THE STATE OF THE SOIL COVER OF UKRAINE IN THE CONTEXT OF BIO-ORGANIC TECHNOLOGIES FOR GROWING AGRICULTURAL CROPS

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Abstract. An urgent problem for Ukraine is the preservation of bio-ecosystems and the balanced development of agriculture based on the principles of energy, food and environmental security. It has been proven that soil cover is one of the main components of the environment, which performs vital biosphere functions. It has been established that soil and plant cover in nature form a single system. The loss of soil fertility, its degradation deprives plants of the ecological foundations of their existence. Therefore, the restoration of the fertility of degraded soils is the restoration of the natural ecological balance of territories disturbed by humans as a result of irrational economic activity. Soils regulate the quality of surface and underground waters, the composition of atmospheric air, are the habitat of most living organisms on the land surface, provide a favorable environment for humans, and are the main source of agricultural production. Therefore, the most important condition for the preservation of the biosphere, normal plant cover and productivity of agriculture is constant care for the protection of the soil, its structure and properties, implementation of a system of measures to increase fertility. Unfortunately, due attention is not paid to the problem of soil condition monitoring in Ukraine. This applies to the scientific field, where due to insufficient funding, full-fledged studies of the spread, causes of occurrence and ways to eliminate degradation are not conducted. The same applies to the legislative and executive authorities, where effective control measures have not been developed. In general, society has not created an

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atmosphere of maximum support for the preservation of soil cover as an irreplaceable national asset. Mass media and educational institutions are indifferent to this problem. Organic substances of the soil, as an integrated indicator of its fertility, take an active part in the nutrition of plants, the creation of favorable physicochemical properties, the migration of various chemical elements in it, because the most important soil processes are primarily related to organic compounds. *Purpose* study is to provide an objective analysis and identify the reasons for the unsatisfactory state of the country's soil cover and, on this basis, to formulate proposals for their solution. *Methodology*. The research methodology is based on experimental studies of scientific topics on the topic: "Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector". Result. In Ukraine, depending on the region, up to 30-60% of land is located on slopes. Deteriorated conditions of soil formation on them as a result of the accumulation of the water regime are reflected both in the formation of different soil profile parameters, and in a significant – by 15-50%, depending on the degree of xeromorphism, in a decrease in their fertility. In addition, they are characterized by the episodic development of erosion, confined to the natural microrelief drainage network in the form of drainage papillae. The reorganization of land management in the course of the land reform led to an increase in the number of borders, roads, etc., as artificial boundaries in the way of the natural discharge of surface runoff, which causes increased water erosion. The *practical value* of the obtained results lies in the fact that their application should contribute to increasing the efficiency and effectiveness of sustainable soil management, primarily at the national level, and to achieving a neutral level of degradation by the content of organic carbon in the soil. It was established that the use of digestate as biofertilizer is an economically and ecologically appropriate method of handling the fermented residue. This, in turn, brings numerous advantages, in particular, it reduces the demand for plant protection products (destruction of weed seeds during fermentation), reduces unpleasant odors or destroys possible pathogens, preserves valuable moisture in the soil, allows you to abandon mineral fertilizers, etc.

1. Introduction

The previous scientific work of the authors includes: theoretical and practical research in the field of rational nature management and soil fertility improvement, the state of modernization of the ecological security system under the conditions of sustainable development was analyzed, the world experience of environmentally safe sustainable development of rural areas, priority directions for the modernization of the ecological security system in the context of achieving sustainable development were developed rural areas. The authors also researched system variants of bio-organic technologies for growing the main leguminous crops used in EU countries and Ukraine. A marketing analysis of the production and use of alternative energy sources at regional levels was conducted. The studies confirmed the presence of significant problems, which led to the need for further scientific research and the need to develop a strategy for environmental security of rural areas based on sustainable development [13–15; 32–33; 41–45; 65].

Soil cover is one of the main components of the environment, which performs vital biospheric functions. Soil and plant cover in nature form a single system. The loss of soil fertility, its degradation deprives plants of the ecological foundations of their existence. Therefore, the restoration of the fertility of degraded soils is the restoration of the natural ecological balance of territories disturbed by humans as a result of irrational economic activity [1; 6; 36; 43].

Soils regulate the quality of surface and underground waters, the composition of atmospheric air, are the habitat of most living organisms on the land surface, provide a favorable environment for humans, and are the main source of agricultural production. Therefore, the most important condition for the preservation of the biosphere, normal plant cover and productivity of agriculture is constant care for the protection of the soil, its structure and properties, implementation of a system of measures to increase fertility. Many countries – such as the USA, Germany, France, Canada, China – have already come to understand that the protection of soils, the fight against their degradation and pollution can be effectively carried out only at the state level. The key principle of foreign legislation is the inadmissibility of such action on the soil, which leads to deterioration of its quality, to degradation, pollution and destruction [21–24; 54; 65].

The decisions of the World Conference on Environment and Development (1992, Rio de Janeiro) determined that the protection and rational use of soils should become the central link of state policy, since the state of the soil determines the nature of human life and has a decisive effect on the environment. Therefore, soil protection should be a priority task for our state [10–12; 25–26].

The soils of Ukraine have been studied quite well, but this did not prevent the intensive development of their degradation processes. About a third of the arable land has been eroded, about 20% of organic matter has been lost, almost all the arable land in the subsoil layer has been compacted, the reserves of nutrient forms of phosphorus and especially potassium are noticeably decreasing, numerous troubles are observed on reclaimed lands [30; 51–53; 63].

The main causes of all kinds of problems with the soil cover are underestimation of the real threat that soil degradation poses to the present and especially future generations, the lack of effective mechanisms for the implementation of laws on soil protection, unbalanced and scientifically unfounded land use [33; 47]. The main reason for the aggravation of the problem in Ukraine is the suspension (actually since 1991) of state and regional programs land protection. Unfortunately, due attention is not paid to the problem of soil condition monitoring in Ukraine. This applies to the scientific field, where due to insufficient funding, full-fledged studies of the spread, causes of occurrence and ways to eliminate degradation are not conducted. The same applies to the legislative and executive authorities, where effective control measures have not been developed. In general, society has not created an atmosphere of maximum support for the preservation of soil cover as an irreplaceable national asset. Mass media and educational institutions are indifferent to this problem.

2. Task and purpose of monographic research

Ukraine has ambitions to become a leading agrarian state with a large export potential of agricultural products. And there are many favorable conditions for this, but many problems must be solved before that. In particular:

– to ensure the rational use and preservation of soils as the most important component of the natural environment;

– to ensure the use of soil protection technologies and other measures to eliminate soil pollution and degradation during economic and other types of activities;

– ensure constant soil monitoring and agrochemical certification of agricultural land;

– detect negative changes in the state of the soil in a timely manner and necessarily take measures to restoration of degraded soils;

– to ensure the scientific validity of soil protection measures;

– to ensure transparency, completeness and reliability of information about the state of the soil, about volumes of applied soil protection measures;

– to ensure public participation in decision-making in the field of soil protection;

– the inevitability of responsibility for damage caused to the soil.

