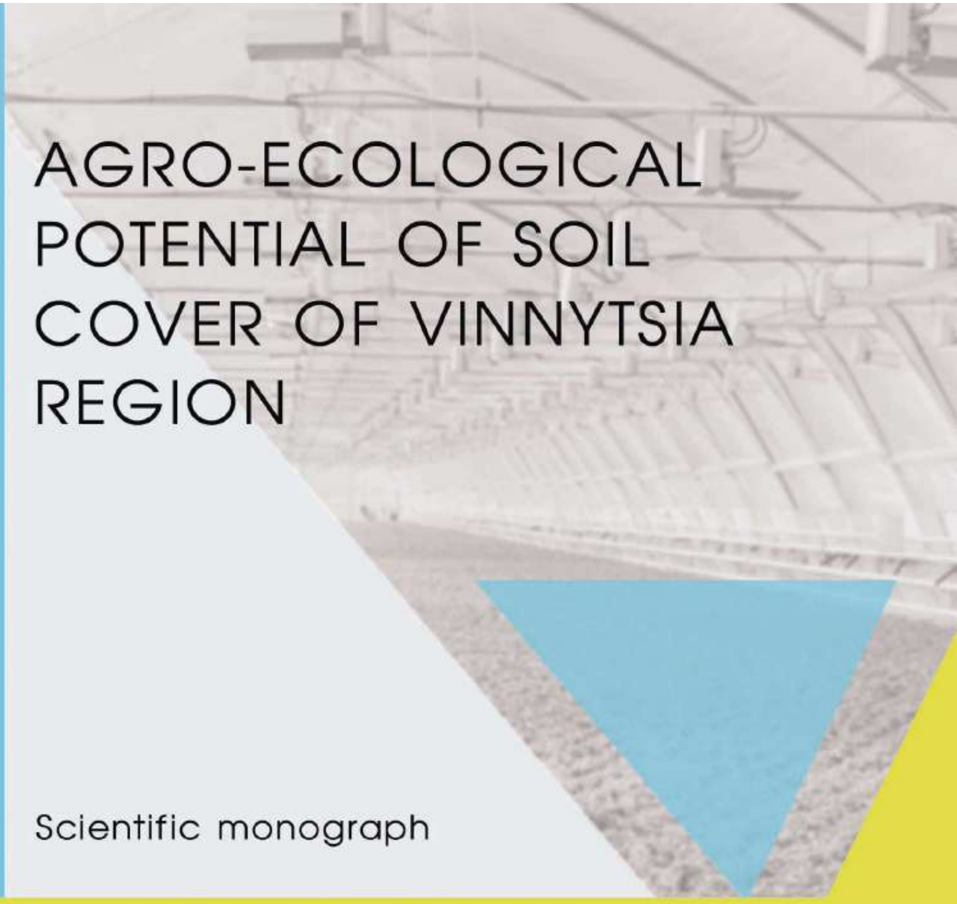


AGRO-ECOLOGICAL POTENTIAL OF SOIL COVER OF VINNYTSIA REGION

Scientific monograph

2023

AGRO-ECOLOGICAL POTENTIAL
OF SOIL COVER OF VINNYTSIA REGION

2023

ISBN 978-9934-26-150-3
9 789934 261503

IZDEVNIECĪBA
BALTIJA
PUBLISHING
baltijapublishing.lv

IZDEVNIECĪBA
BALTIJA
PUBLISHING

AGRO-ECOLOGICAL POTENTIAL OF SOIL COVER OF VINNYTSIA REGION

Scientific monograph

Riga, Latvia
2023

UDC 631.4(477)
Ag730

Title: Agro-ecological potential of soil cover of Vinnytsia region

Subtitle: Scientific monograph

Scientific editor and project director: Anita Jankovska

Authors: Lina Bronnicova, Lyudmila Pelekh, Victoria Verhelis, Olga Mazur, Ihor Didur, Lina Bronnicova, Ruslan Myalkovsky, Hanna Pantsyreva, Hanna Pantsyreva, Oleksiy Alieksieiev, Hanna Pantsyreva, Kateryna Mazur, Lyudmila Pelekh, Tetiana Zabarna, Mykhaylo Polishchuk, Lina Bronnicova, Oleksandr Tkachuk, Oleksiy Alieksieiev

Publisher: Publishing House "Baltija Publishing", Riga, Latvia

Available from: http://www.baltijapublishing.lv/omp/index.php/bp/catalog/book/306

Year of issue: 2023

Agro-ecological potential of soil cover of Vinnytsia region : Scientific monograph. Riga, Latvia : "Baltija Publishing", 2023. 216 p.

ISBN: 978-9934-26-290-6

DOI: https://doi.org/10.30525/978-9934-26-290-6

The monographic study examines the main components of the agroecological potential of the soils of the Vinnytsia region.The scientific work is aimed at forming the concept of modernization of soil conservation and environmental safety, namely, rational nature management at the expense of limited resource provision due to climate change. 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". The expected results of the research are aimed at achieving complex ecological, economic, energy and social effects. The authors have considerable experience in research related to rational nature management, the development of land reclamation measures taking into account the concepts of rational nature management, which ensure the optimization of land use, as well as the biologicalization of agriculture. The scientific research of the authors has been commercialized, in particular, contracts have been concluded for the performance of research within the framework of farm contract and state topics.

Table of Contents

RESEARCH OF LAND RESOURCES AND SOIL COVER OF VINNYTSIA REGION

Lina Bronnicova[1]
Lyudmila Pelekh[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-1

Abstract. It is undeniable that the role of the agricultural sector is extremely high in the formation of sustainable development of any state, region and individual settlement. After all, it is the agricultural sector that provides the population with food and creates favorable conditions for the population to live. Its main components include soils, in particular, cultivated soil for agricultural crops. Unfortunately, today's powerful anthropogenic load on agricultural lands leads to a change in their condition, which is accompanied by a negative balance of humus, a lack of organic matter, important nutrients, pollution by heavy metals, and the activation of degradation processes. This is especially dangerous for the most valuable and widespread Ukrainian chernozems, which are susceptible to technogenic and anthropogenic stress. *The purpose* of the paper is to research hronology of soil formation processes according to the main chronological stages of the development of the territory of Eastern Podillia (Vinnytsia region), own grouping based on the analysis. *Methodology* of the study corresponds to the strategic tasks of the state policy in the field of agricultural land use, in particular, improving the structure of agricultural lands, reproducing their fertility and ensuring rational use and protection of lands based on greening. Therefore, the assessment of the agrochemical condition of soils in our region, Vinnytsia region, is relevant. *Results* taking into account the fact that the majority of food products are obtained by the cultivation of the land and the fact that more than 70% of all pollutants enter the human body with food products, the role of ecologically clean lands as an irreplaceable natural resource and the basis for the production of safe products that directly or indirectly does not create a harmful effect on human health; as

---

[1] Senior Lecturer, Vinnytsia National Agrarian University, Ukraine
[2] Candidate of Agricultural Sciences, Senior Lecturer,
Vinnytsia National Agrarian University, Ukraine

the basis for the formation of ecologically balanced agroecosystems, which require modeling in accordance with the specialization of economic activity. Land resources are the basis of material and spiritual production. The development of productive forces, the scale of production and the material well-being of the people depend on the nature and level of efficiency of land use. Land resources are necessary for all branches of the national economy, but their role in different spheres of social production is not the same. If in industry, except for mining, land is only a spatial base, then in agriculture it is the main means of production. The role of land in agricultural production is determined by the fact that it has a specific unique property – fertility. Thanks to this property, the land actively affects the process of agricultural production. *Practical implications.* The soils of Ukraine suffer significant environmental damage as a result of their pollution by industrial emissions, the indiscriminate use of chemicals in the agricultural sector, as well as the pollution of large areas in the locations of large livestock complexes and poultry farms. Up to 20% of polluted land in urban, suburban and industrial areas is in a state of crisis. Processes of further oxidation of soils, decrease in the content of mobile phosphorus and exchangeable potassium are observed. *Value/originality.* The modern technical state of irrigation and drainage systems, significant areas of flooding of irrigated lands and acid and shrub-covered drained lands led to a decrease in the total yield of agricultural crops relative to the projected level by 30% on irrigated lands and by 15% on drained lands. Vinnytsia due to the significant economic development of the territory and the development of agriculture by reducing the area of natural and natural and anthropogenic landscapes (meadows, forests, marshes) with a simultaneous increase in the specific weight of developed agricultural land, primarily arable land.

1. Introduction

Measures to combat soil pollution, as one of the important problems of the present time, should be solved in Ukraine in two ways, namely: prevention (prevention), i.e. preventing toxicants from entering the soil, as well as cleaning the soil from toxic substances that have already entered it. Intensive technologies for growing field crops increase the possibility of soil contamination with fertilizer residues, toxic chemicals, herbicides and other toxicants. The presence of toxic substances in the soil is accompanied by their accumulation in food, feed, surface and groundwater. Therefore, a clear control is needed correct use of fertilizers, pesticides, chemical meliorants. In particular, the use of mineral fertilizers is regulated by agrotechnical and hygienic regulations: the rate of fertilizers per unit area and the ratio of nutrients for individual crops, the terms and methods of application, the maximum permissible level of nitrates and nitrites in plant products. In today's conditions, many agricultural measures have been developed that do not cause an excess of nitrates in the soil. Among the external factors of nitrate accumulation in crop production, the main role is played by the level of nitrogen nutrition of plants. Excessively high doses of nitrogen fertilizers can increase the nitrate content in plants by 1.5–8 times compared to the optimal and scientifically justified doses of fertilizers, which should be adjusted according to the total reserves of mineral forms of nitrogen in the soil.

Land relations have always played a leading role in the life and business of the Ukrainian people. The transformation of the national economy to market conditions caused the corresponding changes in land relations, which were embodied in land privatization, change of land ownership, the formation of responsibility of economic entities for its rational use and protection. Further development and improvement of land relations in agriculture consist of the implementation of a state policy aimed at high-tech and environmentally friendly land use, which corresponds to the regulated, socially-oriented market economy. As a result of the land reform in Ukraine, a radical degeneration in relations on land ownership issues began, a monetary reward for the opportunity to use the land was introduced. Rental relations have developed, and specific prerequisites have been created for the formation of the land market. During the land reform, practically no attention was paid to such issues as quality situation, fertility, and protection of lands [46; 50–65].

2. Conditions, objective and methods of research

Vinnytsia region was formed on February 27, 1932. The city of Vinnytsia is the regional center. The region is located on the right bank of the Dnieper within the borders of the Dnipro and Podil highlands. The territory of the region is 26517.6 km^2 [6; 30–35].

The administrative-territorial composition of the region includes 27 districts, 2 urban united territorial communities, 1 rural united territorial community, 28 village and 658 village councils, 1,504 settlements, of which 29 are urban-type settlements, 18 cities, including 6 cities of regional significance. The total population of the region as of January 1, 2021 was 1590.4 thousand people. 810.1 thousand people or 50.9% of the total population of the region lived in urban settlements, 780.3 thousand people or 49.1% lived in rural areas [40–44; 67–82].

Vinnytsia region is located in the forest-steppe zone of the central part of the Right Bank part of Ukraine. The territory of the region is divided into two parts by the Pivdenny Bug River: the left bank, which belongs to the Dnieper Highlands, and the right bank, the Podilsky Plateau. The surface of Vinnytsia is a raised plateau, decreasing in the direction from the northwest to the southeast. Most of the territory of the Vinnytsia region is located within the boundaries of the Ukrainian crystalline shield. The complex geological history of the territory influenced the formation of the relief. A significant impact on the formation of the relief was also caused by the work of flowing waters, branched by numerous river valleys, ravines and gullies, especially in the region of Transnistria [12; 75].

The watershed of the basins of the Southern Bug and Dniester rivers passes through the territory of the region. In the central part of the region, the South Bug River flows from the north-west to the south-east, and the Dniester River flows along the south-west border of the region. 204 long rivers flow on the territory of the region more than 10 km each. They belong to the basins of the Southern Bug (Zgar, Riv, Dokhna, Sob, Savranka), Dniester (Murafa, Lyadova, Markivka, Rusava, Nemia) and Dnieper (Ros, Hnylopyat, Guiva). The average density of the river network is 0.38 km/km^2 [12; 26–30].

There are 56 reservoirs within the region, with a total surface area of 11,167 hectares; the largest Ladyzhyn reservoir (2.2 thousand ha), 5,356 ponds with a total surface area of about 30 thousand ha. Rivers and reservoirs are used for fish farming, industrial and communal water supply, land irrigation, and also as a source. A large number of ponds is a potential threat of inundation of settlements and lakes during the flood period, and can also be the cause of catastrophic flooding in the event of the destruction of dams and dams. especially from the Ladyzhynskaya TPP and the Dniester hydrocascade [12].

The land fund of the region is 2,649.29 thousand ha, the land area is 2,605.8 thousand hectares, or 98.4% of the total area of the region, the remaining 43.4 thousand hectares (1.64%) is occupied by internal waters. Two-thirds (2014.5 thousand hectares) of the territory is occupied by agricultural land, under forests and other forested areas – 14.3%, built-up land occupies 4.1%, swamps – 1.1%, other lands (farmyards, roads, sands, ravines, rocky places, etc.) – 2.81% [6; 12].

Vinnytsia, in geostructural terms, is mainly located on the southwestern edge of the Ukrainian crystalline massif (shield), composed of Archean-Proterozoic metamorphic and igneous rocks, the age of which reaches 1.5 – 3.5 billion years. This is the so-called crystalline foundation. And only the southwestern edge of the region is located on the Volyn-Podilsky plate, where the foundation rocks are covered by a relatively thick layer of sedimentary deposits and less often [12].

3. Processes of soil formation in the territory of Vinnytsia

The processes of soil formation in the territory of Vinnytsia region have undergone a rather complex process of genesis (Table 1).

In the studies of S.P. Karmazynenko, Zh.M. Matviishyna, S.P. Karmazynenko, S.P. Doroshkevich established the boundaries of the soil zones (further – the text in the author's edition) for the Kaitsky, Prylutsky, Vytachev and Dauphine paleogeographic stages somewhat further north, with the exception of the boundaries of the sod-podzolic and gray forest soils of the Kaitsky and chernozems of the Prylyutsky period, which were spread further south (Figure 2).

– Kaidatsky stage – turf-podzolic and gray forest soils (kdb1) were common in the south, brown forest-steppe soils (kdb1), dark and light gray soils, chernozems with podzol, close to normal, and southern (kdb2) were common in the north;

– the Prylut stage – further north – dark gray forest and chernozem-like (gray-brown) soils (plb1), typical chernozems, micellar-carbonate chernozems, chernozem-like (brownish-gray) and southern chernozems (plb2), further south – chernozems Burrow-like (plb2);

– Vytachev stage – further north – dark brown and brown forest, gray light brown and brownish-brown (vtb1, vtb2), reddish-brown in a complex with saline (vtb1+b2);

On the basis of established soil types, the dynamics [99; 100] of the decrease in the area of forest habitats (turf-podzolic, gray, brown forest)

Table 1

Chronology of soil formation processes according to the main chronological stages of the development of the territory of Eastern Podillia (Vinnytsia region), own grouping based on the analysis

№	**Period**	**Predominant soil-forming process, soil types**
1	**2**	**3**
1	Eopleistocene (1,8-0,85 million r.t.)	Forest formation
2	Kryzhaniv stage (1,55-1,3 million r.t.)	Brown soils dominated in the western and northern parts of the region, and brown and reddish-brown soils in the southern
3	Shyrokinsky stage (1,2-0,85 million r.t.)	Black earth soils
4	Azov period (850-780 thousands of years)	Subperiglacial forest-steppe landscapes on loess and gray loam
5	Martono stage (780-650 thousands of years)	At its beginning, pseudoglay and reddish-brown loess soils were common, and at the end – brown loess, pseudoglay, and brownish-brown soils
6	Luben stage (600-500 thousands of years)	Periodic change of forest pedogenesis by meadow-steppe and the appearance of genetic types of chernozems and gray forest soils
7	Potyahailovsky stage (230-180 тис. р.т.)	Brown forest loess, brown and chernozem soils
8	Kaydat stage (130-110 thousands of years)	Ocher-iron soils dominated in the north; to the south – meadows with sod and sod soils.
9	Vytachiv (Dubniv) stage (55-27 thousands of years)	During it, there were two sub-stages of soil formation. During the first of them, brown soils predominated in the north and west of Podillia, while brown loam soils prevailed in the south (in Central and Eastern Podillia). At the second sub-stage of soil formation, aridization was observed. Meadow-steppe landscapes on turf-carbonate soils and dry-steppe landscapes on dark brown soils dominated in Central and Eastern Podilly (Figure 1).
10	Dauphin stage (18-15 thousands of years)	In the northern and western parts of Podillia, forest-steppe landscapes on sod-brown soils dominated, in the central and southern parts – steppes on sod-carbonate soils
11	Atlantic time (8,0-4,6 thousands of years)	Gray forest soils are formed along it
12	Early subboreal (4,6-4,1 thousands of years)	Formation of gray forest and chernozem subsoils

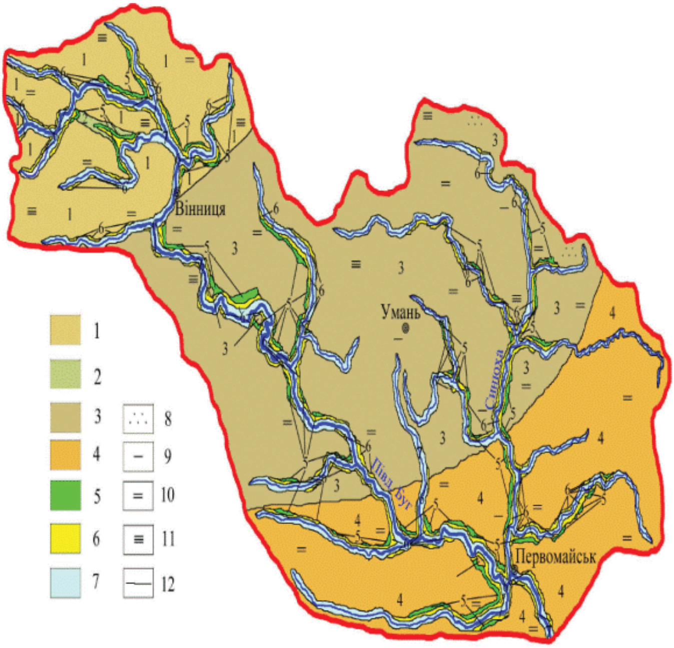


Figure 1. Soil cover of the Middle Pobuzhye in the Vytachev (Dubniv) stage (55-27 thousand of years)

Source: [28]

Genetic types of soils:
1 – brown soil (dark brown and brown), often overgrown, close to meadows;
2 – meadow and meadow-swamp borer-like;
3 – dark brown in the sub-stage vtb1 and brown and light brown in the sub-stage vtb2;
4 – dark brown brown, sometimes saline in the substages vtb1 and brownish-brown, sometimes saline in sub-stage vtb2;
5 – alluvial, meadow-swamp and other hydromorphic soils of floodplains;
6 – alluvial deposits of the supraflood terrace: sand with interlayers of loams and sandy loams, gravel, pebbles;
7 – late erosion of sediments;
Granulometric composition of sediments:
8 – sandy;
9 – slightly loamy;
10 – medium loam;
11 – heavy loam;
12 – approximate distribution limits.

Figure 2. The Vitachiv horizon in a section of Pleistocene sediments (Yakushintsi village, Vinnytsia district, Vinnytsia region)

Source: [24]

and the expansion of the area of steppe soils (chernozems and light brown semi-desert soils) from the Kaitsky to the Dauphine stages were traced, and the trend was confirmed changes in the paleogeographic conditions of the formation of Pleistocene soils: from moderate (Kaidatsky, Prylutsky – brown, gray forest, chernozem soils, which were formed in somewhat evenly moistened conditions compared to modern ones), moderate and more contrasting (Vytachiv – brown, dark brown, reddish brown) to moderately continental and more arid (Dauphinian – southern chernozems, light brown semi-desert soils). The stage was more arid than the previous one (the most humid stage is the Kaidatsky stage, the arid stage is the Dauphine stage).

It has been proven [9–12; 110–111] that the macro- and micromorphological characteristics of Pleistocene soils of different stages of formation (initial, optimal and final) reflect changes in the conditions of soil formation from colder in the initial phase (kda), wetter and warmer in the optimal (kdb1, kdb2, plb1, plb2, vtb1, vtb2, dfb1, dfb2) to more continental and arid at the end of the stage (plc, vtc, dfc). During each paleogeographic stage, the lower soils of the optimal stage, compared to the upper ones, reflect traces of more humid soil formation. It is indicated [19–26] that the micromorphological features of loess are less diverse and individual compared to soils. Yes, S.P. Karmazynenko [29] noted that the brightness of the plasma, the loose composition of the forest particles, their commensuration with the grains of primary minerals with carbonate-clay shells, the impregnation of the plasma with micro- and fine-crystalline calcite indicate cold periglacial conditions during the Tasmin, Udai, Buzy and Black Sea palaeogeographic stages. Tyasminsky and Udai loess are weak, often reworked by subsequent soil formation, sometimes preserved only in patches or are carbonate horizons of overlying soils. Typical loess are lilacs, which have the greatest thickness (up to 7 m). The bg1 substage is characterized by the formation of initial soils (simple carbonate-clay microaggregates separated by pores) as a result of climate oscillations. Loess and loess-like loams of the Black Sea horizon, especially pč3, are located under modern soils and are often significantly reworked by them (presence of molehills, chervoryins, simple carbonate-clay microaggregates, plasma impregnation with microcrystalline calcite). The loess of substages pč1 and pč3 in the south are sometimes divided by initial short-profile and carbonate light-brown and brown desert-steppe soils (pč2) – simple microaggregates, uniform coloring of the plasma with organo-clay substances and its impregnation with microcrystalline calcite.

Thus, the diversity of bioclimatic conditions, types of deposits and the main elementary soil-forming processes led to the formation of modern types of sod-podzolic, gray forest and chernozem-like soils on the territory of Vinnytsia region, which differ in macro- and microstructure features.

The modern soil cover of the Vinnytsia region is represented by various types of soils. The formation of which is connected, first of all, with complex relations between forest and steppe vegetation, as well as various conditions of relief, surface and soil moisture, and other factors [1–12; 24].

On the most elevated and fragmented massifs of the central part of the region (Zhmerynska Vysochyna and the south of Kozyatynska) under the oak-hornbeam forests, strongly podzolized soils – light gray and gray – were formed. The influence of the woody plant formation causes the podzolic process to take place and the formation of less fertile strongly podzolic soils.

On the massifs of the plateau and ancient terraces in the southern and northern parts of the region, with a relatively small dismemberment under the cover of grassy vegetation, soils of the chernozem type were formed as a result of the influence of the sod process. At the same time, dark gray podzolized soils and podzolized chernozems were formed on areas of chernozem soils, later occupied by forests and on massifs of podzolized soils, where herbaceous vegetation was located for some time.

On the massifs freed from under the forest, under the steppe vegetation on the podzolized soils, the sod process takes place and regraded soils are formed.

On the slopes, under the influence of water erosion, soils become weakly, moderately and strongly eroded.

In the floodplains of rivers and streams, together with turf, a swamp process occurs, as a result of waterlogging and the close occurrence of groundwater. The result is the formation of marshy soils, including peatlands.

Thus, under the forest cover, the podashic process of soil formation was constantly taking place; in areas under steppe vegetation, the sod process takes place; regraded soils are formed in areas where the forest vegetation changes to grass (provided the groundwater is within the limits of capillary action and the presence of carbonate soil-forming rocks).

As a result of the sod process, chernozems were formed under the grassy vegetation. Their features are accumulation of humus, nutrients, good water and air regime. In soils of the sod type of soil formation, there are no soluble acidic substances, the presence of carbonates.

With the combined action of podzolic and sod processes of soil formation, sod-podzolic soils, poor in organic substances, with negative water, air and nutrient regimes were formed in Vinnytsia region.

Swamp formation occurs as a result of the waterlogging of water bodies and dry lands, their overgrowth with swamp vegetation, and the formation of peat of various composition. During overgrowth, lowland swamps are formed, and during the growth of floodplains, upper and transitional ones are formed.

Peat formation is the decomposition of dead organic matter under anaerobic conditions. Bog and peat soils contain a large amount of organic matter.

Swampy soils were formed due to seasonal overwetting. They have a significant amount of humus (5%), well supplied with gross forms of nitrogen, phosphorus, and potassium.

Meadow soils are characteristic of areas where deluvial flows do not have a great force (beams, depressions, floodplains of rivers and streams). In the lower horizons of the soil profile, there is a gleiaceous rock, which contains acidic compounds of iron and aluminum that are toxic to plants. Groundwater is at a depth of 1.0-1.5 meters, there are also closer to the surface, depending on the season. These soils have low hydrolytic acidity and a neutral reaction of the soil solution.

Meadow-swamp soils were formed under conditions of excessive moistening caused by groundwater. The lack of oxygen in them leads to the fact that plant residues do not decompose completely, but accumulate in the form of coarse humus (up to 5% in the upper horizon). The reaction of the soil solution is close to neutral.

4. Characteristics of land resources and soil cover of Vinnytsia region

The territory of the region is 26.5 thousand km^2, 4.4% of the territory of Ukraine. The region is located in the forest-steppe belt of the right-bank part of Ukraine.

Vinnytsia region has 202 km of state border with the Republic of Moldova; it also borders 7 region of Ukraine: Zhytomyr, Chernivtsi, Khmelnytskyi, Kyiv, Cherkasy, Kirovohrad, Odesa oblasts.

Vinnytsia region is located in the forest-steppe zone of the central part of the Right Bank part of Ukraine. The land area is 2,606.4 thousand ha, or 98.4% of the total area of the region, the rest (1.6%) is occupied by inland waters. The rivers of the region belong to the basins of the Southern Bug, Dniester and Dnieper: of them: 2 large (Southern Bug and Dniester rivers), 4 medium ones (Sob, Hirskyi (Gnily) Tikich, Murafa, Ros) and 4555 children [12].

With reference to O.O. Shevelyuk and others [12; 19; 34; 56; 78–79; 104], the modern structure of the land fund of the Vinnytsia region was formed over a long period under the influence of various factors. The flatness of the surface, favorable natural and climatic conditions, ancient economic development of the studied territory caused a fundamental transformation of the environment. The total land area within Vinnytsia region is 2,649.2 thousand hectares, and their distribution by main categories is uneven. Among all categories, agricultural land predominates, accounting for 76.1% of the total. Forestry lands occupy the second place in the region in terms of area, after agricultural lands. According to the data of the Main Department of Land Resources in the Vinnytsia region, the area of forests and other forested areas is 378.7 thousand hectares (14.3%), of which 239.6 thousand hectares are covered with forest vegetation. Forest cover in the region is lower than in other regions, which is caused by significant economic development of the studied territory. Lands under water in the district occupy an area of 43.5 thousand hectares (1.6% of the total area of the region) and are represented by lands located under both natural and artificial water bodies.

The main type of land use in the region is agriculture. The share of agricultural land in all categories of land users together with homestead lands is 75.9% from the total area of the region. In their structure, 85.7% is arable land, 9.3% belongs to pastures, 2.5% is allocated to haymakers, and 2.5% to land with perennial crops. The average land security of one inhabitant of the region is 0.98 ha of arable land. Almost half of the agricultural land of the region (49.0%) is distinguished by a fairly high level of natural fertility and is represented by a complex of black-earth and meadow-black-earth soils (Tables 2, Figure 3). More than 17% of the area is occupied by dark gray podizolized soils of medium fertility. However, relatively low-fertility light-gray and gray podzolic soils predominate on a third of the entire land area (31.4%). In addition, on 98.0 thousand ha (5.3%) common low-productivity soil types: sod-podzolic, marshy, meadow-swamp and swampy soils. The area of valuable soils in Vinnytsia region is 835,000 hectares.

In general, Vinnytsia region is characterized by the following soil cover

Figure 3. Vinnytsia region on a satellite image [Google maps]

structure: gray forest soils – 50.5% and black soils – 42.1%. Dominant soil-forming rocks are loess and loess-like loams. Their granulometric composition varies from light loamy (the content of physical clay, particles with a diameter of less than 0.01 mm, is 20-30%) in the north of the region to medium loam (30-45%) in the center and heavy loam (45-60%) in the south with a weighted average volume density in the range of 1.28-1.32 g/cm^3.

Depending on the content of humus, the depth of the humus horizon, the development of the podzolized horizon, and the intensity of color, gray forest soils are divided into three subtypes: light gray, gray, and dark gray. The humus content in these soils varies from 1.85% to 2.4%.

Black earth soils are located in the northeast, southeast, and south of the Vinnytsia region. The following subtypes were found among the chernozems of Vinnytsia: podzolized, regraded, and typical. Fertility ranges from 3.39% in podzolized chernozems to 3.8% in regraded chernozems. The most fertile soils of Vinnytsia are gray and dark-gray podzolized swamps, chernozems, podzolized swamps and swamps. They contain 3.5-5.5% humus and occupy 1.7% of the territory of the region.

The total share of public land is 6.5%, commercial land accounts for 1.6%, mixed-use land accounts for 1.7% of the total area of the region. In total, there are 3,600 rivers and streams in the region with a total length of 11,800 km, the density of the river network is 0.43 km/km^2. Two large rivers (Southern Bug and Dniester), four medium rivers (Sob, Murafa, Ros, Hirskyi Tikich), 226 small rivers with a length of more than 10 km flow within the Vinnytsia region. A significant amount of water resources of the region is accumulated in created reservoirs and lakes. There are 65 reservoirs in the region, with a total surface area of 11,167 hectares and a water volume of 282.6 million m^3; 4,033 ponds with a total surface area of about 20,552 hectares. The lands of the water fund make up 1.6% of the territory of the Vinnytsia region, the largest share falls on ponds (53.1%). Artificial reservoirs (22.8%), natural watercourses (20.8%), artificial watercourses (3.1%). The share of lakes, coastal and closed reservoirs, estuaries is only (0.01%). Most of the land and water resources are concentrated in Bershadsky – 2,780.9 ha, Litynsky – 2,627.9 hectares, Kalinivskyi – 2,465.6 hectares, and the smallest in Pischanskyi – 180.9 hectares, Tomashpilskyi – 282.9 hectares, Kryzhopolskyi – 390.4 hectares, and Chernivtsiskyi – 400.4 hectares. As of January 1, 2010, the area of objects and territories of the nature reserve

Table 2

Nomenclature list of soils of the Vinnytsia region

Soils	Surveyed area, ha	Including arable land	
		ha	% from survey. arable land
Sod-podzolic on ancient alluvial deposits	11547	6561	0,39
including examined	3952	1963	0,12
Gray forest on loess rocks and clays	654792	549143	32,9
They are clearly gray	81873	56705	3,40
Including examined	7158	5355	0,32
Of them are gray	572919	4924389	29,5
Including examined	11890	9734	0,58
regraded	4026	3784	0,23
Alized soils on loess rocks and clays	799834	724831	43,4
Alized soils on loess rocks and clays	345326	304814	18,2
Including examined	24730	21942	1,31
regraded	36517	83670	2,02
Of them, the chernozems are podzolized	454508	420017	25,2
Including examined	11276	10495	0,63
regraded	235738	221708	13,3
Black soils are typical on loess rocks	374263	350658	21,0
Among them, shallow, low-humus chernozems	35148	32953	1,97
Including carbonate	6405	5839	0,35
leached	13523	12857	0,77
Among them, the black soils are deep and low in humus	339115	317705	19,0
including carbonate	60617	58108	3,48
leached	65793	61906	3,71
Other chernozems and chernozem soils	1821	1425	0,08
Meadow chernozem soils	18007	15750	0,94
Meadow soils on deluvial and alluvial deposits	45272	17893	0,94
Meadow-swamp soils on alluvial and deluvial deposits	28669	1609	0,10
Marsh soils on alluvial and deluvial deposits and peatlands	21831	507	0,03
Sod soils on eluvium of carbonate rocks	5565	1236	0,07
Yields of rocks	17210	393	0,02
Together in the region	1978751	1670012	100

fund in the region was 27.3 thousand hectares, which was only 1.03% of the total area.

The entire territory of the Vinnytsia region belongs to the province of the Right Bank Forest Steppe and is divided into two sub-provinces – the northern one with light and medium loamy soils and the southern one with medium and heavy loamy soils in terms of mechanical composition. A detailed list of the soils of Vinnytsia in terms of agro-soil regions is presented sequentially in Table 3.

Information on cadastral zoning and distribution of land cover typology in Vinnytsia.

A detailed list of the soils of Vinnytsia in terms of agro-soil regions is presented sequentially in Table 3.

The soil cover of the Vinnytsia region is relatively homogeneous. The most widespread types of soils are gray forest soils – 1,000.1 thousand ha, which is 50.5%, and black soils – 830.8 thousand ha or 42.1%.

On the other hand, there are criteria for soil suitability for minimization. In particular, I.S. Rabochev and others [15; 98; 104] established that the following soil parameters best correspond to the minimization of cultivation:

– density in the equilibrium state 1.1-1.2;
– total sparability 50-55%;
– aeration gap at low pressure is not <15%;
– water permeability not <1mm/min;
– HB 30-33;
– the content of waterproof aggregates is not <40%.

Zones of efficiency of minimum tillage in Ukraine:

I. The zone of high efficiency includes areas with chernozem soils.

II. Zone of reduced efficiency with gray forest, dark chestnut and chestnut soils.

III. Zone of low efficiency with sod-podzolic, light gray, light chestnut soils.

Based on the soil conditions, in Ukraine the minimum tillage can be applied to 9.2 million hectares, incl. in the Steppe for 4.1 million hectares. Direct sowing of individual crops can be carried out on an area of 1.6 and 0.6 million hectares, respectively.

In accordance with these principles and taking into account the described properties of the soils of Vinnytsia region, the suitability of its soil cover for the introduction of various tillage systems, ranging from the usual

Table 3

Soil characteristics of arable lands within the agro-soil regions of Vinnytsia region

Agro-soil districts and sub-districts	Surveyed, hectare	Soil types, thousand ha								Including eroded ones			
											Of them		
		Sod podzolic	Light gray forest	Dark gray	Black and green	Black soil	Lucni	Meadow – sod	Swampy	In total	Weak	Among	Strong
Khmilnytskyi – Pogrebyschensky district	489,7	2,3	15,7	52	117,8	289,6	11,2	0,1	-	80,8	63,2	15,5	2,2
Khmelnytskyi – Lypovetskyi district	285,1	1,7	7,9	15,5	48,1	205,1	6,5	0,1	-	34,4	28,5	5,4	0,5
Pogrebyschenskoe – Orativskyi	204,6	0,4	7,8	37,3	69,7	84,5	4,7	-	-	46,4	34,7	10,0	1,7
Central district	610,4	4,8	462,4	110,4	20,9	2,9	5,3	0,3	0,1	229,3	177,0	47,3	5,0
Vinnytsia – Nemyrivsky subdistrict	262,5	4,4	183,9	46,9	18,7	2,9	3,5	0,2	-	61,4	44,8	15,1	1,5
Barsko-Shargorod sub-district	347,9	0,4	278,5	64,5	2,2	-	1,8	0,1	0,1	167,9	132,2	32,2	3,5
Yampil district	84,4	-	0,2	0,5	10,2	66,1	1,3	-	1,3	35,4	29,1	5,5	0,8
Mohyliv-Podilsko-Bershadsky district	477,1	0,3	56,9	145,2	169,1	92,4	3,2	0,3	9,4	178,1	131,2	34,4	12,0
Mohyliv-Podilsko-Kryzhopil sub-district	332,5	0,2	53,9	134,5	109,3	23,9	1,8	0,3	8,0	132,6	100,3	24,7	7,0
Teplitsko-Bershadsky subdistrict	144,6	0,1	3,0	10,7	59,8	68,5	1,4	-	1,4	45,5	30,9	9,7	5,0
Total for the region, thousand ha%	1661,7	7,1	535,3	310,7	318,0	451,3	22,5	0,7	15,5	523,9	401,3	102,6	20,0
	100	-	32	19	19	27	2	-	1	32	24	5	2

zonal to zero tillage, was determined for the region. The presented results indicate that the majority of the soil cover is suitable for the introduction of minimized tillage systems, which opens up opportunities for use in the cultivation of the main agricultural crops. crops of modern tillage systems with elements of zero and bioconservative agriculture.

The Vinnytsia region, the most desirable differential approach regarding the alternation of soil cultivation systems, based on the soil and climatic conditions of the territory, resource provision of the enterprise.

Taking into account modern trends in the development of plant technologies, it is important to assess the suitability of the soil cover for the introduction of organic farming systems.

Determining agricultural land suitable for organic farming and the production of organic agricultural products is an urgent task in terms of its development. In addition, at present, the evaluation of the soil according to the indicator of its influence on the growth and productivity of plants is considered insufficient. For its characteristics, it is necessary to involve a wider set of indicators and criteria that are interconnected and interdependent.

High-quality (healthy) soil should, along with providing a productive component, preserve the quality of the environment and not threaten people's health. One of the goals of organic farming is to maintain and develop the quality of the soil and its fertility.

In order to identify agricultural land suitable for organic farming, it is necessary to evaluate it in a specialized laboratory. According to the results of the laboratory analysis, the physical, chemical and biological properties of the soil, contamination with heavy metals, radionuclides, pesticides, and nitrates are determined. Then these results are plotted on a map, which allows manufacturers to determine the technological features of the production process. To date, the zoning of the territory of Ukraine regarding its suitability for growing ecologically clean agricultural products was carried out by V.I. Kisil. Separate issues of structuring regions of Ukraine by types of organic production were carried out by T.O. Seagull. Thus, the regions of Ukraine are divided into unsuitable, limitedly suitable and suitable for organic production. In particular, 60% of Vinnytsia's soil cover is limitedly suitable for conducting organic farming systems [14; 54; 67; 79].

