilizers and the area of their application can be increased while improving environmental safety at the agricultural enterprise and ensuring its energy independence due to implementing waste-free technologies.

One example of the above is the use of plant and animal husbandry waste and food waste for biogas production. In the process of the biodegradation of agrobiomass, biofuel is produced, i.e. biogas and a by-product, namely digestate, which can be used as an organic fertilizer. It can be liquid or solid by its form, and it can be mixed with other types of fertilizers. Applying digestate in crops improves soil fertility, and plants receive additional nutrients while applying liquid digestate provides additional soil moisture. Biogas can be turned into electricity, which can be used for the company's own purposes, or sold at the "green tariff", and the heat can be used to heat greenhouses and other complexes (Fig. 1).

Table 4 shows a successful practice of bioenergy recycling of wastewater of the dairy plant Loostdorf LLC.

According to technical conditions U 20.1-23063575-001:2021 of Loostdorf LLC (hereinafter – TU), digestate from sewage is an ecologically clean organic fertilizer of extended action "LoostEco" (hereinafter – LoostEco fertilizer), which is produced by the aerobic controlled thermophilic biodegradation of organic raw materials under the action of an enzyme, at a temperature not higher than 75°C, due to which the products are completely safe for the environment, humans and animals.

LoostEco fertilizer is intended to be used in the agro-industrial and private sectors, and it is sold through wholesale and retail trade networks and directly to the consumer. LoostEco fertilizer is a high-quality, pasteurized organic fertilizer. It is sanitary-hygienic and quarantine-clean, since during the fermentation process the entire mass is heated to 75°C and kept for several days

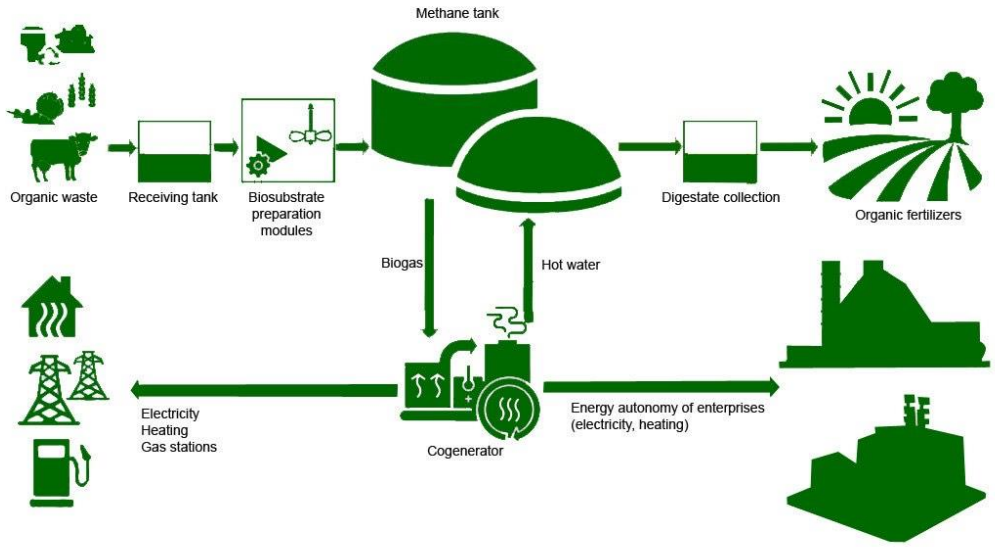

Fig. 1. Technological scheme of implementing waste-free technologies at the enterprises of the agro-industrial complex
Source: developed by the authors

Rys. 1. Schemat technologiczny wdrażania technologii bezodpadowych w przedsiębiorstwach kompleksu rolno-przemysłowego