The purpose of the monographic study is to provide an objective analysis and identify the reasons for the unsatisfactory state of the country's soil cover and, on this basis, to formulate proposals for their solution.

3. General characteristics of soil cover

The basis of sustainable and efficient agricultural production is the rational use of soil resources. The agricultural sector of the economy uses 71% of the total land area of Ukraine, including arable land – more than 32.4 million hectares. A variety of climatic, orographic, lithogranulometric and other environmental factors determined the formation of a variegated soil cover. More than 800 types of soils were identified based on the materials of large-scale research conducted in 1957–1961.

The soil cover of Ukraine is characterized by significant genetic heterogeneity (Table 1).

Turf-podzolic soils of a light granulometric composition are the background for the Polissia zone. They are characterized by a slight accumulation of humus, a weak saturation with bases and an acidic reaction of the soil solution.

Sod glaciated soils lie on low, poorly drained areas and are characterized by increased accumulation of humus in the upper horizon – 2.0-5.0% depending on the granulometric composition, and signs of glaciation in the profile due to stagnation of groundwater. Sod-carbonate soils are characterized by a profile developed up to 50-60 cm, mainly by a neutral

Table 1

General characteristics of soil cover of Ukraine

Soil	Area, thousand ha	
	agricultural land	arable
Sod-podzolic	2511,2	2209,9
Turf is glazed	1674,2	691
Turf-carbonate	146,9	137,8
Gray forest	2620,5	1985,6
Dark gray gilded	1952,0	1867,7
Black soil:		
gilded	2200,1	2048,0
typical	7346,8	6997,8
usual	9250,0	7962,9
southern	3257,5	2993
others	2844,2	1579,6
Dark chestnut salted	1194,5	1090,3
Chestnut salted	100,9	79,8
Burozem is acidic	307,3	85,0
Brown soil-podzolic acid gleyed	105,8	44,8
Meadow-brown soil acid gleyed	104,4	39,3
Brown	29,1	7,6
Meadow black soil and meadow	2996,0	935,7
Meadow-chestnut saline	94,0	112,7
Meadow-swamp and swamp	729,7	115,4
Peatlands	595,8	100,8
others	1564,9	1387,9
Total	41625,8	32473,4

reaction of the soil environment – pH-water. 6.7-7.5, significant humus accumulation – 2.2-3.7% depending on the content of physical clay.

In Ukraine, depending on the region, up to 30-60% of land is located on slopes. Deteriorated conditions of soil formation on them as a result of the accumulation of the water regime are reflected both in the formation of different soil profile parameters, and in a significant – by 15-50%, depending on the degree of xeromorphism, in a decrease in their fertility. In addition, they are characterized by the episodic development of erosion, confined to the natural microrelief drainage network in the form of drainage papillae. The reorganization of land management in the course of the land reform led to an increase in the number of borders, roads, etc., as artificial boundaries in the way of the natural discharge of surface runoff, which causes increased water erosion.

In the 40 years since the end of the large-scale survey of land resources in 1957–1961, the soil cover has undergone changes. In this regard, it is possible to assess the real state of land resources only under the condition of a continuous study of the soil cover. Ukraine is late in solving this issue. Transition to market relations, reformation the agrarian sector of the economy and the introduction of private ownership of land require accurate information about the qualitative composition of land resources to determine their agro-production potential, assess their value, conduct tax policy, monitor the condition of soils in order to prevent their degradation, increase production efficiency through the introduction of adapted to soil and ecological conditions agricultural technologies, etc. The issue of repeated large-scale soil research in Ukraine is on the agenda.

4. Change in humus content in soils

Changes in forms of management and ownership of land, which became the main content of transformations in the agrarian sector of Ukraine in recent years, unfortunately, had a negative impact on soil fertility. They have lost a significant part of the humus, the most fertile chernozems in the world have turned into soils with an average level of fertility and continue to deteriorate. A comparison of the humus content of soils during the time of Dokuchaev (1882) with the current state shows that the relative loss of humus during this almost 120-year period reached 22% in the Forest-Steppe region, 19.5% in the Steppe region, and about 19% in the Poliska zones of Ukraine [49–56].

The greatest losses of humus occurred in the period of the 1960s-1980s of the last century, which is due to the intensification of agricultural production due to the increase in the area of row crops, first of all, sugar beets and corn. During this period, annual losses of humus reached 0.55-0.60 t/ha. Unfortunately, the processes of dehumification during the last 20 years have not stopped, but continue to flow with a sufficiently high intensity. According to the results of agrochemical certification of agricultural lands during the last 4 rounds, the humus content in Ukraine decreased by 0.5% in absolute units (Figure 1).