According to the estimates of N.A. According to Makarenko and others, the majority of the territory of Ukraine is fully suitable for organic farming in terms of the content of Co, Mn, Pb, Ni and conditionally suitable due to the low supply of Zn and Cu soils. The production of high-quality organic products balanced in terms of the content of microelements is possible with the use of auxiliary measures of crop nutrition Zn, Cu, locally Co, Mn [9; 17; 23; 44; 49; 84].

In terms of these indicators, the Vinnytsia region as a whole belongs to the regions suitable for organic farming in terms of the content of most microelements, and limited in terms of the content of heavy metals.

Areas of local soil contamination of Ukraine with heavy metals associated with large industrial centers and abnormally high natural content of mobile forms of these elements in soils were noted. This increases the risk of excessive accumulation of toxicants in plant products and significantly complicates organic production in these territories. Therefore, when certifying land for organic farming at the local level, special attention should be paid to the state of ecological and toxicological indicators of the soil. Thus, the soil cover of Vinnytsia has a whole complex of positive features and properties, which leads the region to a number of promising and efficient agro-industrial areas with a high level of natural conditions of fertility and opportunities for increasing agricultural production, provided the introduction of modern soil-conserving farming systems and the use of alternative its directions in terms of biological preservation, organic, biodynamic, etc. Taking this into account, at the level of Vinnytsia region, the development of a comprehensive and systematic program for the protection of soil fertility and ecologically balanced mechanism of the use of soil and land resources.

5. Practical value and conclusions

In Vinnytsia, the natural and climatic conditions are favorable for the development of agriculture and animal husbandry. The unique investment potential of the Vinnytsia region is the land fund. The region has the largest share of Ukrainian chernozems, a significant part of them, 21%, is chernozem type lands. This is a unique concentration of high-quality land resources. By according to statistical data, more than 2 million hectares of agricultural land, which is 3.3% of the area of Ukraine, have been secured by land users.

Vinnytsia has opportunities for multifaceted aspects of management agro-industrial complex. One of the main natural resources is soil, most of which is used for agricultural production, in some cases more than 80%. Highly fertile soils, in particular chernozems, as well as less fertile ones, such as gray forest soils, are concentrated in Vinnytsia Region.

Currently, high efficiency has been scientifically and practically proven ecological aspects of organizational and technological measures in crop production, which include: the use of siderates, the inclusion of perennial leguminous crops in crop rotation, the use of organic fertilizers and their methods of application, mulching, no-till soil cultivation, increasing the efficiency of insect pollination, etc.

References:

1. Anderson, T.H., Joergensen, R.G. Relationship between SIR and FE estimates of microbial biomass C in deciduous forest soils at different pH. *Soil Biol. Biochem.* 1997, 29, 1033–1042.
2. Arao, T., Kawasaki, A., Baba, K., Matsumoto, S. Effects of arsenic compound amendment on arsenic speciation in rice grain. Environ. Sci. Technol. 2011, 45, 1291–1297.
3. Arao, T., Kawasaki, A., Baba, K., Mori, S., Matsumoto, S. Effects of water management on cadmium and arsenic accumulation and dimethylarsinic acid concentrations in Japanese rice. Environ. Sci. Technol. 2009, 43, 9361–9367.
4. 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, no. 30 (3), pp. 449–459.
5. Balogh-Brunstad, Z., Keller, C.K., Bormann, B.T., O'Brien, R., Wang, D., Hawley, G. Chemical weathering and chemical denudation dynamics through ecosystem development and disturbance. *Glob. Biogeochem. Cycles,* 2008, 22.
6. Balogh-Brunstad, Z., Keller, C.K., Gill, R.A., Bormann, B.T., Li, C.Y. The effect of bacteria and fungi on chemical weathering and chemical denudation fluxes in pine growth experiments. *Biogeochemistry.* 2008, 88, 153–167.
7. Bastian, F., Bouziri, L., Nicolardot, B., Ranjard, L. Impact of wheat straw decomposition on successional patterns of soil microbial community structure. *Soil Biol. Biochem.,* 2009, 41, 262–275.
8. Benner, R. Biosequestration of carbon by heterotrophic microorganisms. *Nat. Rev. Microbiol.,* 2011, 9.
9. Bormann, B.T., Wang, D., Bormann, F.H., Benoit, G., April, R., Snyder, M.C. Rapid, plant-induced weathering in an aggrading experimental ecosystem. *Biogeochemistry* 1998, 43, 129–155.
10. Caporaso, J.G., Kuczynski, J., Stombaugh, J., Bittinger, K., Bushman, F.D., Costello, E.K., Fierer, N., Pena, A.G., Goodrich, J.K., Gordon, J.I., et al. QIIME allows analysis of high-throughput community sequencing data. *Nat. Methods,*

2010, 7, 335–336.

11. Caporaso, J.G., Lauber, C.L., Walters, W.A., Berg-Lyons, D., Huntley, J., Fierer, N., Owens, S.M., Betley, J., Fraser, L., Bauer, M. Ultra-high-throughput microbial community analysis on the Illumina HiSeq and MiSeq platforms. *ISME J.,* 2012, 6, 1621–1624.

12. Castellano, M.J., Mueller, K.E., Olk, D.C., Sawyer, J.E., Six, J. Integrating plant litter quality, soil organic matter stabilization, and the carbon saturation concept. *Glob. Chang. Biol.,* 2015, 21, 3200–3209.

13. Cotrufo, M.F., Wallenstein, M.D., Boot, C.M., Denef, K., Paul, E. The Microbial Efficiency-Matrix Stabilization (MEMS) framework integrates plant litter decomposition with soil organic matter stabilization: Do labile plant inputs form stable soil organic matter? *Glob. Chang. Biol.,* 2013, 19, 988–995.

14. De Souza, J.A.M., Alves, L.M.C., de Mello Varani, A., de Macedo Lemos, E.G. The Family Bradyrhizobiaceae. In *The Prokaryotes*; Springer: Berlin/Heidelberg, Germany, 2014, pp. 135–154.

15. 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. 2020. *Ukrainian Journal of Ecology*, no. 10(5), pp. 54–61.

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

17. Dong, D.T., Yamaguchi, N., Makino, T., Amachi, S. Effect of soil microorganisms on arsenite oxidation in paddy soils under oxic conditions. *Soil Sci. Plant Nutr*., 2014, 60, 377–383.

18. Edgar, R.C., Haas, B.J., Clemente, J.C., Quince, C., Knight, R. UCHIME improves sensitivity and speed of chimera detection. *Bioinformatics,* 2011, 27, 2194–2200.

19. Eskelinen, A., Stark, S., Mannisto, M. Links between plant community composition, soil organic matter quality and microbial communities in contrasting tundra habitats. *Oecologia,* 2009, 161, 113–123.

20. Frommer, J., Voegelin, A., Dittmar, J., Marcus, M.A., Kretzschmar, R. Biogeochemical processes and arsenic enrichment around rice roots in paddy soil: Results from micro-focused X-ray spectroscopy. *Eur. J. Soil Sci*., 2011, 62, 305–317.

21. Garnier, J.M., Travassac, F., Lenoble, V., Rose, J., Zheng, Y., Hossain, M.S., Chowdhury, S.H., Biswas, A.K., Ahmed, K.M., Cheng, Z. Temporal variations in arsenic uptake by rice plants in Bangladesh: The role of iron plaque in paddy fields irrigated with groundwater. *Sci. Total Environ*., 2010, 408, 4185–4193.

22. Gliesche, E.A. Genus Hyphomicrobium Stutzer and Hartleb 1898, 76AL. In *Bergey's Manual of Systematic Bacteriology*; Williams and Wilkins: Baltimore, MD, USA, 2005, pp. 476–494.

23. Hashimoto, Y., Furuya, M., Yamaguchi, N., Makino, T. Zerovalent iron with high sulfur content enhances the formation of cadmium sulfide in reduced paddy soils. Soil Sci. Soc. Am. J., 2016, 80, 55–63.

24. 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, no. 52, pp. 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

25. Houghton, R.A. Balancing the global carbon budget. *Annu Rev. Earth Planet. Sci.,* 2007, 35, 313–347.

26. Jia, Y., Bao, P., Zhu, Y.G. Arsenic bioavailability to rice plant in paddy soil: Influence of microbial sulfate reduction. *J. Soils Sediments*, 2015, 15, 1960–1967.

27. Jiao, N., Herndl, G.J., Hansell, D.A., Benner, R., Kattner, G., Wilhelm, S.W., Kirchman, D.L., Weinbauer, M.G., Luo, T.W., Chen, F., et al. Microbial production of recalcitrant dissolved organic matter: Long-term carbon storage in the global ocean. *Nat. Rev. Microbiol.,* 2010, 8, 593–599.

28. Keiluweit, M., Bougoure, J.J., Nico, P.S., Pett-Ridge, J., Weber, P.K., Kleber, M. Mineral protection of soil carbon counteracted by root exudates. *Nat. Clim. Chang.,* 2015, 5, 588–595.

29. Khan, N., Seshadri, B., Bolan, N., Saint, C.P., Kirkham, M.B., Chowdhury, S., Yamaguchi, N., Lee, D.Y., Li, G., Kunhikrishnan, A., et al. Root iron plaque on wetland plants as a dynamic pool of nutrients and contaminants. In Advances in Agronomy; Sparks, D.L., Ed.; Elsevier: Amsterdam, The Netherlands, 2016, vol. 138, pp. 1–96.

30. Kim, S., Kramer, R.W., Hatcher, P.G. Graphical method for analysis of ultrahigh-resolution broadband mass spectra of natural organic matter, the van Krevelen diagram. *Anal. Chem.,* 2003, 75, 5336–5344.

31. Kindler, R., Miltner, A., Richnow, H.H., Kastner, M. Fate of gram-negative bacterial biomass in soil-Mineralization and contribution to SOM. *Soil Biol. Biochem.,* 2006, 38, 2860–2870.

32. Kindler, R., Miltner, A., Thullner, M., Richnow, H.H., Kastner, M. Fate of bacterial biomass derived fatty acids in soil and their contribution to soil organic matter. *Org. Geochem.,* 2009, 40, 29–37.

33. Kleber, M., Johnson, M.G. Advances in Understanding the Molecular Structure of Soil Organic Matter: Implications for Interactions in the Environment. *Adv. Agron.,* 2010, 106, 77–142.

34. Marschner, B., Brodowski, S., Dreves, A., Gleixner, G., Gude, A., Grootes, P.M., Hamer, U., Heim, A., Jandl, G., Ji, R., et al. How relevant is recalcitrance for the stabilization of organic matter in soils? *J. Plant Nutr. Soil Sci.,* 2008, 171, 91–110.

35. Kleber, M., Mikutta, R., Torn, M.S., Jahn, R. Poorly crystalline mineral phases protect organic matter in acid subsoil horizons. *Eur. J. Soil Sci.,* 2005, 56, 717–725.

36. Köchy, M., Hiederer, R., Freibauer, A. Global distribution of soil organic carbon – Part 1: Masses and frequency distributions of SOC stocks for the tropics, permafrost regions, wetlands, and the world. *SOIL,* 2015, 1, 351–365.

37. Koide, R.T., Kabir, Z. Nutrient economy of red pine is affected by interactions between *Pisolithus tinctorius* and other forest-floor microbes. *New Phytol.,* 2001, 150, 179–188.

38. Kujawinski, E.B., Behn, M.D. Automated analysis of electrospray

ionization Fourier transform ion cyclotron resonance mass spectra of natural organic matter. *Anal. Chem.,* 2006, 78, 4363–4373.

39. Kujawinski, E.B., Longnecker, K., Blough, N.V., Del Vecchio, R., Finlay, L., Kitner, J.B., Giovannoni, S.J. Identification of possible source markers in marine dissolved organic matter using ultrahigh resolution mass spectrometry. *Geochim. Cosmochim. Acta,* 2009, 73, 4384.

40. Kuzyakov, Y., Blagodatskaya, E. Microbial hotspots and hot moments in soil: Concept & review. *Soil Biol. Biochem.,* 2015, 83, 184–199.

41. Kuzyakov, Y., Domanski, G. Carbon input by plants into the soil. Review. *J. Plant Nutr Soil Sci.,* 2000, 163, 421–431.

42. Lawrence, C.R., Neff, J.C., Schimel, J.P. Does adding microbial mechanisms of decomposition improve soil organic matter models? A comparison of four models using data from a pulsed rewetting experiment. *Soil Biol. Biochem.,* 2009, 41, 1923–1934.

43. Lehmann, J., Kleber, M. The contentious nature of soil organic matter. *Nature,* 2015, 528, 60–68.

44. Liang, C., Balser, T.C. Microbial production of recalcitrant organic matter in global soils: Implications for productivity and climate policy. *Nat. Rev. Microbiol.,* 2011, 9.

45. Lorenz, K., Lal, R., Preston, C.M., Nierop, K.G.J. Strengthening the soil organic carbon pool by increasing contributions from recalcitrant aliphatic bio(macro)molecules. *Geoderma,* 2007, 142, 1–10.

46. Madhaiyan, M., Poonguzhali, S., Kang, B.G., Lee, Y.J., Chung, J.B., Sa, T.M. Effect of co-inoculation of methylotrophic Methylobacterium oryzae with Azospirillum brasilense and Burkholderia pyrrocinia on the growth and nutrient uptake of tomato, red pepper and rice. *Plant Soil,* 2010, 328, 71–82.

47. Madsen, I.C., Scarlett, N.V.Y. Quantitative Phase Analysis. In *Powder Diffraction: Theory and Practice*; Dinnabier, R.E., Ed.; Royal Society of Chemistry: London, UK, 2008.

48. Marschner, H. *Marschner's Mineral Nutrition of Higher Plants*, 3rd ed.; Academic Press: Cambridge, MA, USA, 2012.

49. 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. *Ukrainian Journal of Ecology*, 2020, no. 10(1), pp. 101–105.

50. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons*, 2021, 24(7), 53–60. DOI: 10.48077/scihor.24(7).2021.53-60

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

52. 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, no. 8(4), 26–33.

53. 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, pp. 50–55. https://www.ujecology.com/archive.html

54. 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, vol. 8, pp. 148–153.

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

56. 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.

57. 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

58. 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

59. 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.,* 2020, 18(1), 177–182.

60. Mazur V.A., Zabarna T.A. Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry*, 2018, issue 2(9), pp. 5–17.

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

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

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

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

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

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

67. 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, 8(4), 148–153.

68. Mazur, V.A., Pantsyreva, H.V., Mazur, K.V. Didur, I.M. Influence of the

assimilation apparatus and productivity of white lupine plants. *Agronomy research,* 2019, 17(1), 206–219.

69. McDonald, D., Price, M.N., Goodrich, J., Nawrocki, E.P., DeSantis, T.Z., Probst, A., Andersen, G.L., Knight, R., Hugenholtz, P. An improved Greengenes taxonomy with explicit ranks for ecological and evolutionary analyses of bacteria and archaea. *ISME J.,* 2012, 6, 610–618.

70. Mendes, R., Garbeva, P., Raaijmakers, J.M. The rhizosphere microbiome: Significance of plant beneficial, plant pathogenic, and human pathogenic microorganisms. *Fems Microbiol. Rev.,* 2013, 37, 634–663.

71. Mikutta, R., Kleber, M., Torn, M.S., Jahn, R. Stabilization of soil organic matter: Association with minerals or chemical recalcitrance? *Biogeochemistry,* 2006, 77, 25–56.

72. Moreno-Jimenez, E., Meharg, A.A., Smolders, E., Manzano, R., Becerra, D., Sanchez-Llerena, J., Albarran, A., Lopez-Pinero, A. Sprinkler irrigation of rice fields reduces grain arsenic but enhances cadmium. Sci. Total Environ., 2014, 485, 468–473.

73. Nakamura, K., Katou, H. Arsenic and cadmium solubilization and immobilization in paddy soils in response to alternate submergence and drainage. In Competitive Sorption and Transport of Heavy Metals in Soils and Geological Media; Selim, H.M., Ed.; CRC Press: Boca Raton, FL, USA, 2012; pp. 379–404.

74. Neiko, I.S. Forest genetic component as the basis of key territories of the ecological network of Eastern Podillia. *Bulletin of the Zhytomyr National Agroecological University*, 2009, issue 2 (25), pp. 170–174.

75. Nickson, R.T., McArthur, J.M., Ravenscroft, P., Burgess, W.G., Ahmed, K.M. Mechanism of arsenic release to groundwater, Bangladesh and west Bengal. Appl. Geochem., 2000, 15, 403–413.

76. Oburger, E., Schmidt, H. New Methods To Unravel Rhizosphere Processes. *Trends Plant Sci.,* 2016, 21, 243–255.

77. Okamura, K., Kanbe, T., Hiraishi, A. Rhodoplanes serenus sp nov, a purple non-sulfur bacterium isolated from pond water. *Int. J. Syst Evol. Microbiol.,* 2009, 59, 531–535.

78. Oren, E.A. The family Hyphomicrobiaceae. In *The Prokaryotes*; Springer: Berlin/Heidelberg, Germany, 2014; pp. 247–281.

79. Pantsyreva H., Stroyanovskiy V., Mazur K., Chynchyk O., Myalkovsky R. The influence of bio-organic growing technology on the productivity of legumins. *Ukrainian Journal of Ecology,* 2021, 11 (3), pp. 35–39. DOI: 10.15421/2021_139

80. Pantsyreva, H.V. Doslidzhennia sortovykh resursiv liupynu biloho (Lupinus albus L.) v Ukraini. *Silske hospodarstvo i lisivnytstvo*, 2016, 4, 88–93.

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

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

83. Pancyreva G.V. Doslidzhennya sortovyx resursiv lyupynu bilogo

(LUPINUS ALBUS L.) v Ukrayini. *Zbirnyk naukovyx pracz*. VNAU, 2016, 4, 88 p.

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

85. Pett-Ridge, J., Firestone, M.K. Using stable isotopes to explore root-microbe-mineral interactions in soil. *Rhizosphere,* 2017, 3, 244–253.

86. Phillips, L.A., Ward, V., Jones, M.D. Ectomycorrhizal fungi contribute to soil organic matter cycling in sub-boreal forests. *ISME J.,* 2014, 8, 699–713.

87. Potthoff, M., Dyckmans, J., Flessa, H., Beese, F., Joergensen, R.G. Decomposition of maize residues after manipulation of colonization and its contribution to the soil microbial biomass. *Biol. Fertil. Soils,* 2008, 44, 891–895.

88. Price, M.N., Dehal, P.S., Arkin, A.P. FastTree: Computing Large Minimum Evolution Trees with Profiles instead of a Distance Matrix. *Mol. Biol. Evol.,* 2009, 26, 1641–1650.

89. Rasse, D.P., Rumpel, C., Dignac, M.F. Is soil carbon mostly root carbon? Mechanisms for a specific stabilisation. *Plant Soil,* 2005, 269, 341–356.

90. Razanov S.F., Tkachuk O.P., Mazur V.A., Didur I.M. Effect of bean perennial plants growing on soil heavy metal concentrations. Ukrainian Journal of Ecology, 2018, 8 (2), pp. 294–300.

91. Rognes, T., Flouri, T., Nichols, B., Quince, C., Mahe, F. VSEARCH: A versatile open source tool for metagenomics. *PeerJ,* 2016, 4, e2584.

92. Schimel, J. Soil Carbon Microbes and Global Carbon. *Nat. Clim. Chang.,* 2013, 3, 867–868.

93. Schmidt, H., Eickhorst, T., Tippkötter, R. Monitoring of root growth and redox conditions in paddy soil rhizotrons by redox electrodes and image analysis. *Plant Soil,* 2010, 341, 221–232.

94. Schmidt, M.W.I., Torn, M.S., Abiven, S., Dittmar, T., Guggenberger, G., Janssens, I.A., Kleber, M., Kogel-Knabner, I., Lehmann, J., Manning, D.A.C., et al. Persistence of soil organic matter as an ecosystem property. *Nature,* 2011, 478, 49–56.

95. Shah, F., Nicolas, C., Bentzer, J., Ellstrom, M., Smits, M., Rineau, F., Canback, B., Floudas, D., Carleer, R., Lackner, G., et al. Ectomycorrhizal fungi decompose soil organic matter using oxidative mechanisms adapted from saprotrophic ancestors. *New Phytol.,* 2016, 209, 1705–1719.

96. Shi, Z.Q., Balogh-Brunstad, Z., Grant, M., Harsh, J., Gill, R., Thomashow, L., Dohnalkova, A., Stacks, D., Letourneau, M., Keller, C.K. Cation uptake and allocation by red pine seedlings under cation-nutrient stress in a column growth experiment. *Plant Soil,* 2014, 378, 83–98.

97. Simpson, A.J., Simpson, M.J., Smith, E., Kelleher, B.P. Microbially derived inputs to soil organic matter: Are current estimates too low? *Environ. Sci. Technol.,* 2007, 41, 8070–8076.

98. Six, J., Conant, R.T., Paul, E.A., Paustian, K. Stabilization mechanisms of soil organic matter: Implications for C-saturation of soils. *Plant Soil,* 2002, 241, 155–176.

99. Sy, A., Timmers, A.C.J., Knief, C., Vorholt, J.A. Methylotrophic metabolism is advantageous for Methylobacterium extorquens during colonization of Medicago truncatula under competitive conditions. *Appl. Environ. Microbiol.,*

2005, 71, 7245–7252.

100. Tfaily, M.M., Chu, R.K., Tolic, N., Roscioli, K.M., Anderton, C.R., Pasa-Tolic, L., Robinson, E.W., Hess, N.J. Advanced Solvent Based Methods for Molecular Characterization of Soil Organic Matter by High-Resolution Mass Spectrometry. *Anal. Chem.,* 2015, 87, 5206–5215.

101. Uebayasi, M., Tomizuka, N., Kamibayashi, A., Tonomura, K. Autotrophic Growth of a Hyphomicrobium Sp and Its Hydrogenase Activity. *Agric. Biol. Chem.,* 1981, 45, 1783–1790.

102. Vdovenko, S.A., Pantsyreva, G.V., Palamarchuk, I.I., Lytvyniuk, H.V. 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*, 2018, 8(3), 270–274.

103. Vdovenko, S.A., Prokopchuk, 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 J Ecol*, 2018, 8(4), 1–5.

104. Violante, A., Barberis, E., Pigna, M., Boero, V. Factors affecting the formation, nature, and properties of iron precipitation products at the soil-root interface. *J. Plant Nutr*., 2003, 26, 1889–1908.

105. von Lutzow, M., Kogel-Knabner, I., Ekschmitt, K., Matzner, E., Guggenberger, G., Marschner, B., Flessa, H. Stabilization of organic matter in temperate soils: Mechanisms and their relevance under different soil conditions – A review. *Eur. J. Soil Sci.,* 2006, 57, 426–445.

106. Wieder, W.R., Bonan, G.B., Allison, S.D. Global soil carbon projections are improved by modelling microbial processes. *Nat. Clim. Chang.,* 2013, 3, 909–912.

107. Wieder, W.R., Grandy, A.S., Kallenbach, C.M., Bonan, G.B. Integrating microbial physiology and physio-chemical principles in soils with the MIcrobial-MIneral Carbon Stabilization (MIMICS) model. *Biogeosciences,* 2014, 11, 3899–3917.

108. Xu, X.Y., McGrath, S.P., Meharg, A.A., Zhao, F.J. Growing rice aerobically markedly decreases arsenic accumulation. *Environ. Sci. Technol*., 2008, 42, 5574–5579.

109. Yamaguchi, N., Nakamura, T., Dong, D., Takahashi, Y., Amachi, S., Makino, T. Arsenic release from flooded paddy soils is influenced by speciation, Eh, pH, and iron dissolution. *Chemosphere*, 2011, 83, 925–932.

110. Yamaguchi, N., Ohkura, T., Takahashi, Y., Maejima, Y., Arao, T. Arsenic distribution and speciation near rice roots influenced by iron plaques and redox conditions of the soil matrix. *Environ. Sci. Technol*., 2014, 48, 1549–1556.

111. Yang, C.H., Crowley, D.E. Rhizosphere microbial community structure in relation to root location and plant iron nutritional status. *Appl. Environ. Microbiol.,* 2000, 66, 345–351.

112. Yu, H.Y., Wang, X.Q., Li, F.B., Li, B., Liu, C.P., Wang, Q., Lei, J. Arsenic mobility and bioavailability in paddy soil under iron compound amendments at different growth stages of rice. *Environ. Pollut*., 2017, 224, 136–147.

113. Zhu, L., Gao, K.T., Jin, J., Lin, H.Z., Xu, X.Y. Analysis of ZVI corrosion products and their functions in the combined ZVI and anaerobic sludge system. *Environ. Sci. Pollut. Res*., 2014, 21, 12747–12756.

AGRO-ECOLOGICAL AND TOXICO-ECOLOGICAL INDICATORS OF CORN AND SUNFLOWER AGRO-ECOSYSTEMS ON SLOPING LANDS

Victoria Verhelis[1]
Olga Mazur[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-2

Abstract. On weakly washed ashed black soil of heavy loams, the humus content decreases by 12.9%, compared to unwashed soils. Weakly washed ashed black soil had a content of easily hydrolyzed nitrogen by 13.3% less than unwashed ones. The content of mobile forms of phosphorus in poorly washed soils decreased by 51.1%. The content of mobile potassium on the unwashed heavy loam was 34.9% higher than on the slightly washed soil.

Result. Observation of medium-washed ashed heavy loam black soil showed that the humus content decreased by 8.8%, compared to lightly washed. The content of easily hydrolyzed nitrogen decreased by 14.3%. The content of mobile forms of phosphorus increased by 15.3%. The content of mobile forms of potassium increased by 42.9%. Hydrolytic acidity of slightly washed soil increased by 4.9%. The reaction of the soil solution is 1.8%. The amount of absorbed bases increased by 11.4%. Medium-washed heavy loamy black soil had 11.3% higher hydrolytic acidity than lightly washed black soil. The reaction of the soil solution was 1.7% lower. The amount of absorbed bases was the same. Changes in the indicators of the agrochemical composition of ashed heavy loam black soil on unwashed and slightly washed lands showed that weak soil washing leads to a decrease in the content of humus, easily hydrolyzed nitrogen, mobile forms of phosphorus and potassium, an increase in the value of hydrolytic acidity, the amount of absorbed bases, and optimization of the pH reaction of the soil solution. The largest decrease in the content of mobile forms of phosphorus was revealed – by 51.1%, and the smallest and almost identical decrease in the content of humus and easily hydrolyzed nitrogen – by 12.9-13.3%. Among the indicators

---

[1] Assistant, Vinnytsia National Agrarian University, Ukraine
[2] Assistant, Vinnytsia National Agrarian University, Ukraine

of acidity of the slightly washed black soil, the amount of absorbed bases increased by 11.4%, compared to the unwashed one, and the least – the reaction of the pH of the soil solution – by 1.8%.

From an agro-ecological point of view, weak soil leaching leads to the deterioration of such indicators of soil fertility as a decrease in the content of humus, easily hydrolyzed nitrogen, mobile forms of phosphorus and potassium, and an increase in the hydrolytic acidity of the soil. At the same time, the indicators of the reaction of the soil pH saline solution improve in the neutral direction, and the amount of absorbed bases increases.

A similar dependence is observed when comparing the agrochemical parameters of weakly and moderately washed ashed black soil heavy loam. In particular, a decrease in the content of humus, easily hydrolyzed nitrogen, a decrease in the reaction value of the soil solution pH, and an increase in hydrolytic acidity, which are negative factors, were revealed. The largest negative manifestation was observed in the decrease in the value of the hydrolytic acidity of the medium-washed soil – by 14.3%, and the smallest – in the value of the reaction of the soil solution pH – by 1.7%.

At the same time, the increase in the degree of soil erosion from weakly washed to moderately washed caused an increase in the content of mobile forms of phosphorus and especially potassium in medium-washed ashed black soil in heavy loam, the content of which increased by 42.9 %. A comparison of the changes in the agrochemical state of ashed black soil heavy loam lightly washed with medium washed showed that the humus content decreases more intensively in lightly washed soil, compared to medium washed, by 4.1%; the content of easily hydrolyzed nitrogen decreased more intensively in moderately washed soil, compared to lightly washed soil, by 1%. Hydrolytic acidity increased by 6.4% more intensively on moderately washed soil, compared to slightly washed soil.

Value/originality. In Ukraine, about a third of all arable land is exposed to water erosion. The reasons for the development of erosion processes are the plowing of sloping lands with a steepness of more than 3°, the cultivation of row crops on them, mainly corn and sunflower, and intensive tillage with overturning of the soil.When agricultural crops are grown on such lands, their productivity is significantly reduced, but the question of changes in the indicators of nutrition and ecological safety of the products obtained on power lands has not been investigated.

Research was carried out by establishing field experiments on sloping lands with the spread of weakly and moderately washed erosion processes and growing corn and sunflower on them. Laboratory studies were carried out in the certified Scientific and Measuring Agrochemical Laboratory of the Vinnytsia National Agrarian University. The change in the content of protein and nitrates in plant products was determined depending on the slope.

When corn and sunflower are grown on sloping lands, the highest content of protein and nitrates is observed in their products from the lower part of the slope. The lowest protein content in sunflower seeds was found in the middle part of the slope, which was 4.0% less than in the bottom part of the slope. The lowest corn grain protein content was observed in the upper part of the slope, which was 0.3% less than in the lower part of the slope. The lowest nitrate content in corn grain was found in the upper part of the slope, which was 21.0% less than in the lower part of the slope. The lowest nitrate content in sunflower seeds was found in the middle part of the slope and was 20.0% lower than at the bottom of the slope.

1. Introduction

The current crisis state of Ukraine's land resources, the decrease in soil fertility and the large-scale spread of degradation processes lead to the need for significant changes in economic activity and nature management. The development and implementation of measures to increase soil fertility on agricultural lands, their protection and reproduction primarily require information on the agrochemical state of soils [1; 34; 40–43].

The development of intensive farming technologies has caused many problems and changes in soil cover. In this regard, the issue of studying the dynamics of soil processes and their agrochemical indicators under the influence of economic activity is gaining special relevance [2; 33].

Land resources and favorable climatic conditions of Ukraine create adequate potential for highly efficient farming and other branches of agriculture, but an extensive approach to the use of the main means of agricultural production – soil – has led to its degradation on large areas. For many years, the expansion of the area of agricultural land and arable land was almost the only measure to increase production. In pursuit of additional centners of production, everything was plowed up: steep slopes, protective zones along reservoirs and pastures, roadsides [3; 35; 44].

In the 90s of the last century, the deterioration of the country's land was especially rapid due to the aggravation of crisis phenomena in the economy of Ukraine. Due to the lack of funds, the implementation of the system of agriculture with the contour-reclamation organization of the territory was stopped, the irrigated lands became abandoned, no reclamation measures were carried out on them; agriculture was conducted according to a sharply negative balance of organic matter, the main biogenic elements, which led to the loss of about 10% of its energy potential [4; 36].

A decrease in humus reserves and a decrease in the content of mobile forms of phosphorus and potassium in the soil became characteristic for all regions of Ukraine, since for many years the amount of fertilizers applied to the soil was much less than what was carried with cultivated plants [5; 37].

2. Analysis of recent research and publications

Erosion processes cause irreparable damage to the land cover of Ukraine. Thus, the annual loss of soil in the country reaches about 600 million tons, which is equivalent to the loss of almost 120,000 hectares of land with a humus horizon 50 cm thick. In the Forest Steppe, 23.4% of the territory was damaged by erosion (mostly Kharkiv, Vinnytsia, Khmelnytsky, Ternopil and Cherkasy region) [6; 50–53].

Erosion processes on sloping lands with light loamy black soil, in the absence of agrotechnical measures, are manifested already at a steepness of 1°. As a result of the comparison of the morphometric indicators of the relief and the materials of the soil survey, a direct relationship between the area of washed soils and the steepness of the slopes was established (the correlation coefficient is 0.90–0.95). This pattern is observed only on slopes occupied by agricultural land [7; 45–50].

The tendency to increase the area of eroded soils was found on slopes with a length of 500 to 800 m. As the length increases, the area of washed soils decreases, which is associated with the steepness and reduction of run off [7; 30–32].

Erosion processes lead to the transformation of the soil cover, changes in soil fertility indicators. Thus, the loss of 10 cm of the humus layer means that more than 1,000 tons of soil is moved from 1 ha, and up to 5,000 tons from a medium and strong degree of erosion [4; 27–29; 38].

According to Yablokova A.V., with modern application technologies, 97-99% of insecticides and fungicides and 80-95% of herbicides fall into the soil, water bodies, and air. The negative effect of mineral fertilizers is that when they are systematically applied to the soil, harmful stationary substances accumulate – heavy metals (arsenic, cadmium, chromium, cobalt, copper, lead, vanadium, zinc, etc.). With each ton of phosphorus applied to the fields, up to 160 kg of fluorine enters the soil, the high concentration of which changes the direction of biological processes in the soil [8].

The development of erosion processes on sloping lands leads to the formation of washed-out soils. The washed soil is characterized by the violation of the upper humus horizon, as a result of which its fertility decreases and agro-ecological characteristics deteriorate. According to the degree of washing, unwashed, slightly washed, medium and strongly washed soils are distinguished. The degree of soil washout is determined by comparing the profile of the reference (unwashed) soil with the washed-out profile. No more than half of the H humus horizon was washed away in weakly washed soils, more than half of the humus horizon was washed away in moderately washed soils, and the upper part of the transitional (illuvial) horizon was washed away in strongly washed out soils. In eroded soils, the entire profile is destroyed by erosion, and soil-forming rocks come to the surface [9; 20–24; 39–40].

Long-term use of intensive farming measures on sloping lands leads to powerful degradation processes, strong soil erosion and changes in their ecological and agrochemical characteristics. A similar trend is characteristic of the agricultural lands of the Tomashpil district in Vinnytsia region, the soils of which are located within the Volyn-Podilsky upland, are characterized by significant hilliness, complex undulating topography, and heavy mechanical composition.

Arable land in Ukraine occupies 57% of the country's area, which is more than in all other EU countries. A large part of these lands is located on slopes. One of the most dangerous factors of soil degradation on sloping lands is water erosion. Its intensity increases with a high level of land plowing, with the placement of row crops on slopes, tillage with the rotation of the plow, a decrease in the share of perennial grasses in the structure of sown areas, rectilinear placement of field borders, and a low level of afforestation of the agrolandscape. Water erosion of the soil is characterized by plane washing or surface erosion and linear or furrow water erosion [10; 25; 28].

The materials of scientific research testify that the degree of soil erosion increases with the increase in the steepness of the slopes. On slopes with a steepness of up to 1º, weakly eroded soils prevail, occupying approximately 16% of the entire slope area. As the steepness of the slopes increases, both the total area of washed away soils and the degree of their washing away increases sharply. On slopes of 1-3º, the area of eroded soils occupies more than 60% of the slope, but weakly eroded soils also prevail here [11].

Weakly eroded soils also prevail on slopes with a steepness of 3-5º, but here the share of moderately eroded soils is increasing, accounting for more than 20%. The washing away of soils on slopes of more than 5º, where medium and strongly eroded lands make up more than 60%, is especially sharply increased. Based on this, slopes that have a steepness of more than 5º must be taken out of cultivation and transferred to permanent afforestation and afforestation [12].

Differentiation of the relief of different agricultural regions of Ukraine determines the distribution of arable land according to the steepness of the slopes. In Ukraine, slopes with a steepness of up to 3° prevail. They make up 88.5% of the entire area of arable land in our country. Arable land on slopes with a steepness of more than 3° is the most dangerous for agricultural use. Their share is 11.5%, and in some regions of Ukraine – up to 20%, which indicates significant potential prerequisites for the development of degradation, in particular, erosion processes [13].

In Ukraine, the area of eroded and erosion-dangerous soils is about 17 million hectares. The most washed-out soils are in Luhansk, Vinnytsia, Dnipropetrovsk, and Odesa regions, where the share of washed-out soils is 53-66% of the total arable land area [14]. The total area of agricultural lands of Ukraine, which are constantly affected by water erosion, is 13.4 million hectares, of which 10.6 million hectares are arable land (32% of the total area of these lands). Eroded lands include 4.5 million hectares with moderately and severely eroded soils, including 68,000 hectares of those that have completely lost the humus horizon [15].

In the Vinnytsia region, 851,100 ha were damaged by water erosion, of which 743,800 ha were agricultural land or 30% of the total area of such land, including 628,000 ha of arable land (36%), which is a third of the total arable land [16].

The emergence and development of erosion processes in soils is associated with many reasons. One of them is the irrational use of soils, which is facilitated by the intensive plowing of sloping lands with a slope of more than 3º and the cultivation of row crops on them (especially sugar beets, corn, sunflower); lack of a comprehensive approach in carrying out anti-erosion measures; oversaturation of the structure of sown areas with row crops [17].

The highest percentage of eroded land is in the Bar, Kryzhopol, Tomashpil, Murovano-Kurilovets, Chechelnytsky, and Shargorod districts (60–67%), the lowest is in the Lypovetsky, Kalynovsky, and Vinnytsia districts (9–14%) of the Vinnytsia region [18].

Studies of the influence of the degree of soil erosion on the efficiency of their use show that depending on the increase in the specific gravity of the areas, which are subject to water erosion, the efficiency of land use is significantly reduced. Oversaturation of the structure of sown areas with row crops – mainly corn and sunflower, significant plowing of sloping lands and mass cultivation of row crops on them leads not only to a decrease in their productivity on such lands, but also to a deterioration in the nutritional value and ecological safety of the products obtained. If the issue of reducing the yield of agricultural crops when growing them on slopes with the manifestation of erosive processes has been sufficiently studied, then the change in indicators of the nutritional value and ecological quality of such products has not been studied enough, which determines the need for conducting research.