Table 4. Characteristics of the biogas complex

Tabela 4. Właściwości kompleksu biogazowego

No.	Indicator	Characteristics
1	Address of the biogas complex location	Loostdorf LLC, 1, Kotsyubynskogo Street, Illintsi, Vinnytsia region, Ukraine, 22700
2	Production capacity of the company (milk processing)	450 t/day
3	Date of the biogas complex launch	October 10, 2019
4	Duration of the project implementation	6 months
5	Raw material for the biogas production	Industrial wastewater of the enterprise producing dairy products
6	The capacity of treatment facilities of the biogas plant	2 ln l/day
7	The cost of the project	USD 6.5 million
8	The area of the treatment complex	7.3 thousand m^2
9	The number of employees of the biogas complex	8 persons
10	Biogas output	1.2 thousand m^3/day
11	The volume of obtained organic fertilizer (digestate)	2–3 m^3/day

Source: developed by the authors based on the data provided by Loostdorf LLC (2023).

(sufficient pasteurization conditions). It contributes to increasing productivity, the prevention of plant diseases and the restoration and preservation of soil fertility; furthermore, the presence of calcium in the composition of LoostEco fertilizer contributes to the reduction of soil acidity.

By its agrochemical properties, LoostEco fertilizer is complex, moisture-retaining, heat-insulating, and amenable to granulation. LoostEco fertilizer improves the physical and agrochemical properties of the soil, and because the organic mass has undergone intensive processing by microorganisms in the fermentation stages, most of the nutrients are in a form available for assimilation by plants. Mandatory requirements for the quality of LoostEco ensuring safety for the life and health of the population and the environment are listed in Table 5.

Table 5. Basic chemical indicators of organic fertilizer "LoostEco"

Tabela 5. Podstawowe wskaźniki chemiczne nawozu organicznego „LoostEco"

No. p/p	Indicator	Norm	Method of control
1	Moisture [%]	70–75	DSTU EN 12048
2	pH of water	8.0–8.3	10.4 TU U 20.1-23063575-001:2021
Absolute dry matter content			
3	Organic matter [%]	62.1–67.5	DSTU EN 3039:2005; DSTU 4289:2004
4	Total nitrogen (N) [%]	2.0–2.2	DSTU 7629
5	Phosphorus (P_2O_5) [%]	8.1–10.1	DSTU 7628
6	Potassium (K_2O) [%]	0.2–0.6	DSTU 7626
7	Calcium (CaO) [%]	30.1–32.1	DSTU 7631

Source: developed by the authors based on the data provided by Loostdorf LLC (2023).

Depending on the input raw materials, 1 ton of LoostEco contains 103–129 kg of active substance (NPK): nitrogen (N) – 20–22 kg; phosphorus (P) – 81–101 kg; potassium (K) – 2–6 kg. One ton of fertilizer corresponds to 3.5–5.5 tons of litter manure in terms of active substance content. LoostEco fertilizer has a loose, finely divided structure with a particle size of 2–5 mm, it is brown in color; the volume weight of the product is 0.6–0.8 t/m^3. As for the agrochemical properties, LoostEco contains all macroelements (nitrogen, phosphorus, potassium, calcium) and trace elements (copper, zinc, magnesium, boron, molybdenum, manganese, iron, and cobalt).

The fertilizer is convenient and easy to dose. The equipment for applying mineral fertilizers is suitable; does not require any preparation and is completely ready to be used according to the manufacturer's instructions.

The products can be supplied to the domestic market and exported. When supplying products for export, additional requirements for the name, quality and safety indicators, packaging and labeling must be stipulated in the agreement or in the contract. An example of a conventional designation of products when ordering is 'LoostEco organic fertilizer, TU U 20.1-23063575-001:2021'.

As a result of the research, it was established that the yield increased to 30% when applying the liquid fraction of digestate from biogas plants as the main fertilizer at Organic LLC, Theofipol Energy Company LLC, a separate division "Biogas Ladyzhyn" of Vinnytsia Poultry Farm LLC and Oril-Leader PJSC.

In addition to the increase in the yield of corn and winter wheat, the application of digestate resulted in a signification reduction in the cost of purchasing fertilizers. An example of this is the fact that, according to the experiment calculations, Organic LLC reduced it by 3,798.67 UAH/ha in 2020.