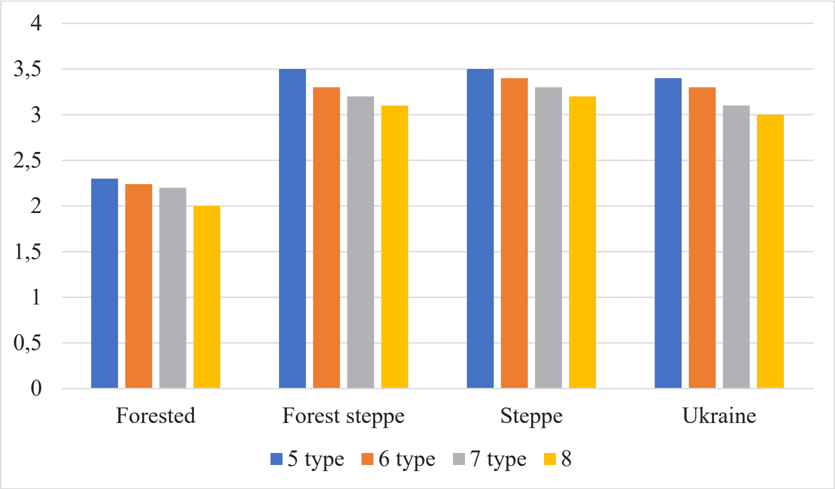

Figure 1. Dynamics of humus content in the soil for 2000–2020

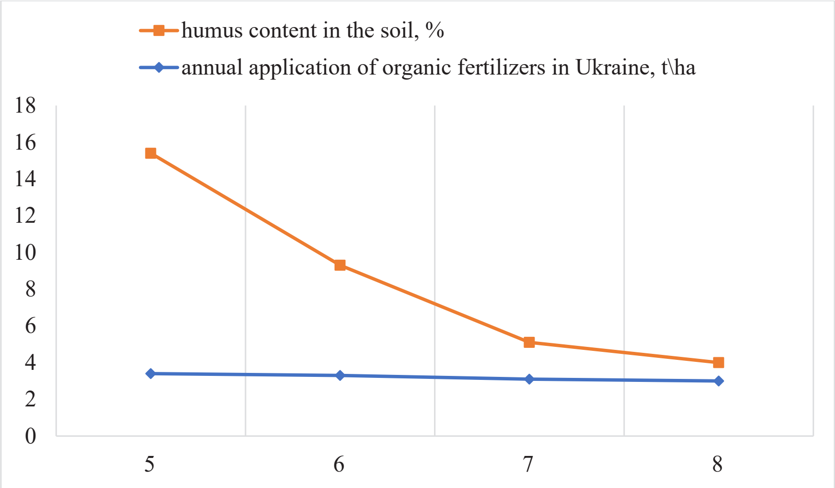

Figure 2. Dynamics of humus content in the soil and application of organic fertilizers

Particularly significant losses of humus occurred between the 5th and 6th rounds – 0.37%, when the volume of organic fertilizer application began to decrease sharply (Figure 2), and the formation of the crop occurred at the expense of the potential fertility of the soil. According to the State Committee of Statistics of Ukraine, the rate of application of organic fertilizers was 0.6 t/ha, while at the end of the 80s of the last century it was 8.6 t/ha.

A decrease in the weighted average indicator of humus content, accordingly, affects changes in the redistribution of areas according to its availability. In particular, areas of soil with high and very with high content decreased, and with high and medium content, on the contrary, increased. That is, by losing humus, soils move from a group with a high to a group with a low supply.

5. Change in the reaction of the soil solution

The agroecological assessment of soils is based on a complex of indicators of soil regimes, among which an important place is assigned to the reaction of the soil solution (pHN_2O and pHKCl) and hydrolytic acidity (Hg). These characteristic values directly affect the growth and development of plants, the activity of soil organisms and the degree of solubility of hard-to-reach forms of nutrients, coagulation and peptization of soil colloids, and the effectiveness of fertilization [39; 54].

An acidic soil environment is one of the factors that limit obtaining high and high-quality crops. Under-harvest of major crops due to the negative impact of soil acidity is about 1 million 350 thousand tons of grain units every year. Gross harvests of wheat, barley, corn, sugar beet and rapeseed are decreasing the most.

The main reasons for the formation of an acidic soil environment are as follows: climatic conditions (wash water regime), properties of the parent rock (acidic or carbonate) and anthropogenic factors (human activity). Among the anthropogenic factors of acidification, an important role is played by the use of large amounts of physiologically and chemically acidic fertilizers, acid precipitation. The soil undergoes significant acidification as a result of decalcification: removal of calcium by crops and its infiltration with meltwater and rainwater. The acidity index is significantly affected by climate warming that has occurred in recent decades.

Acidification is accompanied by a complex deterioration of the physical, physicochemical, agrochemical and biological properties of the soil, which manifests itself in the following changes:

– peptization of colloids, which leads to the destruction of the structure;

– inhibiting the growth and development of the root system, which affects the winter resistance and drought resistance of crops;

– reducing the payback of nitrogen and phosphorus fertilizers;

– suppression of vital activity of nitrogen-fixing free-living and nodular bacteria, preferential development of fungal microflora, as a result of which the damage to plants by fungal diseases increases;

– increased weediness of fields, as most weeds can withstand the acidic reaction of the soil environment.

6. Provision of soils with trace elements

Based on the grouping of soils by the level of provision of physiologically necessary microelements for plants with low and increased removal of microelements, the examined soils are very colorful. The content of trace elements in soils depends on the granulometric composition of soil-forming rocks, the granulometric composition of soils and the content of organic substances. In Western Polissia, the zinc content ranges from 0.28 mg/kg of soil in sod-podzolized clayey soil to 2.21-7.35 mg/kg in peat-swamp and sod-podzolized soils, which corresponds to the low and high supply of plants with this element. According to the content of manganese, the soils of this region belong to the group with a high level of security, even for crops with increased removal, copper and cobalt – to the group with an average content for the same crops [37].

The soils of the Central Polissia are sufficiently supplied with cobalt, copper and manganese, but the provision of zinc in most cases is low – < 1 mg/kg of soil.

In the soils of the Forest Steppe (Western, Right-Bank and Left-Bank) cobalt content varies from 0.07 mg/kg of soil to 0.67, which corresponds to a low and high level of providing plants with this element, but mainly corresponds to an average level with a content fluctuation of 0,15 to 0.5 mg/kg. The content of copper in individual soils of the Forest Steppe is equal to 0.06-0.07 mg/kg of soil, which does not correspond to the gradation of even low security These are typical chernozems and meadow-chernozem soils, and in general, the content of this element ranges from 0.10 to 0.55 mg/kg of soil. The provision of the absolute majority of forest-steppe soils with the mobile form of manganese is high, and zinc is low, even for crops with a low level of removal.

The soils of Donbas and the Steppe are well supplied with mobile forms of cobalt, copper and manganese, and the zinc content in most soils corresponds to a low level of supply – < 1 mg/kg of soil.

The content of cobalt, copper and manganese in the soils of Transcarpathia corresponds to a high level of provision, and zinc – to a low level. The content of the mobile form of boron in the soils of Ukraine varies from the minimum (trace) amount in the sod-podzolic sandy soils of Polissia to 3.37 mg/kg of soil – in chernozems of saline soils. Thus, the soils of Polissia should be classified as soils with a pronounced boron deficiency, and the sod-podzolic surface-glazed soils of the Carpathians are classified as having an average boron content of 0.3-0.5 mg/kg of soil. Forest-steppe soils with a boron content of 0.18-2.30 mg/kg of soil belong to the group with a high content of this element.

The obtained data indicate a deficiency of the mobile form of zinc in most of the examined soils, and boron in the sandy and sandy soils of Polissia. The content of other trace elements in the absolute majority of soils corresponds to medium and high levels of availability.

7. Changes in agrophysical properties of soils

In connection with excessive plowing, deficient balance of biogenic elements, insufficient application of organic substances, mineral fertilizers, meliorants, pollution etc., the soils of Ukraine are degrading in modern conditions. Physical degradation also became widespread.

Physical degradation, as a result of intensive agricultural use of land, namely, excessive plowing of soils, intensive mechanical cultivation and a decrease in the content of organic matter in the soil, has practically covered the entire arable land of Ukraine. It manifests itself in the destructuring of the upper layer, lumpiness after plowing, flooding and crust formation, the presence of a plow sole, over-compaction of subsoil and deeper layers. Physically degraded soils are prone to erosion, absorb and retain atmospheric moisture worse, limit the development of plant root systems.