3. Conditions and methods of research

The research was carried out on the basis of the processing of Materials for monitoring and ecological and agrochemical certification of agricultural lands of the FG "August V.A." Markivka village of Tomashpil district, which were developed by the Vinnytsia branch of the State Institution "Institute of Soil Protection of Ukraine" [19]. The soil of the experimental site is black soil, gold-plated heavy loam with different degrees of washability: unwashed, slightly washed, medium washed.

The following ecological and agrochemical indicators of the soil were analyzed: humus – according to Tyurin [11]; hydrolytic and exchange (pH) acidity [12]; base saturation; the content of nutrients available to plants:

phosphorus and potassium – by the Chirikov method [13], nitrogen – by the Kornfield method [14].

Agrochemical survey of farm soils was conducted on a total area of 740.5 hectares. The selection of samples was carried out in accordance with the methodical instructions for large-scale agrochemical examination of soils in the system of the agrochemical service of Ukraine.

Field research was conducted during 2018-2021 on the lands of the FG "August V.A." Markivka village, Tomashpil district, Vinnytsia region. The soil of the experimental site is black soil, gold-plated, heavy loam with different degrees of washability: unwashed, slightly washed, and moderately washed, which also depended on the steepness of the slopes.

Two crops were grown: corn and sunflower, with sowing on the slope plots in such a way that the experimental plots covered the top, middle part and bottom of the slope. The content of protein, nitrates and moisture in corn and sunflower seeds was determined depending on the location of the experimental plot at the top, middle part and bottom of the slope. Experiments are repeated four times, placement of options is systematic multi-tiered. The sown area of the plot is 30 m^2, the accounting area is 25 m^2.

In the experimental plots, the average content of humus was 2.94%, the content of easily hydrolyzed nitrogen – 113 mg/kg, mobile forms of phosphorus – 137 mg/kg, mobile potassium – 152 mg/kg. The hydrolytic acidity was 2.34 mg-equiv./100 g. The reaction of the soil solution was 5.5 pH. The amount of absorbed bases was 25.6 mg-equiv./100 g.

Laboratory studies were conducted in the certified Scientific and Measuring Agrochemical Laboratory of the Department of Ecology and Environmental Protection of the Vinnytsia National Agrarian University. The content of protein in sunflower seeds and corn grains was determined by the Kjeldahl method [10], nitrates by the spectrometric method of molecular absorption [10], and moisture by the method of drying a weight of plant mass by the thermostatic weight method in accordance with DSTU 29144:2009 ISO 711-85 [10]. Grain and seed samples were taken in accordance with the requirements of DSTU 4117:2007 [11]. We carried out mathematical and statistical processes of the obtained research results with the determination of the average deviation, correlation coefficients, determination, construction of the equation and regression diagram.

Only mineral fertilizers were used when growing sunflowers. In particular, when sowing, N16P16K16 was applied in the form of a complex mineral fertilizer, nitroammophos. Nitrogen mineral fertilizers in the total amount of N70 were applied before sowing. Nitrogen mineral fertilizer ammonium nitrate was used. When growing corn, only mineral fertilizers were also used. In particular, during sowing, N16P16K16 was applied in the form of a complex mineral fertilizer, nitroammophos. Nitrogen mineral fertilizers in the total amount of N100 were applied before sowing. Nitrogen mineral fertilizer ammonium nitrate was used. Sowing of corn and sunflower, as well as soil cultivation, was carried out across the slope.

4. Changes in soil fertility indicators depending on the degree of soil erosion

The main indicators of soil fertility are the content of humus, easily hydrolyzable nitrogen, mobile forms of phosphorus and potassium, hydrolytic acidity, the pH reaction of the soil solution, and the amount of absorbed bases. Under the conditions of the development of soil erosion processes and varying degrees of their washing away, a change in soil fertility indicators is possible.

The humus content was 2.94% on the unwashed black soil of ashed heavy loam by mechanical composition. On weakly washed soils, the humus content decreases by 12.9% and amounts to 2.56%. The content of easily hydrolyzed nitrogen in unwashed soils was 113 mg/kg. The analysis of lightly washed ashed black soil established the content of easily hydrolyzed nitrogen at 98 mg/kg, which was 13.3% less than in unwashed soils. The content of mobile forms of phosphorus in unwashed soils was 137 mg/kg, and in weakly washed soils it decreased by 51.1% and amounted to 67 mg/kg. The content of mobile potassium on unwashed ashed black soil heavy loam was 152 mg/kg. This was 34.9% more than on lightly washed soil, where the content of mobile potassium was 99 mg/kg (Table 1).

Observation of a site of ashed heavy loam black soil with slightly and moderately washed-out degrees showed that the humus content on slightly washed-out soil was 2.94%, and on moderately washed-out soil it decreased by 8.8% and amounted to 2.68%. The content of lightly hydrolyzed nitrogen on slightly washed ashed black soil heavy loam amounted to 112 mg/kg, and on medium washed it decreased by 14.3% and was 96 mg/kg. The content

Table 1

Changes in soil fertility indicators depending on the degree of soil erosion

Type of soil	Mechanical componants	Degree of washing	Humus content, %	Content of easily hydrolyzed nitrogen, mg/kg	The content of mobile phosphorus, mg/kg	The content of mobile potassium, mg/kg
Ashed black soil	Heavy loam	unwashed	2,94	113	137	152
		Weak washed	2,56	98	67	99
Ashed black soil	Heavy loam	Weak washed	2,94	112	50	89
		Medium washed	2,68	96	59	156

of mobile forms of phosphorus on lightly washed soil was 50 mg/kg, and on moderately washed soil it increased by 15.3% and amounted to 59 mg/kg. The content of mobile forms of potassium on slightly washed ashed black soil heavy loam amounted to 89 mg/kg, and on medium washed soil it increased by 42.9% and amounted to 156 mg/kg.

5. Changes in soil acidity indicators depending on the degree of soil erosion

The degree of leaching of ashed heavy loamy black soil had a direct effect on soil acidity indicators – hydrolytic, the reaction of the soil pH solution, the amount of absorbed bases. In particular, the hydrolytic acidity of the unwashed soil was 2.34 mg-eq./100 g, and the slightly washed soil increased by 4.9% and amounted to 2.46 mg/100 g. The reaction of the soil solution on the unwashed soil was 5.5 pH, and on slightly washed – increased by 1.8% and amounted to 5.6 pH (Table 2).

The amount of absorbed bases in unwashed heavy loamy black soil was 25.6 mg-equiv./100 g, and in weakly washed black soil it increased by 11.4% and amounted to 28.9 mg-equiv./100 g.

Observations of the acidity indicators of another soil area, where the degree of washing was greater, revealed the hydrolytic acidity of

Table 2

Changes in soil acidity indicators depending on the degree of soil erosion

Type of soil	Mechanical components	Degree of washing	Hydrolytic acidity, mg-equiv./ 100 g	The reaction of the soil solution, saline pH	The amount of absorbed bases, mg-equiv./ 100 g
Ashed black soil	Heavy loam	unwashed	2,34	5,5	25,6
		Weak washed	2,46	5,6	28,9
Ashed black soil	Heavy loam	Weak washed	1,72	5,8	29,2
		Medium washed	1,94	5,7	29,2

slightly washed soil of 1.72 mg-eq./100 g. The medium-washed black soil, gold-plated heavy loam, had a hydrolytic acidity 11.3% higher – 1.94 mg-eq./100 g. The reaction of the soil solution of weakly washed soil was 5.8 pH, and that of moderately washed soil was 1.7% lower – 5.7 pH. The amount of absorbed bases of weakly and moderately washed soils was the same and amounted to 29.2 mg-eq./100 g.

The analysis of the changes in the agrochemical composition of ashed heavy loam black soil on unwashed and slightly washed lands showed that weak soil washing leads to a decrease in the content of humus and nitrogen of easily hydrolyzable, mobile forms of phosphorus and potassium, increasing the value of hydrolytic acidity, the amount of absorbed bases, and optimizing the reaction of the pH of the soil solution. In particular, the largest decrease in the content of mobile forms of phosphorus was found – by 51.1%, and the smallest and almost identical decrease in the content of humus and easily hydrolyzed nitrogen – by 12.9-13.3%.

Compared to the unwashed soil, the amount of absorbed bases increased the most among the indicators of the acidity of the slightly washed black soil, by 11.4%, and the reaction of the pH of the soil solution – by 1.8%. From an agro-ecological point of view, weak soil leaching leads to the deterioration of such indicators of soil fertility as a decrease in the content of humus, easily hydrolyzed nitrogen, mobile forms of phosphorus and potassium, and an increase in the hydrolytic acidity of the soil. At the same time, the indicators of the reaction of the soil pH saline solution improve in the neutral direction, and the amount of absorbed bases increases. A similar dependence is observed when comparing the agrochemical parameters of weakly and moderately washed ashed black soil heavy loam. In particular, a decrease in the content of humus, easily hydrolyzed nitrogen, a decrease in the reaction value of the soil solution pH, and an increase in hydrolytic acidity, which are negative factors, were revealed.

The greatest negative manifestation was observed in the reduction of the value hydrolytic acidity of medium-washed soil – by 14.3%, and the smallest – on the value of the reaction of the pH soil solution – by 1.7%. At the same time, the increase in the degree of soil washing from slightly washed to medium-washed caused an increase in the medium-washed black soil, ashed heavy loam content of mobile forms of phosphorus and especially potassium, the content of which increased by 42.9%. A comparison of the changes in the agrochemical state of ashed black soil heavy loam lightly washed with medium washed showed that the humus content decreases more intensively in lightly washed soil, compared to medium washed, by 4.1%; the content of easily hydrolyzed nitrogen decreased more intensively in moderately washed soil, compared to lightly washed soil, by 1%.

Hydrolytic acidity increased by 6.4% more intensively on moderately washed soil, compared to slightly washed soil.

6. The content of protein, nitrates and moisture in corn grain grown on sloping lands

The protein content of corn grain grown in the upper part of the slope was 5.8%. In the middle part of the slope, the protein content in grain decreased by 0.2% and amounted to 5.6%. In the lower part of the slope, the protein content, relative to its upper part, increased by 0.1% and amounted to 5.9%. The highest protein content in corn grain was established when it was grown in the lower part of the slope – 5.9%, and the lowest – 5.6%, in the middle part of the slope (Table 3).

The content of nitrates in corn grain grown in the upper part of the slope was 600 mg/kg. In the middle part of the slope, the nitrate content increased by 6.3% and amounted to 640 mg/kg. At the bottom of the slope, the nitrate content, relative to its upper part, increased by 21.1% and amounted to 760 mg/kg. Thus, it was found that the highest content of nitrates

Table 3

The content of protein, nitrates and moisture in corn grain grown on sloping lands, M±m

Placement of crops relative to the slope	Contents		
	protein, %	nitrates, mg/kg	moisture, %
Upper of the slope	5,8±0,1	600±11	12,9±0,1
Middle of the slope	5,6±0,1	640±10	13,7±0,2
Bottom of the slope	5,9±0,1	760±13	12,8±0,1

was established in the grain of corn grown at the bottom of the slope – 760 mg/kg, and the lowest – at the top of the slope – 600 mg/kg.

The moisture content of corn grain grown at the top of the slope was 12.9%. In the middle part of the slope, the grain moisture content increased by 0.8% and amounted to 13.7%. In the lower part of the slope, the moisture content, relative to the upper part of the slope, decreased by 0.1% and amounted to 12.8%. Thus, the highest moisture content in corn grain was established when it was grown in the middle part of the slope – 13.7%, and at the bottom and top of the slope, the moisture content in corn grain was the same – 12.8-12.9%.

7. Protein, nitrate and moisture content of sunflower seeds grown on sloping lands

Observation of the protein content in sunflower seeds grown in the upper part of the slope revealed its 21.3%. In the middle part of the slope, the protein content in sunflower seeds decreased by 4.6% and amounted to 16.7%. At the bottom of the slope, compared to its upper part, the protein content in sunflower seeds increased by 0.4% and amounted to 21.7%. Thus, it was established that the highest protein content was observed in sunflower seeds grown at the bottom of the slope – 21.7%, and the lowest – in the middle part of the slope – 16.7% (Table 4).

The nitrate content in sunflower seeds grown at the top of the slope was 1960 mg/kg. In the middle part of the slope, it decreased by 18.4% and amounted to 1600 mg/kg. In the lower part of the slope, relative to the upper one, the nitrate content in sunflower seeds increased by 2.0% and amounted to 2000 mg/kg. That is, the highest content of nitrates in sunflower seeds was found when it was grown at the bottom of the slope – 2000 mg/kg, and the lowest – in the middle part of the slope – 1600 mg/kg.

Table 4

Protein, nitrate and moisture content of sunflower seeds grown on sloping lands, M±m

Placement of crops relative to the slope	Contents		
	protein, %	nitrate, mg/kg	moisture, %
Upper of the slope	21,3±0,2	1960±14	14,1±0,3
Middle of the slope	16,7±0,1	1600±12	15,0±0,2
Bottom of the slope	21,7±0,2	2000±15	12,5±0,2

The moisture content of sunflower seeds grown in the upper part of the slope was 14.1%. In the middle part of the slope, it increased by 0.9% and amounted to 15.0%. In the lower part of the slope, the moisture content of sunflower seeds, compared to the upper part of the slope, decreased by 1.6% and amounted to 12.5%. Therefore, the highest moisture content in sunflower seeds was found when it was grown in the middle part of the slope – 15.0%, and the lowest – in the lower part of the slope – 12.5%.

Correlation-regression analysis of changes in the quality indicators of corn grain grown on different parts of the slope showed the presence of an average positive correlation between protein content and nitrates ($r = 0.577$), a strong negative correlation between protein content and grain moisture ($r = – 0.973$). This indicates that with a decrease in the moisture content of corn grown on sloping lands, its protein content increases, and also with an increase in the protein content of corn grown on sloping lands, its nitrate content increases. Based on the fact that protein is formed at the expense of nitrogenous substances during nitrogen mineral nutrition of crops, then, accordingly, when the content of protein in grain increases, the content of nitrates also increases in it.

A strong positive correlation was established between the content of protein and nitrates in sunflower seeds grown on different parts of the slope ($r = 0.999$), and a strong negative correlation was found between the content of protein and moisture in sunflower seeds grown on sloping lands ($r = – 0.819$), a strong negative correlation was also found between the content of nitrates and moisture in sunflower seeds grown on sloping lands ($r = – 0.829$). In addition to the revealed correlation-regression dependences on the example of corn grain, a strong dependence was also established for sunflower seeds between the increase in nitrate content and the decrease in moisture content in its seeds.

The coefficient of determination $R^2 = 0.8415$ shows that when the protein content in sunflower seeds changes by 1%, the nitrate content in it changes directly proportionally by 0.84%.

The coefficient of determination $R^2 = 0.3804$ shows that when the moisture content in sunflower seeds changes by 1%, the protein content in it changes inversely proportionally by 0.38%.

The coefficient of determination $R^2 = 0.2033$ shows that when the moisture content in sunflower seeds changes by 1%, the nitrate content in it changes inversely proportionally by 0.20%.

Justifying the change in the protein content of sunflower seeds and corn grains in different parts of the slope, it should be noted that the processes of soil washing are just beginning in the upper part of the slope, so there is still a certain supply of humus and nutrient minerals.

In the middle part of the slope, there is a strong washout of the soil both from the upper part of the slope and from its middle part. Therefore, the lowest protein content in sunflower seeds and corn grains was found here. In the lower part of the slope, there is deposition, accumulation and accumulation of humus and nutritious mineral parts of the soil that moved from the upper and middle part of the slope. Because of this, the highest protein content was found in sunflower seeds and corn grains in the lower part of the slope.

A similar dependence is observed in the change of nitrate content in sunflower seeds and corn grain, in particular, the highest nitrate content was found in sunflower seeds and corn grain grown in the lower part of the slope. The lowest content of nitrates in sunflower seeds was found in the middle part of the slope, and in corn grains – in the upper part of the slope.

8. Nitrate content in corn grains and sunflower seeds relative to the maximum permissible concentration

Nitrates in seeds and grains of agricultural crops are an ecological factor of product safety. Their content in seeds and grains is regulated by the maximum permissible concentration (MPC), which for the studied crops is 500 mg/kg (Table 5).

An excess of nitrate content relative to MPC was found in corn grain by 1.2-1.5 times in all studied points, and in sunflower seeds by 3.2-4.0 times.

Table 5

Nitrate content in corn grains and sunflower seeds relative to the maximum permissible concentration

Placement of crops relative to the slope	MPC of nitrates for corn grain and sunflower seeds, mg/kg	Nitrate content in corn grain, mg/kg	Exceeding the content of nitrates in corn grain relative to MPC, times	Nitrate content in sunflower seeds, mg/kg	Exceeding the content of nitrates in sunflower seeds relative to MPC, times
Upper of the slope	500	600±11	1,2	1960±14	3,9
Middle of the slope	500	640±10	1,3	1600±12	3,2
Bottom of the slope	500	760±13	1,5	2000±15	4,0

The lowest nitrate content was observed in corn grain grown in the upper part of the slope and in sunflower seeds grown in the middle part of the slope. A significant excess of the permissible limits of nitrates in sunflower seeds, compared to corn grain, is caused by a shorter growing season of sunflower and a much lower level of yield of its seeds.

9. Conclusions

The development of erosion, which leads to the formation of washed ashed black soil heavy loam, leads to a decrease in the content of humus, easily hydrolyzed nitrogen, mobile forms of phosphorus and potassium, and an increase in hydrolytic acidity. The further development of erosion, which leads to the formation of moderately washed soils, leads to acidification of the reaction of the soil solution.

When corn and sunflower are grown on sloping lands, the highest content of protein and nitrates is observed in their products from the lower part of the slope. The lowest protein content in sunflower seeds was found in the middle part of the slope, which was 4.0% less than in the bottom part of the slope. The lowest corn grain protein content was observed in the upper part of the slope, which was 0.3% less than in the lower part of the slope. The lowest nitrate content in corn grain was found in the upper part of the slope, which was 21.0% less than in the lower part of the slope. The lowest nitrate content in sunflower seeds was found in the middle part of the slope and was 20.0% lower than at the bottom of the slope.

References:

1. Chir N. Ecological and agrochemical condition of the soils of the Vizhyvka river basin in modern farming conditions. *Ecology and environmental protection. Current issues of humanitarian sciences*. 2014. Issue 8. P. 413–419.

2. Tkachuk O.P., Zaitseva T.M. Indicators of agroecological stability of soils and factors affecting them. *Agriculture and forestry*. 2017. No. 5. P. 137–145.

3. Balyuk S.A., Medvedev V.V., Tarariko O.H. National report on the state of soil fertility in Ukraine. Kyiv: "VYK PRINT" LLC, 2010. 111 p.

4. Ivancha A., Rybarak A., Malyuk T.V. Patterns of changes in indicators of the humus state of soils in horticulture in the south of Ukraine. *Innovative agricultural technologies*: materials VI All-Ukrainian. science and practice Inter.-conf. Melitopol: TDATU, 2019. Issue VI. P. 9–12.

5. Tkachuk O.P., Zaitseva T.M., Dubovy Yu.V. The influence of agricultural toxicants on the agroecological state of the soil. *Agriculture and forestry*. 2017. No. 6. Volume 2. P. 102–109.

6. Bakka M.T., Strelchenko V.P. Fundamentals of agricultural management and land protection. Zhytomyr. 2000. 366 p.

7. Voloshchuk M.D. Erosional degradation of black soil of the southwestern part of Ukraine and the Republic of Moldova. *Bulletin of the Dnipropetrovsk State Agrarian and Economic University. The series "Agricultural ecology. Agronomic sciences"*. 2016. No. 4 (42). P. 41–51.

8. Yablokov A.V. About the underestimation of the negative consequences of pesticide application and the importance of developing other ways of agricultural development. Pushchino, 1988. 100 p.

9. Hrabak N.H., Topiha I.N., Davydenko V.M., Shevel I.V. Basics of agriculture and land protection. 2006. 496 p.

10. Materials for monitoring and ecological and agrochemical certification of agricultural lands of FG "August V.A." with. Markivka of Tomashpil district of Vinnytsia region. Vinnytsia branch of the state institution "Institute of Soil Protection of Ukraine". Agronomichne. 2017. 50 p.

11. DSTU 7828:2015 Soil quality. Determining the group and fractional composition of humus according to Tyurin's method as modified by Ponomaryova and Plotnikova. [Effective from 2016-07-01]. Kyiv, 2015. 14 p. (Information and documentation).

12. DSTU ISO 10390-2007. Soil quality. Determination of pH. [Effective from 2009-10-01]. Kyiv, 2012. 13 p.

13. DSTU 4115-2002 Soils. Determination of mobile compounds of phosphorus and potassium according to the modified Chirikov method. [Effective from 2003-01-01]. Kyiv, 2002. 10 p.

14. DSTU 7863:2015 Soil quality. Determination of easily hydrolyzable nitrogen by the Kornfield method. [Effective from 2016-07-01]. Kyiv, 2015. 9 p.

Grekov V.O., Panasenko V.M. The state of soil fertility of Ukraine according to the data of the VIII round of agrochemical certification of agricultural lands. Kyiv: Ministry of Agricultural Policy, Center State Fertility, 2009. 48 p.

15. M.V. Prysiazhniuk, S.I. Melnyk, V.A. Zhilkin. National report on the state of soil fertility in Ukraine. Kyiv: Ministry of Agrarian Policy, State Fertility Center, National Academy of Sciences, NSC "IGA named after O.N. Sokolovsky", NUBiP, 2010. 113 p.

16. Lupenko Yu.O. Strategic directions of agricultural development of Ukraine for the period until 2020. Kyiv: NNC "IAE", 2012. 182 p.

17. Razanov S.F., Tkachuk O.P. Intensive chemicalization of agriculture is a prerequisite for the contamination of grain products with heavy metals. Technology of production and processing of animal husbandry products. Bila Tserkva, 2017. No. 1(134). P. 66–71.

18. Tkachuk O.P., Zaitseva T.M. Indicators of agroecological stability of soils and factors affecting them. Agriculture and forestry. *Collection of scientific works of the Vinnytsia National Agrarian University*. 2017. No. 5. P. 137–145.

19. Golubchenko V.F., Yamkova N.A. Assessment of soil fertility by ecological and agrochemical indicators. *Agroecological journal*. 2010. No. 4. P. 53–56.

20. Verhelis V.I. Changes in ecological and agrochemical indicators of the soil depending on its degree of washing away. *Agriculture and forestry*. 2021. No. 3 (22). P. 209–220.

21. Tkachuk O., Verhelis V. Intensity of soil pollution by toxic substances depending on the degree of its washout. *Scientific Horizons*. 2021. Vol. 24. No. 3. P. 52–57.

22. Bilyavskyi G.O., Verestun N.O. Agroecological monitoring is the basis for ensuring the balanced development of the agricultural sector of Vinnytsia. *Collection of scientific works of the Vinnytsia National Agrarian University*. 2011. No. 8(48). P. 93–99.

23. Fodder: evaluation, use, livestock products, ecology / M.F. Kulyk et al. Vinnytsia: PP "Thesis Publishing House", 2003. 334 p.

24. DSTU 4117:2007 Grain and its processing products. Determination of quality indicators by infrared spectroscopy. [Effective from 2007.08.01]. Kyiv.

25. Tkachuk O., Verhelis V. Intensity of soil pollution by toxic substances depending on the degree of its washout. *Scientific Horizons*. 2021. Vol. 24. No. 3. P. 52–57.

26. Tkachuk O.P. Prerequisites for the transition of agriculture in Ukraine to ecologically balanced principles. *Environmental sciences*. 2022. No. 5 (44). P. 144–149.

27. Tkachuk O.P., Vradiy O.I. The balance of nutrients in the soil during the cultivation of leguminous crops. *Environmental sciences*. 2022. No. 2 (41). P. 43–47.

28. Tkachuk O. Biological features of the distribution of root systems of perennial legume grasses in the context of climate change. *Scientific Horizons*. 2021. Vol. 24. No. 2. P. 70–76.

29. V.A. Mazur, H.V. Pantsyreva, K.V. Mazur and I.M. Didur. Influence of the assimilation apparatus and productivity of white lupine plants. *Agronomy Research.* 2019. No. 17. P. 206–219.

30. V.A. Mazur, K.V. Mazur, H.V. Pantsyreva. 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. Volume 9. P. 50–55.

31. Vdovenko S.A., Palamarchuk I.I., Pantsyreva H.V. and ets. Energy efficient growing of red beet in the conditions of central forest steppe of Ukraine. *Ukrainian Journal of Ecology*. 2018. Volume 8. P. 34–40.

Vdovenko S.A., Pantsyreva H.V., Palamarchuk I.I., Lytvynuk H.V. Symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biological products in agrocoenosis of the RightBank Forest-steppe of Ukraine. *Ukrainian Journal of Ecology*. 2018. No. 8 (3). P. 270–274.

Vdovenko S.A., Procopchuk 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. No. 8 (4). P. 1–5.

32. Victor Mazur, Oleksandr Tkachuk, Hanna Pantsyreva, Ihor Kupchuk, Myroslava Mordvaniuk, Oleksandr Chynchyk. Ecological suitability peas (Pisum sativum) varieties to climate change in Ukraine. Agraarteadus. *Journal of Agricultural Science*. 2021. No. 2. Vol. XXXII. P. 276–283.

33. Viktor Mazur, Ihor Didur, Oleksandr Tkachuk, Hanna Pantsyreva, Vitaliy Ovcharuk. Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. *Scientific Horizons*. 2021. Vol. 24. No. 1. P. 54–60.

34. Olexander Tkachuk, Myroslava Mordvaniuk. Research of technological indicators of grain quality of legumes as objects of storage and processing. Development of scientific, technological and innovation space in Ukraine and EU countries. Riga, Latvia: "Baltija Publishing", 2021. P. 221–240.

35. Pantsyreva H., Stroyanovskiy V., Mazur K., Chynchyk O., Myalkovsky R. The influence of bio-organic growing technology on the productivity of legumins. *Ukrainian Journal of Ecology*. 2021. No. 11 (3). P. 35–39. DOI: https://doi.org/10.15421/2021_139

36. Pantsyreva, H.V. Morphological and ecological-biological evaluation of the decorative species of the genus Lupinus L. *Ukrainian Journal of Ecology*. 2019. № 9(3). P. 74–77. 21997 DOI: https://doi.org/10.15421/2019_711

37. 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.

38. Puyu V., Bakhmat M., Pantsyreva H., Khmelianchyshyn Y., Stepanchenko V., Bakhmat O. Social-and-Ecological Aspects of Forage Production Reform in Ukraine in the Early 21st Century. *European Journal of Sustainable Development*. 2021. Vol. 10(1). P. 221–228.

39. 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. *Ukrainian Journal of Ecology*. 2020. No. 10 (1). P. 101–105. DOI: https://doi.org/10.15421/2020_16

40. Mazur V., Pantsyreva H., Mazur K., Myalkovsky R., Alekseev O. Agroecological prospects of using corn hybrids for biogas production. *Agronomy Research*. 2020. Volume 18. P. 205–219.

41. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. Quality of pea seeds and agroecological condition of soil when using structured water. Scientific Horizons. 2021. Vol. 24(7). P. 53–60.

42. Mazur V.A., Didur I.M., Pantsyreva H.V., Telecalo N.V. Energy-economic efficiency of growth of grain-crop cultures in the conditions of right-bank Forest-Steppe zone of Ukraine. *Ukrainian Journal of Ecology*. 2018. Volume 8. No. 4. P. 26–33.

43. Mazur V.A., Mazur K.V., Pantsyreva G.V. Production and export of grain and leguminous crops under martial law. *Agriculture and forestry*. 2022. Issue 3 (26). P. 66–76. DOI: https://doi.org/10.37128/2707-5826-2022-3-5

44. 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.

Mazur V.A., Myalkovsky R.O., Pantsyreva H.V., Didur I.M., Mazur K.V., Alekseev O.O. Photosynthetic productivity of potato plants depending on the location of rows placement in agrophytocenosis. *Ecology, Environment and Conservation*. 2020. Vol. 26. No. 2. P. 536–545.

45. 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. DOI: https://doi.org/10.15421/2019_807

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

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. *Ukrainian Journal of Ecology*. 2020. 10(1), 101–105.

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

48. Mazur, V.A., Pantsyreva, H.V., Mazur, K.V., & Monarkh, V.V. Ecological and biological evaluation of varietal resources Paeonia L. in Ukraine. *Acta Biologica Sibirica.* 2019. No. 5 (1). P. 141–146. DOI: https://doi.org/10.14258/abs.v5.i1.5350

STUDY OF THE SOILS OF THE VINNYTSIA REGION IN SECTION OF THE MAIN FACTORS OF THEIR GENESIS

Ihor Didur[1]
Lina Bronnicova[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-3

Abstract. Vinnytsia is a powerful and promising region from the point of view of assessing its land-resource potential: in terms of the specific weight of land resources in its total natural-resource potential (79.11%), Vinnytsia ranks first among other regions for the average level of this indicator in Ukraine – 44 .38%. On the other hand, the population of the planet is growing every year and people have problems with food and housing. Therefore, we face the problem of increasing soil fertility as the main means of agricultural production. In this regard, there is a need for careful and rational use of soils. Every farmer must improve his knowledge of soil properties and must be able to regulate soil processes. After all, in different geographical conditions, different soils are formed, different plants are cultivated and they react differently to negative phenomena. *The purpose.* Study of the soils of the Vinnytsia region in terms of the main factors of their origin. *Methodology* of the study statistical probability. Measures to prevent and eliminate them require special studies, sometimes very subtle and complex, and necessarily with the necessary statistical probability. That is why insufficient knowledge of the natural conditions and characteristics of the soil cover is one of the reasons for the decrease in fertility and loss of crops. *Result*. Thus, today the main task is the rational use of land and resource potential in agricultural production, which requires proper scientific support. It is the comprehensive analysis of the soil cover of Vinnytsia from the point of view of the assessment of soil formation factors, regime characteristics in terms of the main types of soils and, on the basis of which, the analysis of the key directions of increasing the overall efficiency of land use in the region is the goal of this monograph. *Practical*

---

[1] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine

[2] Senior Lecturer, Vinnytsia National Agrarian University, Ukraine

implications. Its content will also help the future specialist to successfully master the features of the soil and land potential of the Vinnytsia region, will allow him to effectively take into account the agro-technological features of its use and improvement in his professional activity. *Value/originality.* The content of the monograph is aimed at practical and theoretical assistance in the study of the substantive part "Genesis, properties and distribution of the main types of soils of the Vinnytsia region" in the section of the curriculum in the discipline "Soil science", and will also be a significant help to the agrarians of the region in forming a clear vision of the properties of the soil cover of the region and rational ecologically oriented directions of its use.

1. Introduction

Land is the most important component of natural resources, the basis of plant and animal life, a reservoir of natural wealth, the operational basis of industry, settlements and roads, the main means of production in agriculture. And that is why rational land use is a mandatory component of a complex system of exploitation and protection of natural resources. For agricultural production, the most important part of the earth is called soil – a special natural formation, which is characterized by the features of living and non-living nature, formed as a result of the long-term transformation of the surface layers of the lithosphere under the joint and mutually determined influence of the hydrosphere, atmosphere, living and dead organisms: it is one of the components of the environment environment, its most important property – fertility, which plays a leading role in human life, is the most important condition for existence and reproduction, which constantly replace each other in human generations.

Soil is the main component of terrestrial ecosystems, which was formed during geological epochs as a result of the constant interaction of biotic and abiotic factors. Today, the problem of soil protection has become particularly relevant in connection with the increase in the Earth's population and the food crisis. Therefore, maintenance and improvement of soil fertility, prevention of soil depletion, erosion, salinization, waterlogging, and contamination with various toxic substances are the key to high harvests, growth of the population's well-being, and environmental cleanliness.

Soil is traditionally the main means of agricultural production and the most valuable wealth of our country. The land fund of Ukraine is 5.7% of the territory of all of Europe and is 60,354,800 hectares, and in terms of the area of agricultural land and arable land, Ukraine ranks first in Europe. At the same time, owning such a large-scale land fund of the world's richest chernozems, which, according to various estimates of scientists, are able to provide food for 250-320 million people, Ukraine cannot even guarantee its own food security [1; 3–5; 24–33].

2. Conditions, objective and methods of research

The position of the Vinnytsia region in the system of units of physical-geographical zoning of the country is as follows: physical-geographical country – Southwest of the East European plain – physical-geographical zone – Forest-steppe – physical-geographical region – Dniester-Dnieper forest-steppe region – physical-geographical region – North Dnipro region Upland Region, Transnistrian-Eastern Podilsk Upland Region, Serednyobuz Upland Region, Yuzhno-Podilskyi upland region. On the territory of the region, forest-steppe upland disarticulated, forest and forest-steppe upland-plain disarticulated, broadleaf forest upland disarticulated and terraced, floodplain landscapes are common [5–14] (Figure 1).

Most of the territory of the Vinnytsia region is located within the Ukrainian crystalline shield, which is part of the East European platform. In the north and northeast, the foundation of the shield rises above the surface at 100-280 m above sea level. m. The relief of the foundation is complicated by numerous local tectonic uplifts and depressions, which are reflected in its current state.

The foundation of the shield within Vinnytsia region is composed of igneous and metamorphic crystalline rocks of the Archaean and Lower Proterozoic. On top of the crystalline basement of the region is a low-thickness sedimentary layer formed from rocks of the Upper Proterozoic and Cretaceous, Paleogene, Neogene, and Quaternary systems of the Phanerozoic, on its southwestern edge. The geological history of the region is complex. It also influenced the formation of the relief [10; 14; 68]. The foundation of the territory [5; 14; 38] consists of rocks, the formation of which refers to the Precambrian time. They are represented mainly by granitogneiss. Outcrops of Precambrian rocks on the surface of the day occur in deep ravines, gullies and in the form of rapids on rivers (especially on the Southern Buza and its tributaries and the Dniester –

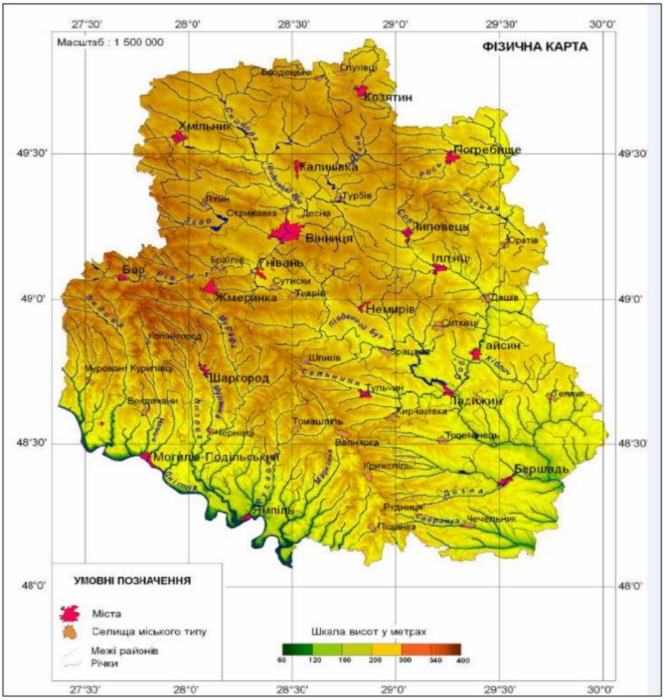


Figure 1. Physical map of Vinnytsia region (geodesic format)

Source: [11]

in the Yampol region). Reddish and gray granites of Precambrian origin occur in outcrops along the course of the Markivka and Rusava rivers. The largest number of outcrops of crystalline rocks on the surface is observed in the strip between the lines (conditionally) Kozyatyn – Pogrebyshche and Mohyliv-Podilskyi-Yampil. The part of the Ukrainian crystalline shield, which is located within the Vinnytsia region, has a general inclination to the west – southwest. Therefore, in the Dnieper region, crystalline rocks are covered by a thick layer of sedimentary deposits of the Paleozoic and Mesozoic ages [1–8; 12–16; 55].

Marine sediments of the Silurian period are quite common in the Dnieper region. They are represented by coarse-grained sandstones, green, gray and purple shales, limestones. Silurian deposits are widespread in the area bounded (conditionally) by a line passing through the village of Zhvan (Murovano-Kurilovetsky district), Nemerchi station to the village of Chernivtsi Further to the southeast, Silurian deposits are widespread in the lower reaches of the Rusava and Yalanka rivers, up to the confluence of the Markivka and the Dniester. In some places, Silurian sediments are 250 to 350 m thick. Cretaceous sediments (Mesozoic era) are quite common in Transnistria. Like the Silurian deposits, the chalk rocks extended in a wide strip along the Dniester, from the Zhvan and Karaets rivers to the Kamianka river basin. The thickness of sediments of the Cretaceous period reaches 40, sometimes 60 m. Compared with Paleozoic and Mesozoic sediments, Neogene sediments, in particular, Sarmatian and Baltic strata, are widespread on a much larger part of the territory of the region [9–19].

The relief of the territory is heterogeneous, because neotectonic movements of the earth's crust, climate and other factors played a significant role in its formation, and in general assessment it is elevated in relation to the sea level (Figures 2, 3).