As a result of the study, it was established that the digestate application affects the reduction of soil acidity, which has a positive impact on the restoration of soil fertility (Kaletnik et al. 2020).

SAs a consequence of the above, the use of digestate (solid and liquid fractions) as organic fertilizers in the fields by agricultural enterprises would allow almost complete abandonment of the use of mineral fertilizers, while the crop yield would belong to the "Eco" category and would be sold at a higher price. In addition, liquid digestate can be sold to the public for feeding trees and plants; however, for this purpose, a standard for digestate as an organic fertilizer has to be adopted.

Conclusions

The agro-industrial complex has an untapped potential for scaling up the successful experience of using waste-free biofuel production technologies. The implementation of these technologies would contribute to the reduction of ecological pollution of the environment and products and produce an alternative type of fuel and organic fertilizers. The scaling of these technologies in the practice of Ukraine's agricultural enterprises and households would allow speeding up the implementation of the program goals of the European Green Course and ensure the reduction of greenhouse gas emissions by the agro-industrial complex of Ukraine, energy independence and the autonomization of the production and formation of the country's food security.

1. Participation in educational programs for the formation of a conscious attitude to the protection of the soil resources of Ukrainians as a valuable resource that cannot be substituted.

2. Encouraging the rational and economical use of soil cover properties.

3. The implementation of bio-organic technologies for growing agricultural products to reduce the agrochemical load.

4. The application of ecological and resource-saving methods of soil cultivation.

5. The creation of a system of soil condition monitoring indicators for prompt intervention on the negative impact of some factors.

6. The development of state programs with the implementation of tools for soil restoration that will become the basis of agrarian policy in the field of land relations.

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Bezodpadowe technologie produkcji biopaliw jako sposób na Europejski Zielony Ład

Streszczenie

W artykule przeanalizowano perspektywę wdrożenia wskaźników docelowych w zielonej transformacji kompleksu rolno-przemysłowego Ukrainy. Ustalono, że degradacja gleby nabrała wymiaru globalnego i stała się poważnym problemem o charakterze społeczno-gospodarczym ze względu na działania wojskowe na Ukrainie. Analiza stanu gruntów rolnych została przeprowadzona w oparciu o następujące wskaźniki: zawartość próchnicy w glebie, ilość stosowanych nawozów organicznych i mineralnych, pestycydów, powierzchnia gruntów pod produkcją ekologiczną itp. Celem badania jest ocena wpływu wdrożenia bezodpadowych technologii produkcji biopaliw w przedsiębiorstwach kompleksu rolno-przemysłowego na osiągnięcie celów ekologicznych Europejskiego Zielonego Ładu. W artykule przedstawiono docelowe wy-

tyczne dotyczące osiągnięcia celów ekologicznych Europejskiego Zielonego Ładu. Zaproponowano dalsze kroki niezbędne do przezwyciężenia obecnych problemów w zakresie zgodności z normami prawodawstwa UE w zakresie ochrony środowiska w przedsiębiorstwach rolnych w celu sprzedaży produktów rolnych na rynki europejskie. Naukowo udowodniono, że kompleks rolno-przemysłowy Ukrainy ma niewykorzystany potencjał redukcji emisji gazów cieplarnianych poprzez ekologiczną modernizację i wdrażanie bezodpadowych technologii produkcji. Sugeruje się wykorzystanie biogazowni jako obiecującego sposobu rozwiązywania problemów utylizacji odpadów, poprawy sytuacji ekologicznej, zmniejszenia zależności energetycznej i zwiększenia żyzności gleby. Została udowodniona skuteczność stosowania nawozów organicznych, a mianowicie pofermentu, produktu ubocznego fermentacji metanowej, jako bionawozów w gospodarstwach rolnych. Przedstawiono zalecenia dotyczące środków regeneracji gleby na Ukrainie w przyszłości.

Słowa kluczowe: kompleks rolno-przemysłowy, degradacja gleby, poferment, recykling bioenergii, biogaz