Soil compaction is a well-known problem in Ukraine, accompanied by adverse environmental consequences and significant economic losses. When growing grain crops, approximately 20% of the country's arable land has a density of structure in the root layer higher than these crops require.

In general, optimal conditions for cultivation and obtaining the best quality of arable land are noted in a relatively small (2.56 million ha) area of the Central and Left Bank Forest-steppe, where typical and podzolic chernozems of light and medium loamy composition, moderately humus, with high potential and actual level of aggregation are widespread. Moderately pronounced strength indicators and a fairly long period with moisture of physical maturity allow processing them in the period of the best crumbling with minimal energy consumption. Moreover, there are all opportunities to minimize tillage and even completely abandon it, that is, to minimize the mechanical load on the soil and protect it from physical degradation. In this case, the danger of over-compaction, spraying and the formation of blocks is eliminated. In addition, there are practically no factors that complicate processing (crushing, salinity, and siltiness).

However, along with the high value of arable land, it must be stated that there are quite enough other less valuable territories in Ukraine. Even in Polissia, where soils of light granulometric composition dominate, the cultivation of which does not create any significant difficulties, the soil and technological conditions, however, are assessed as difficult and very difficult. The reason is the extremely high equilibrium density of the structure, the very low potential and actual level of aggregation, the existence of the danger of spraying and the rather frequent presence of oozing in the surface layer.

8. Development of erosion processes

Soil erosion is the main factor in the degradation of agricultural landscapes in many countries of the world, including Ukraine. During the last decades, environmental and economic losses of the country's agricultural production due to the anthropogenic increase in soil erosion have taken on threatening proportions. The reasons for this are long-term ecologically unreasonable intensive exploitation of land resources, excessive plowing of the soil cover, disturbance of the balance of cycles of chemical elements in agro-ecosystems [24–29].

The negative consequences of modern anthropogenic erosion concern not only the field of agricultural production, but also all components of the natural environment – relief, surface and underground waters, plant cover and the entire biota. The area of Ukraine is 60.3 million hectares of land, of which 41.6 million hectares are agricultural land; of them, 32.5 million hectares are arable land (Figure 3).

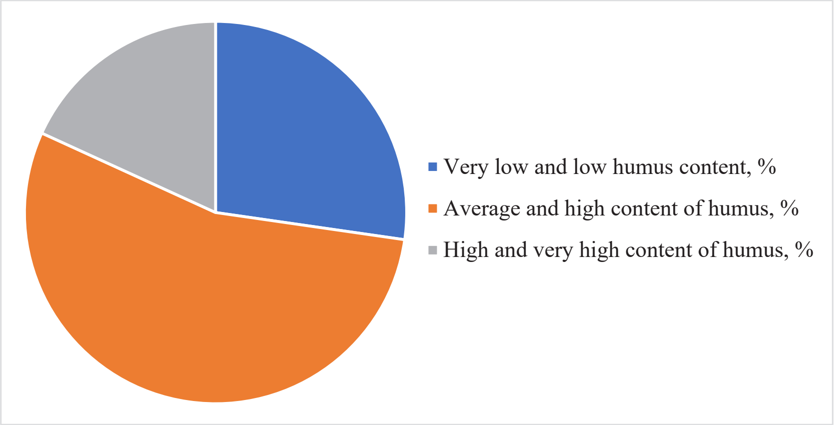

Figure 3. Structure of agricultural land for content of humus

The plowed area is 53.9% of the total area of Ukraine, and 78.1% of agricultural land. In some regions, it reaches 80-90% (Table 2). The most developed countries of the world did not know such a level of poverty.

Table 2

Regions of Ukraine with the highest degree of plowed agricultural land

Region	Plowability, %	Region	Plowability, %
Vinnytsia	85,7	Mykolayiv	84,5
Donetsk	81,0	Odesa	79,7
Zaporizhzhia	84,8	Ternopil	81,4
Kirovohradsk	86,4	Kherson	90,2
Luhansk	66,4	Cherkasy	87,6

As a result of high plowing of the territory, the erosion rate of agricultural land is 38.4%, arable land is 40%. In absolute terms, this amounts to 15.9 million hectares of land, in the volume including 12.9 million hectares of arable land. In some regions, the percentage of eroded land is significantly higher than the national rate.

Ukrainian scientists have long proven the need to remove 8-10 million hectares of eroded land from arable land (from 24 to 33% of arable land). In fact, from 1991 to 2009, only 0.96 million hectares were removed, which is 2.9% of the arable land area, including 0.07 million hectares (0.4%) in the steppe zone. Further intensive use of eroded lands may have negative consequences for Ukraine.

The introduction of scientifically based norms for reducing the share of arable land will bring the plowing of the territory of Ukraine closer to the optimal level, as a result of which the area of natural fodder lands will increase by 2.4 times, forest strips and forests by 1.8 times.

Out of all branches of the economy of Ukraine, the agrarian sphere experiences the greatest direct losses from erosion. The average annual loss of soil from water and wind erosion is 15 t/ha. This means that the soil cover of the country loses about 740 million tons of fertile soil every year, which contains about 24 million tons of humus, 0.7 million tons of mobile phosphates, 0.8 million tons of potassium, 0.5 million tons of nitrogen and large amounts of trace elements.

Erosive processes, destroying soils, affect, first of all, their provision of organic matter. Thus, the humus content in weakly eroded chernozems decreases by 5-10%, moderately eroded by 25-30%, strongly eroded by 35-40% compared to their full-profile counterparts.

The amount of land in Ukraine damaged by water erosion reaches 32% of the total area or 13.3 million hectares. Of these, 4.5 million hectares with moderately and strongly washed soils, including 68 thousand hectares, have completely lost the humus horizon.

In Ukraine, more than 6 million hectares are systematically exposed to the harmful effects of wind erosion, and in years with dust storms up to 20 million hectares. The Southern Steppe is a particularly potentially dangerous zone in Ukraine. Thus, the number of days per year with dust storms in the Southern Steppe is 159, in the Northern and Central Steppe – 88, and in the Forest Steppe and Polissia – about 33 days.

9. The state of modernization of the environmental safety system under the conditions of sustainable development

The authors of the monographic study have considerable experience in issues related to rational nature management, increasing the level of environmental security, energy security, and economic stability in the context of sustainable development of bioecosystems and rural areas.