According to the scheme of geomorphological zoning, the territory of Vinnytsia is located within the boundaries of two geomorphological regions: Volyn-Podilskyi and Transnistrian-Pryazovsky region, and the following geomorphological subregions are distinguished within these two regions: Podilsk structural-denudation upland, Baltic alluvial-delta plain, North-Dnieper moraine-water-glacial and cut plain, West Dnieper Denudation Upland and Central Dnieper Denudation Upland within the boundaries of two geomorphological provinces – Podilska and Prydniprovska. The Dnieper upland is gradually passing to Podilsk in the territory of the Vinnytsia region. The watershed of the Dniester and the Southern Bug, mainly its northeastern slopes, is a conventional geomorphological boundary between the Dnieper and Podilsky uplands [21–24].

In the relief of the Vinnytsia region, the Podilsk and Dniprovsk highlands stand out. The border between them is conventionally drawn along the valley of the South Bug River. Most of the territory of the Vinnytsia region is occupied by the Podil structural-denudation upland. The maximum height of the Podilsk Highlands is located in the area of the Zhmerinsky uplift near the village. Borschi-Chemeryske and is 370 meters above sea level. r. m [25; 34; 68].

Figure 2. Volumetric relief map of Vinnytsia

Source: [41]

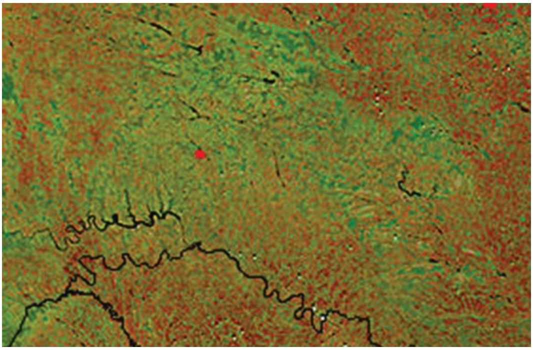


Figure 3. Satellite image of the relief structure of the Podillia territory

Source: [41]

The geological development of the territory of Vinnytsia underwent a corresponding evolution with the formation of a corresponding modern geological structure [7; 25–40]. In the late Mesozoic and Cenozoic, the Ukrainian crystalline shield was affected by differentiated block movements. As a result, the raised plain of the shield was divided into five geomorphological stages. The Buzhsko-Dnieper geomorphological grade is located within the Vinnytsia region. Its structural basis is tectonic blocks: Vinnytsia, Berdychevsky, Haysynsky, Yampilsky.

The Buzhsko-Dnieper geomorphological grade has absolute heights of 200-300 meters. The surface is a weakly undulating plain. Of the rocks, granites, granite-gneisses and others are most common here. The maximum absolute heights are found in the extreme southwestern part of the region, where they reach 330-340 meters; in the watersheds of the Snyvoda, Gnylopyat, Rostavitsa, and Rosa rivers, the heights are slightly lower, 280-300 meters. To the southwest of the city of Khmilnyk near the village of Pedosy is the highest point of the Dnieper Highlands – 340 meters.

From the north-west to the south-east, not only the general slope of the uplift surface is observed, but also its greater length (more than 200 kilometers, with an average width of 60-80 kilometers) [37; 48; 69–74].

The relief of the Dnieper Upland is not completely uniform. In the western part, it is calmer: the river and stream system is relatively not dense, the river cuts are shallow; but in the east, and especially in the southeast, the nature of the terrain changes a lot: there are a lot of ravines, and the number of beams and slopes is increasing.

The Podilsk uplift (elevated plain) has a geostructural basis of the southwestern part of the Ukrainian crystalline shield and the Podilsk plate, which is located only at its eastern edge within the Vinnytsia region.

The basic basis for the modern relief is the Sarmatian-Pontic surface with the development of ancient alluvial, deltaic and typical sea Sarmatian Pontic plains. The period of continental rift began here after the retreat of the Sarmatian Sea.

3. Soil characteristics of the Vinnytsia region

In terms of geomorphology, the territory of Vinnytsia Oblast is within the limits of the Right Bank Upland, which is mainly represented by the Podilsky Plateau, the Dnieper Upland, and the Southern Pobuzhye, or by two geomorphological regions – Azov-Prydniprovsky and Volyn-Podilsky, respectively, the sub-regions of Prydniprovsky and Podilsk Highlands [26].

The Podilsk Plateau occupies most of the region and lies to the west of the conventional line: the upper reaches of the Snivoda River – the city of Kalynivka – the upper reaches of the Sob River and further along its valley and the South Bug valley to the border of the region. This is the most elevated, dismembered and eroded territory, especially that part of it that is inclined to the Dniester. Researchers believe that the relatively rapid uplift of this territory, which was observed in anthropogenic times, led to increased erosion of the southwestern slopes of the Podilsky Plateau. The eastern and northeastern parts of the plateau are much less fragmented. The Dnieper Upland extends from the headwaters of the Snyvoda River to Girsky Tikich (north-eastern part of the region). Their slopes are also incised by numerous river valleys, but the general dismemberment of the surface is much less and the territory has the appearance of a gently undulating plain.

According to the structure and shape of the relief and river valleys, the subregion of the Dnieper Highlands is divided into a number of geomorphological regions.

KOZYATINSKA STRUCTURAL AND DENUDATION WATER DIVISION, as a geomorphological region, it is the watershed of the confluence of the Southern Bug and the Dnieper, their numerous tributaries: the Snyvoda, Desna, Gnylopyati, Guiva, Rostavitsa, Rosi, Roska, Sobu rivers.

The Kozyatyn watershed is one of the largest in the region in terms of distribution area. The southern border in the extreme northwestern part coincides with the well-defined valley of the Khvosa River and runs along the line of the villages of Tesy – Ivanivtsi – Shevchenkovo.

Kozhuhyiv – Bruslynyv and further east through the villages of Bruslynyv – Penkivka – Mizyakiv, where it coincides with the valleys of Zgar and Southern Bug; from the headwaters of the Desna, the southern border coincides with the direction of the channel, and from Turbov along the Vilshanka river valley, it is directed to Vakhnivka – Zoziv Lypovets-Dashiv, along the valley of the Sob river to its confluence with the Soroka stream, along the valley of which it goes beyond the boundaries of the region [15; 24; 28].

Kozyatynska upland is the most peaceful area of Vinnytsia. Although it is quite elevated above sea level – the absolute heights here are 290-305 meters, however, the fragmentation of the territory is insignificant, the valleys of streams and rivers have shallow cuts and gentle slopes. The watershed plateaus here are relatively wide, weakly undulating and predominate in terms of the area of the slopes.

On the territory of the highlands there is a well-defined valley between the headwaters of the Hnylopyati and Rostavytsia rivers. The valley is composed of hydro-glacial deposits. Its depth does not exceed 30 meters. In addition to the passable valley, in the northern part of the Kozyatynska upland on the border with Zhytomyr and Kyiv regions, there is a whole system of passable valleys between the rivers Teterev and Snivoda, Glylopyat and Postolova, Gnylopyat and Guiva, Guiva and Rostavytsia, Rostavytsia and Desna, Rostavitsa and Ros, etc. They are not always well expressed in the relief and do not always attract the attention of researchers.

VINNYTSIA DENUDATION AND ACCUMULATION WAVY PLAIN occupies the central part of the region from the South Bug valley in the west to the Sob river valley in the east; in the north, it passes into the Kozyatynsk watershed upland, and in the south, where its boundary is not clearly traced, borders the northern slopes of the Podilsk upland [31; 65].

A detailed analysis of the relief and geological structure of the area makes it possible to reveal the difference in the geomorphological structure of its left-bank and right-bank parts, and therefore two geomorphological subdistricts can be distinguished within this territory: left-bank (main) and right-bank.

The left bank sub-district is relatively less elevated and dissected. Average heights above sea level are 280-300 meters, reaching 310 meters in the extreme west near the village of Yaryshivka and decreasing to 235-240 meters in the eastern part. The right-bank territory is slightly higher at 290-323 meters.

The left bank is inclined in the south and southeast directions, the right bank is more to the north. The left-bank part is weakly dissected by river valleys, except for the Southern Bug and the Sobu, at least some significant rivers are practically absent here. Thus, only one Voronka stream flows through Voronovytsia in the direction of the Southern Bug, and only in the villages of Korzhivka, Raigorod, and Nizhnya Kropivnya small streams flow into the Southern Bug.

The hydrographic grid of the Sobu basin is somewhat denser. The floodplain of the Sob River in the middle course (from Illintsy to Bubnivka) is relatively wide, swampy in places, and well terraced. The right bank is less terraced than the left, and terraces are found only in the area of the villages of Dzvonikha, Kolyuhiv, Rogozna, Pechera, Markovo, and Bratslav.

The topography is connected with the widespread distribution of forests in the region in the past, and, accordingly, podzolized soils. The general branching of the surface caused the formation of various degrees of eroded soils in the region.

LETYCHIV-LYTIN HYDROGLACIAL ALLUVIAL PLAIN is a peculiar geomorphological region of the Dnieper Highlands. Geologically speaking, the Lytyn plain consists of a thin layer of water-glacial sandy and sandy sediments on loess loams. The plain is a valley-like terraced depression between Letychev (the upper reaches of the Southern Bug) and Lityn (the valley of the Zgar River).

The total length of the plain does not exceed 75-80 kilometers, with a width of 12-16 kilometers, although within the region the plain itself is clearly defined only along the meridian Lityn – Selishche, and further to the east it turns into an undulating depression, which is divided into two bands: one of them stretches along the valley of the Zgar River to its junction with the Southern Bug and further in the direction of Lavrivka – Stryzhavka; the second, much wider in area and better defined in the relief, is located in the direction of the rivers Riv and Rivets, forming a kind of intermediate valley between the valley of the latter and the valley of the Southern Bug.

The eastern border of the Letychiv-Lytyna plain is the South Bug valley.

In general, the Litynska plain has a gently undulating flat surface with depressions.

The Podilsk Highlands are also divided into a number of geomorphological districts and sub-districts.

As a geomorphological region, the Zhmeryn Dismembered Forest Highland occupies the most elevated part of the region. Absolute marks are 364-370 meters (near Baru). This is the territory of Barskyi, Zhmerinskyi, part of Tyvrivskyi, Shargorodskyi and Tulchynskyi administrative districts.

In the north and northeast, the elevation borders the Letychevsko-Lytyn plain and the Vinnytsia denudation-accumulative plain, in the south with Mogilev-Podilskyi Transnistria. The total length of the upland is more than 110 kilometers, and it reaches Vapnyarka at its eastern end. The width in the western and central parts is 40-50 kilometers. The Zhmeryn upland has the shape of a triangle with a base of 50 kilometers in the western part on the border with the Khmelnytskyi region and lateral sides with a length of 110-115 kilometers [31].

From a geomorphological point of view, the Zhmeryn upland is the interfluve of the Southern Bug and Dniester river massifs.

The territory is densely and deeply dissected by a rafter-beam system. Wet, narrow, sometimes swampy floodplains are found only in the valleys of the large tributaries of the Dniester – the Lyadova and Murafa rivers. In general, the height slopes from the northwest to the southeast, decreasing near Vapnyarka to 298 meters.

The Zhmeryn upland is the center of active modern water surface and deep erosion, where the entire surface is constantly washed away, and in 20%-30% of cases it is severe, which leads to an annual loss of 45-50 tons of fertile fine soil on each hectare of arable land.

MOHILIV-PODIL'S DIVIDED DOWNTOWN PLAIN, as a geomorphological district, occupies the southern part of the region. Sometimes this area is called Vinnytsia or Mogilev-Podilskyi Transnistria. It stretches in a narrow strip along the entire course of the Dniester from the western border of the region.

The geological base of Transnistria is (partially) the southwestern edge of the Ukrainian Shield. The driving part of the district is calmer and less fragmented by relatively wide beams; the Transnistrian part is very complex in relief, cut by canyon-like deep river valleys into a system of narrow sections inclined from north to south. Therefore, four geomorphological subregions are distinguished: the Kopaihorod erosion-denudation undulating plain, the Vapniar erosion-denudation undulation plain, the Dniester supracanyon terraces and the Dniester canyon [40–43].

The Kopaigorod erosion-denudation low-wave plain covers the territory of the mouth and middle course of the Zhvan, Lyadova, Nemiya, Murafa rivers and a narrow strip of 15-20 kilometers extends from the western border of the region to the strip of the Sarmatian layer, which crosses Transnistria in a sub-meridional direction along the Tomashpil line – Vilshanka.

This is a watershed area of Transnistria with heights of 300-310 meters and a relatively calm, gently undulating, relatively flat terrain.

The headwaters of the rivers are slightly curved to the northwest. They acquired a meridional direction after the formation of the river network and rapid geological elevation of the terrain surface.

The plain consists of crystalline rocks of the Podilsk charnokite formation. Above them lies a sedimentary complex of sand-limestone rocks of the Lower Sarmatian. Sometimes the slopes are composed of crystalline rocks and partly Sarmatian limestones.

The limestone erosion-denudation undulating plain is a constituent part of the Baltic Pliocene plain. It covers the confluence of the Markovka, Vilshanka, and Kamianka rivers and lies to the east of the Kamenska reef ridge, which is weakly expressed in the relief in the Tomashpol area. The river valleys here are not very terraced. Due to the large slope of the area to the southwest towards the Dniester, the river-beam network is more developed than on the Kopaigorod plain. At the base of this plain are crystalline rocks – pygmatites.

Quaternary sediments are represented mainly by deluvial loams, sometimes with admixtures of Carpathian pebbles. They lie mainly on the slopes of streams, they are absent on watersheds. River floodplains in the upper reaches are wider than in the lower reaches, sometimes slightly swampy.

The relief of the northern part of this subdistrict to the latitude of Horodkivka – Kryzhopol is relatively calm. The territory is raised an average of 300 meters above sea level. Although the southern half of the subdistrict, the eastern border of which is the watershed between the Nizhny Bug and Dniester rivers, is very complex: the topography is mostly narrow watershed strips and sloping lands of a very complex shape. This territory is the most affected by water erosion among all geomorphological regions of the region.

The area of the Dniester canyon terraces stretches up to 30 kilometers along the Dniester channel from the northwest to the southeast. Two parts of the sub-district are distinguished: the outer one, which borders the Kopaihorod erosion-denudation low undulating plain, and the inner, bordering sub-district of the Dniester Canyon.

The outer part is the territory with absolute heights of 250-270 meters and deepening (cutting) of riverbeds into the surface up to 150-200 meters. According to the geomorphological structure, this is the territory of the fourth and fifth terraces, raised above the level of the Dniester river bed by 50-60 and 90-100 meters. The slopes of the valleys are steep, and the rivers have the character of mountain streams.

The inner part is the territory of mainly the first, second and third floodplain terraces of the Dniester. Rapid currents, river regimes, the structure of valleys resemble real mountain rivers. In the upper part of the slopes of the canyons along the rivers Zhvan, Karaets, Lyadova, cornices formed by weathered limestones are developed on both sides of the valleys. Cenomanian siliceous marls, Cambrian sandstones and shales are exposed below on the slopes. Floodplains are very narrow, sometimes completely absent [19; 78–80].

A fourth geomorphological subregion stands out within the boundaries of Mohyli-Podilskyi Transnistria, where the edge of the shield caused the Dniester valley to change direction from east to south-east, the Vinnytsia Dniester Canyon. It differs from Khmelnytsky Transnistria. First of all, there is a different climate here, which contributes to the development of viticulture and horticulture, as well as resort science. Four over-canyon terraces are developed within the canyon. Lowland terraces are erosive and accumulative, upper ones are mostly erosive. The first terrace is covered with pebbly alluvium and loam; the second – pebbles and loamy loams. Cenomanian marls and Middle Sarmatian limestones were deposited on the third and especially the fourth.

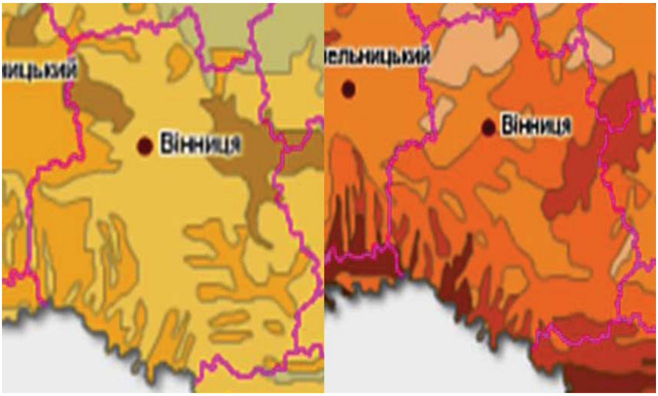
BALTIC EROSION-DENUDATION DIVIDED PLAIN as a geomorphological region, the is the southern edge of the most lowered and narrowed part of the Podilsk Highlands. In general, this gently sloping territory is elongated in the southeast direction and is represented by a very narrow Dniester-Buzhsky watershed within the southeastern part of Kryzhopolsky and Pishchansky districts, as well as Chechelnytskyi. The general slope of the territory is mainly to the east and southeast, and partly to the south. The highest surface mark near Vapnyarka – Kryzhopol – Yavorivka – Rudnytsia is 308-303 meters [15; 54; 68]. The lowest – on the eastern edge of the district near Kydrasovka – Goldashivka – Berezok Chechelnytskyi – 218-224 meters; in the southern direction, the slope is insignificant, the heights do not fall below 259-243 meters (Brytavki Lubomyrka); in the northern part of the territory 277-265 meters (Kytaihorod – Budy).

The height difference from west to east does not exceed 60 meters, therefore the river courses are relatively calm, their valleys are wide, as a rule, they have waterlogged, swampy, and sometimes peaty floodplains, although terracing is almost absent.

The depth of the local bases of erosion is within 100 meters (250 meters of height on the plakors, 130-160 meters in the valleys of rivers and streams). This area corresponds to the Tulchyn-Bershad type of eroded territories (erodedness is 30-40%) (Figure 4).

The most erosively dissected relief according to the criterion of the sum of the areas with a steepness of slopes greater than 50 was determined for the districts of the Barsky region (15.8% of the surveyed area), Zhmerynskyi (15.68%), Kryzhopolskyi (18.73%), Pogrebyschenskyi (16.15%), Chechelnytskyi (28.23%), Shargorodskyi (11.06%) (Table 1).

In general, the soil cover of Vinnytsia according to the development of erosion (Table 2) can be divided into three main zones, of which the North-East and South-West are the most eroded. It should also be noted that for the conditions of the studied region, the composition of eroded soils is dominated by weakly eroded lands – 4.71-36.6% (by district of the region), and the smallest share – strongly eroded 0.01-4.24%. The conditions of Chechelnytsy (4.24% of heavily eroded lands), Pogrebyschensky (3.35%), Bershadsky (1.93%), Kryzhopolsky (1.52%) districts, etc., are particularly threatening. It can be concluded that only on the fourth part of the territory of the Vinnytsia region, land use is not related to problems with land cultivation and cultivation of agricultural crops. From the point of view of the relief of the area, intensive soil protection technologies should be applied on half of the lands of Vinnytsia, especially in its southern part, because every year more than 45-55 tons of fertile fine soil is lost, which is washed away by erosion flows.



Density and depth of relief dissection

Figure 4. Morphometric analysis of the relief of the Vinnytsia region

Source: [2]

Table 1

Characteristics of Vinnytsia region by land slopes and technological groups (own grouping), %

Area	Slope, 0								Technological groups		
	to 10	1-20	2-30	3-50	5-7 0	7-100	10-150	>150	I to 30	II 3-70	III > 70
Barsky	4,57	25,38	24,24	30,01	12,78	2,81	0,21	0,00	54,20	42,78	3,02
Bershadsky	39,63	25,14	13,38	12,99	6,04	2,72	0,10	0,00	78,16	19,02	2,82
Vinnytsia	65,63	17,94	6,01	6,46	2,70	1,15	0,11	0,01	89,58	9,15	1,27
Haysynskyi	43,13	28,06	10,46	11,36	4,46	2,12	0,38	0,04	81,65	15,81	2,54
Zhmerinsky	17,26	22,95	17,51	26,60	11,17	3,97	0,49	0,04	57,72	37,76	4,51
Illinetskyi	48,81	32,74	3,10	10,29	3,51	1,37	0,18	0,01	85,49	13,03	1,47
Kalinovsky	62,95	24,28	4,30	4,69	2,55	1,18	0,06	0,00	91,53	7,23	1,24
Kozyatinsky	46,16	24,03	6,12	10,14	8,15	5,06	0,34	0,00	76,31	18,29	5,39
Kryzhopolskyi	16,12	19,01	17,88	28,25	13,12	4,86	0,75	0,01	53,54	40,78	5,68
Lipovetskyi	61,03	23,31	6,02	4,89	2,78	1,59	0,37	0,00	90,35	7,68	1,97
Litinsky	43,75	25,42	6,17	13,00	7,37	3,61	0,68	0,00	75,34	20,37	4,29
Mohylov-Podolsky	20,09	33,23	15,38	23,19	5,67	1,83	0,53	0,07	68,72	28,85	2,43
Masonry-Kurilovetskyi	7,70	25,46	24,40	29,60	10,31	2,33	0,19	0,00	57,56	39,91	2,53
Nemyrivskyi	44,52	26,01	11,64	10,12	5,00	2,47	0,23	0,01	82,17	15,12	2,71
Orativskyi	34,26	20,06	12,57	16,55	9,24	6,26	1,05	0,02	66,89	25,77	7,34
Pischanskyi	8,88	17,50	21,25	31,31	16,23	4,46	0,35	0,03	47,61	47,55	4,84
Pogrebyschenskyi	26,51	27,74	8,52	21,09	8,42	4,60	3,08	0,05	61,23	28,78	9,99
Teplytskyi	42,34	25,37	14,65	12,06	4,00	1,43	0,15	0,00	82,36	16,06	1,58
Tyvrovsky	32,76	27,89	15,48	14,52	7,09	2,06	0,20	0,00	76,13	21,61	2,26
Tomashpilskyi	13,15	29,74	13,87	32,68	7,39	2,69	0,32	0,17	56,77	40,05	3,18
Trostyanetskyi	28,62	27,31	17,91	15,51	6,68	3,53	0,43	0,02	73,83	22,19	3,98
Tulchynskyi	30,85	29,76	15,01	13,92	7,24	2,80	0,41	0,02	75,62	21,16	3,22
Khmilnytskyi	50,84	26,15	7,43	6,90	5,35	2,88	0,46	0,00	84,42	12,24	3,34
Chernivtsi	23,44	38,72	17,91	10,48	6,60	2,15	0,62	0,08	68,71	28,85	2,43
Chechelnytskyi	13,45	16,27	15,79	26,26	16,15	10,52	1,46	0,09	45,53	42,41	12,06
Shargorodskyi	10,09	25,11	28,26	25,48	7,96	2,80	0,24	0,07	63,51	33,45	3,04
Yampilskyi	24,09	34,91	13,98	20,93	4,29	1,53	0,22	0,05	72,98	25,21	1,80

According to B. D. Panasenko and based on his analysis, the following forms of microrelief and their corresponding geotopes are distinguished within the field landscapes of the Vinnytsia region:

1) beam-like depressions and semi-closed depressions;

2) the foot of terraces and ledges with an even transverse profile;

3) even sections of the slope (in the longitudinal and transverse directions), including subhorizontal surfaces;

4) edges of terraces and ledges with an even transverse profile;

5) ridges with an even longitudinal profile;

6) ridges with a convex profile, including hills and peaks. Selected geotopes in their territorial combinations form the next, higher hierarchical level of local geosystems – part of the catchment in watercourses of the 1st order (according to the Horton-Strahler classification).

This part of the catchment corresponds to a complex of slope tracts. The elementary catchment consists of several slopes with different solar exposure. Elementary types of locations are evaluated primarily by their place in the system of local conjugations (paragenesis) characteristic of the region. For this purpose, the listed geotopes are distributed according to certain categories of paragenetic links of the paragenetic series. The paragenetic series includes the following elementary landscapes: eluvial, or autonomous, transeluvial, transaccumulative, accumulative, and superaquatic, or surface. The field landscapes of watersheds and hilltops belong to eluvial landscapes, the edges of terraces and ledges, as well as the upper parts of slopes – to transeluvial, the middle and lower gently sloping parts of slopes – to transaccumulative, and the foot of terraces and the bottom of basins – to accumulative landscapes [17; 56].

There are also accumulative-eluvial landscapes confined to closed and semi-closed depressions in local watersheds and transaquatic-superaquatic (floodplain) complexes, characterized by sharp seasonal changes in the water regime. Each type of elementary landscape is divided into subtypes and types based on the elevation of the area, exposure and slope, the position of the geotope in the system of different watercourses, lithology and the mechanical composition of the soil-forming rocks. All these features are of decisive importance in the territorial differentiation of field landscapes. Regional elementary field landscapes of Podillia correspond to three main groups of relief types:

1) eluvial – positive morphostructures, in particular plakors, heights and high plains;

2) accumulative – lowlands, valleys, etc.;

3) transeluvial and transaccumulative occupy the slopes of highlands and valleys.

Such factorial-dynamic series within the Vinnytsia region have a certain peculiarity, because one of the upper links of the landscape conjugation (eluvial or transeluvial) often falls out here, and the two lower links (transaccumulative and accumulative) in the conditions of a flat relief often it is difficult to distinguish, because they simply overlap each other.

Within Vinnytsia region, the most diverse types of field landscapes are usually characteristic of gently undulating and hilly watersheds with erosive and erosive-denudation relief. Considerable, although noticeably less, landscape-species diversity is characteristic of the middle sections of gently undulating slopes of mezhyrivers, which occupy a transit location. Transaccumulative and accumulative elementary landscapes are primarily formed by the features of the lithological composition of the genetic types of soil-forming rocks and features of the relief. The region is characterized by a long-term manifestation of erosion-denudation processes with the formation of various forms of relief of the "stratified" type at the interfluves and a cover of slope deposits of various mechanical composition and thickness.

Within Vinnytsia region, three territories are distinguished based on the predominance of types of field landscapes by type of location:

1) north-eastern – erosional-denudational with a predominance of eluvial-transeluvial (52% of the area) and transaccumulative (26%) elementary landscapes within gently sloping slopes Dnieper Highlands;

2) internal (South Bug valley) with the development of fluvial processes, accumulation and valley complexes; within its borders, transaccumulative and accumulative elementary landscapes prevail (42% of the area), which, together with transeluvial ones, occupy 82% of the territory;

3) southwestern with a predominance of transeluvial (58% of the area) and transaccumulative (28%) elemental landscapes within the Podilsk Highlands.

The north-eastern part is almost homogeneous in terms of soil types – 60% of arable land is occupied by typical and strongly regraded chernozems, 24% by podzolized and slightly regraded chernozems. There are more accumulative and transaccumulative elementary landscapes in the northwest of this part, and eluvial and transeluvial landscapes in the northeast. The South Bug Valley is distinguished by the dominance of gray podzolized soils with low humus reserves.

The area of transeluvial elementary landscapes decreases here from west to east, and transcumulative ones increases in the same direction. Such an important feature of field landscapes, which they acquired as a result of anthropogenic development, is directly related to the types of locations. It defines their property as the degree of hydromorphism. At the same time, the change in the content in the upper horizons of the soil of silty-dusty fractions, which come with lateral material flows from neighboring relatively higher areas, is of great importance. An increase in such fractions makes the mechanical composition heavier and at the same time increases the humidity of the arable layer due to the content of bound water. At the same time, however, the water-air regime of the arable layer deteriorates significantly and soil fertility decreases. The removal of small particles is noticeable on well-drained, especially dissected uplands, therefore, hydromorphization is characteristic of lowland-valley geotopes, where the accumulation of finely dispersed material is observed. For a multidimensional landscape-ecological analysis, the types of field landscapes of Vinnytsia region were combined into groups of species taking into account the types of location, genetic unity of species, lithology and mechanical composition of the arable layer and edaphic moisture, which determine the potential fertility of soils [23; 67].

Also, the relief is related to the wide spread of forests in the past in the territory of the region, which resulted in the formation of charred soils.

4. Practical value and conclusions

Land is the most important component of natural resources, the basis of plant and animal life, a reservoir of natural wealth, the operational basis of industry, settlements and roads, the main means of production in agriculture. And that is why rational land use is a mandatory component of a complex system of exploitation and protection of natural resources. For agricultural production, the part of the earth called soil is of the greatest importance – a special natural formation, which is characterized by the features of living and non-living nature, formed as a result of the long-term transformation of the surface layers of the lithosphere under the joint and mutually determined influence of the hydrosphere, atmosphere, living and dead organisms : it is one of the components of the environment, its most important property is fertility, which plays a leading role in human life, is the most important condition for existence and reproduction, which constantly change each other in human generations.

Soil is the main component of terrestrial ecosystems, which was formed during geological epochs as a result of the constant interaction of biotic and abiotic factors. Today, the problem of soil protection has become particularly relevant in connection with the increase in the Earth's population and the food crisis. Therefore, maintenance and improvement of soil fertility, prevention of soil depletion, erosion, salinization, waterlogging, pollution with various toxic substances is a guarantee of high yields, growth of population welfare and clean environment.

Vinnytsia is a powerful and promising region from the point of view of assessing its land-resource potential: in terms of the specific weight of land resources in its total natural-resource potential (79.11%), Vinnytsia ranks first among other regions for the average level of this indicator in Ukraine – 44.38%.

References:

1. Agrarstrukturelle Entwicklungsplanung für das Saarland. Endfassung Planungsgutachten / Erarb. durch: Dipl. Ing. agr. Jens Thös // Landwirtschaftskammer fьr das Saarland. Saarbrücken. Juni 2001. 198 s.

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, no. 30 (3), pp. 449–459.

3. Arao, T., Kawasaki, A., Baba, K., Mori, S., Matsumoto, S. Effects of water management on cadmium and arsenic accumulation and dimethylarsinic acid concentrations in Japanese rice. *Environ. Sci. Technol*., 2009, 43, 9361–9367.

4. Bober, A., Calka, B. and Bielecka E. (2016a). Synthetic Landscape Differentiation Index a Tool for Spatial Planning. In 2016 Baltic Geodetic Congress (BGC Geomatics). Gdansk, Poland, 2016, pp. 234–238. DOI: https://doi.org/10.1109/BGC.Geomatics.2016.49

5. Bober, A., Calka, B., and Bielecka, E. (2016b). Application of state survey and mapping resources for selecting sites suitable for solar farms. Inf., Geoinform. and Remote Sens. Conf. Proceedings, SGEM 2016, vol I. Book Series: International Multidisciplinary Scientific GeoConference-SGEM (pp. 593–600).

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. 2020. *Ukrainian Journal of Ecology,* no. 10(5), pp. 54–61.

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

8. Mostovenko V., Didur I. Economic and energy efficiency of growing vegetable peas. *Colloquium-journal*, 2021, no. 12 (99), pp. 47–52.

9. Dong, D.T., Yamaguchi, N., Makino, T., Amachi, S. Effect of soil microorganisms on arsenite oxidation in paddy soils under oxic conditions. *Soil Sci. Plant Nutr*., 2014, 60, 377–383.

10. Frommer, J., Voegelin, A., Dittmar, J., Marcus, M.A., Kretzschmar, R. Biogeochemical processes and arsenic enrichment around rice roots in paddy soil: Results from micro-focused X-ray spectroscopy. *Eur. J. Soil Sci*., 2011, 62, 305–317.

11. Garnier, J.M., Travassac, F., Lenoble, V., Rose, J., Zheng, Y., Hossain, M.S., Chowdhury, S.H., Biswas, A.K., Ahmed, K.M., Cheng, Z. Temporal variations in arsenic uptake by rice plants in Bangladesh: The role of iron plaque in paddy fields irrigated with groundwater. Sci. Total Environ., 2010, 408, 4185–4193.

12. 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, no. 52, pp. 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

13. Hashimoto, Y., Furuya, M., Yamaguchi, N., Makino, T. Zerovalent iron with high sulfur content enhances the formation of cadmium sulfide in reduced paddy soils. Soil Sci. Soc. Am. J., 2016, 80, 55–63.

14. Honcharuk I., Pantsyreva H., Mazur V., Didur I., Tkachuk O., Telekalo N. Integration of traditional and innovation processes of development of modern science. Collective monograph. Publishing House "Baltija Publishing", Riga, Latvia, 2020, pp. 42–108.

15. Jia, Y., Bao, P., Zhu, Y.G. Arsenic bioavailability to rice plant in paddy soil: Influence of microbial sulfate reduction. *J. Soils Sediments*, 2015, 15, 1960–1967.

16. Kaletnik G.M., Zabolotnyi, G.M. Kozlovskyi S.V. "Innovative models of strategic management economic potential within contemporary economic systems", *Actual Problems of Economics*, 2011, vol. 4(118), p. 11.

17. Kaletnik H., Pryshliak V., Pryshliak N. Public Policy and Biofuels: Energy, Environment and Food Trilemma. *Journal of Environmental Management & Tourism*, 2019, vol. 10, issue 2 (24), pp. 479–487.

18. 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

Khan, N., Seshadri, B., Bolan, N., Saint, C.P., Kirkham, M.B., Chowdhury, S., Yamaguchi, N., Lee, D.Y., Li, G., Kunhikrishnan, A., et al. Root iron plaque on wetland plants as a dynamic pool of nutrients and contaminants. In Advances in

Agronomy; Sparks, D.L., Ed.; Elsevier: Amsterdam, The Netherlands, 2016, vol. 138, pp. 1–96.

19. Klapp, E. Wiesen und Weiden. Eine Grunlandlehre. 4. Aufl. Berlin und Hamburg: Verlag Paul Parey, 1971. 620 s.

20. Kuramata, M., Sakakibara, F., Kataoka, R., Abe, T., Asano, M., Baba, K., Takagi, K., Ishikawa, S. Arsenic biotransformation by Streptomyces sp isolated from rice rhizosphere. Environ. Microbiol., 2015, 17, 1897–1909.

21. Kyuma, K. Paddy Soil Science; Kyoto University Press: Kyoto, Japan; Trans Pacific Press: Melbourne, Australia, 2004.

22. Li, J., Dong, F., Lu, Y., Yan, Q., Shim, H. Mechanisms controlling arsenic uptake in rice grown in mining impacted regions in south China. PLoS ONE 2014, 9.

23. Li, R., Zhou, Z., Zhang, Y., Xie, X., Li, Y., Shen, X. Uptake and accumulation characteristics of arsenic and iron plaque in rice at different growth stages. Commun. Soil Sci. Plant Anal., 2015, 46, 2509–2522.

24. Liu, W.J., Zhu, Y.G., Hu, Y., Williams, P.N., Gault, A.G., Meharg, A.A., Charnock, J.M., Smith, F.A. Arsenic sequestration in iron plaque, its accumulation and speciation in mature rice plants (Oryza sativa L.). Environ. Sci. Technol., 2006, 40, 5730–5736.

25. Liu, W.J., Zhu, Y.G., Smith, F.A. Effects of iron and manganese plaques on arsenic uptake by rice seedlings (Oryza sativa L.) grown in solution culture supplied with arsenate and arsenite. Plant Soil, 2005, 277, 127–138.

26. Ludwig, R.D., Smyth, D.J.A., Blowes, D.W., Spink, L.E., Wilkin, R.T., Jewett, D.G., Weisener, C.J. Treatment of arsenic, heavy metals, and acidity using a mixed PVI-compost PRB. Environ. Sci. Technol., 2009, 43, 1970–1976.

27. Makino, T., Nakamura, K., Katou, H., Ishikawa, S., Ito, M., Honma, T., Miyazaki, N., Takehisa, K., Sano, S., Matsumoto, S., et al. Simultaneous decrease of arsenic and cadmium in rice (Oryza sativa L.) plants cultivated under submerged field conditions by the application of iron-bearing materials. Soil Sci. Plant Nutr., 2016, 62, 340–348.

28. Manning, B.A., Goldberg, S. Arsenic(III) and arsenic(V) absorption on three California soils. Soil Sci., 1997, 162, 886–895.

29. Matsumoto, S., Kasuga, J., Makino, T., Arao, T. Evaluation of the effects of application of iron materials on the accumulation and speciation of arsenic in rice grain grown on uncontaminated soil with relatively high levels of arsenic. Environ. Exp. Bot., 2016, 125, 42–51.

30. Matsumoto, S., Kasuga, J., Taiki, N., Makino, T., Arao, T. Inhibition of arsenic accumulation in Japanese rice by the application of iron and silicate materials. Catena, 2015, 135, 328–335.

31. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons*, 24(7), 53–60. DOI: https://doi.org/10.48077/scihor.24(7).2021.53-60

32. 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. *Ukrainian Journal of Ecology*, 2020, no. 10(1), pp. 101–105.

33. 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, no. 8(4). P. 26–33.

34. 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, pp. 50–55. Available at: https://www.ujecology.com/archive.html

35. 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, vol. 8, pp. 148–153.

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

37. 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.

38. 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

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

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

41. 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,* 2020, 18(1), 177–182.

42. Mazur V.A., Zabarna T.A. Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry,* 2018, issue 2(9), pp. 5–17.

43. 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.

44. 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.

45. 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

46. 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.

47. 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.

48. 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.

49. Moreno-Jimenez, E., Meharg, A.A., Smolders, E., Manzano, R., Becerra, D., Sanchez-Llerena, J., Albarran, A., Lopez-Pinero, A. Sprinkler irrigation of rice fields reduces grain arsenic but enhances cadmium. *Sci. Total Environ*, 2014, 485, 468–473.

50. Nakamura, K., Katou, H. Arsenic and cadmium solubilization and immobilization in paddy soils in response to alternate submergence and drainage. In Competitive Sorption and Transport of Heavy Metals in Soils and Geological Media; Selim, H.M., Ed.; CRC Press: Boca Raton, FL, USA, 2012, pp. 379–404.

51. Neiko, I.S. Forest genetic component as the basis of key territories of the ecological network of Eastern Podillia. *Bulletin of the Zhytomyr National Agroecological University*. Zhytomyr, 2009, issue 2 (25), pp. 170–174.