The previous scientific work of the authors includes: theoretical and practical research in the field of rational nature management and soil fertility improvement, the state of modernization of the ecological security system under the conditions of sustainable development was analyzed, the world experience of environmentally safe sustainable development of rural areas, priority directions for the modernization of the ecological security system in the context of achieving sustainable development were developed rural areas. The authors also researched system variants of bio-organic technologies for growing the main leguminous crops used in EU countries and Ukraine. A marketing analysis of the production and use of alternative energy sources at regional levels was conducted. The studies confirmed the presence of significant problems, which led to the need for further scientific research and the need to develop a strategy for environmental security of rural areas based on sustainable development [13–15; 32–33; 41–45; 65].

Amanpreet S. and others (2020) proposed models of organic crop rotations with elements of biologization when they are saturated with leguminous crops, and also made proposals for the comprehensive development of the field of organic production. Nosheen S. and others. (2021) summarized the results of using biofertilizers of organic origin to preserve soil fertility. Mukhuba M., Roopnarain A., Adeleke R., Moeletsi M., Makofane R. (2018) investigated the issue of anaerobic digestion leading to two valuable products which are biogas and nutrient-rich organic fertilizer (digestate). As a result, it was found that digestion caused a decrease in the content of heavy metals and some potential pathogenic bacteria, unlike manure. Based on the results of the study, digestate has a greater potential than undigested manure as an organic fertilizer with signs of increasing humus content in soils. Palamarchuk V.D. proves that a scientifically based system of using organic fertilizers significantly improves the physical and water-physical properties of the soil, the water-air regime and physico-chemical indicators of fertility are optimized, especially the absorption capacity and buffering capacity of the soil increases [65].

As a result of all these processes, the nutrition conditions of agricultural crops are optimized. In addition, the study of bio-organic technologies for growing agricultural crops by V.A. Mazura. aimed at the production of increased quality of grown products that will meet world standards in the field of organic and biological agriculture and the modern structure of the potential fodder base [18–25].

Ali et al. (2022) determine that the key aspects of the technology in order to solve the problem of providing the soil with organic matter and the macro- and microelements necessary for the growth and development of plants are the use of the non-marketable part of the crop of crop rotation for the fertilization system with its combination with animal manure, which has previously undergone anaerobic fermentation in biogas stations. Kaletnik G.M. etc. (2019) examined the state's energy, environmental, and food security and the impact of biofuel production and use on energy, environment, and food security. On the basis of calculations of biogas output from various raw materials on domestic agricultural productions, it has been proven that the use of biogas plants ensures the energy autonomy of agricultural enterprises and the energy independence of the agricultural sector in general, the ecological disposal of agricultural waste, the reduction of carbon dioxide emissions, the increase of the yield of agricultural crops, the increase of soil fertility, reduction of soil acidity, reduction of costs for the introduction of mineral fertilizers due to the introduction of digestate and increase in the profitability of agricultural enterprises. The agrochemical analysis of digestate as an organic fertilizer was studied and it was proposed to use it for the development of organic agricultural production [14].

10. Use of digestate as an organic fertilizer for the development of organic agricultural production

For intensive agricultural production and complete reproduction of humus reserves in Ukraine, 320-340 million tons of organic fertilizers should be applied annually. Previously, this balance was maintained mainly at the expense of domestic livestock. However, the number of livestock in Ukraine has decreased significantly. Currently, 1 hectare of arable land in Ukraine has ten times less cattle than in the countries of Western

Europe [65]. In recent years, an average of 20 times less organic fertilizers than necessary have been applied to crops. Therefore, the soil without organic substances is depleted and yields are reduced. It is known that the loss of 0.1% of humus in the soil reduces grain yield by 0.5 t/ha. If the trend continues, then in the near future Ukraine may experience a humus famine – a serious ecological disaster. And then no agrotechnical, land reclamation, nature protection and organizational and economic measures will be able to restore the agrotechnical potential of the land [12; 14]. In modern conditions of agriculture in Ukraine, the real source of organic matter is straw, stubble, stalks and other post-harvest residues, siderates, therefore it is very important to justify the price of these wastes [14].

Organic substances of the soil, as an integrated indicator of its fertility, take an active part in the nutrition of plants, the creation of favorable physicochemical properties, the migration of various chemical elements in it, because the most important soil processes are primarily related to organic compounds [13–15; 32–33; 41–45; 65].

Digestate is organic substrates after fermentation in biogas plants, saturated with nutrients and excellent for soil fertilization [14]. Re-fermented sludge (digestate) is a highly effective disinfected fertilizer that returns nutrients and lignin to the soil as the basis of humus formation and ensures the production of ecologically clean products [65].

There is global experience in the use of biofertilizers (digestate), in particular, they are widely used in Holland, Germany, England, Finland, Italy, China, India and other countries. In the conditions of Ukraine, very good results of applying fertilizer are obtained during the cultivation of vegetable and berry crops, as well as cereals, fodder and lawn grasses, decorative flowers, such as roses, daffodils, peonies, etc. [28].

The production of digestate and the stability of anaerobic digestion processes strongly depend on the composition of waste, process conditions, and the activity of microbial colonies in the system. In this sense, certain ratios of mixing and co-digestion can also lead to antagonistic interactions that reduce the productivity of the biogas plant [65].

Ukraine has a fairly powerful raw material potential for the production of biogas and digestate [14]. Livestock complexes and poultry farms can be considered primarily as producers of waste, since the volumes of manure and droppings are hundreds and thousands of times greater than the volumes of the main products, and this is ecological problem [65]. Evaluation of the yield of manure, litter, biogas and digestate depends significantly on specific conditions and technology. In particular, the yield of manure (and, to a lesser extent, litter) depends on the age of the animals, as well as on local framework conditions and conditions of maintenance (feed) [40; 57].

The functioning of biogas plants is associated with the formation of a large amount of fermented substrate – digestate. It can be characterized as a liquid resulting from the anaerobic decomposition of animal and plant waste. Digestate contains a significant amount of mineral elements (nitrogen, phosphorus, potassium). In terms of speed of action (absorption of elements by plants), it resembles mineral fertilizers, since the elements N, P and K are easily available to plants. Cellulose after digestion also contains a part of organic matter, which has a positive effect on the physical and chemical properties of fertilized soils. The amount of digestate is approximately similar to the mass of the loaded substrate used in the anaerobic process in the biogas plant. This necessitates the construction of special places for temporary storage of fermented substrate, occupation of new territories for sites, increases transport costs for its transportation, etc. Instead, the mass of the digestate of biogas plants can be reduced if part of the process liquid is returned to the fermentation compartment of the biogas plant [14]. In addition, the fermented substrate can either be stored and used as enzymes, or it can be separated into liquid and solid fractions. The separation will result in two different fertilizers with contrasting properties: a liquid fertilizer and a solid organic residue that can be used directly as an organic additive or can be composted or dehydrated before application to the soil. In turn, it is possible to achieve the optimal mass and required moisture content of the digestate by using one of the known technologies, in particular, separation, centrifugation, concentration, drying, granulation or the extraction of individual elements from its composition.