52. Nickson, R.T., McArthur, J.M., Ravenscroft, P., Burgess, W.G., Ahmed, K.M. Mechanism of arsenic release to groundwater, Bangladesh and west Bengal. Appl. *Geochem*, 2000, 15, 403–413.

53. On Land Protection4. (2003). Law of Ukraine on June 19, 2003, No. 962-IV Document 962-IV, valid, current version. Revision on December 18, 2017, on the basis – 2059-VIII. Available at: http://zakon4.rada.gov.ua/laws/show/962-15/page2

54. Pantsyreva, H.V. (2016). Doslidzhennia sortovykh resursiv liupynu biloho (Lupinus albus L.) v Ukraini. *Silske hospodarstvo i lisivnytstvo*, 4, 88–93.

55. 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.

56. Pantsyreva H., Stroyanovskiy V., Mazur K., Chynchyk O., Myalkovsky R. The influence of bio-organic growing technology on the productivity of legumins. *Ukrainian Journal of Ecology,* 2021, 11 (3), pp. 35–39. DOI: https://doi.org/10.15421/2021_139

57. 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.

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

59. Schmidt, H., Eickhorst, T., Tippkötter, R. Monitoring of root growth and redox conditions in paddy soil rhizotrons by redox electrodes and image analysis. P*lant Soil.,* 2010, 341, 221–232.

60. Seyfferth, A.L., Ross, J., Webb, S.M. Evidence for the root-uptake of arsenite at lateral root junctions and root apices in rice (Oryza sativa L.). Soils, 2017, 1, 3.

61. Seyfferth, A.L., Webb, S.M., Andrews, J.C., Fendorf, S. Arsenic localization, speciation, and co-occurrence with iron on rice (Oryza sativa L.) roots having variable Fe coatings. *Environ. Sci. Technol*., 2010, 44, 8108–8113.

62. Shimizu, M., Arai, Y., Sparks, D.L. Multiscale assessment of methylarsenic reactivity in soil. 2. Distribution and speciation in soil. *Environ. Sci. Technol*., 2011, 45, 4300–4306.

63. Shimizu, M., Arai, Y., Sparks, D.L. Multiscale assessment of methylarsenic reactivity in soil. 1. Sorption and desorption on soils. *Environ. Sci. Technol*., 2011, 45, 4293–4299.

64. Suda, A., Baba, K., Akahane, I., Makino, T. Use of water-treatment residue containing polysilicate-iron to stabilize arsenic in flooded soils and attenuate arsenic uptake by rice (Oryza sativa L.) plants. *Soil Sci. Plant Nutr*., 2016, 62, 111–116.

65. Suda, A., Baba, K., Yamaguchi, N., Akahane, I., Makino, T. The effects of soil amendments on arsenic concentrations in soil solutions after long-term flooded incubation. *Soil Sci. Plant Nutr*., 2015, 61, 592–602.

66. Suda, A., Makino, T., Yamaguchi, N., Taniguchi, H. Arsenic immobilization in anaerobic soils by application of by-product iron materials obtained from the casting industry. *Soil Sci. Plant Nutr*., 2017.

67. Syu, C.H., Jiang, P.Y., Huang, H.H., Chen, W.T., Lin, T.H., Lee, D.Y. Arsenic sequestration in iron plaque and its effect on as uptake by rice plants grown in paddy soils with high contents of as, iron oxides, and organic matter. *Soil Sci. Plant Nutr.,* 2013, 59, 463–471.

68. Syu, C.-H., Lee, C.-H., Jiang, P.-Y., Chen, M.-K., Lee, D.-Y. Comparison of as sequestration in iron plaque and uptake by different genotypes of rice plants grown in as-contaminated paddy soils. *Plant Soil,* 2014, 374, 411–422.

69. Takahashi, Y., Minamikawa, R., Hattori, K.H., Kurishima, K., Kihou, N. Arsenic behavior in paddy fields during the cycle of flooded and non-flooded periods. *Environ. Sci. Technol*., 2004, 38, 1038–1044.

70. Ultra, V.U., Nakayama, A., Tanaka, S., Kang, Y.M., Sakurai, K., Iwasaki, K. Potential for the alleviation of arsenic toxicity in paddy rice using amorphous iron-(hydr)oxide amendments. *Soil Sci. Plant Nutr*., 2009, 55, 160–169.

71. 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.

72. 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.

73. Violante, A., Barberis, E., Pigna, M., Boero, V. Factors affecting the formation, nature, and properties of iron precipitation products at the soil-root interface. *J. Plant Nutr*., 2003, 26, 1889–1908.

74. Xu, X.Y., McGrath, S.P., Meharg, A.A., Zhao, F.J. Growing rice aerobically markedly decreases arsenic accumulation. *Environ. Sci. Technol.,* 2008, 42, 5574–5579.

75. Yamaguchi, N., Nakamura, T., Dong, D., Takahashi, Y., Amachi, S., Makino, T. Arsenic release from flooded paddy soils is influenced by speciation, Eh, pH, and iron dissolution. *Chemosphere,* 2011, 83, 925–932.

76. Yamaguchi, N., Ohkura, T., Takahashi, Y., Maejima, Y., Arao, T. Arsenic distribution and speciation near rice roots influenced by iron plaques and redox conditions of the soil matrix. *Environ. Sci. Technol*., 2014, 48, 1549–1556.

77. Yu, H.Y., Wang, X.Q., Li, F.B., Li, B., Liu, C.P., Wang, Q., Lei, J. Arsenic mobility and bioavailability in paddy soil under iron compound amendments at different growth stages of rice. *Environ. Pollut*., 2017, 224, 136–147.

78. Zhu, L., Gao, K.T., Jin, J., Lin, H.Z., Xu, X.Y. Analysis of ZVI corrosion products and their functions in the combined ZVI and anaerobic sludge system. *Environ. Sci. Pollut. Res*., 2014, 21, 12747–12756.

THE USE OF DIGESTATE FOR THE DEVELOPMENT OF ORGANIC AGRICULTURAL PRODUCTION

Ruslan Myalkovsky[1]
Hanna Pantsyreva[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-4

Abstract. Global climate changes and their impact on agricultural production are studied. The state of the humus content in the soils of Ukraine, the situation with land degradation, and the degree of plowing of agricultural land today were studied. A comparative analysis of the ratio of plowed agricultural land and the share of agro-industrial complex in the world GDP is given. The use of animal manure, plant residues and food waste as raw materials for biogas production was analyzed. The scientific aspects of the development of waste-free agricultural production for an important contribution to the fight against climate change through sustainable production and protection of natural resources are revealed. The scientific work is *aimed* research of agrochemical analysis of digestate as an organic fertilizer and it is proposed to use it for the development of organic agricultural production. *Methodology*. The conducted studies are substantiated 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". The expected *results* of the research are aimed at achieving complex ecological, economic, energy and social effects. The authors have considerable experience in research related to rational nature management, the development of land reclamation measures taking into account the concepts of rational nature management, which ensure the optimization of land use, as well as the biologicalization of agriculture. The scientific research of the authors has been commercialized, in particular, contracts have been concluded for the performance of research within the

---

[1] Doctor of Agricultural Sciences, Professor,
State Agrarian and Engineering University in Podilya, Ukraine

[2] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine

framework of farm contract and state topics. It was established that in order to ensure a deficit-free balance of humus in soils and their deoxidation, an urgent task is to change the fertilizer application system with a reorientation to increase the share of organic fertilizers. *Practical implications.* The problems of land degradation and desertification are exacerbated by crop rotation violations, an imbalance in the production of livestock and crop production, a significant decrease in the number of cattle, the concentration of export-oriented agricultural crops in vertically integrated agricultural structures, which leads to soil mineralization, and also due to the rapid pace of climate change; which are accompanied. *Value/originality.* Based on the data analysis, it was proven that the use of digestate ensures the energy independence of enterprises and the industry in general, ecological capacity, leads to an increase in the yield of agricultural crops, an increase in soil fertility, a decrease in soil acidity, a decrease in the cost of applying mineral fertilizers due to the introduction of digestate, and an increase in the yield of agricultural crops. 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.

1. Introduction

Land resources play an important role in the development of Ukraine's productive forces. The modern land use system is a complex object, characterized by various forms of ownership, targeted use, dynamic development (change in the composition of land, economic objects), as well as obtaining the maximum economic profit in the process of use. This, in turn, deepens the problems of anthropogenic load on land resources, irrational land use, land structure, etc. The economic model, according to which agricultural production is developing in Ukraine, causes extremely high risks for society. Reckless use of natural capital – soil, water, air pollution leads to irreversible changes in ecosystems. Limited or insufficient implementation of measures aimed at preserving this capital inevitably lead to an increase in costs for its replacement. It is also important that as a result of the imbalance in ecosystems, their ability to support growth is reduced, which inevitably leads to a decline in the current level of consumption.

At the current stage, there is a need to change the paradigm economic growth both in the economy in general and in the industry agricultural production in particular. New models of production and consumption are needed, as well as a fundamentally different approach to defining the concept of "growth" and measuring its results, where the ecological component of development is the main one.

For intensive agricultural production and full restoration of humus reserves in Ukraine requires the annual application of 320-340 million tons of organic fertilizers. Previously, this balance was maintained mainly at the expense of domestic livestock. However, today the livestock population in the UK rainini is nullified. Thus, on 1 ha of arable land in Ukraine, there are ten times fewer cattle than in the countries of Western Europe [1, p. 45–47].

In recent years, an average of 17 times less organic fertilizers than necessary have been applied to crops. Therefore, the soil without organic substances is greatly 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 be on the verge of humus starvation – a serious ecological disaster. And then no agrotechnical, reclamation, nature protection and organizational and economic measures will be able to restore the agrotechnical potential of the land [2; 3].

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 [4].

Soil organic matter, as an integrated indicator of its fertility, takes an active part in plant nutrition, creation of favorable physico-chemical properties, migration of various chemical elements in it, because the most important soil processes are primarily related to organic compounds [5; 6]. Despite the fact that Ukraine has a large export potential of agricultural products, the agricultural sector of our country still cannot be called ecological.

The production of agricultural products leads to the emission of three greenhouse gases: carbon dioxide, methane and nitrous oxide. Agriculture accounts for almost half of the global emissions of the two most powerful greenhouse gases, after carbon dioxide, nitrous oxide and methane. Nitric oxide is formed during microbiological and chemical transformations of organic matter, both in oxidation (nitrification) and reduction reactions (denitrification). The volume of emissions depends on the type of soil, humidity, temperature and soil cultivation system. So, the expected results of the research are aimed at achieving complex ecological, economic, energy and social effects.

2. Analysis of recent research and publications

Hryhoriy Kaletnik carried out calculations of the needs for land resources to solve the outlined problems.

Victor Mazur singled out the main sources of pollution of the agricultural sector – the use of fossil fuels, burning of plant residues in the fields, non-compliance with the norms of waste disposal of plant and animal products, food waste, principles of land use, etc.

Inna Honcharuk comprehensively considered the concept of energy independence from the standpoint of ensuring the country's food and environmental security. And also revealed the role of the agro-industrial complex of Ukraine in solving the problems of energy and environmental security of the state.

Hanna Pantsyreva determined that the agricultural sector suffers from changes the most out of all branches of the country's economy climate, however, it is also not ecological and affects climate change.

Lina Bronnikova examined the state of humus content in the soils of Ukraine, the actual situation with land degradation, the degree of plowing of agricultural lands in the Vinnytsia region.

Oleksiy Alieksieiev carried out a comparative analysis of the ratio of plowed agricultural land and the share of agriculture in the GDP of the countries of the world.

A number of foreign researchers claim that the use of fermented sludge stimulates the growth of soil microorganisms and their metabolic activity [19]. As a result, faster ammonia oxidation is observed, general nitrogen mineralization and denitrification processes increase. Phosphorus in aerated sludge is mainly in the form of phosphates and nucleoproteins, and potassium is contained in the form of digestible salts, which ensures their better consumption by plants. Moreover, during the fermentation process in the biogas plant, the potassium content practically does not change increases, however, the amount of absorbed phosphorus doubles. Of the other macroelements, calcium (1.0-2.3%), magnesium (0.3-0.7%) and sulfur (0.2-0.4%) are also present in the carbonated sludge [20].

Many scientists in their writings proposed the concept of development of rural areas with the introduction of complex environmentally safe technologies for the production and use of biofuels [10–11]. However, issues regarding the prospects of using digestate in the agricultural sector as a source (way) of increasing energy independence and soil fertility remain insufficiently clarified.

3. Literature review

The main chemical elements, thanks to the presence of which in the fertile layer of the soil increase the yield of grain, leguminous and industrial crops, are nitrogen, phosphorus, potassium, and for some plants – magnesium. Data on the cost of nutrients in widely used inorganic fertilizers – urea, ammonium nitrate, ammonium sulfate, ammophos, diamofoska, nitroamofoska, superphosphate, KAS-32, potassium chloride – were selected from scientific and reference literature, summarized and analyzed. In these fertilizers, such nutrients as nitrogen, phosphorus, potassium and magnesium are in the form of salts – nitrates, phosphates, potassium and magnesium. Taking into account the chemical formulas of fertilizer salts, the share of each of the elements was determined, and based on the price of the mineral fertilizer and the share of each of the constituent nutrients, the cost of each element was calculated.

Digestate is organic substrates after fermentation in biogas plants, saturated with nutrients and excellent for soil fertilization [12]. 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 [12–14; 37–38]. Any organic waste of plant and animal origin can be used to obtain digestate [25; 26]. The source of organic nitrogen is the microorganisms of the alimentary tract of animals.

Biofertilizer is applied to agricultural, decorative and vegetable crops in a water-diluted form, by fertilizing, surface watering the soil or spraying the leaf surface of plants [30]. Having a slightly alkaline environment (pH 7.6-8.2), reduces the acidity of the soil. It is used in in all climatic zones, for all types of soils, increasing their fertility and improving their ecological condition, increases the resistance of plants to adverse environmental conditions, especially during late frosts, microbiological processes in the root zone of plants occur with the release of heat necessary for the protection of seedlings. Fertilizer application improves survival of transplanted fruit crops both in spring and autumn. One to three tons of liquid fertilizer is equivalent to 50-100 tons of manure in terms of effectiveness [31; 36].

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 fertilizer application are obtained when growing vegetable and berry crops, as well as cereals, fodder and lawn grasses, ornamental plants [19; 35].

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, co-digestion can also lead to antagonistic interactions that reduce the productivity of the biogas plant [8; 19; 34].

Ukraine has a fairly powerful raw material potential for the production of biogas and digestate [14; 33]. 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 [6; 15; 32]. 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) [35]. The amount of waste from the agro-industrial complex of Ukraine today reaches 290 million tons per year (108 million tons of dry matter) [4]. In Ukraine, about 50% of livestock farms are industrial [2; 14; 31].

The concept of development of rural areas with the introduction of complex eco-safe technologies for the production and use of biofuels has been developed in the world, the implementation of which will ensure the restoration of soil fertility by establishing a balance between the fields of plant and animal husbandry, will allow increasing the employment of the rural population by installing biogas complexes directly at the enterprises of the agro-industrial complex, and will ensure the energy independence of farms and rural communities through the introduction of complex eco-safe technologies for the production and use of biofuels in agricultural formations from existing resources [22–30; 40–44].

4. Conditions, objective and methods of research

The scientific work is aimed research of agrochemical analysis of digestate as an organic fertilizer and it is proposed to use it for the development of organic agricultural production. Methodology. The conducted studies are substantiated 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". When conducting observations, accounting and analysis, generally recognized methods were used, in particular "Fundamentals of scientific research in agronomy") [19].

5. Prospects for the use of digestate in Ukraine and the world

The by-product of fermentation – digestate – is usually used in agriculture in two forms: liquid and solid. Due to the content of readily available forms of nitrogen, phosphorus, potassium, sulfur and trace elements, digestate is a complete fertilizer, which, thanks to its properties, can replace mineral fertilizers [18]. The content of nitrogen compounds in the digestate is preserved on average by 70%, the content of potassium and phosphorus – by 100%. The estimated nitrogen content is 4.3-5.4 kg, phosphorus – 2-2.5 kg, and potassium – 8.8-13.1 kg per ton of re-fermented manure [15].

From the point of view of the legislation of Ukraine (Law of Ukraine "On Pesticides and Agrochemicals"), agrochemicals are organic, mineral and bacterial fertilizers, chemical meliorants, plant growth regulators and other substances used to increase soil fertility, yield of agricultural crops and improve the quality of plant products [11; 29].

Therefore, having fertilizing properties when applied to the soil, digestate formally falls under the concept of agrochemicals. In addition, digestate is a special type of organic fertilizer because it has a variable composition throughout the year and from year to year. This is due to the difficulty of maintaining stable technological regimes during the operation of biogas plants. Due to the variability of digestate composition, its state registration as conventional fertilizers is a practical nonsense [15].

Organic fertilizers are traditionally considered to be manure or droppings from animal husbandry, sapropel, composts. But with the development of biogas production technologies in Ukraine from by-products and raw materials of agricultural origin, more and more digestate is formed – mass re-fermented in anoxic conditions [23].

Such digestate is also a valuable resource for restoring soil fertility, as it contains a complex of nutrients and microelements in forms available to soil biota, allows for deacidification and moistening of soils, and is a source of soil-beneficial bacteria. As an organic fertilizer or soil improver, digestate at almost all active biogas plants in Ukraine is only a by-product of the biogas production process. And the most rational way to use it is to apply it to the soil [17].

Regular application of fertilizers in them helps to maintain the health of the soil. The use of mineral fertilizers made it possible to intensify agricultural production, make it more predictable and, accordingly, economically feasible [10].

But one of the main factors in restoring the fertility of Ukrainian lands is organic fertilizers: plant residues, by-products, siderates, etc. The introduction of organic matter improves the agrochemical, physical and water-air properties of soils [17].

6. Research of raw materials for the production of digestate

Digestate is a highly effective organic fertilizer that passes through stages of fermentation, destruction of harmful substances, has useful elements for plants and soil.

Currently using modern technologies to obtain biofertilizers can be used to process various types of organic waste.

Main types of waste:

1. Cattle manure (cattle).
2. Chicken droppings.
3. Pig manure.
4. Sugar beet tops.
5. Straw and grass.
6. Forestry waste.
7. Sediment and wastewater.
8. Dairy waste (lactose, whey).

Wastes of animal and bird origin are the most valuable organic fertilizers, which include liquid and solid excretions of animals. They contain important elements for the growth and nutrition of plants.

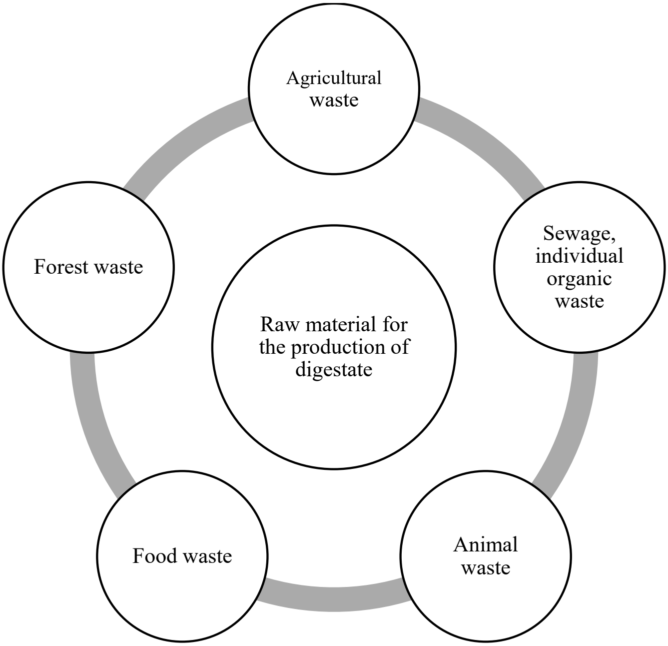


Figure 1. Raw materials that can be used to produce digestate

Source: the figure was created by the author based on the data of the State Statistics Service of Ukraine and the Institute of Soil Science and Agrochemistry

For example, waste from agricultural enterprises, livestock complexes, poultry farms, food and processing industries, and generally various types of plant and animal waste are used for biogas production. First of all, this applies to waste prone to the process of biodegradation. Today, biogas is mainly produced by from by-products of vegetable and animal origin: silage mass, beet pulp, liquid manure, chicken droppings with litter, etc.

Biogas obtained from biomass is used as a fuel that is not harmful to the environment, as it does not cause additional emissions of the greenhouse gas CO_2 and reduces the amount of organic waste. Unlike wind energy and solar radiation, biogas can be obtained regardless of climatic and weather conditions.Manure is the main organic fertilizer in all regions of Ukraine. It is a mixture of solid and liquid secretions of agricultural animals (chicken droppings, manure of cattle and pigs), with bedding (solid fraction) and without it (liquid manure). Straw, sawdust, etc. serve as litter. Manure has all the useful elements that plants need.

The quality of manure may depend on the species of animals, the composition of feed, the amount and quality of litter, the method of accumulation and storage conditions (Table 1).

Table 1

Chemical composition of litter-free manure of different types animals, %

Indexes medium content	Cattle	Pigs	Chickens
Dry matter	10,00	10,00	20,00
Organic substances	6,80	7,70	14,90
N	0,40	0,65	1,52
P	0,06	0,14	0,61
K	0,46	0,27	0,50
Ca	0,21	0,25	1,04
Mg	0,05	0,07	0,11
Na	0,06	0,08	0,12
pH	7,8	6,7	6,8

The collection and storage of organic fertilizers (bedding manure, manure, bird droppings) takes place in special places: manure storage, storage for bird droppings, sites to prevent the infiltration of biogenic elements and toxic substances to the groundwater level. If the dry fraction of manure contains more than 30%, it is stored in the sides, and to prevent the evaporation of nutrients, they are covered with a film or a layer of straw. Litter-free manure is collected in large quantities on farms and livestock complexes.

7. Characteristic features of digestate obtained after anaerobic fermentation of manure

Organic matter serves as a powerful energy material for soil microorganisms, which is why its application in the soil activates nitrogen-fixing and other microbiological processes. Tables 2 and 3 show the chemical composition of biological fertilizers [30; 31; 32].

Table 2

Chemical composition of biofertilizers from the biogas plant. Solid fraction 75% moisture*, kg/t

Biofertilizer (fermented mass)	Chemical composition				
	N	NH_4-N	P_2O_5	K_2O	MgO
Pig manure	6,3	1,8	5,5	6,2	1,7
Bird droppings	17,1	3,4	10,5	8,6	4,3
Grass silage	3,2	1,1	1,5	4,4	0,7
Corn silage	3,1	1,2	1,2	4,1	0,9
Sugar beet tops	2,1	1,2	1,1	3,6	0,8
Grain waste	8,7	2,1	5,7	5,6	1,2
Rapeseed meal	5,3	-	3,5	5,4	3,2

The value of biological fertilizer also lies in the fact that when the manure ripens, it gets rid of some of the nitrites and nitrates that are excessively contained in the manure of birds and domestic animals. In the fermentation process, they are fermented to ammonia and methane. Useful phosphorus, potassium and nitrogen contained in the fermented mass remain completely in biological fertilizers.

Table 3

Chemical composition of biofertilizers from a biogas plant. Liquid fraction 95% humidity

Biofertilizer (fermented mass)	Chemical composition				
	N	NH_4-N	P_2O_5	K_2O	MgO
Pig manure	3,3	2,3	2,4	2,3	0,9
Bird droppings	8,7	3,4	5,6	7,6	2,1
Grass silage	2,2	0,6	0,8	2,1	1,0

With traditional methods of preparation of organic fertilizers (composting) nitrogen losses reach 30-40%. Fourfold processing of anaerobic manure – compared to unfermented manure – increases the content of ammonium nitrogen (20-40% of nitrogen is converted into ammonium). As a result, compared to ordinary manure, in equivalent doses, the yield increases by 10-20%. The high profitability of biogas technologies is ensured by the simultaneous production of highly effective organic fertilizers, 1 ton (due to the impact on agricultural crops) corresponds to 70-80 tons of natural waste from livestock and poultry farming. Biosludge can be divided into two fractions: liquid and solid with the help of screw separators. Both are fertilizers.

After processing by a biogas plant, biofertilizers have the following advantages:

1. Absence of pathogenic microflora.
2. Maximum accumulation and preservation of nitrogen-containing compounds.
3. Absence of weed seeds.
4. Lack of storage period.
5. Ecologically effective impact on the soil.
6. Resistance to leaching of useful elements from the soil.

Fermented materials improve the physical properties of the soil.

Mineral components are a source of energy and nutrition for underground microorganisms, improve the assimilation of nutrients by plants. This biological fertilizer contains many organic substances that contribute to increasing the permeability of the soil and its hygroscopicity, improve the general condition of the soil and prevent the occurrence of erosion.

Biofertilizers are also the basis for the development of microorganisms. With their help, nutrients are transformed into a form that is easily absorbed by plants. Digestate accelerates seed germination, rapid plant survival, and reduces stress during transplanting.

8. Effectiveness of using digestate in increasing soil fertility

Due to increased anthropogenic impact on soils, they acquire the relevance of methods that make it possible to detect signs in time anthropogenically caused soil degradation of natural ecosystems and agroecosystems. Recently, the active use of microbiological and biochemical methods of biodiagnosis of anthropogenic disturbances in soils is associated with the rapid reaction of microorganisms to any deviations from the norm in the environment. Degradation phenomena in soils primarily affect biological objects, in particular microorganisms, which leads to a decrease in biological activity and, as a result, soil fertility. In addition, the physical, physico-chemical and chemical characteristics on which soil diagnostics are based are quite conservative and reflect changes in soil properties under the intense or prolonged action of negative anthropogenic factors, when they become noticeable and even sometimes irreversible.

The most important role in maintaining the ecological balance in the soil is played by the supply of humus, which is a nutrient medium for microorganisms that stimulate plant nutrition and their growth processes.

The basis of natural humus is the remains of organic plant substances: fractions that have decomposed the least, fractions that are still decomposing, complex substances obtained as a result of hydrolysis and oxidation of organic substances, which are the result of the viable activity of microorganisms.

Humus includes humic acids, fulvic acids and salts of these acids, as well as humin. Humic has a significant specific surface (600-1000 m^2/g) with a high adsorption capacity. After adding a small amount of humus to the soil, compared to other fertilizers, not only the chemical composition and qualitative physical and chemical characteristics of the soil changes, but also the composition and structure of the microflora, which, in turn, leads to a change microbiological regime in the soil, activating the processes of transformation of matter and energy. As a result, metabolic processes accelerate, new cycles of microflora development are included, in particular, the activity of nitrogen-fixing bacteria increases.

Humic substances resulting from the decomposition of organic substances actively participate in all important processes of soil formation and form its fertility. The main indicator of soil humus is the content of organic matter, as it significantly improves the physical, chemical and biological properties of the soil, and contributes to fertility. The humic materials produced during fermentation in the methane tank improve the physical properties of the soil: aeration, water retention and soil infiltration, as well as the rate of cation exchange (Table 4).

When using humus, a significant increase can be achieved yield and its quality. Wheat yields 15-20% more, corn – 20-30%, potatoes up to 30%, sugar beet up to 20%.

Biohumus has many advantages:

1. Increases moisture resistance and moisture capacity.
2. Mechanical strength of granules.
3. Does not contain weed seeds.
4. Contributes to the development of a large number of various useful microorganisms, the formation of antibiotics, enzymes.
5. Does not have a harmful effect on the soil.

Table 4

Normative indicators of humus for various organic of waste (kg of humus in 1 ton of substrate)

Substrate	Dry matter content, % (in fresh mass)	Humus content, kg (in 1 t of fresh mass)
Fermented mass (liquid fraction)	4–10	6–12
Fermented mass (solid fraction)	25–35	36–54
Filtration sludge	10–20	10–15

Source: [42]

In Ukraine and in Western countries, biohumus is divided into three fractions. Each of them has its own function: the smallest is used for "treatment" of plants, because it is easily absorbed by plants, promotes the development of small roots; small – for feeding greenhouse and garden crops (flowers, vegetables), large – in horticulture and crop production. In many countries (Denmark, Germany, India, China) since the 1990s, a number of tests have been conducted, the results of which show a significant increase in yield when using digestate as fertilizer.

It was calculated that the use of biogas technology for the processing of organic substances allows not only to completely eliminate the threat to the environment, but also to obtain an additional 95 million tons of standard fuel annually (about 60 billion m^3 of burning methane or biogas, 190 billion kWh). and more than 140 million tons of highly effective fertilizers, which would significantly reduce the extremely energy-intensive production of mineral fertilizers (about 30% of all electricity consumed by agriculture) and help avoid secondary soil acidification, which is often caused by excessive application of nitrogen and phosphorus fertilizers.

9. Practical value

Our research confirms the real benefit and effectiveness of using digestate from biogas plants in agriculture as a highly effective organic fertilizer. After all, during the use of digestate, it was found that it is universal and suitable for all soils, as well as for feeding all types of plants; increases the content of organic matter (humus); improves the water and air conditions of the soil; it can be made at any time; has neutral acidity and deacidifies the soil; absence of pathogenic organisms; allows you to increase the yield, as it contains a complete set of necessary macro and microelements, organic compounds that improve the soil structure, and humic acids; creates prerequisites for the development of organic agricultural production and increased income from the sale of products.

10. Conclusions

The process of complex processing of manure simultaneously has three advantages: obtaining energy from biogas, improving the ecological situation around livestock farms, obtaining environmentally friendly and agronomically effective fertilizers. The role of manure in agriculture is well known, and its role as the main element of a proper fertilization system did not decrease even when relatively large doses of mineral fertilizers were applied. Thanks to them, traditionally, from 30 to 50% of the plants' nutritional needs were met. An example of this is the developed countries of Europe – Germany, Great Britain, and the Netherlands, which, along with applying a significant amount of mineral fertilizers (350-800 kg/ha per year), apply high rates of organic fertilizers of 26-75 tons per hectare of arable land.

It should be noted that the use of biogas plants can reduce the anthropogenic impact on the environment due to the processing of agricultural waste and waste from other industries. As a raw material for obtaining digestate, not only pig or cattle manure is used, but also straw, dairy and forestry waste.

Currently, soils in Ukraine are subject to unjustified land reclamation, improper and irrational use of chemical fertilizers and pesticides. The greatest damage to land is caused by salinization, soil acidification, waste pollution, wind and water erosion, drying, waterlogging, non-renewable losses of humus.

To improve the condition of the soil and increase its fertility, the use of fermented sludge is suggested. In its composition, digestate contains many useful substances, such as calcium (1.0-2.3%), magnesium (0.3-0.7%), sulfur (0.2-0.4%). Biofertilizer also contains trace elements, as well as amino acids, hydrolysis enzymes, nucleic, humic and organic acids (fulvic acids), monosaccharides, phytohormones (gibberillin, auxin, cytokenins), B vitamins, some antibiotics and other biologically active substances. Nitrogen is stored in ammonia (up to 50-75%) and organic form. Phosphorus occurs in the form of phosphates and nucleoproteins, and potassium in the form of digestible salts (which ensures their better absorption by plants). After the process of anaerobic fermentation, there is a much smaller number of pathogens, larvae and worm eggs.

References:

1. Bandura V., Mazur V., Yaroshenko L., Rubanenko O. (2019). Research on sunflower seeds drying process in a monolayer tray vibration dryer based on infrared radiation. *INMATEN – Agricultural Engineering*, vol. 57, no. 1, pp. 233–242.

2. Del Borghi, A. (1999). Hydrolysis and thermophilic anaerobic digestion of sewage sludge and organic fraction of municipal soil waste. *Bioprocess Engineering*, vol. 20, issue 6, pp. 553–560. DOI: https://doi.org/10.1007/s004490050628

3. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology,* 10(5), 54–61.

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

5. Golub N., Shinkarchuk M., Kozlovets A. (2019). Biotechnology of leather production fat-containing waste recycling using co-fermentation. *The scientific heritage*, 39:63–8.

6. Honcharuk, I. (2020). “Biogas production in the agricultural sector the way to increase energy independence and soil fertility”. *Agrosvit*, vol. 15, pp. 18–29. DOI: https://doi.org/10.32702/2306-6792.2020.15.18

7. Kaletnik G.M., Zabolotnyi, G.M. Kozlovskyi S.V (2011). “Innovative models of strategic management economic potential within contemporary economic systems”, *Actual Problems of Economics*, vol. 4(118), p. 11.

8. Kaletnik G., Honcharuk I., Yemchyk T., Okhota Yu. (2020). The World Experience in the Regulation of the Land Circulation. *European Journal of Sustainable Development,* 9 (2), 557–568. DOI: https://doi.org/10.14207/ejsd.2020.v9n2p557

9. Kaletnik H., Pryshliak V., Pryshliak N. (2019). Public Policy and Biofuels: Energy, Environment and Food Trilemma. *Journal of Environmental Management & Tourism*, vol. 10, issue 2 (24), pp. 479–487.

10. 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

11. Marchain, U. Biogas process for sustainable development. In: FAO Agricultural Service Bulletin, 9–5. Food and Agricultural Organization. U. Marchain. Rome, Italy, 1992. 25.

12. Matsumoto, S., Kasuga, J., Taiki, N., Makino, T., Arao, T. Inhibition of arsenic accumulation in Japanese rice by the application of iron and silicate materials. Catena, 2015, 135, 328–335.

13. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. (2020). The productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. *Ukrainian Journal of Ecology*, 10(1), 101–105.

14. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons,* 24(7), 53–60. DOI: https://doi.org/10.48077/scihor.24(7).2021.53-60

15. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons,* 24(7), 53–60. DOI: https://doi.org/10.48077/scihor.24(7).2021.53-60

16. Mazur V.A., Didur I.M., Pantsyreva H.V., Telekalo N.V. (2018). Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 8(4), 26–33.

17. Mazur V.A., Mazur K.V., Pantsyreva H.V. (2019). 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*, 9, 50–55. Available at: https://www.ujecology.com/archive.html

18. 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, 148–153.

19. Mazur V.A., Pantsyreva H.V. (2020). Rid Lupinus L. v Ukraini: henofond, introduktsiia, napriamy doslidzhen ta perspektyvy vykorystannia. VNAU, p. 235.

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

21. 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

22. 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

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

24. Mazur V.A., Zabarna T.A. (2018). Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry*, 2(9), 5–17.

25. 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

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 Journal of Ecology*, 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. Palamarchuk V., Honcharuk I., Honcharuk T., Telekalo N. (2018). 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*, 8(3), 47–53.

34. Pancyreva G.V. (2016). Doslidzhennya sortovyx resursiv lyupynu bilogo (Lupinus albus L.) v Ukrayini. Vinnycya, 4, 88–93.

35. 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

36. Pantsyreva, H. V. (2016). Doslidzhennia sortovykh resursiv liupynu biloho (Lupinus albus L.) v Ukraini. *Silske hospodarstvo i lisivnytstvo*, 4, 88–93.

37. 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.

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

39. Ivanyshyn O., Khomina V., Pantsyreva H. (2021). Influence of fertilization on the formation of grain productivity in different-maturing maize hybrids *Ukrainian Journal of Ecology*, 11 (3), 262–269. DOI: https://doi.org/ 10.15421/2021_170

40. Mazur V., Didur I., Tkachuk O., Pantsyreva H., Ovcharuk V. (2021). Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change**.** *Scientific Horizons*, no. 1, vol. 24, pp. 54–60.

41. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons*, 24(7), 53–60.

42. Honcharuk I., Matusyak M., Pantsyreva H., Kupchuk I., Prokopchuk V., Telekalo N. (2022). Peculiarities of reproduction of pinus nigra arn. in Ukraine.

Bulletin of the Transilvania University of Brasov, Series II: Forestry, Wood Industry, Agricultural Food Engineering, vol. 15 (64), no. 1, pp. 33–42.

43. 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.

44. Selde H., Beier C., Kedia G., Henrik Lystad H. Digestate as Fertilizer. Fachverband Biogas e.V. 2018. Germany, 64 p. Available at: https://issuu.com/fachverband.biogas/docs/digestate_as_fertilizer

45. The official website of the United National Climate Change. GHG total without LULUCF. Available at: https://di.unfccc.int/time_series

46. The official website of the United Nations Economic Commission for Europe. Available at: https://w3.unece.org/PXWeb/ru/Table?IndicatorCode=6

47. 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.

48. Vdovenko S.A., Prokopnuk 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), 1–5.

49. 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 Journal of Ecology*, 8(3), 270–274.

50. 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), 1–5.

51. Vitalii Palamarchuk, Inna Honcharuk, Tetiana Honcharuk, Natalia Telekalo (2018). 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*, 8(3), 47–53.