It was established that the use of digestate as biofertilizer is an economically and ecologically appropriate method of handling the fermented residue. This, in turn, brings numerous advantages, in particular, it reduces the demand for plant protection products (destruction of weed seeds during fermentation), reduces unpleasant odors or destroys possible pathogens, preserves valuable moisture in the soil, allows you to abandon mineral fertilizers, etc.

The digestate contains a number of nutrients, such as: nitrogen: 2.3-4.2 kg/t, phosphorus: 0.2-1.5 kg/t, potassium: 11.3-5.2 kg/t, a number of meso – and trace elements that play a significant role in the development of crops (Ca, Mg, Mn, B, Fe). In addition, the digestate contains organic carbon, including humic substances (1%-3% by weight), has a high proportion of nitrogen available for plants (up to +10...70% compared to non-fermented materials), is optimal for the soil the C:N ratio, the optimal pH value for the soil is 6.8-7.5, contains active populations of bacteria that contribute to the decomposition of organic matter in the soil [12].

After a detailed consideration of the physicochemical properties of the digestate, the main direction of using the fermented residue should be its use as a biofertilizer, which will strengthen the ecological and economic aspect of the entire biogas industry.

11. Conclusions

The research methodology is based on experimental studies of scientific topics on the topic: "Development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector". Real intensification and greening of the agro-industrial complex of Ukraine is impossible without optimizing the ratio of land plots as the basis for their protection and restoration. It can be considered optimal when the ratio of unstable factors (arable land, orchards) to stable ones (natural fodder areas, forests, forest strips) does not exceed unity. Urbanized and man-made territories are not included in this calculation. This means that the plowed area of the territory should be in the range of 40-50% for the steppe zone of Ukraine. The reduction of arable land will not lead to a decrease in marketable crop production, if the necessary economic order is given in the use of land that remains in intensive cultivation. Removal of unproductive lands from intensive agricultural use (degraded, underdeveloped, low-technology, etc.).

World experience shows that increasing the efficiency of agriculture is possible only under the conditions of intensive use of highly fertile soils and reduction of investments in low-productivity lands. Reduction of arable land will improve the fodder base of animal husbandry with returns from natural fodder lands. This will make it possible to leave the non-marketable part of crop production in the field, as well as to return, with the help of animal husbandry, the vector of the flow of biophilic substances from fodder lands to intensively used fields. A perspective opens up real harmonization of "relations" between animal husbandry and crop husbandry. Only products of deep processing of animal and plant raw materials and high-quality food grains should go outside the agricultural landscape.

It was established that the use of digestate as biofertilizer is an economically and ecologically appropriate method of handling the fermented residue. This, in turn, brings numerous advantages, in particular, it reduces the demand for plant protection products (destruction of weed seeds during fermentation), reduces unpleasant odors or destroys possible pathogens, preserves valuable moisture in the soil, allows you to abandon mineral fertilizers, etc.

References:

1. Adeyolanu O.D., Ogunkunle A.O. (2016). Soil Quality Assessment for Sustainable Land Use and Management. *International Journal of Plant & Soil Science*, 13(6), 22136.

2. Hudzevych, L. Nikitchenko, L. Hudzevych, L. Bronnikova, R. Demets. Approaches to organize the econetwork of the Transnistria region in the conditions of urban landscape. *Journal of Geology, Geography and Geoecology.* 2021. № 30 (3). P. 449–459.

3. Ansong Omari R., Bellingrath-Kimura S. D., Sarkodee Addo E., Oikawa Y., Fujii Y. (2018). Exploring Farmers' Indigenous Knowledge of Soil Quality and Fertility Management Practices in Selected Farming Communities of the Guinea Savannah Agro-Ecological Zone of Ghana. Sustainability, 10, 1034. DOI: https://doi.org/10.3390/su10041034

4. Baliuk S.A., Medvedev V.V., Miroshnichenko M.M., Skrylnik Ye.V., Timchenko D.O., Fatieev A.I., Khristenko A.O., Tsapko Yu.L. (2012). Environmental state of soils in Ukraine. *Ukrainian geographical journal*, 2, 38–42.

5. Baritz R., Wiese L., Verbeke I., Wargas R. (2017). Voluntary Guidelines for Sustainable Soil Management: Global Action for Healthy Soils. *International Yearbook of Soil Law and Policy*, 17–36. DOI: https://doi.org/10.1007/978-3- 319-68885-5_3

6. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology*. 2020. № 10(5). 54–61.

7. Didur I., Pantsyreva H., Telekalo N. Agroecological rationale of technological methods of growing legumes. *The scientific heritage*. 2020. 52. P. 3–14.

8. Falcone, G., Stillitano, T., Montemurro, F., De Luca, A.I., Gulisano, G., Strano, A. (2019) Environmental and economic assessment of sustainability in Mediterranean wheat production. *Agronomy Research*, 17(1), 60–76. DOI: https://doi.org/10.15159/AR.19.011

9. Ginzky H., Dooley E., Heuser I. L., Kasimbazi E., Markus T., Qin T. eds. (2017). International Yearbook of Soil Law and Policy 2017. Springer International Publishing. DOI: https://doi.org/10.1007/978-3-319-68885-5

10. Helming K., Daedlow K., Hansjürgens B. Koellner T. (2018). Assessment and Governance of Sustainable Soil Management. *Sustainability*, 10, 4432. DOI: https://doi.org/10.3390/su10124432

11. Hudzevich A., Liubchenko V., Bronnikova L., Hudzevich L. Landscape approach to take into account regional features organization of environmental management of the protected area. *Visnyk Kharkivskoho natsionalnoho universytetu V.N. Karazina. Seriia "Heolohiia. Heohrafiia. Ekolohiia".* 2020. № 52. P. 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

12. Jónsson J.Ö.G., Davíðsdóttir B., Nikolaidis N.P., Giannakis G.V. (2019). Tools for Sustainable Soil Management: Soil Ecosystem Services, EROI and Economic Analysis. *Ecological Economics*, 157(C), 109–119. DOI: https://doi.org/10.1016/j.ecolecon.2018.11.010

13. Kaletnik H., Prutska O., Pryshliak N. Resource potential of bioethanol and biodiesel production in Ukraine. *Visegrad Journal on Bioeconomy and Sustainable Development.* 2014. № 1. P. 9–12.

14. Kaletnik, G., & Lutkovska, S. (2020). Innovative Environmental Strategy for Sustainable Development. *European Journal of Sustainable Development*, 9(2), 89. DOI: https://doi.org/10.14207/ejsd.2020.v9n2p89

15. Kaletnik, G., Honcharuk, I. & Okhota, Y. (2020). The Waste-Free Production Development for the Energy Autonomy Formation of Ukrainian Agricultural Enterprises. *Journal of Environmental Management and Touricm*. Vol. XI, 3(43), 513–522.

16. Kuria A.W., Barrios E., Pagella T., Muthuri C.W., Mukuralinda A., Sinclair F.L. (2019). Farmers' knowledge of soil quality indicators along a land degradation gradient in Rwanda. *Geoderma Regional*, 16, e00199. DOI: https://doi.org/10.1016/j.geodrs.2018.e00199

17. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. The productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. 2020. *Ukrainian Journal of Ecology*. № 10(1). P. 101–105.

18. Mazur V.A., Didur I.M., Pantsyreva H.V., Telekalo N.V. Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*. 2018. № 8(4). P. 26–33.

19. Mazur V.A., Mazur K.V., Pantsyreva H.V. Influence of the technological aspects growing on quality composition of seed white lupine (Lupinus albus L.) in the Forest Steppe of Ukraine. *Ukrainian Journal of Ecology*. 2019. Vol. 9. P. 50–55. Available at: https://www.ujecology.com/archive.html

20. Mazur V.A., Mazur K.V., Pantsyreva H.V., Alekseev O.O. Ecological and economic evaluation of varietal resources Lupinus albus L. in Ukraine. *Ukrainian Journal of Ecology*. 2018. Volume 8. P. 148–153.

21. Mazur V.A., Pantsyreva H.V. "Rid Lupinus L. v Ukraini: henofond, introduktsiia, napriamy doslidzhen ta perspektyvy vykorystannia". VNAU, 2020. P. 235.

22. Mazur V.A., Pantsyreva H.V., Didur I.M., Prokopchuk V.M. Liupyn bilyi. Henetychnyi potentsial ta yoho realizatsiia u silskohospodarske vyrobnytstvo. VNAU, 2018. P. 231.

23. Mazur, V. A. (2018). Primary introduction assessment of decorative species of the lupinus generation in Podillya. *Scientific Bulletin of UNFU*, 28(7), 40–43. DOI: https://doi.org/10.15421/40280708

24. Mazur V.A., Pantsyreva H.V., Mazur K.V., Didur I.M. (2019). Influence of the assimilation apparatus and productivity of white lupine plants. Agronomy Research, 17(X), 206–209. DOI: https://doi.org/10.15159/AR.19.024

25. Mazur V.A., Pantsyreva H.V., Mazur K.V., Myalkovsky R.O., Alekseev O.O. Agroecological prospects of using corn hybrids for biogas production. *Agronomy Research,* 18(1), 177–182, 2020.

26. Mazur, V.A., & Pantsyreva, H.V. (2017). Vplyv tekhnolohichnykh pryiomiv vyroshchuvannia na urozhainist i yakist zerna liupynu biloho v umovakh Pravoberezhnoho Lisostepu. *Silske hospodarstvo i lisivnytstvo*, 7, 27–36.

27. Mazur, V.A., Myalkovsky, R.O., Mazur, K.V., Pantsyreva, H.V., Alekseev, O.O. (2019). Influence of the Photosynthetic Productivity and Seed Productivity of White Lupine Plants. *Ukrainian Journal of Ecology*, 9(4), 665–670.

28. Mazur, V.A., Prokopchuk, V.M., & Pantsyreva, G.V. (2018). Primary introduction assessment of decorative species of the lupinus generation in Podillya. *Scientific Bulletin of UNFU*, 28(7), 40–43. DOI: https://doi.org/10.15421/40280708

29. Mazur, V.A., Branitskyi, Y.Y., Pantsyreva, H.V. (2020). Bioenergy and economic efficiency technological methods growing of switchgrass. *Ukrainian Journal of Ecology*, 10(2), 8-15.

30. Mazur, V.A., Didur, I.M., Pantsyreva, H.V., & Telekalo, N.V. (2018). Energy-economic efficiency of grain-crop cultures in the conditions of the right-bank Forest-Steppe of Ukraine. *Ukrainian J Ecol*, 8(4), 26–33.

31. Mazur, V.A., Mazur, K.V., Pantsyreva, H.V., Alekseev, O.O. (2018). Ecological and economic evaluation of varietal resources Lupinus albus L. in Ukraine. *Ukrainian Journal of Ecology*, 8(4), 148-153.

32. Mazur, V.A., Pantsyreva, H.V., Mazur, K.V. & Didur, I.M., (2019). Influence of the assimilation apparatus and productivity of white lupine plants. *Agronomy research*, 17(1), 206–219.

33. Mohammed, Y.M., Arimoro, F.O., Ayanwale, A.V., Adamu, K.M., Keke, U.N., Abubakar, M.D., Achebe, A.C. (2021). The current state of water quality and benthic invertebrate fauna in Chikke Stream (North-Central Nigeria). *Ukrainian Journal of Ecology*, 11 (3), 26-34.

34. Monarkh Veronika Valentynivna, Pantsyreva Hanna Vitaliivna (2019). Stages of the Environmental Risk Assessment. *Ukrainian Journal of Ecology*, 9(4), 484–492. DOI: 10.15421/2019_779

35. Mustapha, M.K. (2008). Assessment of the Water Quality of Oyun Reservoir, Offa, Nigeria, Using Selected Physico-Chemical Parameters Turkish *Journal of Fisheries and Aquatic Sciences,* 8, 309–319.

36. Mykhailov V.H., Shcherbyna O.Z., Romaniuk P.S., Starychenko V.M. (2011). Kharakterystyka skorostyhlykh i serednostyhlykh sortiv soi dlia zony lisostepu i Polissia Ukrainy. *Selektsiia i nasinnytstvo*, no. 100. DOI: https://doi.org/10.30835/2413-7510.2011.66659

37. Nahornyi V.I. (2010). Vplyv strokiv i sposobiv sivby na urozhainist sortiv soi. *Kormy i kormo vyrobnytstvo*, vol. 66, pp. 91–95.

38. Nicola, G.G., Almodóvar, A. & Elvira, B. (2010). Effects of environmental factors and predation on benthic communities in headwater streams. *Aquatic Science*, 72, 419–429.

39. Nkwoji J.A., Yakub, A., Ajani, G.E., Balogun, K.J., Renner, K.O., Igbo, J.K., Ariyo, A.A. & Bello, B.O. (2010). Seasonal variations in the water chemistry and benthic macroinvertebrates of a south western Lagoon, Lagos, Nigeria. *Journal of American Science*, 6(3), 85–92.

40. Nyenje, P.M., Foppen, J.W., Uhlenbrook, S., Kulabako, R. & Muwanga, A. (2010). Eutrophication and nutrient release in urban areas of sub-Saharan Africa – A review. *Science & Total Environment*, 408, 447–455.