STUDY OF SOIL CONSERVATION TECHNOLOGY AND ENVIRONMENTAL STABILITY OF RURAL AREAS TAKING INTO ACCOUNT LIMITED RESOURCES AND CLIMATE CHANGE

Hanna Pantsyreva[1]
Oleksiy Alieksieiev[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-5

Abstract. The applied monograph is designed to solve the current problems of climate change, which is one of the most urgent threats with a long-term negative impact on the population, the environment, and the economy. The scientific work is *aimed* at forming the concept of modernization of soil conservation and environmental safety, namely, rational nature management at the expense of limited resource provision due to climate change. Significant attention is paid to the impact of global climate change on land resources, agriculture, forestry, water resources, bioenergy and biodiversity. The implementation of the proposed modernization system will be implemented based on the study of international experience of adaptation to climate change and the possibility of its application in Ukraine under martial law in a complex with the provision of ecological and social effects, guaranteeing the reduction of the impact of the degradation processes of the soil cover of Ukraine. *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". The expected *results* of the research are aimed at achieving complex ecological, economic, energy and social effects. The authors have considerable experience in research related to rational nature management, the development of land reclamation measures taking into account the concepts of rational nature

---

[1] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine

[2] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine

management, which ensure the optimization of land use, as well as the biologicalization of agriculture. The scientific research of the authors has been commercialized, in particular, contracts have been concluded for the performance of research within the framework of farm contract and state topics. *Practical implications.* Previous scientific work of the authors includes: theoretical and practical research in the field of rational nature management and increasing soil fertility, land resources, agriculture and forestry, bioenergy and biodiversity. The state of modernization of the ecological security system under the conditions of sustainable development of rural areas was analyzed, priority directions of modernization of the ecological security system were developed in the context of achieving sustainable development of rural areas. The research will involve the development of alternative farming systems in the direction of the development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector, as well as the processing of products of the main agricultural crops, in accordance with the directions of the Strategy for Environmental Security and Adaptation to Climate Change until 2030. *Value/originality.* The authors also researched system variants of bio-organic technologies for growing the main agricultural crops used in EU countries and Ukraine. 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.

1. Introduction

The global trend of global warming and, as a result, climate change, characterized by an increase in temperature and a decrease in precipitation. All this leads to soil degradation from year to year – to the erosion, pollution, acidification and salinization mentioned above. According to FAO data, 20% of Ukrainian agricultural lands have undergone significant degradation, the rest are under threat. Ukrainian soils have lost about 30% of humus over the past 130 years, and the level of plowing in Ukraine is one of the highest in Europe – 53%. For comparison, in Poland this indicator is 36%, in Germany 34%, in the USA 17%. According to NAAS estimates, this situation leads to losses of about UAH 40 billion/year, and this became the impetus for Ukraine's accession to the Sustainable Development Program. According to the State Statistics Service of Ukraine, the structure of the soil cover of Ukraine is 24 million hectares, and in addition, Ukraine has 8% of the world's chernozem reserves and a high level of plowed soils. Fields contain different amounts of humus. The content of humus in the soils of Ukraine varies from 0.8 to 6.5%. The greatest decrease in soil fertility was noted in the eastern part and in the north. These are Chernihiv, Sumy, Kharkiv, Donetsk, Luhansk, Kirovohrad and Mykolaiv regions [1; 3–5; 12; 15; 25; 36–39].

2. Analysis of recent research and publications

The research will involve the development of alternative farming systems in the direction of the development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector, as well as the processing of products of the main agricultural crops, in accordance with the directions of the Strategy for Environmental Security and Adaptation to Climate Change until 2030.

Scientifically oriented aspects of the basics of global climate change, land resources, agriculture, forestry, water resources, bioenergy and biodiversity are highlighted in the works of Ukrainian and foreign scientists. Theoretical, methodological, methodical and instrument provisions of soil conservation and ecological safety of rational nature management of bioecosystems Mazura V.A. aimed at greening agriculture at the expense of limited resource provision due to climate change [21–38; 41–46; 50–56; 78].

Scientifically oriented aspects regarding the foundations of economic and energy autonomy of agricultural enterprises, refusal to purchase mineral fertilizers, additional profit, ecological effect, etc. were substantiated by G.M. Kaletnik. etc. (2019).

On the basis of research carried out by Honcharuk I.V. (2020) established the provision of energy independence of agricultural enterprises and the agricultural sector in general, ecological disposal of agricultural waste, reduction of carbon dioxide emissions, increase in the yield of agricultural crops, increase in soil fertility, reduction in soil acidity, reduction in the cost of applying mineral fertilizers due to the introduction of digestate and increase in profitability agricultural enterprises [2–8; 59–60].

Tsytsiura Y.G. proves that biological agriculture can contribute to soil conservation, especially for the cultivation of sideral crops. 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 [2–12; 37–39; 55].

Buchynskyi I.E. believes that climate fluctuations are a common phenomenon in nature, have a relatively orderly nature and occur in a wave-like manner. It makes many people think that the climate is changing "before our eyes". However, this is a fake climate change, it is only its "regular" fluctuation, and not a stable change in one direction.

Chabanyuk Y.V. (2018) substantiates the results of the comparison of correlation matrices of natural ecosystems, which demonstrated the formation of specific soil properties under the action of abiotic and biotic factors. Using a mathematical approach, it has been proven that chernozems are more stable, compared to gray forest soils, which quite easily lose their fertility due to anthropogenic influence, and also require ecologically stabilizing measures and protection in the process of agricultural use) [6; 13; 14–21; 35; 70–72].

Issues in the field of organic and biological agriculture are covered in the works of O. Demidenko and others. Experimental studies of Shkatula Yu.M. it has been proven that the use of mineral nitrogen fertilizers, which is not coordinated with the content of fresh organic matter in the soil, leads to the destruction of the organic composition of soils, the consequence of which is a decrease in their fertility. Atudorei D. developed models of crop rotations with elements of biologization when they are saturated with leguminous crops, and proposals were also made for the comprehensive development of the field of grain production [1; 2; 14; 36; 49; 80–84].

The analysis of international and domestic scientific sources and departmental materials shows the expediency of using biotesting methods, with the use of representatives of systematic groups of different ecosystems due to limited resource provision due to climate change. Obtaining reproducible and comparable data for determining the priority areas of modernization of the environmental safety system in the context of achieving the sustainability of the development of rural areas with the subsequent assessment of their risks is possible only by using the methods recommended by the Organization for Economic Cooperation and Development (OECD), when performed in laboratories accredited in accordance with the requirements ISO/IEC 17025 and GLP. These findings will form the basis of guidelines for environmental testing in Ukraine [22–28; 40; 42; 60–67].

Studies show that the climate of Ukraine has already started to change over the past decades (temperature and some other meteorological parameters differ from the values of the climatic norm) and according to the results of modeling, the air temperature will continue to rise for the territory of Ukraine in the future (although the magnitude of the changes is slightly different according to different forecast models) and there will be a change in the amount of precipitation during the year. This can lead to a shift in climatic seasons, a change in the duration of the growing season, a decrease in the duration of stable snow cover, and a change in the water resources of the local runoff [7–15; 29–39].

3. Literature review

Scientific work affects several related fields of science, in particular environmental, energy, economic, agricultural, balanced nature management, which will further contribute to the development of relevant fields of knowledge. Also, the implementation of the project is important for the implementation of a number of legislative and regulatory acts that will contribute to the development of the country, namely the Law of Ukraine "On Environmental Impact Assessment", the Law of Ukraine "On Alternative Fuels", the Law of Ukraine "On Combined Production of Thermal and Electric Energy (cogeneration) and use of waste energy potential", of the State Regional Development Strategy for 2021–2027, of the regional development program "New Ukrainian Village". The goals of the project will be aimed at solving environmental, energy, economic and social problems. Solving environmental problems by increasing the efficiency of the use of land resources while maintaining the protein balance and soil fertility. Along with that, in the conditions of climate change, it will be necessary to form a single agricultural policy, which will be implemented at the expense of informational and advisory work among agricultural enterprises, farms, and households with the aim of forming a nature-oriented and environmentally friendly worldview.

In order to achieve the set goals, the implementation of the project involves solving the following tasks:

– to determine the conceptual provisions of the process of modernization of the system of soil conservation and ecological stability based on the structure and requirements of environmentally safe sustainable development;

– to form a system of factors, criteria, indicators from the positions of implementation of environmental modernization measures;

– to develop a system of stabilization of the structure of sown areas with a normative share of agricultural crops with resource-possible application of organic fertilizers of the new generation, the non-marketable part of the crop, the mass of sideral crops;

– development of soil protection systems of tillage and implementation of ecologically regulated system of protection of agricultural plants from harmful organisms;

– to develop a technology for improving the agro-ecological condition of the soils of rural areas through forestry management;

– to develop an information-analytical, science-based system of environmental safety monitoring at the regional level and forecasting for the long- and short-term perspective;

– to develop optimized and adapted systems of application of bio-organic agrochemicals in the system of soil use based on mobilization agrochemical approaches;

– to develop an algorithm for the implementation of the resource-innovative strategy of environmentally safe sustainable development, which will include the introduction of modern innovative industrial technologies both on the basis of supporting the development of high-tech and medium-tech industries, and stimulating the creation of new innovative poles of development;

– to develop a partnership model of interaction of agricultural enterprises in the production of biofuels to increase energy and economic independence.

Climate change refers to environmental risks that determine the ecological safety of the environment and are considered as long-term changes in meteorological elements (air temperature and humidity, precipitation, wind speed, cloudiness, etc.), deviation of their parameters from the climatic norm for a certain geographical latitude. This process is primarily accompanied by a change in air temperature and precipitation.

The signing of the UN Framework Convention on Climate Change by representatives of 175 countries shows that climate change is a significant threat to the environment and economic development [17–21; 35; 49–53].

Climate change is already happening and this process will intensify. Therefore, regardless of whether a person is involved in this or not, it is necessary to take measures to counteract these changes, to restrain the rate of temperature increase in order to avoid dangerous and irreversible consequences for the environment, economy and society in the future. It is necessary to try to adjust (adapt) and minimize the negative effects of the predicted climate changes, to use the benefits from them as effectively as possible where possible [27].

On the territory of Ukraine over the past 100 years, the average annual air temperature has increased by 0.7°C and the trend of its increase is maintained. Ukraine is threatened by abnormal temperature conditions, the transformation of steppes into deserts, a lack of drinking water, floods, and strong winds. All this negatively affects the economic development, environmental and national security of the state [77].

4. Conditions, objective and methods of research

The monograph has an interdisciplinary nature and is aimed at solving the current problems of today, namely socio-ecological-economic scientific research of integration processes and the development of technologies for the formation and functioning of ecological systems in conditions of sustainable development. The idea is to ensure the achievement of energy, economic and ecological stability and the development of sustainable land use while implementing a set of complementary components that provide for the improvement of the formation of modern environmental policy and the rational use of natural resources. Working hypotheses: development of technologies for soil conservation and ecological stability of rural areas, which provide for balanced management of natural ecosystems and forest management while implementing climate change prevention and adaptation measures (1); use of European experience in the development of organic, ecologically adapted technologies for growing agricultural crops on the basis of effective environmental protection in order to adapt to the natural and climatic potential of Ukraine (2); increasing the productivity of growing agricultural crops on the basis of a bioadaptive approach to the realization of genetic potential while simultaneously preserving soil fertility and stabilizing soil-accumulating processes using natural processes of their provision and the formation of a deficit-free balance of organic matter in soils, which will guarantee their constant productivity and ecological sustainability (3); development of technological measures of adaptation to climate change and risk reduction for the spheres of health care, people's livelihoods, sectors of the economy and natural ecosystems (4); the system of the latest approaches to the organization of rural areas and forest management, regarding the placement of remedial forest plantations to obtain the maximum protective and ecological effect (5); application of biofertilizers in order to increase soil fertility, change their acidity, dispose of agricultural waste and reduce costs for the purchase of mineral fertilizers (6); the formation of an environmental security strategy through the environmentalization of agricultural production in the face of changing climatic conditions, pollution of water resources, air and soil contributed to the creation of alternative and sustainable ways of meeting the growing energy needs under ecological stability and sustainable development of rural areas (7).

The purpose of the research is to form a strategy for the ecological stability of rural areas based on the development of a methodology for the analysis and evaluation of the processes of modernization of the soil conservation system and ecological stability of sustainable development, which includes general, specific and auxiliary indicators and indicators that characterize the state of the environment and the level of anthropogenic load on its individual components. as well as introduced modernization measures. The study of domestic and foreign experience in the creation and organization of eco-friendly reproduction of the fertility of agricultural lands, sustainable development of the branches of agriculture, balance and optimization of a rational combination of the branches of crop production. To assess the competitiveness of the products of commodity branches of agriculture through the creation of production and service cooperatives, clusters and associations in the conditions of the organization of ecological production in the branches of agriculture and processing industry. Development and transfer of innovative projects for the production of organic food products and alternative types of renewable energy in the multifunctional development of rural areas due to the rational use of natural and forest resources under the organization of cross-border cooperation, in particular the market for innovations, labor, products and services. To develop new competitive bio-organic technologies for growing agricultural crops, which provide for the development of regulations for the use of a complex of alternative types of fertilizers for their cultivation in terms of short-term and long-term action, a basic superstructure of the factor assessment of the block of soil fertility conditions, hydrothermal conditions of the territory, resource provision of enterprises in view of climate changes.

To achieve the goal, the following tasks are expected to be solved: the development of a new bio-organic technology for growing agricultural crops on the basis of soil conservation and sustainable development and food security (1); development of effective technologies for the application of various options for biofertilization of agricultural crops while preserving soil fertility and increasing yield (2); development of technological parameters for reducing the resource and energy intensity of technologies for reproducing soil fertility and ensuring stable, highly productive production of high-quality forestry products (3); development of models of energy-saving, soil-protecting tillage systems, frugal involvement in the biological cycle of biogenic elements of industrial origin with rational use of plant and animal husbandry waste for fertilizer (4); practical implementation, which involves production verification of the proven new bio-organic technology for growing agricultural crops, informational and advisory practice with the involvement of a network of agricultural formations of various forms of ownership with further promotion and production implementation (5).

5. Adapting to climate change in green post-war reconstruction

While Russia continues the war in Ukraine, it is difficult to think about climate change. However, even if the war ends today and greenhouse gas emissions are reduced to zero tomorrow, the climate will continue to change and must be adapted to. Adaptation to climate change refers to the adaptation of natural or human systems (such as forests, rivers, cities and even individual streets) to the potential or actual impact of climate change. If you don't adapt, children will play on playgrounds in the summer, the surface of which heats up to almost 60°C, people with weak cardiovascular systems will faint from the heat, and trees will fall on cars and power lines from gale force winds [34].

The research will involve the development of alternative farming systems in the direction of the development of bio-organic technologies for growing agricultural crops for the production of biofuels and ensuring the energy independence of the agricultural sector, as well as the processing of products of the main agricultural crops, in accordance with the directions of the Strategy for Environmental Security and Adaptation to Climate Change until 2030.

According to the study, 1 dollar invested in adaptation will help prevent the expenditure of 6 dollars in liquidation of the consequences of natural disasters. That is, adapting to climate change is much cheaper than dealing with the consequences. For Ukraine, this issue is currently very relevant. The fight against the consequences of climate change already costs Ukraine millions of hryvnias every year, and in 2020, 2,689 million hryvnias were allocated from the State Budget of Ukraine. For the prevention and liquidation of emergency situations is more than, for example, the annual budget of the entire Vinnytsia city united territorial community [24; 35; 67; 69; 73].

Adaptation will mitigate their impact on people's lives and nature. This is no less relevant for the regions that suffered as a result of Russian aggression, and now must look for ways to restore normal life, taking into account, in particular, the challenges associated with the environment. Taking into account the principles of environmental protection in reconstruction formed the basis of the concept of Green Reconstruction of Ukraine. In particular, these principles emphasize the need to implement the Strategy for Environmental Security and Adaptation to Climate Change, which was adopted in 2021. Adaptation is also listed as one of the priority directions in the ecological security section of the Recovery Plan of Ukraine [12–14; 31–45; 68–69; 74].

Each region is unique in its microclimate, landscape and geographical location. Therefore, the necessary adaptation measures for each of the communities will depend on their vulnerability to various manifestations of climate change: an increase in the duration of droughts, heat waves, gale-force winds, rising sea levels, severe frosts and snowfalls, abnormal downpours and floods, etc. In order to be ready for these challenges, the local authorities, together with the community, should identify individual vulnerable zones for each settlement and, based on the received information, develop an adaptation plan.

In Ukraine, according to the Ministry of Environmental Protection and Natural Resources of Ukraine, the average annual temperature has increased by more than 2°C since the beginning of the 20th century, including 1.2°C over the past 30 years (Figure 1).

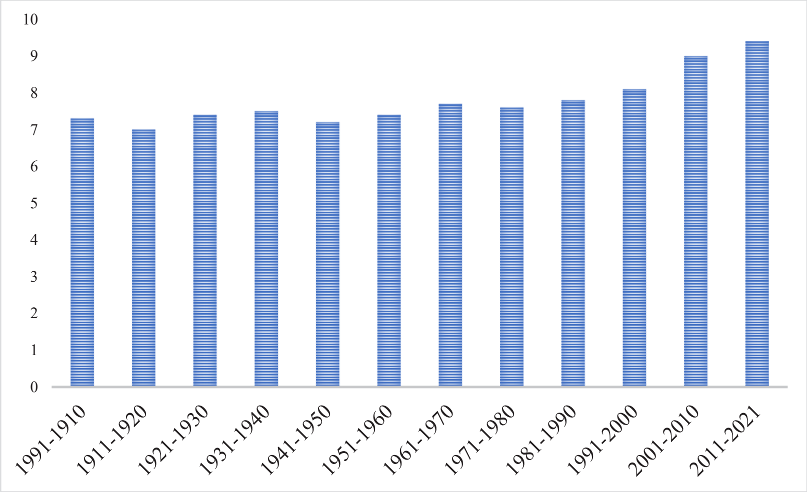


Figure 1. Average annual temperature in Ukraine

Source: according to the Ministry of Environmental Protection and Natural Resources of Ukraine

In recent years, the frequency of days with maximum summer temperatures above 35 and 40°C, which belongs to extreme weather phenomena, has almost doubled. In the greater part of Ukraine, there is already a trend towards increased droughts, an increase in the number and duration of hot periods and an increase in fire danger, the frequency and intensity of thunderstorms, heavy downpours, hail, and squalls have increased. Climate change on the territory of Ukraine increases risks for the health of the population, ecosystems, water and forest resources, sustainable functioning of the energy infrastructure and the agro-industrial complex, which can cause and is already causing colossal losses [24; 35].

UN data show that climate change will have devastating consequences for people living in poverty. Even under the best scenario, hundreds of millions of people will face threats to food security, forced migration, disease and death. And in the conditions of war, the number increases many times. In the future, climate change threatens human rights and the progress made in development, global health and poverty reduction over the past fifty years. The continuation of such a process will be detrimental to the world economy and will lead to a significant spread of poverty.

6. The current state and consequences of climate change. Land resources, agriculture, forestry

One of the important environmental problems of the 21st century is the change of the global climate. Climate change for agriculture in Ukraine is caused, first of all, by global warming, the direct consequence of which is droughts, which negatively affect the yield of agricultural crops, since the weather component of the harvest in our country is more than 50% [7; 24–28; 35; 67–68].

Therefore, the most important task of land users is the search and implementation of effective techniques for accumulation and rational use of available moisture reserves in the soil. In the modern world, agriculture remains a key branch of the economy, ensuring food security and the production of important types of raw materials. But it is a significant source of greenhouse gases. Therefore, there is a need to modernize existing models of agricultural production and improve methods of managing agricultural systems taking into account climate change. The fifth assessment report of the Intergovernmental Panel on Climate Change demonstrates the urgent need for substantial and sustainable decarbonization and climate change adaptation measures in the area of food security. Forecast estimates given in the Report demonstrate the negative impact of climate change on the yield of agricultural crops. In particular, in regions with a tropical and temperate climate, an increase in temperature by 2°C without adaptation to it will negatively affect the yield of wheat, corn, soybeans, and rice, although in some regions it will have positive consequences. An increase in the global temperature by 4°C, which will be accompanied by a reduction in the volume of water resources and an increase in competition for them, will become a risk factor for food security on a global scale [70].

The general conclusions for Ukraine regarding climate change according to the four scenarios of Representative Concentration Pathways (RCP) are as follows:

– temperature increase is expected throughout Ukraine: about 1.65°C (Steppe) and 1.74°C (Forest Steppe) for the RCP 4.5 scenario and between 2.68°C (mixed forest zone) and 2.98°C (Step) for the RCP 8.5 scenario;

– climate change will not significantly affect the level of precipitation. Under the RCP 4.5 scenario, the change in precipitation will vary from 13 mm in the Steppe zone to 55 mm in the Forest Steppe. The changes will be more noticeable under the conditions of the RCP 8.5 scenario – more than 80 mm in the zone of mixed forests and less than 13 mm in the Steppe zone;

– the largest reduction in production by 2070 due to climate change is possible in the Steppe zone: a probable reduction in wheat production by 11% for the RCP 4.5 scenario and 18% for the RCP 8.5 scenario. Currently, the agricultural sector of Ukraine is not extremely vulnerable to climate change.

However, changes in weather conditions (increased air temperature, uneven distribution of precipitation, which has a torrential nature in the warm period, ineffective accumulation of moisture in the soil) lead to an increase in the number and intensity of drought events. Together with other negative factors of anthropogenic influence, this can lead to the expansion of the zone of risky agriculture and to desertification in the southern regions of Ukraine. As a result of intense warming in recent decades, there have been changes in the structure of agricultural production, the area of field crops and their yield level.

The data show that the Steppe zone, in which 46% of the grain crops are concentrated, now provides only 35% of the total grain production, compared to 45% in 1990. The average grain yield in this zone over the past five years, despite its growth at 21% on a national scale, decreased from 35.8 t/ha in 1990 to 32.2 t/ha in 2013–2017. In Polissia and the Forest Steppe, an increase in yield was recorded from 30-37 t/ha to 48-53 c/ha Thanks to this, 65% of grain is produced in these zones, although the share of crops of this group of crops here is only 53%.

In addition to the significant territorial redistribution of the structure of agricultural crops, uneven dynamics and growth rates of their productivity are noted. Thus, compared to 1990, the average yield of grain and leguminous crops in the Forest Steppe and Polissia increased by 46– 61%, while in the Steppe it decreased by 10%. A similar situation can be observed in relation to the change in the level of productivity of the rest of the main crops. In general, the overall increase in grain and leguminous yields in Ukraine was due to the more moisture-provided regions of the state, the Forest-Steppe and especially Polissia.

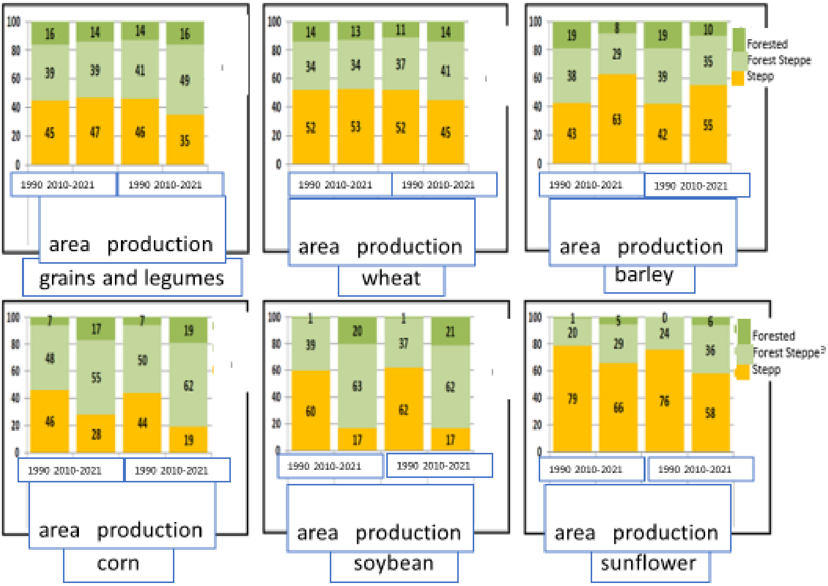


Figure 2. Change in the structure of crops and production of the main agricultural crops, % of the total for the country

In the conditions of climate change, the level and conditions of moisture in the territory of the state is the leading factor limiting the level of production productivity and the use of the natural potential of agriculture. In order to mitigate the negative processes of climate change on agricultural production, it is necessary to implement the objectives of the Irrigation and Drainage Strategy in Ukraine for the period until 2030. Recurrence of droughts in different agro-climatic zones is 20–40%. Over the past 20 years, droughts have recurred almost twice as often. There is a dangerous tendency to increase the recurrence of dry conditions in the zone of sufficient atmospheric moisture, covering Polissia and the northern regions of the Forest Steppe.

According to the fifth information report on climate change in Ukraine, favorable conditions are expected for the intensive development of dairy cattle breeding and pig breeding in the western Polissia and the right-bank forest-steppe, and meat cattle breeding in the Steppe and western regions of Polissia.

Therefore, from the point of view of increasing agricultural productivity, climate change has both positive and negative consequences. The positives include: improvement of conditions and shortening of harvest times; the possibility of effective introduction of late-ripening varieties (hybrids), which require more thermal resources; improvement of overwintering conditions of agricultural crops and perennial grasses; increasing the efficiency of fertilizer application. The negative ones include: deterioration of grain quality due to an increase in the concentration of carbon dioxide in the air; more frequent and stronger droughts during the growing season; acceleration of humus decomposition in soils; deterioration of soil moisture in the southern regions; failure to ensure complete vernalization of cereals; an increase in the number of pests, the spread of pathogens of plant diseases and weeds due to favorable conditions for their overwintering; the increase in wind and water erosion of the soil, caused by the increase in the number of droughts and extreme precipitation; an increase in the risk of freezing of winter crops due to the lack of stable snow cover with a significant decrease in temperature.

Manifestations of climate change, which are critical for the agricultural sector, also affect forestry, changing the optimal indicators of ecological conditions for forest ecosystems. Thus, the increase in summer extreme temperatures threatens the disappearance of certain species and the appearance of new (including invasive) species, which will affect the species composition and reduce the area of forests. In particular, the study provides the following forecasts for the main forest-forming species:

– common oak – until the end of the 21st century, favorable conditions for the growth of oak will remain only in the west – in the Carpathians and foothills, and satisfactory – in the Lviv region, in the rest of the territory of the modern zone of mixed broad-leaved forests, the conditions for oak will be unsatisfactory and even extreme;

– European spruce – there will be an even further narrowing of the zone of suitable conditions for this species, in fact there will be no favorable conditions for its growth in Ukraine;

– Scots pine – conditions suitable for pine growth (mostly extreme and unsatisfactory) will remain only in the west and on a small area in the north, which will lead to a significant deterioration of the state of pine forests in Ukraine;

– forest beech – conditions suitable for beech growth will be found only in the Carpathians and foothills;

– hanging birch, black alder – there will gradually be a narrowing and displacement of zones with conditions suitable for the growth of these species (especially birch). Conditions optimal for alder and suboptimal for birch will remain only in Transcarpathia (Dniester basin).

7. Vulnerability assessment of the city of Vinnytsia

Vinnytsia is the administrative center of Vinnytsia Oblast, located in the right-bank part of Ukraine within the Podilsk Highlands (Figure 3). The geographical location of the city contributes to the formation of a temperate continental climate on its territory. Vinnytsia occupies an area of 113 km^2 and has a population of 371 thousand people. The city on the banks of the Southern Bug, the administrative center of the region and the modern cultural and economic center of Ukraine. A large number of green areas, park areas, architectural monuments, hotels, shopping centers, themed pubs and restaurants – all this is here in sufficient quantity for even the most demanding tourists. We can say with full confidence that Vinnytsia is quite legitimately considered a real pearl of Podillia, combining comfort and a unique atmosphere of a city that carefully preserves its history and skilfully uses modern opportunities.

Despite the participation of relevant specialists, the assessment results can serve as a pilot illustration showing the procedure for applying the methodology and cannot be the only basis for developing a plan of adaptation measures for these cities. A comprehensive assessment of the city's vulnerability to climate change using the proposed methodology requires the presence of a working group of specialists and thorough

Figure 3. Location of Vinnytsia on the map of Ukraine

preliminary work of its representatives with the necessary statistical information. However, even a cursory assessment by a specialist of seven groups of indicators allows to see the vulnerable elements of the urban ecosystem and can be the basis for priority adaptation measures.

Research results indicate that the climate of Vinnytsia [6; 7], as well as the whole of Ukraine, has already begun to change. According to forecasts, the changes will continue in the future, which may cause significant negative consequences for the nature, population and infrastructure of the city. Table 1 presents the results of this assessment. The description of vulnerability indicators is presented in descending order – from the most vulnerable to the least vulnerable group. Recommendations for increasing Vinnytsia's resilience to climatic manifestations are also presented. The city of Vinnytsia is most vulnerable to flooding (16 points) and to natural hydrometeorological phenomena (14 points). The reason for this is the presence of large water bodies on the territory of the city, the shallowness of groundwater, as well as the wear and tear of the sewage and stormwater systems.

The climate of Vinnytsia is temperate-continental with mild summers, mild winters and a sufficient amount of precipitation (within 550 mm). The most precipitation falls in summer (almost 75%), the least in winter. In summer, there are frequent showers, thunderstorms, sometimes hail. Winds are typical for all seasons, especially for summer. The snow cover is available on the territory of the city from the second half of December to the

Table 1

Vulnerability assessment of the city of Vinnytsia

№ indicator	Group 1. Vulnerability to heat stress	Group 2. Vulnerability to flooding	Group 3. Vulnerability of urban green areas	Group 4. Vulnerability of persistent hydrometrological phenomena	Group 5. Vulnerability to deterioration of water quantity and quality	Group 6. Vulnerability to infectious diseases	Group 7. Vulnerability of the city's energy systems
1	1	0	1	4	0	0	2
2	2	2	1	2	0	4	4
3	1	1	1	2	0	2	2
4	1	2	1	4	0	0	0
5	0	2	0	2	0	4	2
6	0	0	0	-	1	-	-
7	0	1	0	-	2	-	-
8	1	2	0	-	1	-	-
9	0	2	0	-	1	-	-
10	0	2	1	-	1	-	-
11	0	1	0	-	1	-	-
12	0	1	1	-	0	-	-
In total	**7**	**16**	**6**	**14**	**8**	**10**	**10**

beginning of March, its height is 8-10 cm. The annual humidity coefficient is 0.92. The thermal regime is characterized by features of continentality (a change in the large amplitude of temperature fluctuations between winter and summer, which for Ternopil is 23−24ºC). The average temperature of the warmest month (July) is +18...+19°C, and the coldest (January) is -4.5...-5°C. The invasion of continental air masses leads to significant temperature fluctuations: in summer up to +37°C, in winter up to -34°C. The duration of the frost-free period is 150-165 days. The vegetation period of plants is 205-209 days, the period of active vegetation is from the first decade of April to the end of October.

Many weather-related risks in the city will intensify as climate change intensifies, however, if a plan of measures for the adaptation of the city (taking into account the characteristics of the city and expected climate changes) is developed and implemented responsibly, then the expected consequences can be mitigated and somewhat minimize. That is why it is important to take into account the results of the assessment of the vulnerability of cities to the consequences of climate change during the preparation of the General Development Plans of the cities of Ukraine and local plans of adaptation measures to climate change.

Based on the modeling of climate change processes carried out by climatologists of the Cambridge Group from different countries of the world under the auspices of the UN FAO, a further increase in air temperature in the range of 2 to 6ºC in the period up to 2100 is predicted. Such an increase in temperature and concentration of CO_2 in the air will have a direct impact on the Earth's biosphere, in particular on the productivity of the agro-industrial complex, yield and quality of agricultural crops. The negative climate changes in the near term include an increase in air temperature, increased effect of droughts, reduction of snow cover, violation of uniformity the arrival of atmospheric precipitation, which in the complex leads to the activation of erosion processes and soil degradation.

The greatest increase in temperatures occurred in the winter period – December and January by 1.9 and 2.0ºC, respectively. In the summer months – in June and August, the temperature increased by 1.5 and 1.6ºC, respectively. The transition from winter to spring also accelerated, with the temperature rising in March by 1.4°C and in April by 1.1°C.

The increase in air temperature during this period led to an increase in heat input during the growing season. Thus, the sum of positive temperatures during this period increased by 736º, and effective temperatures above 5ºC – by 673º C. This growth was especially noticeable in the last 10-12 years.

Strategy of adaptation of crop production to climate changes involves a scientifically based selection of crops suitable for cultivation both under favorable conditions of moisture supply and capable of withstanding moisture deficits and reacting less to drought.

The optimal parameters of these indicators have been determined for hybrids of different maturity groups. Another group of measures aimed at reducing the risk of regional climate changes should include the following:

– optimization of the specific weight of black steam in individual areas of the region;

– development and implementation of resource-saving, ecologically safe and soil-protecting methods of watering agricultural crops for reducing the dependence of productivity of the plant industry on the influence of adverse weather conditions;

– improvement of soil properties for better moisture accumulation;

– restoration of forest protection strips in order to prevent soil degradation and land desertification;

– development of innovative technologies for growing agricultural crops aimed at accumulation and economical use natural moisture.

8. Climate modeling of the city of Vinnytsia

Studies of the climate of Ukraine show that during the last ten years the temperature and some other meteorological parameters differ from the values of the climatic norm (1960–1990). The average annual air temperature over the past twenty years (1991–2010) has increased by 0.8°C relative to this indicator, there has been a redistribution of the amount of precipitation by regions of Ukraine and by seasons (although in general the amount of precipitation has remained practically unchanged during the year) and an increase in the amount the manifestation of individual storms (very heavy rain, strong wind, very heavy snowfall, heavy fog, etc.), as well as the occurrence of heat waves became more frequent during the last decade.

Climate modeling for the territory of Ukraine indicates that the increase in air temperature in general will continue. A further change in the amount of precipitation during the year will lead to a shift in the climatic seasons, a change in the length of the growing season, a decrease in the duration of the permanent snow cover, a change in the water resources of the local runoff, etc. The consequences of climate change, manifested in the urban environment, cause a negative impact on it.

The concentration of a significant number of people in cities, the peculiarities of the local microclimate, which may exacerbate some of the negative consequences of climate change, a change in the dominant supporting surfaces of the city, high-rise buildings, the presence of a network of urban transport and a well-developed infrastructure (which may suffer damage from the negative impact of climate change and cause significant discomfort for the city's population) makes the city significantly more vulnerable to the manifestations of climate change compared to other territories.

The main potential negative consequences of climate change that can manifest in cities include: heat stress; flooding; reduction of areas and disturbance of the species composition of urban green zones; spontaneous hydrometeorological phenomena; decrease in the quantity and deterioration of the quality of drinking water; increase in the number of infectious diseases and allergic manifestations; disruption of the normal functioning of the city's energy systems. In order to assess the vulnerability of cities to the negative consequences of climate change, we have developed seven groups of indicators, with the help of which it is possible to determine the most dangerous consequences of climate change for the city and establish for which of these consequences it is necessary to develop adaptation measures, for which it is desirable and for which it is unnecessary.

Groups of indicators were tested to assess the vulnerability of the city of Vinnytsia, which is located in the center of Ukraine. To facilitate the preparation of the city's adaptation plan, a list of adaptation measures (by individual consequences) has been drawn up and the main principles of its preparation have been defined:

1. Adaptation to climate change in the city requires a comprehensive approach and implementation of measures at different levels.
2. During the formation of the city-wide plan for adaptation of the city to climate change, it should be noted that there are measures that help to mitigate several negative consequences of climate change at once, therefore, their implementation will be the most effective for the adaptation of the city.
3. If the plan is developed by industry or by negative consequences, it should be carefully analyzed to see if there are any measures that contradict each other.
4. For certain negative consequences of climate change, it is important to develop a system of monitoring/early warning of the population/risk management – this will make it possible to at least partially minimize the damages caused by meteorological factors;
5. One of the important organizational tasks during the development of city adaptation measures is the implementation of a powerful information campaign aimed at different target audiences (from the youngest residents of the city to the oldest).

9. Practical value and conclusions

Global climate change has become one of the most urgent environmental problems to which humanity's attention is focused. Its consequences are dangerous weather cataclysms, sudden weather changes, floods, floods, strong winds, showers and rains, hail, droughts, which lead to significant ecological and economic losses all over the world. According to the World Meteorological Organization, the last three years have been the three warmest years on record. Increasing unpredictability of weather conditions threatens food production, rising sea levels increases the risk of natural disasters. Adaptation to global climate change is the process of adaptation in natural or human systems in response to actual or expected climatic impacts, which will reduce their negative consequences and take advantage of favorable opportunities. The humanitarian and environmental consequences of climate change and the pattern of extreme weather are likely to be significant. Globally, more and more people are expressing concern about the potential negative impacts of climate change on society and the economy, which could harm sectors ranging from agriculture to water resources. The worst impacts of climate change are likely to fall disproportionately on the poorest and most vulnerable, who already have few resources to evacuate in the event of a disaster and are ill-prepared to deal with the new challenges of climate change.

References:

1. Adger, W.N., Arnell N.W., Tompkins E.L. (2005). Successful adaptation to climate change across scales. *Global Environment*, 15, 77–86.

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. No. 30 (3). P. 449–459.

3. Amanpreet S., Harmandeep S. Organic Grain Legumes in India: Potential Production Strategies, Perspective and Relevance. *Legume Crops – Prospects, Production and Uses.* 2020. P. 1–18.

4. Atudorei, D., Stroe, S., Codina, G. Physical, physiological and minerals changes of different legumes types during the germination process. *Ukrainian Food Journal*. 2020. Volume 9. Issue 4. P. 844–863.

5. Bakhmat O.M. (2012). Modeliuvannia adaptyvnoi tekhnolohii vyroshchuvannia soi. Modeling adaptive technology of soybean cultivation: monohrafiia. Kamianets-Podilskyi: Vydavets: PP Zvolenko D. H.

6. Bandura V., Mazur V., Yaroshenko L., Rubanenko O. (2019). Research on sunflower seeds drying process in a monolayer tray vibration dryer based on infrared radiation. *INMATEN – Agricultural Engineering*, vol. 57, No. 1. P. 233–242

7. Bondarenko V., Havrylianchik R., Ovcharuk O., Pantsyreva H., Krusheknyckiy V., Tkach O. and Niemec M. Features of the soybean photosynthetic productivity indicators formation depending on the foliar nutrition. *Ecology, Environment and Conservation*. 2022. Vol. 28. P. 20–26. DOI: https://doi.org/10.53550/EEC.2022.v28i04s.004

8. Bulgakov V., Adamchuk V., Kaletnik G., Arak M., Olt J. (2014). Mathematical model of vibration digging up of root crops from soil. *Agronomy Research*. No. 12 (1). P. 41–58.

9. Chabanyuk Y.V., Brovko I.S., Mazur S.O., Tymoshenko V.V., Nikyforenko V.M. Biological properties of soils under the action of agrotechnical factors. *Agroecological journal*. 2018. No. 1. P. 115–123.

10. Demydenko O., Bulygin S., Velychko V., Kaminsky V., Tkachenko M. Soil moisture potential of agrocenoses in the Forest-Steppe of Ukraine. *Agricultural Science and Practice,* 8 (2), 49–61.

11. 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. 2020. *Ukrainian Journal of Ecology*. No. 10(5). 54–61.

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

13. Environmental Problems of Agriculture: Tutorial: V.P. Gudz, M.F. Rybak, S.P. Tanchyket al.; Ed. V. Gudz. Zhytomyr National Agroecological University Press, 2010. 708 p.

14. Ermakov, A., Arasymovych, V., Yarosh, N. et al. (1987). Methods Studies biochemically plants. L.: Agropromizdat, p. 430.

15. Garnier, J.M., Travassac, F., Lenoble, V., Rose, J., Zheng, Y., Hossain, M.S., Chowdhury, S.H., Biswas, A.K., Ahmed, K.M., Cheng, Z. Temporal variations in arsenic uptake by rice plants in Bangladesh: The role of iron plaque in paddy fields irrigated with groundwater. *Sci. Total Environ.* 2010, 408, 4185–4193.

16. Gupta S., Bhatia V.S., Kumawat G., Thakur D., Singh G., Tripathi R., Satpute G., Devadas R., Husain S.M., Chand S. Genetic analyses for deciphering the status and role of photoperiodic and maturity genes in major Indian soybean cultivars. *Journal of Genetics*. 2017, 96(1): 147–154.

17. Hashimoto, Y., Furuya, M., Yamaguchi, N., Makino, T. Zerovalent iron with high sulfur content enhances the formation of cadmium sulfide in reduced paddy soils. *Soil Sci. Soc. Am. J.* 2016, 80, 55–63.

18. 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. No. 52. P. 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

19. Hydrological characteristics of the Vinnytsia region. Available at: www.novaecologia.org/voecos-2143-1.html

20. Jia, Y., Bao, P., Zhu, Y.G. Arsenic bioavailability to rice plant in paddy soil: Influence of microbial sulfate reduction. *J. Soils Sediments.* 2015, 15, 1960–1967.

21. Kaletnik G.M., Zabolotnyi G.M., Kozlovskyi S.V (2011). "Innovative models of strategic management economic potential within contemporary economic systems". *Actual Problems of Economics*, vol. 4(118), pp. 11.

22. Kaletnik H., Pryshliak V., Pryshliak N. Public Policy and Biofuels: Energy, Environment and Food Trilemma. *Journal of Environmental Management & Tourism*. 2019. Vol. 10. Issue 2 (24). P. 479–487.

23. 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

24. Kamins′kyy V.F., Vyshnivs′kyy P.S., Dvorets′ka S.P., Holodna A.V. (2005). Znachennya zernovykh bobovykh kul′tur ta napryamky intensyfikatsiyi yikh vyrobnytstva. [Importance of grain legumes and directions of intensification of their production]. *Selektsiya i nasinnytstvo – Breeding and seed production*. Vol. 90. P. 14–22.

25. Kantolic A.G., Peralta G.E., Slafer G.A. Seed number responses to extended photoperiod and shading during reproductive stages in indeterminate soybean. *European Journal of Agronomy*. 2013, 51: 91–100.

26. Kirilesko O.L., Movchan K.I. (2016). Formuvannya vrozhaynosti zernobobovykh kul′tur v umovakh Zakhidnoho Lisostepu Ukrayiny [Formation of legume yields in the Western Forest-Steppe of Ukraine]. *Kormy i kormo vyrobnytstvo – Feed and feed production.* V. 82. S. 127–132.

27. Kober, R., Welter, E., Ebert, M., Dahmke, A. Removal of arsenic from groundwater by zerovalent iron and the role of sulfide. *Environ. Sci. Technol.* 2005, 39, 8038–8044.

28. Kolesnik S. (2012). Bacterial fertilizer to optimize nitrogen and phosphorus nutrition soybeans, chickpeas, peas, lentils and commit. *Feed and fodder*, 73:145–151.

29. Langewisch T., Lenis J., Jiang G.L., Wang D.C., Pantalone V., Bilyeu K. The development and use of a molecular model for soybean maturity groups. Bmc Plant Biology. 2017; 17:13.

30. Li, J., Dong, F., Lu, Y., Yan, Q., Shim, H. Mechanisms controlling arsenic uptake in rice grown in mining impacted regions in south China. PLoS ONE 2014, 9.

31. Li, R., Zhou, Z., Zhang, Y., Xie, X., Li, Y., Shen, X. Uptake and accumulation characteristics of arsenic and iron plaque in rice at different growth stages. Commun. Soil Sci. Plant Anal. 2015, 46, 2509–2522.

32. Liu, W.J., Zhu, Y.G., Hu, Y., Williams, P.N., Gault, A.G., Meharg, A.A., Charnock, J.M., Smith, F.A. Arsenic sequestration in iron plaque, its accumulation and speciation in mature rice plants (Oryza sativa L.). *Environ. Sci. Technol*. 2006, 40, 5730–5736.

33. Liu, W.J., Zhu, Y.G., Smith, F.A. Effects of iron and manganese plaques on arsenic uptake by rice seedlings (Oryza sativa L.) grown in solution culture supplied with arsenate and arsenite. *Plant Soil.* 2005, 277, 127–138.

34. Ludwig, R.D., Smyth, D.J.A., Blowes, D.W., Spink, L.E., Wilkin, R.T., Jewett, D.G., Weisener, C.J. Treatment of arsenic, heavy metals, and acidity using a mixed PVI-compost PRB. *Environ. Sci. Technol*. 2009, 43, 1970–1976.

35. Makino, T., Nakamura, K., Katou, H., Ishikawa, S., Ito, M., Honma, T., Miyazaki, N., Takehisa, K., Sano, S., Matsumoto, S., et al. Simultaneous decrease of arsenic and cadmium in rice (Oryza sativa L.) plants cultivated under submerged field conditions by the application of iron-bearing materials. *Soil Sci. Plant Nutr*. 2016, 62, 340–348.

36. Manning, B.A., Goldberg, S. Arsenic(III) and arsenic(V) absorption on three California soils. *Soil Sci*. 1997, 162, 886–895.

37. Matsumoto, S., Kasuga, J., Makino, T., Arao, T. Evaluation of the effects of application of iron materials on the accumulation and speciation of arsenic in rice grain grown on uncontaminated soil with relatively high levels of arsenic. Environ. Exp. Bot. 2016, 125, 42–51.

38. Matsumoto, S., Kasuga, J., Taiki, N., Makino, T., Arao, T. Inhibition of arsenic accumulation in Japanese rice by the application of iron and silicate materials. Catena. 2015, 135, 328–335.

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. *Ukrainian Journal of Ecology*. 2020. No. 10(1). P. 101–105.

39. 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. No. 8(4). P. 26–33.

40. 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

41. 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

42. 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.

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

44. 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.

45. 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

46. 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

47. 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.* 2020, 18(1), 177–182.

48. Mazur V.A., Zabarna T.A. Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry*. 2018. Issue 2(9). P. 5–17.

49. 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.

50. 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.

51. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons*, 24(7), 53–60. DOI: 10.48077/scihor.24(7).2021.53-60

52. 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.

53. 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

54. 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.

55. 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.

56. 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.

57. 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.

58. Methodology for conducting an examination of varieties for performance, uniformity and stability (VOS). Grain beans of culture. Kyiv, 2000.

59. Methods of qualification examination of plant varieties for suitability for distribution in Ukraine. The general part. 4th ed., Corr. and ext.Vinnitsa. 2017. 119 p.

60. Neiko I.S. Forest genetic component as the basis of key territories of the ecological network of Eastern Podillia. *Bulletin of the Zhytomyr National Agroecological University*. Zhytomyr. 2009. No. 2 (25). P. 170–174.

61. Nosheen S., Ajmal I., Song, Y. Microbes as Biofertilizers a Potential Approach for Sustainable Crop Production. *Sustainability.* 2021. 13 (4), 1868. P. 1–20.

62. OECD Position Paper Regarding the Relationship between the OECD Principles of GLP and ISO / IEC 17025 // ENV/ JM/ MONO 2021.

63. Ona-Nguema, G., Morin, G., Wang, Y.H., Foster, A.L., Juillot, F., Calas, G., Brown, G.E. XANES evidence for rapid arsenic(III) oxidation at magnetite and ferrihydrite surfaces by dissolved O_2 via Fe^{2+}-mediated reactions. *Environ. Sci. Technol.* 2010, 44, 5416–5422.

64. 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.

65. Pancy`reva G. V. (2016). Doslidzhennya sortovyx resursiv lyupynu bilogo (Lupinus albus L.) v Ukrayini. Vinnycya, 4, 88–93.

66. 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.

67. 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

68. Pantsyreva, H. V. (2016). Doslidzhennia sortovykh resursiv liupynu biloho (Lupinus albus L.) v Ukraini. *Silske hospodarstvo i lisivnytstvo*, 4, 88–93.

69. 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.

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

71. Shkatula Yu.M. Agro-ecological substantiation of meliorative measures to improve the condition of the soils of the Kalyniv district. *Agriculture and forestry*. 2019. Issue 3(14). P. 220–230.

72. Sichko T.V., Khomenyuk V.O. Analysis of the use of the resource potential of soils of the Vinnytsia region. *Collection of Scientific Works of VNAU. Series Agriculture and forestry*. Issue 5.

73. Tsytsiura Y.G. Evaluation of the soil cover of Vinnytsia for suitability for organic production. *Agriculture and forestry*. 2020. Issue 1 (16). P. 13–27.

74. 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.

75. 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.

76. 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.

77. 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.

78. 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. No. 8(3). 47–53.

79. Wide unified CMEA classifier and the international CMEA classifier of the genus Glycine Willd. Leningrad: VIR, 1981; 1990 p.

80. Wolters D., Beste A. Biomasse – umweltfreundlicher Energieträger? Ökologie und Landbau. 116, 4, 2000. S. 12–14.

81. Xing, X., Jiang, H., Zhou, Q., Xing, H., Jiang, H., & Wang, S. (2016). Improved drought tolerance by early IAA – and ABA-dependent H_2O_2 accumulation induced by α-naphthaleneacetic acid in soybean plants. Plant Growth Regulation, 80(3), 303–314.

82. Yanovych, V., Honcharuk, T., Honcharuk, I. & Kovalova, K. (2017). Design of the system to control a vibratory machine for mixing loose materials. *Eastern-European Journal of Enterprise Technologies*, 6(3-90), 4–13.

83. Yanovych, V., Honcharuk, T., Honcharuk, I. & Kovalova, K. (2018). Engineering management of vibrating machines for targeted mechanical activation of premix components. *INMATEH – Agricultural Engineering*, 54(1), 25–32.

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

Hanna Pantsyreva[1]
Kateryna Mazur[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-6

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

---

[1] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine
[2] Candidate of Economics Sciences, Professor, Associate Professor,
Vinnytsia National Agrarian University, Ukraine

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).

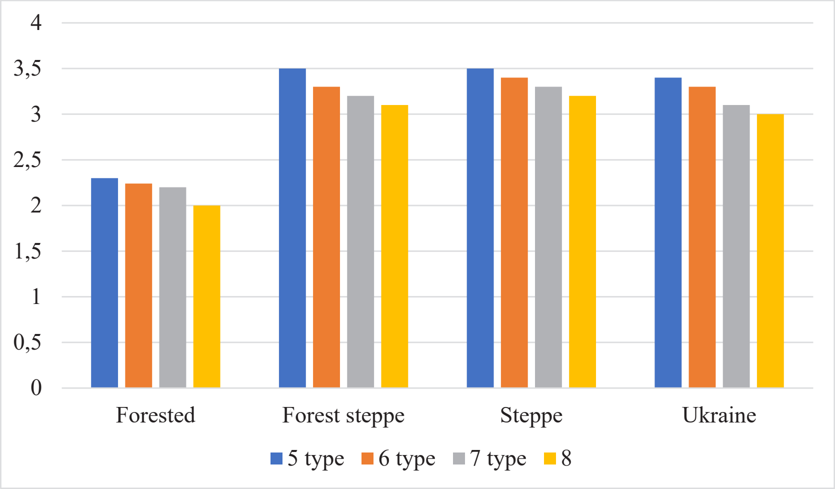


Figure 1. Dynamics of humus content in the soil for 2000–2020

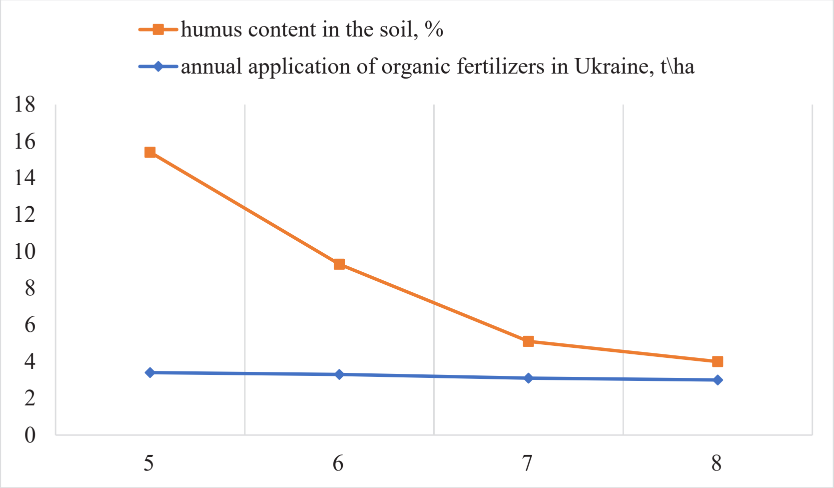


Figure 2. Dynamics of humus content
in the soil and application of organic fertilizers

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).

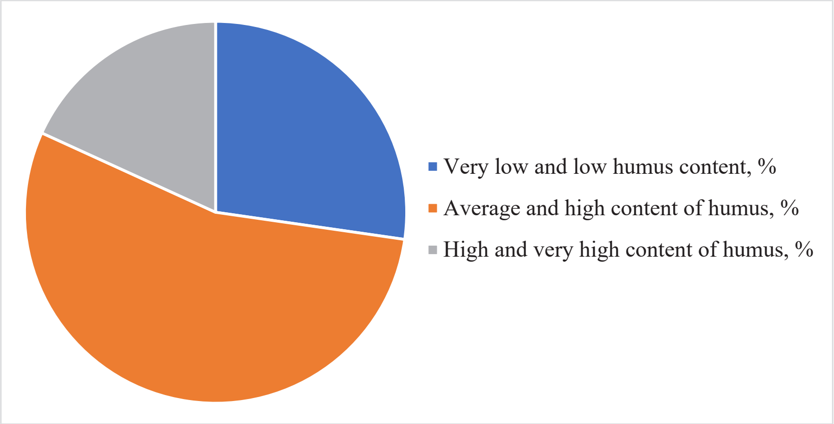


Figure 3. Structure of agricultural land for content of humus

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.

CURRENT STATE OF THE DEVELOPMENT OF DEGRADATION PROCESSES IN THE SOIL COVER OF VINNYTSIA REGION

Lyudmila Pelekh[1]
Tetiana Zabarna[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-7

Abstract. Soil resources are the basis of the development of the agrarian sector of the country's economy and ensuring a favorable environment for humans, therefore the protection and rational use of soils is an important component of national security. In terms of the quality of soil resources, Ukraine occupies one of the leading places in the world, and the concept of "Ukrainian chernozem" is our image feature. *The purpose.* Study of the degradation processes of the soil cover of the Vinnytsia region. *Methodology*. In the course of researching the topic of our work, we used the materials of the annual statistical reports of the main statistics department in the Vinnytsia region, as well as materials provided by the Vinnytsia branch of the Institute of Soil Protection of Ukraine, the State Environmental Inspection in the Vinnytsia region. *Result*. Unfortunately, due to the inefficient management of soil resources in Ukraine over the last quarter of a century, most of the soil is in a pre-crisis state, and in some places in a crisis state with a tendency to deteriorate. A third of Ukraine's arable land is eroded, about 40% is over-compacted and 20% has unregulated acidity, almost 70% of arable land has a deficit of available moisture for plants, and the balance of nutrients remains deficient. In recent years, in connection with global climate changes, the consequences of crisis phenomena in the state of soils have become even more tangible and threatening, and the introduction of the land market necessitates their urgent overcoming. *Practical implications.* The unsatisfactory state of affairs in this area requires comprehensive consideration and the implementation of appropriate regulatory measures.

---

[1] Candidate of Agricultural Sciences, Senior Lecturer,
Vinnytsia National Agrarian University, Ukraine
[2] Candidate of Agricultural Sciences, Senior Lecturer,
Vinnytsia National Agrarian University, Ukraine

On the other hand, the scientifically based use of Ukraine's unique soil resources will contribute to Ukraine's successful promotion to the world food market, as well as the diversification of economic development. *Value/originality.* This indicates the relevance and necessity of solving the problem of sustainable management of the country's soil resources. Out of 60.3 million hectares of its territory, 42 million hectares are agricultural lands, 33.2 million hectares are under arable land. Over the last 30 years, the area of eroded arable land increased by 1.9 million hectares, that is, 64 thousand hectares were lost every year, and now the area of eroded land is 11.3 million hectares, or almost a fifth of the entire territory of Ukraine. Application of monocultures in large regions, violation of crop rotation, almost complete rejection of organic fertilizers, reduction of the share of leguminous crops lead to dehumification of soils, reduction of yields.

1. Introduction

The main problem of soil resources in Ukraine, as well as in other countries with an underdeveloped system of soil protection, which poses a threat to national security, is soil degradation. The most characteristic degradation processes in soils are the following: losses of humus with an intensity of 0.42–0.51 t/ha per year and nutrients, especially phosphorus and potassium; erosion losses of the upper fertile layer; over-compaction, destruction of the structure, lumpiness and crust formation; acidification of soils, especially in Polissia and the Carpathian region; secondary salinization and salinization of irrigated soils; activation of peatlands; pollution by radionuclides (11.1% of arable land), pesticides (9.3%) and heavy metals (8%) [12].

In recent years, many new ideas and approaches aimed at protecting soil resources have been born in the world. The Global Soil Partnership (GSP), whose mission is to improve the global management of the planet's limited soil resources to ensure healthy and productive soil for world food security, as well as to support other key ecosystem activities on which our society depends, including regulating water regimes and provision of clean water, climate regulation, preservation of biodiversity and cultural heritage [26; 56].

The main priorities for the European region are: "sealing" or sealing of soil, salinization and pollution. Soil "sealing" and land extraction. In the densely populated countries of Western Europe, soil sealing is one of the most dangerous phenomena. The European Commission has already carried out significant work to raise awareness of this problem and proposals to eliminate the negative trend.

Salinity and acidity. Salinity is a widespread threat in Central Asia, and it is a challenge in parts of Spain, Hungary, Turkey and Russia. With considering the importance of the problem in Eurasia, this the topic will be considered in the framework of this plan for the implementation of the EGP and the sub-regional soil partnership for Eurasia [60; 65].

Soil pollution. Soil pollution is a widespread problem in Europe and manifests itself most strongly locally. The most common pollutants there are heavy metals and mineral oils. Situation is already improving in most regions and has been specifically reviewed by the European Environment Agency (EEA) EIONETNRC network.

Proposals for discussion for future participants of the UEP:

a) the most common pollutants are agrochemicals that degrade soil biodiversity and are closely related to ecosystem activities;

b) diffuse pollutants.

These additional threats to the maintenance of a wide range of soil functions, which are necessary to meet many of the Sustainable Development Goals, are also worthy of consideration by the EGP. At the EU level, as stated in the 2012 report of the Commission on the Implementation of the Soil Thematic Strategy and Current Activities, soil degradation is increasing in the EU.

Let's consider the indicated problems in a little more detail. The EHP report is of some interest in terms of information, because it contains the latest materials on the state of European soils.

In addition, the authors of the report suggest focusing the efforts of the future members of the UEP on identifying and overcoming various problems of soil degradation in their countries.

Soil sealing (permanent covering of the soil with impermeable material) and related land acquisition lead to loss of important soil functions (for example, water filtration and storage, and food production). Between 1990 and 2000, at least 275 hectares of soil were lost per day in the EU, amounting to 1,000 square kilometers per year. Between 2000 and 2006, average soil loss in the EU increased by 3%, including 14% in Ireland and Cyprus, and 15% in Spain. Between 1990 and 2006, 19 EU member states lost potential agricultural production equivalent to a total of 6.1 million tonnes of wheat, with large regional variations.

A recent new water-induced soil erosion model built by the JRC (EU Joint Research Center in Ispra, Italy) estimated the affected surface area in the EU27 at 1.3 million km². Almost 20% of them have soil losses exceeding 10 t/ha/year. Erosion is not only a serious problem for soil functions (estimated to cost €53m per year in the UK alone); it also affects fresh water quality because it leaches nutrients and pesticides into water bodies. For example, agricultural losses of phosphorus exceed 0.1 kg/ha/year in most of Europe, and reach a level of more than 1.0 kg/ha/year in problem areas (hot spots). The fight against the prevention and prevention of erosion will be a key contribution to the achievement of the EU goals. Soil erosion is particularly intense in wildfire areas, which are estimated at 500,000 ha/year according to the European Forest Fire Information System (EFFIS) and leads to the loss of soil carbon.

The risk of erosion is highest in Spain (up to 44% of the territory), Slovakia (up to 40%), Portugal (up to 33%), Bulgaria, Andalusia, Corsica, central Italy and Greece. The smallest is in northern Europe. It is difficult to give a quantitative assessment of local soil pollution in full, because most of the EU member states do not have comprehensive studies and comparable information. In 2006, the European Environment Agency estimated that there was a total of 3 million hectares of contamination (European Information and Observation Network EIONET and National Soil Reference Centers NRC), potentially 250,000 contaminated sites in the EU. Remediation is underway, although there are large variations between EU member states reflecting the presence or absence of national legislation. It was estimated that in 2004, costs for soil restoration in the EU27 amounted to €5.2 billion, of which 21.6% in Germany, 20.5% in the Netherlands, and 5.9% in France and Great Britain [25; 44].

Soil biodiversity provides solutions to numerous issues, including the transformation of nutrients into forms that can be used by plants and other organisms, water purification by removing pollutants and pathogenic microorganisms from it, maintaining the composition of the atmosphere in a favorable state, participation in the carbon cycle, and also as a major source of genetic and chemical resources (for example, antibiotics). The indicator-based map prepared by the JRC shows a preliminary assessment of the regions where it is located soil biodiversity is under threat. It includes areas with high population density and/or intensive agricultural activity (for example, cultivation of grain and industrial crops, livestock, greenhouses, orchards, vineyards and horticulture).

2. Analysis of recent research and publications

A significant part of the country's land fund is subject to degradation, and in the case of its uncontrolled development, it can replenish the share of land in need of conservation. Loss of humus. For 140 years, since the first measurements of the humus content in the soils of Ukraine, carried out by V.V. Dokuchaev, humus losses in the soils of the forest-steppe reached an average of 22%, in the soils of the steppe – 19.5%, and in the soils of Polissia – about 19%. The greatest losses of humus occurred in the 1970s, when the share of row crops – sugar beets and sunflowers – increased dramatically in the structure of crops. It was possible to partially stop humus losses thanks to the annual application in the country of an average of 8.4 t/ha of manure and about 170 kg of d.r.y. of mineral fertilizers per 1 ha of arable land. In subsequent years, the decrease in fertilizer application led to a gradual decrease in humus content from 3.36% in 1986–1990 to 3.14% in 2006–2010.

In 2011–2015, agricultural enterprises applied from 2.5 to 4, 8 t/ha of straw and 11.6–16.6 t/ha of siderates annually, which contributed to stopping the decrease in humus content. Loss of nutrients. Until 1990, in Ukraine, on average, about 150 kg of d.r./ha was applied with a N:P:K ratio of 1:0.7:0.7 on an area of about 90% of arable land. Until 1996–1998, the restructuring of social and economic relations was accompanied by a sharp decrease in the level of agricultural chemicalization to 20–30 kg d.y./ha, but since the beginning of the century and until now, there has been a gradual increase in the use of mineral fertilizers to the level of 80–110 kg d.y. ./ha on an area of 80% arable land with a N:P:K ratio of 1:0.2:0.2. According to the State Committee of Statistics of Ukraine, in 2017, agricultural enterprises contributed 48.9 kg of NPK per 1 ha of agricultural land. The balance of NPK in the agriculture of Ukraine in 2017 was negative for all nutrients and totaled 36.0 kg/ha.

Soil erosion. Compared to European countries, whose arable land makes up 30–32% of the total area, plowed land in Ukraine reaches 53.8%. Such an imbalance in the structure of agricultural land was formed half a century ago during the campaign in the former USSR to increase the area of arable land at the expense of erosion-dangerous, eroded, low-fertility slopes, as well as valuable and irreplaceable in the aspect of environmental protection. As a result of the extremely high level of plowing of agricultural land, there was a very high risk of water and wind erosion. The total area of eroded land has now increased to 13.4 million hectares, and arable land to 10.6 million hectares (32% of all arable land). Up to 500 million tons of topsoil is washed away from arable land every year, with which 24 million tons of humus are lost, and losses of agricultural products from soil erosion, according to expert estimates, exceed 9–12 million tons of grain units per year. The eroded lands include 4.5 million hectares with moderately and severely eroded soils, including 68,000 hectares that have completely lost the humus horizon. More than 50% of Ukraine's arable land is deflationally dangerous, 12.4 million hectares of which are located in the steppe zone. Physical degradation of soils. Phenomena of physical soil degradation are observed on more than half of the arable lands. Physically degraded soils are vulnerable to erosion, absorb and retain atmospheric moisture worse, limit the development of plant root systems. Soil compaction is the most dangerous consequence of intensive mechanical cultivation in all natural zones of Ukraine, which is accompanied by adverse ecological consequences and significant economic losses. The high vulnerability of soils to overcompaction is noted in chernozem soils with low equilibrium density and moisture, which is equal to or higher than the moisture of physical maturity. Almost 22 million hectares of arable land are at real risk of over-compaction. Secondary salinization and salinization of soils. According to the State Geocadastre, there are 2.8 million hectares of saline soils in Ukraine, 2 million hectares of which are used as arable land, and about 0.7 million hectares are irrigated.

Over the past twenty years, measures for reclamation of saline soils in Ukraine have been carried out unsatisfactorily. The volumes of gypsum and other gypsum-containing rocks decreased from 1341 thousand tons in 1990 to 16 thousand tons in 2015, and the area – from 305 thousand hectares to 7.1 thousand hectares, respectively. Under such a system of agriculture, there is a widespread deterioration of the quality of the solontic soils, the loss of their fertility and the productivity of agrocenoses on these lands. Other degradation processes and damages from degradation. The qualitative state of land resources is significantly affected by hydrometeorological and dangerous exogenous geological processes and phenomena (slides, landslides, landslides, karst, soil subsidence, abrasion, destruction of reservoir banks, etc.), which are spread over more than 50% of the territory. Flooding processes are developing on 17% of the territory. According to various estimates, the area of degraded and infertile soils in arable land is from 6.5 to 10 million hectares, or more than 20% of the area. Direct annual losses only from crop failure due to the main types of soil degradation reach a total of about UAH 33.6 billion in Ukraine. As a result of the spread of degradation, the soil potential for grain production in Ukraine, which is 80–100 million tons, is realized by only 70%.

3. Literature review

Analysis of the latest research and publications shows that the problem of sustainable soil management is currently being actively studied by foreign scientists. So, for example, the Voluntary Guidelines for Sustainable Soil Management (VGSSM) and global actions to ensure soil health are in the field of view of scientists [1]; evaluation and regulation of the implementation of sustainable soil management practices [2]; managing the solution of soil protection problems [3], including through relevant legislation and policy [4]; long-term effectiveness of sustainable land management practices to control runoff, soil erosion, and nutrient loss in agroecosystems [5]; opportunities and barriers for sustainable management of soil resources [6]; tools of sustainable soil management: soil ecosystem services, energy and economic analysis [7]; assessment of soil quality for sustainable land use and management [8]; analysis of the possibilities of using consulting services to support sustainable soil management [9]. At the same time, domestic scientists are investigating the genetic and production aspects of the development of Ukrainian agronomic soil science [10]; the role of soils in the development of society [11]; formation of sustainable systems of land use and soil protection in modern conditions [12]; scientific principles of sustainable management of soil resources of Ukraine [13]; the influence of soil fertility and land quality on the formation of sustainable competitiveness of agricultural enterprises [14]; efficiency of agricultural land use [15]; spatial features of soil cover as the basis of sustainable soil management [16]. The ecological and economic foundations of a holistic concept of sustainable soil management in Ukrainian agriculture are outlined in the monograph of one of the co-authors [17]. In previous studies, it was established that the existing soil resource management system in Ukraine is not sufficiently balanced and does not ensure the preservation of soil fertility, therefore the problem of preserving soil resources and overcoming soil degradation in Ukraine requires new approaches and a comprehensive solution in the legislative, organizational, institutional, informational, technological and financial aspects [12–23]. Therefore, it is necessary to solve the issue of scientific substantiation of the national strategy of sustainable management of soil resources in order to achieve a neutral level of degradation and guarantee national security.

4. Intensity of contamination of agricultural soils with toxicants

In Vinnytsia, the natural and climatic conditions are favorable for the development of agriculture and animal husbandry. The unique investment potential of the Vinnytsia region is the land fund. The region has the largest share of Ukrainian chernozems, a significant part of them, 21%, is chernozem type lands. This is a unique concentration of high-quality land resources. According to statistical data, more than 2 million hectares of agricultural land, which is 3.3% of the area of Ukraine, are reserved for land users.

It is known that soil quality is a combination of its physical, chemical and biological properties, which have undergone significant changes due to an ineffective system of economic land use, soil reproduction and progressive degradation of agricultural landscapes.

Ukrainian lands, in particular, the soils of the Vinnytsia region, are degrading as a result of negative processes that accompany the use of agricultural lands, namely: loss of humus and nutrients; drying (desertification) and overwetting (waterlogging), salinization and acidification, pollution by discharges, emissions, waste, chemical means of plant protection, erosion damage. Summarizing these changes, it can be noted that the condition of the soils causes a decrease in their functions in agro-ecosystems. Characteristics of soil quality are based on characteristics of soil processes, as well as indicators acquired as a result of economic activity or anthropogenic changes.

It is known that the increase in soil acidity contributes to a noticeable decrease in the yield of agricultural crops and reduces the quality of produced products, which requires an additional increase in the use of mineral fertilizers and, as a result, an increase in soil pollution with heavy metals, nitrates and other harmful substances. The dynamics of soil acidity in the Vinnytsia region according to the data of the Vinnytsia branch of the Institute of Soil Protection of Ukraine is shown in Figure 1.

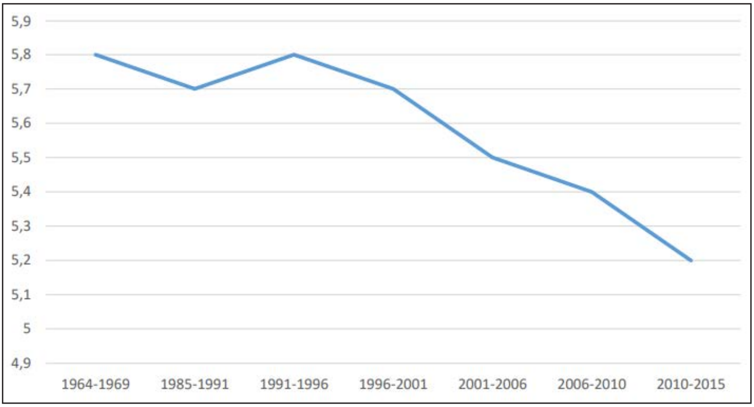


Figure 1. Dynamics of soil acidity in the Vinnytsia region (Institute of Soil Protection of Ukraine)

So, at present, the methods of improving the soil have been determined. The main ones are formed in the following directions:

– increasing the sustainability of agricultural landscapes;
– increasing the level of natural biogeochemical cycles;
– restoration of soil fertility;
– ensuring environmental cleanliness of all types of agricultural products.

5. Current state of the development of degradation processes in the soil cover of Vinnytsia region

It is reported [13] that soil degradation is the deterioration of useful properties and soil fertility due to the influence of natural or anthropogenic factors. Land degradation – natural or anthropogenic simplification of the landscape, deterioration of the condition, composition, useful properties and functions of the land and other natural components organically connected to the land. Soil pollution – accumulation of substances in soils that negatively affect their fertility and other useful properties. The main cause of soil degradation is human activity (anthropogenic intervention). Humanity, with a population of more than 5 billion people and an annual increase of 80-85 million, having mastered various technologies to ensure the desired benefits and life comfort, is changing the nature of the planet on a global scale. Unaware of the dangers, individual nations and humanity as a whole involve the Earth in a grandiose experiment, the course and consequences of which people can neither predict nor control. Degradation, soil erosion, reduction of the humus cover of the planet, contamination with poisonous chemical and biological compounds and radionuclides are the obvious consequences of anthropogenic influence on the earth. Industrial society involuntarily accelerates processes of a planetary scale, which it is not ready to manage either morally, intellectually, or materially clearly defined.

Out of 60.3 million hectares of its territory, 42 million hectares are agricultural lands, 33.2 million hectares are under arable land. Over the last 30 years, the area of eroded arable land increased by 1.9 million hectares, that is, 64 thousand hectares were lost every year, and now the area of eroded land is 11.3 million hectares, or almost a fifth of the entire territory of Ukraine. Application of monocultures in large regions, violation of crop rotation, almost complete rejection of organic fertilizers, reduction of the share of leguminous crops lead to soil dehumification, reduction of yield.

Natural fodder lands and pastures, too so-called public, practically never received either organic or mineral fertilizers. Ukrainian farmers, who currently use 2.6% of agricultural land and produce 0.9% of crop and 0.4% of livestock products, use almost no fertilizers.

Norms for indicators of land degradation are established for each category of land in order to prevent deterioration of their condition and are used to control the use and protection of land. Standards for indicators of land degradation include indicators of the maximum permissible deterioration of the state and properties of land resources due to anthropogenic influence and negative natural phenomena, as well as standards for the intensity of agricultural land use. The use in agricultural production of agricultural machinery, the specific pressure of the running parts of which exceeds the standards, is prohibited. Indicators of the intensity of agricultural land use are established taking into account the

Table 1

Distribution and types of soil degradation in Ukraine

Types of soil degradation	Spread (% of the total area) according to the degree			
	weak	medium	strong	all
Loss of humus and nutrients	12	30	1	43
Condensation	10	28	1	39
Swimming and crust formation	12	25	1	38
Water erosion	3	13	1	17
Acidification	5	9	0	14
Waterlogging	6	6	2	14
Pollution with radionuclides	5	6	0,1	11,1
Wind erosion, loss of the top layer of the soil	1	9	1	11
Pollution by pesticides and other organic substances	2	7	0,3	9,3
Pollution by heavy metals	0,5	7	0,5	8
Salting, alkalizing, salting	1	3	0,1	4,1
Water erosion, formation of ravines	0	1	2	3
Side effect of water erosion (due to siltation of reservoirs, etc.)	1	1	1	3
Lowering of the upper level of the daytime surface	0,05	0,15	0,15	0,35
Deformation of the Earth's surface by wind	0,04	0,23	0,08	0,35
Aridization of soils	0,04	0,18	0	0,21

data of agrochemical land certification. When establishing indicators of the intensity of agricultural land use, agricultural crops whose cultivation is limited or prohibited are determined, as well as technologies and separate agrotechnical operations for their cultivation. Indicators of the intensity of agricultural land use are used in the process of drawing up design and technological documentation for the cultivation of agricultural crops. In Ukraine, there is a need to significantly reduce the percentage of plowed areas, turn arable land into cultivated pastures, return the land to its natural state, apply economical methods of farming and animal husbandry, and rationalize all expenses for the production of bread and food.

Vinnytsia, as an intensively active agro-industrial region, has not remained aloof from the outlined directions of soil cover degradation. As will be shown in the following subsections, the issue of dehumification and decalcification of soils, contamination by radionuclides, heavy mists and pesticide residues, general signs of agrophysical degradation (overcompaction, decrease in the content of agronomically valuable structures, the content of water-soluble of such units, etc.

6. Development of erosion processes

In Vinnytsia region, 79% of agricultural land and 75.5% of arable land are degraded to varying degrees (including 9.4% – highly degraded). The main cause of soil degradation is accelerated water and wind erosion, as a result of the location of arable land on slopes of more than 20, as well as the use of environmentally dangerous equipment and technologies, etc. According to SE "Vinnytsia Institute of Land Management", there are 641.9 thousand hectares of erosion-hazardous land in the region. Such scientists as O.V. Mudrak, O.V. Dedov, M.M. Hanchuk, H. Denisyk. On the basis of the generalization of their scientific research and the results of reports on the state of the region's environment, this subsection was written [1; 23; 29; 39; 68].

The soil cover of the region is one of the most eroded (41.2%) among the regions of Ukraine, including 35.6% of arable land. The general characteristics of the erosion of the territory and its analysis from the standpoint of geomorphology and anthropogenic landscape changes and covered in recent publications [16; 52].