41. Odume, O.N., Muller, W.J., Arimoro, F.O., & Palmer, C.G. (2012). The impact of water quality deterioration on macroinvertebrate communities in the Swartkops River, South Africa: a multimetric approach. *African Journal of Aquatic Science,* 37 (2), 191–200.

42. Palamarchuk V., Honcharuk I., Honcharuk T., Telekalo N. Effect of the elements of corn cultivation the technology on bioethanol production under conditions of the rightbank forest-steppe of Ukraine. *Ukrainian Journal of Ecology*. 2018. Vol. 8(3). P. 47–53.

43. Palamarchuk, V. & Telekalo, N. The effect of seed size and seeding depth on the components of maize yield structure. Bulgarian Journal of Agricultural Science, 24(5), 2018. 785–792.

44. Palamarchuk, V., Telekalo, N. (2018). The effect of seed size and seeding depth on the components of maize yield structure. *Bulgarian Journal of Agricultural Science*, 24(5), 785–792.

45. Pancy'reva G.V. (2016). Doslidzhennya sortovy'x resursiv lyupy'nu bilogo (Lupinus albus L.) v Ukrayini. Vinny'cya, 4, 88–93.

46. Pantsyreva H.V. (2018). Research on varietal resources of herbaceous species of Paeonia L. in Ukraine. *Scientific Bulletin of the NLTU of Ukraine*, 28 (8), 74–78. DOI: https://doi.org/10.15421/40280815

47. Pantsyreva, H.V. (2019). Morphological and ecological-biological evaluation of the decorative species of the genus Lupinus L. *Ukrainian Journal of Ecology*, 9(3), 74–77.

48. Pantsyreva, H.V. (2017). Formation of grain productivity of white lupine depending on technological methods in the right-bank forest-steppe. Dissertation for obtaining a scientific degree of the candidate of agricultural sciences. Kam'ianets-Podilskyi, 100–101.

49. Pantsyreva, H.V. Technological aspects of biogas production from organic raw materials. *Bulletin of KhNTUSG them. P. Vasilenko*. Kharkiv, 2019. P. 276–290.

50. Pancyreva G.V. Doslidzhennya sortovyx resursiv lyupynu bilogo (LUPINUS ALBUS L.) v Ukrayini. *Zbirnyk naukovyx pracz*. VNAU. 2016. 4. 88 p.

51. Pantsyreva, H.V., Myalkovsky, R.O., Yasinetska, I.A., Prokopchuk V.M. (2020). Productivity and economical appraisal of growing raspberry according to substrate for mulching under the conditions of podilia area in Ukraine. *Ukrainian Journal of Ecology*, 10(1), 210–214.

52. Pozniak S.P. (2016). Chernozems of Ukraine: geography, genesis and current conditions. *Ukrainian geographical journal*, 1, 9–13. DOI: https://doi.org/10.15407/ugz2016.01.009

53. Telekalo N., Mordvaniuk M., Shafar H., Matsera O. Agroecological methods of improving the productivity of niche leguminous crops. *Ukrainian Journal of Ecology*. 2019. № 9(1). P. 169–175.

54. Telekalo N.V. Economic evaluation of the efficiency of pea growing technology. *Collection of scientific works of VNAU "Agriculture and forestry"*. 2016. 4. P. 63–71.

55. Thorsøe M.H., Noe E.B., Lamandé M., Frelih-Larsen A., Kjeldsen C., Zandersen M., Schjønning P. (2019). Sustainable soil management – Farmers' perspectives on subsoil compaction and the opportunities and barriers for intervention. *Land Use Policy*, 86, 427–437. DOI: https://doi.org/10.1016/j.landusepol.2019.05.017

56. Tkachuk, V.P., Tymoshchuk, T.M. (2020) Influence of sowing dates on winter wheat productivity. *Bulletin of Agricultural Science*, 3, 38–44. DOI: https://doi.org/10.31073/agrovisnyk202003-05

57. Towhid O. K. (2018). Management of Soil Problems. Springer International Publishing, XX. DOI: https://doi.org/10.1007/978- 3-319-75527-4

58. Ulich, O.L. (2018). Trends in sowing dates of soft winter wheat (Triticum aestivum L.) in the southern part of the Right-Bank Forest-Steppe of Ukraine during climate transformation. *Bulletin of Agricultural Science,* 6, 19–24. DOI: https://doi.org/10.31073/agrovisnyk201806-03

59. Umar, D.M., Hardling J.S. & Winterbourn, M.J. (2013). Photographic guide of freshwater Invertetbrates of the Mambilla Plateau Nigeria. Published by School of Biological Sciences University of Canterbury, New Zealand.

60. M.M. Marenych, V.F. Kaminsky, C.Yu. Bulygin, V.V. Hanhur, I.V. Korotkova, S.O. Yurchenko, A.V. Bahan, S. V. Taranenko, V.V. Liashenko (2020) Optimization of factors of managing productive processes of winter wheat in the Forest-Steppe. *Agricultural Science and Practice*, 7(2), 44–54. DOI: https://doi.org/10.15407/agrisp7.02

61. Vdovenko S.A., Prokopchuk V.M., Palamarchuk I.I., Pantsyreva H.V. (2018). Effectiveness of the application of soil milling in the growing of the squash (Cucurbita pepo var. giraumontia) in the right-benk forest stepp of Ukraine. *Ukrainian Journal of Ecology*, 8(4), 1–8.

62. Vdovenko S.A., Prokopnuk V.M., Palamarchuk I.I., Pantsyreva H.V. Effectiveness of the application of soil milling in the growing of the squash (Cucurbita pepo var. giraumontia) in the right-benk forest stepp of Ukraine. *Ukrainian Journal of Ecology*. 2018. № 8 (4). P. 1–5.

63. Vdovenko, S.A., Pantsyreva, G.V., Palamarchuk, I.I., & Lytvyniuk, H.V. (2018). Symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biological products in agrocoenosis of the right-bank forest-steppe of Ukraine. *Ukrainian J Ecol*, 8(3), 270–274.

64. Vdovenko, S.A., Prokopchuk, V.M., Palamarchuk, I.I., & Pantsyreva, H.V. (2018). Effectiveness of the application of soil milling in the growing of the squash (Cucurbita pepo var. giraumontia) in the right-benk forest stepp of Ukraine. *Ukrainian J Ecol*, 8(4), 1–5.

65. Vitalii Palamarchuk, Inna Honcharuk, Tetiana Honcharuk, Natalia Telekalo. Effect of the elements of corn cultivation technology on bioethanol production under conditions of the right-bank forest-steppe of Ukraine. *Ukrainian Journal of Ecology*. 2018. № 8(3). P. 47–53.