Therefore, some of the indicators will be duplicated in the context of a more detailed assessment of soil erosion in the region. 851.1 thousand ha were damaged by water erosion, which is 37.2% of the total area of agricultural land, including arable land located on a slope of more than 2-70 – 575.7 thousand ha (31%) and 40 thousand hectares of fodder land, and more than 70 – 20.5 thousand hectares (see table 2). As part of the soil cover, light gray and gray podzolic soils are the most eroded (36-39.8% of eroded soils from the total survey area according to various estimates) [3; 19; 26; 38; 48],

Light gray and gray forest soils have the lowest anti-erosion ability among the soils of the region – their erodibility is 37.2% with an erosion instability coefficient of 0.47 – 0.57 for unwashed soils, up to 0.66 – 0.74 in lightly washed soils and almost 1 .0 in the middle and strong declensions. The area of their distribution in the region is 632.7 thousand hectares.

Unlike deep, shallow, low-humus chernozem soils, they have a very high percentage of erosion – 49% (more than that of charred soils), but they have a small distribution area – 1.6%. This intensive development of erosion is explained by their location, namely, the steepness of the slopes and the southern exposure, where the temperature regime of snowmelt promotes erosion. These soils are common in the south of the region in the land uses of Chechelnytskyi, Kryzhopolskyi and Pishchanskyi districts.

Black soils and turf soils on dense and loose carbonate and non-carbonate rocks, which were formed in the conditions of steep and steep slopes in the large catchment areas of the Yampil, Mogilev-Podilsky, and Shargorod districts, have a very low anti-erosion ability. The erodibility of these soils is 97.3%. But the area of their distribution is insignificant (0.1%) and therefore they have little effect on the general erosion of the territory of the region.

In addition, the danger of erosion development is closely related to the following factors:

Table 2

Distribution of soils in Vinnytsia according to gradations of slope steepness and degree of erosion

Steepness of slopes, degrees	The area of the village land		Uneroded		Weakly eroded		Moderately eroded		Strongly eroded		% of all eroded lands within gradations
	thousand hectares	%	thousand hectares	%	thousand hectares	%	thousand hectares	%	thousand hectares	%	
0–2	1225,4	66,6	1188,1	97,0	37,3	3,0	-	-	-	-	3,0
2–5	444,8	24,2	274,5	16,7	333,8	75,1	33,8	7,6	2,7	0,6	83,3
5–10	154,9	8,4	3,9	2,5	43,9	28,3	79,9	51,6	27,2	17,6	97,5
10	14,2	0,8	-	-	-	-	4,7	33,0	9,5	67,0	100
Total, hectare	1839,3		1266,5		415,0		118,4		39,4		
%	100,0		68,9		22,6		6,4		2,1		

1) water permeability, which, along with the intensity of precipitation, determines the possibility and intensity of runoff formation;

2) anti-erosion resistance of soils – their ability to resist washing and erosion, water flows and

3) the general level of soil fertility, which largely determines the level of the ability of agricultural crops to protect the soil.

Water permeability is the most important property of the soil, which best characterizes the soil in physical terms and determines its water regime. The water balance of the soil, including the surface runoff, and, therefore, the erosion resistance of the soil largely depends on the water permeability.

Therefore, the water permeability of soils is understood as the phenomenon that occurs in the soil during the entry of water onto its surface, that is, it is the ability soil to pass water through itself. The phenomenon of water permeability consists of two phases:

1) soil saturation with water (absorption or infiltration) and

2) penetration of water through the soil layer that is maximally saturated with water (seepage or filtration). Therefore, in the process of conducting the experiment, we determine two values that characterize water permeability: the rate of absorption and the rate of filtration. The speed of absorption is determined by the amount of water that has passed per unit of time for the maximum saturation of the studied soil layer (up to the maximum field moisture capacity). The rate of filtration is the rate of passage of water through the soil layer that is maximally saturated with water. Naturally, there is no solid boundary between the first and second phases.

The first phase can be divided into two stages. The first stage is pure absorption, when water enters the soil, which does not reach the field moisture capacity, and moves in it under the action of the suction forces of the surface of soil particles and capillary menisci. The action of gravity is not significant. In the second stage, discharge prevails. At this stage, the absorbent capacity of the soil is reduced to a minimum, and the film, capillary and gravitational movement of water prevails.

The transition to the second stage occurs faster in those soils and soils with greater non-capillary porosity. Through non-capillary pores, water moves under the influence of gravity, the effect of molecular forces in non-capillary pores is negligible. Thus, water retention in the soil is determined by its capillary permeability, and filtration depends on non-capillary spaces in the soil. And, finally, in the filtration phase, water moves through the studied soil horizon under the influence of gravity.

When characterizing the water permeability of the soil, in addition to the speed of absorption and the speed of filtration, the total amount of absorption for a certain period of time is also given – the water layer (in millimeters). Absorption and filtration rates are usually given in millimeters per minute. O.N. Kaczynskii proposed the gradation of soils by water permeability. If the soil passes more than 1000 mm of water in 1 hour at a pressure of 5 cm and a temperature of 10 C, the water permeability is considered poor, from 1000 to 500 mm – excessively high, from 500 to 100 – the best, from 100 to 70 mm – good, from 70 to 30 mm – satisfactory, less than 30 mm – unsatisfactory.

Thus, the speed and quality of soil water permeability determines the potential risk of soil erosion.

7. Practical value and conclusions

The results of the analysis of the dynamics and current condition of soils and their fertility are objective evidence of the growth of their degradation rates: reduction of humus and nutrients reserves, over-compaction, erosion, acidification, salinization, salinization, etc. – about 17 types in total. The main causes of degradation are a shortage of organic and mineral fertilizers, a decrease in the amount of chemical reclamation, insufficient protection of soils by agroforestry measures, but most importantly, insufficient interest of land users in preserving and restoring soil fertility. Currently, the area of degraded and infertile soils is more than 8 million hectares, and the direct annual loss of income only from crop failure due to the main types of soil degradation reaches a total of about 33.6 billion UAH in Ukraine. Despite the strengthening of soil degradation processes, funding for anti-erosion and soil protection measures is decreasing. During 2009–2014, the amount of state budget funds for the implementation of land protection works decreased by almost 20 times compared to previous years. During 2015–2020, the state budget did not allocate funds for soil conservation and reproduction works, ensuring their rational use, which made it impossible to implement the necessary measures. The Law of Ukraine "On Land Protection" provides for the development of the National Program for Land Protection. However, until now, such a program has not been approved in Ukraine. Article 184 of the Land Code of Ukraine, Article 36 of the Law of Ukraine "On Land Management" and Article 54 of the Law of Ukraine "On Land Protection" determine the need for a periodic (every 20 years) continuous survey of the soil cover of Ukraine. Unfortunately, such surveys have not been conducted for 40 years, although the soil cover has undergone significant changes. Among the strategic priorities for solving problems, the following are the main ones: adoption and practical implementation of the National (nationwide) soil protection program; carrying out a repeated solid survey of soils; strengthening of state control over the preservation of soils and their fertility, organization of soil monitoring taking into account European experience, ensuring the functioning of the soil information center; improvement of the legislative provision of soil protection; introduction of organic and mineral fertilizers, chemical meliorants in full to ensure a deficit-free balance of humus and nutrients in the soil, optimization of the reaction of the soil solution; improvement of economic stimulation of the implementation of soil protection measures by subjects of economic activity.

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. A. Hudzevych, L. Nikitchenko, L. Hudzevych, L. Bronnikova, R. Demets (2021). Approaches to organize the econetwork of the Transnistria region in the conditions of urban landscape. *Journal of Geology, Geography and Geoecology,* 30 (3), 449–459.
3. Baliuk S.A., Kucher A.V. (2019). Spatial features of the soil cover as the basis for sustainable soil. *Ukrainian Geographical Journal*, 3, 3–14. DOI: https://doi.org/10.15407/ugz2019.03.003
4. Baliuk S., Miroshnychenko M., Medvedev V. (2018). Scientific bases of stable management of soil resources of Ukraine. *Bulletin of Agricultural Science*, 11, 5–12. DOI: https://doi.org/10.31073/agrovisnyk201811-01
5. Bandura V., Mazur V., Yaroshenko L., Rubanenko O. (2019). Research on sunflower seeds drying process in a monolayer tray vibration dryer based on infrared radiation. *INMATEN – Agricultural Engineering*, vol. 57, no. 1, pp. 233–242.
6. 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
7. Bondarenko V., Havrylianchik R., Ovcharuk O., Pantsyreva H., Krusheknyckiy V., Tkach O. and Niemec M. (2022). Features of the soybean pho-

tosynthetic productivity indicators formation depending on the foliar nutrition. *Ecology, Environment and Conservation*, 28, 20–26. DOI: https://doi.org/10.53550/EEC.2022.v28i04s.004

8. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology*, 10(5), 54–61.

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

10. Hudzevich A, Liubchenko V., Bronnikova L., Hudzevich L. (2020). 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",* 52, 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

11. 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

12. Honcharuk I., Matusyak M., Pantsyreva H., Kupchuk I., Prokopchuk V., Telekalo N. (2022). Peculiarities of reproduction of pinus nigra arn. in Ukraine. *Bulletin of the Transilvania University of Brasov, Series II: Forestry, Wood Industry, Agricultural Food Engineering*, vol. 15 (64), no. 1, pp. 33–42. DOI: https://doi.org/10.31926/but.fwiafe.2022.15.64.1.3

13. Ingram J., Mills J. (2019). Are advisory services "fit for purpose" to support sustainable soil management? An assessment of advice in Europe. *Soil Use and Managemen*t, 35(1), 21–31. DOI: https://doi.org/10.1111/sum.12452

14. Ivanyshyn O., Khomina V., Pantsyreva H. (2021) Influence of fertilization on the formation of grain productivity in different-maturing maize hybrids. *Ukrainian Journal of Ecology*, 11 (3), 262–269. DOI: https://doi.org/10.15421/2021_170

15. 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

16. Kirichenko K. (2019). Analysis of the efficiency of use of agricultural land in Kharkiv region. *Agricultural and Resource Economics: International scientific e-journal,* 5(3), 63–76. Available at: are-journal.com DOI: https://doi.org/10.22004/ag.econ.293986

17. Kucher A. (2020). Soil fertility, financial support, and sustainable competitiveness: evidence from Ukraine. *Agricultural and Resource Economics: International scientific e-journal*, 6, 2, 5–23. Available at: are-journal.com DOI: https://doi.org/10.51599/are.2020.06.02.01

18. Li, J., Dong, F., Lu, Y., Yan, Q., Shim, H. Mechanisms controlling arsenic uptake in rice grown in mining impacted regions in south China. PLoS ONE, 2014, 9.

19. Li, R., Zhou, Z., Zhang, Y., Xie, X., Li, Y., Shen, X. Uptake and accumulation characteristics of arsenic and iron plaque in rice at different growth stages. Commun. Soil Sci. Plant Anal, 2015, 46, 2509–2522.

20. Makino, T., Nakamura, K., Katou, H., Ishikawa, S., Ito, M., Honma, T., Miyazaki, N., Takehisa, K., Sano, S., Matsumoto, S., et al. Simultaneous decrease of arsenic and cadmium in rice (Oryza sativa L.) plants cultivated under submerged field conditions by the application of iron-bearing materials. Soil Sci. Plant Nutr. 2016, 62, 340–348.

21. Manning, B.A., Goldberg, S. Arsenic(III) and arsenic(V) absorption on three California soils. Soil Sci., 1997, 162, 886–895.

22. Martínez-Mena M., Carrillo-López E., Boix-Fayos C. et al. (2020). Long-term effectiveness of sustainable land management practices to control runoff, soil erosion, and nutrient loss and the role of rainfall intensity in Mediterranean rainfed agroecosystems. Catena, 187, 104352. DOI: https://doi.org/10.1016/j.catena.2019.104352

23. Matusyak M.V., Pantsyreva H.V., Prokopchuk V.M. (2021). Assessment of decorative value and prospects of the genus Magnolia compositional use on the territory of Vinnytsia. *Silske hospodarstvo ta lisnytstvo,* 4 (23), 137–147.

24. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. (2020). The productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. *Ukrainian Journal of Ecology*, 10(1), 101–105.

25. 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

26. Mazur V., Pantsyreva H. (2021). Scientific aspects of technologies of growing, storage and processing of legumins: collective monograph. Publishing House "Baltija Publishing", Riga, Latvia. P. 195–220.

27. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons*, 24(7), 53–60.

28. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizon*s, 24(7), 53–60. DOI: https://doi.org/10.48077/scihor.24(7).2021.53-60

29. Mazur V.A., Didur I.M., Pantsyreva H.V., Telekalo N.V. (2018) Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 8(4), 26–33.

30. Mazur V.A., Mazur K.V., Pantsyreva H.V. (2019). 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*, 9, 50–55. Available at: https://www.ujecology.com/archive.html

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, 148–153.

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

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

34. 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

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

36. Mazur V.A., Zabarna T.A. (2018). Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry,* 2(9), 5–17.

37. 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.

38. 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.

39. Mazur V., Didur I., Tkachuk O., Pantsyreva H., Ovcharuk V. (2021). Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. *Scientific Horizons*, 1 (24), 54–60.

40. 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

41. 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.

42. 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 Journal of Ecology*, 8(4), 26–33.

43. 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.

44. 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.

45. Methodology for conducting an examination of varieties for performance, uniformity and stability (VOS). Grain beans of culture. Kyiv, 2000.

46. Osman K.T. (2018). Management of Soil Problems, XX. DOI: https://doi.org/10.1007/978-3-319-75527-4

47. Pancyreva G.V. (2016). Doslidzhennya sortovyx resursiv lyupynu bilogo (Lupinus albus L.) v Ukrayini. Vinnycya, 4, 88–93.

48. Pantsyreva H., Mazur K. (2022) Research of early rating soybean varieties on technology and agroecological resistance. Theoretical and practical aspects of the development of modern scientific research: Scientific monograph. Part 2. Riga, Latvia: Baltija Publishing. P. 84–108. DOI: https://doi.org/10.30525/978-9934-26-195-4-18

49. 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

50. 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.

51. Pantsyreva H., Mazur K. (2021). The influence of bio-organic growing technology on the productivity of legumes. *Colloquium-journal,* 12(99), 25–31.

52. 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.

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

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

55. Puyu V., Bakhmat M., Pantsyreva H., Khmelianchyshyn Y., Stepanchenko V., Bakhmat O. (2021) Social-and-Ecological Aspects of Forage Production Reform in Ukraine in the Early 21st Century. *European Journal of Sustainable Development,* 10(1), 221–228.

56. Polupan M.I., Velychko V.A., Solovej V.B. (2015). Development of Ukrainian agronomical pedology: genetic and production aspects. Kyiv, 400 p.

57. Pozniak S.P., Havrysh N.S. (2019). The role of soils in social development of society. *Ukrainian Geographical Journal*, 2, 57–61. DOI: https://doi.org/10.15407/ugz2019.02.057

58. Shkatula Yu.M. (2019). Agro-ecological substantiation of meliorative measures to improve the condition of the soils of the Kalyniv district. *Agriculture and forestry*, 3(14), 220–230.

59. Tarariko O.H., Ilienko T.V., Kuchma T L. (2016). Sustainable land use management and soil conservation: urgency and challenges in modern conditions. *Ukrainian Geographical Journa*l, 3, 56–60. DOI: https://doi.org/10.15407/ugz2016.03.056

60. Thorsøe M.H., Noe E.B., Lamandé M., Frelih-LarsenA., 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

61. Tsytsiura Y.G. (2020). Evaluation of the soil cover of Vinnytsia for suitability for organic production. *Agriculture and forestry*, 1 (16), 13–27.

62. 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.

63. Vdovenko S.A., Prokopnuk 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), 1–5.

64. 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 Journal of Ecology*, 8(3), 270–274.

65. 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), 1–5.

66. Yanovych, V., Honcharuk, T., Honcharuk, I. & Kovalova, K. (2018). Engineering management of vibrating machines for targeted mechanical activation of premix components. *INMATEH – Agricultural Engineering*, 54(1), 25–32.

RESEARCH OF HYDROGRAPHIC RESOURCES OF VINNYTSIA REGION

Mykhaylo Polishchuk[1]
Lina Bronnicova[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-8

Abstract. An assessment of the state of the soil cover of the Vinnytsia Oblast basin is presented. A review of literary sources on the functioning of river basins depending on external conditions and anthropogenic activity was carried out. Considered the main problems that arise as a result of intensive economic activity and irrational use of water and land resources in river basins, destruction of natural landscape complexes of river valleys and adjacent territories as a result of agricultural use. After conducting a study of individual areas, it was established that the anthropogenic impact of types of economic activity in the floodplain is quite significant. *The purpose.* Study of the hydrographic resources of Vinnytsia region. *Methodology* of the study statistical probability. An extensive method of management with a violation of the permissible limits of the development of basins, backward industrial technologies and low culture of the population caused an excessive load on water bodies, their degradation – extreme depletion, siltation, clogging and pollution. *Result*. Therefore, further research should be directed at carrying out an ecological and agrochemical assessment of agricultural lands located within the boundaries of the region in order to prevent a negative impact on the soil cover and the quality of the hydrological fund of Ukraine. At the current stage of the development of economic activity, the need to have clean rivers and lakes remains relevant. In this regard, there was an urgent need to improve the ecological condition of rivers, to protect them from pollution and depletion. It was established that the largest river that flows through the territory of the region for a considerable length (317 km) and divides it into two almost equal parts is the Southern Bug. The length of

---

[1] Candidate of Agricultural Sciences, Associate Professor,
Vinnytsia National Agrarian University, Ukraine
[2] Senior Lecturer,
Vinnytsia National Agrarian University, Ukraine

the Southern Bug is 792 km, the area of the basin (together with Ingul) is 63,700 square meters. km The Southern Bug is the third largest river in Ukraine. It originates on the Volyn-Podilsky upland near the village. *Value/ originality.* Kupela in the Khmelnytskyi region at an altitude of 340 m above sea level. After receiving the Buzhok, Vovk, and Ikva tributaries, the Southern Bug near the villages of Guli and Dumenka (Khmilnytskyi district) enters the territory of the Vinnytsia region.

1. Introduction

In the conditions of growing water scarcity, water resources are currently one of the most important factors of economic development, and clean fresh water is a valuable and increasingly limited mineral resource. The growth of cities, the rapid development of industry, the significant expansion of irrigated land areas, the improvement of cultural and household conditions, and a number of other factors are increasingly complicating the problems of water supply [3]. Therefore, the question of using water resources requires an actual study of the hydrological network.

Different classification models are used when studying river systems, their functioning, dynamics and history of development. In their study, two qualitatively different stages are distinguished. The first stage covers the period from the beginning of the 1930s to 1966 and is associated with the works of RE Horton [Horton, 1948]. He proposed a system of ordinal classification (SPC) of rivers and established a number of quantitative statistical regularities of their structure, which later, with additions made by S. Shumm (Shumm, 1956)), received the name "Horton's laws". As actual material on the topology of river systems accumulates, the ordinal classification in a number of cases no longer meets the requirements of practice. It should be noted that R.E. Horton himself understood the imperfection of his SPK and recommended its modification, which was done by A. Straler (Strahleg, 1952). The essence of the changes made by Straler in Horton's SPK is the following. According to R. E. Horton's proposal, the smallest (elementary) flow that does not have tributaries is called a first-order flow. A river formed by the confluence of two first-order streams is considered a second-order river. The latter can receive an arbitrary number of elementary tributaries and changes its order to the third only in case of confluence with another river of the second order.

A stream of the third order, respectively, can receive an arbitrary number of tributaries of the first and second orders and increases its class by one only after meeting another river of the third order. In other words, a stream of order K is formed by the merger of at least two tributaries of order (K = 1), but can receive an unlimited number of tributaries of order K = 1. Therefore, Horton's classification is characterized by some uncertainty regarding the quantitative characteristics of the water network. As the network becomes more complicated from the source to the mouth, the order of the river system increases by leaps and bounds in such a way that it acquires whole values K = 1, 2, 3,...

2. Literary analysis

The analysis of the current ecological state of rivers and the organization of management for the protection and use of water resources outlined the most urgent problems that need to be solved. The basin of the small river is an indicator of the state of the environment caused by the level of anthropogenic load on the components of its landscape complexes.

A hydrographic network is a set of all water bodies in a certain territory, which can be divided into two groups – natural and artificial water bodies. The first includes rivers, lakes and swamps, the second includes reservoirs, ponds, canals (etc.). Among natural water bodies, rivers form the largest network.

Modern approaches to the study of anthropogenic impact on water intakes and in river valleys are based on the ecosystem or basin approach, which consists in a comprehensive assessment of the use of water and land resources, the structure of landscapes and their pollution [3].

Soil cover is one of the main components of the environment, performing vital biosphere functions [9]. Soils participate in the process of regulating the quality of surface and underground water, the composition of atmospheric air, are the habitat of most living organisms on the land surface, provide a favorable environment for humans and the production of agricultural products [8]. In the decisions of the World Conference on Environment and Development, it was stated that the protection and rational use of soils should become a central link state policy, since their condition determines the nature of human life and decisively affects the environment. The main factors of anthropogenic impact on soils are violations of the rules of soil cultivation, application and storage of protection products and fertilizers, generation of industrial and household waste, emissions of pollutants and radionuclides, inflow of polluted wastewater, etc.

One of the consequences of the excessive impact of economic activity on the surrounding natural environment is a noticeable decrease in the productivity of natural and anthropogenic landscapes due to the loss of soil fertility due to the progressive development of their degradation processes (erosion, deflation, dehumification, compaction, acidification, salinization, salinization, waterlogging, waterlogging, pollution, etc.) [7; 8; 10]. All this, ultimately, leads not only to the ecological destabilization of land use, but also to the deterioration of the environment and human health, and also limits the socio-economic development of the country. It is through the urgent task of today should be the gradual restoration of disturbed ecosystems to a level that will guarantee their stability in the future. The issue of protection and reproduction of soil fertility should become a problem of the state's national security [7]. Intensive economic activity in the basin of any river significantly affects the quantitative and qualitative indicators of its condition and leads to certain anthropogenic loads. Therefore, one of the important issues today in the field of environmental protection and rational use of natural resources is the ecological situation in the basins of medium and small rivers. Modern extensive use of water and land resources in these ecosystems led to the disturbance of the ecological balance and the emergence of such problems as: pollution of water bodies, destruction of natural landscape complexes of river valleys and adjacent territories, engineering reconstruction of riverbeds and floodplains as a result of reclamation works [1; 2; 33–38].

Analysis of recent research and publications. In Ukraine, V. Khilchevskyi, A. Yatsyk [12], O. Klymenko, Y. Hryb, O. Obodovskyi, I. Kovalchuk, S. Kukuruza, M. Kyrylyuk, Ye. Hopchenko et al. According to the results of their research, it was established that livestock grazing, drainage, and even more plowing of floodplains led to the degradation of river valleys and floodplains. As noted by M.O. Klymenko and O.A. Liho [5; 6; 16–20; 70–74] the basin of the small river is a complex self-regulating system that has the ability to function regardless of changes in external conditions. Establishing the anthropogenic impact on the basin of small and medium-sized rivers in the existing socio-economic conditions is important, because the possible loss of these ecosystems will lead to a number of more global environmental problems (reduction of the water level of first-order rivers, loss of valuable biological species, etc.) [56; 64; 67]. Therefore, there is now a need to develop a strategy for their revival, the scientific basis of which is real information about the ecological state of river water intakes.

3. Water resources of Ukraine

Water resources are reserves of surface water suitable for human use in any form and need, as well as glacier water, atmospheric water vapor, soil moisture. In the narrow sense under the water resources of large territories understand the value of the average annual flow of rivers per year (m^3). When assessing the water resources of individual regions, reserves of underground, lake and other types of water are also taken into account [1; 23; 57–64].

In modern science and practice, the concept of "water resources" in the broadest sense means all the waters of our planet, that is, surface and underground water, ground and underground waters, mountain and polar glacier waters, sea and ocean waters, atmospheric waters and waters of artificial water bodies. objects. According to the needs of material production, water resources should be understood as usable reserves of surface and underground waters of a certain territory. These are mainly fresh waters (rivers, lakes, reservoirs, glaciers, ground and underground waters). However, due to the fact that groundwater, as well as the waters of lakes, swamps and glaciers are currently used relatively little and all of them are connected with the waters of rivers, the water resources of large territories and states are understood only as the average annual flow of rivers. When assessing the water supply of individual regions and economic districts, reserves of underground, lake and other types of water can also be taken into account.

Water is one of the most important natural resources. First of all, this concerns fresh water, which Academician O. Fersman called "the most important mineral on Earth". Fresh water reserves on the globe (97% of all its reserves are in seas and oceans) are limited [1]. They make up only 3%, of which 2% are in polar glaciers, and only 1% is in a usable liquid state. Water availability per person per day is different in different countries of the world. In a number of countries with a developed economy, the threat of water shortage is looming. The shortage of fresh water on Earth is growing exponentially.

Water resources of Ukraine – volumes of surface, underground and sea waters of Ukraine. Water resources act as a source of industrial and economic and drinking water supply, and therefore play a decisive role in the development of the entire national economy and in the life of the population [14; 34–43].

Due to the specific features that distinguish them from other natural resources (high dynamism and interconnectedness, which is explained by the objective processes of the water cycle in nature), water resources can be used multiple times and for different purposes, which allows optimizing the use of water.

The water resources of our planet are about 1.5 billion cubic meters. km However, 98% of them are salty waters of the World Ocean, and only 28 million cubic meters. km – fresh water. But thanks to the technological possibilities of desalination of salty seawater, the water of oceans and salty lakes can be considered as potential water resources, the use of which is quite possible in the future.

River runoff resources of Ukraine amount to an average of 87 billion cubic meters. m per year (in a low-water year, this indicator decreases to 56 billion cubic meters). The river network of Ukraine consists of more than 71,000 rivers with a total length of more than 170,000 km. Its average density is 0.25 km/km^2. Almost all rivers belong to the basins of the Black and Azov Seas, and only 4% belong to the Baltic Sea. Ukraine's water resources are formed mainly due to the flow of the Dnipro, Dniester, Siverskyi Donets, Pivdennyi Bug, and Tisza rivers, on which reservoirs are built. The specific supply of river runoff in Ukraine is about 1,000 cubic meters. m per person per year, which is 2.5 times lower than in Germany and Sweden, 3.5 times lower than in France and 5 times lower than in England.

Water resources of Ukraine consist of local runoff, which is formed in the river network on the territory of Ukraine, and the flow that enters the territory from the adjacent areas along the Dnieper (and its tributaries), the Dniester, the Seversky Dinets, the Danube and other rivers.

The main source of feeding rivers and the formation of water resources of Ukraine is atmospheric precipitation, which falls on average per year at 366 km^3 (or 609 mm). However, only a small part of them (about 50 km^3, or 83 mm) forms the annual runoff. The rest of the moisture is spent on evaporation. On average, 159 km^3 of water enters the territory of Ukraine per year from outside its borders. So, the total water resources are 209 km^3-123 km^3 flows into Ukraine via the Kilii mouth of the Danube (the total average annual flow of the Danube is 203 km^3), 36 km^3 via other rivers [41–44].

Thus, Ukraine has quite significant total water resources. In at the same time, according to the reserves of local water resources per inhabitant (about 1 thousand m^3 per year), Ukraine is one of the countries with a low water supply – on average in Europe, water resources per capita are 5.2 thousand m^3 per year The total water resources of the rivers of Ukraine are about 87 km^3 (excluding the Danube). They consist of local river runoff – 52 km^3, as well as transit runoff – 35 km^3. The specific water resources of local runoff per 1 km^2 area in Ukraine are almost 87 thousand m^3/year, and the total – 144 thousand m^3/year. Fresh underground water in general recovers very slowly, its estimated reserves amount to more than 27 km^3, of which 8.9 km^3 are not related to surface runoff.

Water resources experience significant fluctuations in time and very unevenly distributed across the territory of Ukraine. A negative factor that limits the possibilities of using available water resources is the deterioration of water quality due to the discharge of wastewater into water bodies, as a result of which water becomes polluted, loses its useful qualities and often becomes unsuitable for certain types of use. Water resources on the territory of Ukraine are distributed as follows: in the north they are sufficient, but the southern territory has a water deficit due to the intensive development of irrigated agriculture.

To improve water consumption in the central part and the south of Ukraine, a number of canals were built: North Crimean and Main Kakhovsky trunk canal, Siverskyi Donets-Donbas, DniproDonbass, Dnipro-Kryvyi Rih, Dnipro-Ingulets, Danube-Sasyk and others.

In the scientific literature of the last decades, devoted to the study hydrological and water management features of Ukraine, it was traditional to show an acute shortage of water resources. In dry years, this deficit occurs. Recently, due to the prolonged economic crisis, water consumption in the country has significantly decreased. At the same time, certain climate changes took place in Ukraine. Therefore, a trend towards an increase in the natural river flow began to be traced, and the water deficit decreased. Significant floods have become more frequent in the western region.

4. Hydrology of the Vinnytsia region

The hydrography of the Vinnytsia region is represented by a dense network of rivers, lakes, ponds, swamps and underground waters.

Water bodies in the region are represented by rivers, streams, reservoirs and ponds. According to the data of the Land Cadastre and accounting data of the Regional Agricultural Service, the total area of the water fund of the region is 108,258 hectares, including occupied [34; 35; 58–65]:

– rivers and streams – 9019 ha;
– reservoirs and ponds – 31,719 hectares;
– canals, collectors and ditches – 1401 ha;
– hydrotechnical structures – 386 hectares;
– open wetlands – 29,576 ha;
– coastal protective strips – 41,222 hectares (including 4,723 hectares of swamps).

The rivers of the region [19; 58] belong to the basins of the Southern Bug, Dniester, and Dnieper (the Ros River), which account for 62.28 and 10 percent of the territory of the region (Table 1). They are mainly fed by snow and rain and belong to the type of plains. The density of the river network in the region is 0.14-0.21 km per 1 sq. m. km (taking into account rivers less than 10 km long). River valleys are 1 to 2 km wide. The height of the slopes of the valleys reaches 180 m. These slopes are moderately steep, but sometimes they are also steep. In the floodplains of rivers there are mostly meadows or shrubs, sometimes – swamps.

The tributaries of the P. Bug and Dnipro are characterized by a slight slope of the channel, the tributaries of the Dniester are hollow. Rivers are fed by rain (48%), snow (25%) and underground water (27%).

Hydrocarbonate-calcium water mineralization. Almost all rivers of the region are characterized by a water regime with a noticeable spring flood. They are used for drinking and technical water supply, shipping, land irrigation and hydropower. The main supplier of water in the region is the rivers of the Southern Bug basin – this amounts to 112.8 million m^3 or 97.9% of the region's water intake, the catchment area is 16,400 km^2.

In general, the rivers of the Vinnytsia region can be divided into the following categories (Table 1) [58; 60; 61]:

1. Large rivers – 2 (Southern Bug and Dniester).

2. Medium rivers – 4 (Sob, Girsky Tikich, Muraba, Ros).
3. Small rivers (less than 10 km long) – 226.
4. Streams (less than 10 km long) – 3368.

A total of 3,600 rivers flow through the territory of the region, with a total length of 11,800 km. The average density of the river network is 0.45 km/km^2.

Table 1

River network of Vinnytsia region

The main river (large, medium)	Area of the pool, km^2	River length, km	Number of small rivers		Total length of small rivers, km	Including L<10 km	Density of the river network, km/km^2
			everything	including L<10 km			
Southern Bug	16400 / 63700	352 / 806	2227	2086	6748	4046	0,43
Sob	2600 / 2840	115	365	340	1144	730	0,48
Mountain Tikich	118 / 3511	11 / 167	21	20	67	56	0,56
Dnister	7500 / 59690	166 / 925	910	860	2931	1600	0,41
Murafa	2410	163	258	239	804	412	0,40
Dnipro	2600 / 292700	0 / 1121	457	422	1256	754	0,48
Sluch	10 / 13800	0 / 451	4	3	4	2	0,40
Teterov	670 / 15100	0 / 365	124	114	344	210	0,53
Ros′	1920 / 12600	58 / 346	329	305	908	542	0,50
Together in the region	26500	865	3594	3368	10935	6400	0,45

The rivers of the region are characterized by a high degree of regulation by artificial reservoirs – reservoirs and ponds. Vinnytsia Region has 65 reservoirs (including 2 reservoirs of the Dniester Cascade) with a total area of 11,200 hectares, and there are more than 4,000 ponds with a total area of more than 20,000 hectares. The saturation of ponds in Vinnytsia region is one of the highest in the country. Most of the ponds and reservoirs are in the basins of large rivers. There are no natural lakes in the region.

The rivers of the region are also characterized by a significant channel slope (especially in Transnistria). In connection with this, their flow is very fast (0.2-0.7 m/sec). The riverbeds are winding. Some of them have thresholds. In most rivers, depths of 0.3-0.8 m predominate, in floodplains they increase to 1.5-4 m. At the end of November – at the beginning of December, ice formation begins on the rivers of the region, which sometimes lasts for 1-1.5 months. Due to the fact that there are mostly thaws in Vinnytsia in winter, the rivers are crossed and freed from ice several times during the winter. The melting of the ice on the rivers begins already at the end of February and the beginning of March. The earliest ice begins to melt on the rivers of Transnistria. The rivers of the Dniester basin are freed from ice in the first half of March, the Southern Bug and Rosa basins – at the end of March.

In February-April, the rivers of the region carry 45-55% of the annual water flow, in May-November – 35-40%, in December-January – 10-15%.

The largest river that flows through the territory of the region for a considerable length (317 km) and divides it into two almost equal parts is the South Bug. The length of the Southern Bug is 792 km, the area of the basin (together with Ingul) is 63,700 square meters. km The Southern Bug is the third largest river in Ukraine. It originates on the Volyn-Podilsky upland near the village. Kupela in the Khmelnytskyi region at an altitude of 340 m above sea level. After receiving the Buzhok, Vovk, and Ikva tributaries, the Southern Bug near the villages of Guli and Dumenka (Khmilnytskyi district) enters the territory of the Vinnytsia region.

From Khmilnyk to Gushchynets (Kalynivskyi district), the river carries its waters in a southeasterly direction. The valley here is narrow throughout (up to 600 m) and has an asymmetrical shape. The right bank is high and rocky, the left bank is lower, partly swampy, especially in the mouth of the Snyvoda and Postolova.

From Gushchynets to Gnivani, the Southern Bug flows in a southerly direction. At the Vinnytsia – Sabaryv section, the river enters the band of distribution of crystalline rocks. Its valley here is compressed by granite banks that rise to 30-50 m. The width of the river does not exceed 300 m. The width of the river bed in the Vinnytsia region is 100-130 m, and below the Sabarivskaya HPP dam – 70-85 m.

Below Vinnytsia, terraces (the first floodplain, the second and the third) can be distinguished on the Southern Buza, which are most clearly identified around Selyshche (Vinnytsia district), Hnivani and Sutysok (Tyvrivskyi district).

Near the village There are rapids and rapids on the Yuzhnoye Buza ridge, there are also them in the section Rogizna (Nemirivskyi district) – Pechora (Tulchynskyi district). Large granite barriers project into the river bed near c. Korzhovoy. In general, in the area from Vinnytsia to the exit of the Southern Bug, outcrops of granite rocks can be traced in the river bed and valley. The Southern Bug has the fastest current in the sections Rogizna – Sokolets, Pechora – Hlybochok. This structure of the bed and banks is very convenient for the construction of hydroelectric power stations.

The Southern Bug usually freezes in the second half of December and freezes in March. The flood lasts from the first half of March to April 15, with deviations in individual years. The water level in the river rises by 3-3.5 m, but in some years it can be even higher. During a spring flood, the river is high for about 15 days. It depends on the thickness of the snow cover on the fields. The thickness of the ice is 35-45 cm, rarely reaches 85-100 cm.

Summer floods occur in May-June, when the most rain falls. However, they are insignificant.

The Southern Bug within the region receives 14 tributaries from the left side and the same number from the right.

Near the village Mizyakov (Kalynivskyi district) from the right into the Southern Bug flows the Zgar River, which originates in the territory of the Khmelnytskyi region. The river valley has a slight slope of the bed and is very swampy. The terraces rise up to 4 m above the floodplain and stand out well near Mykulynets and Bagrynovets (Lytyn district). In a number of places, in particular, near Suprunov (Lytyn district), granite outcrops occur along the banks of the river.

A little lower into the Southern Bug flows the Riv River, which flows in a strip of spread of Sarmatian sediments. The river valley is narrow and deep. A chain of ponds stretches along the entire length of the valley from Bar to the mouth.

In the lower reaches, between Brailiv and Demydivka (Zhmeryn district), the River, having cut through the Sarmatian sediments, already flows in a granite bed.

Small rivers flow from the Dniester-Buz watershed, the right tributaries of the Southern Bug – Vyshnya, Krasnyanka, Shpykyvka, Trostianets, Dokhna, Savranka. There are many ponds in the valleys of these rivers.

The largest left tributary of the Southern Bug is the Sob. It flows completely within the boundaries of the region. Its length is 125 km.

The source of the Sobi River is located northwest of the village. Zozova (Lypovetsky district). The Sob receives about 25 tributaries (Pohanka, Skakunka, Sobyk, Kublych, Soroka, Verbych, etc.), its channel is laid in crystalline rocks and products of rock denudation. Granite outcrops are observed, for example, in Lipovka, and limestone outcrops can be found near the village of Attacks

The width of the river in the middle course is 5-10 m, at the mouth – 50 m, the depth – 1.5-2 m.

A three-kilometer sand terrace stretches along the left bank of the Sobi River from Gordiivka (Lypovetskyi district) to Zhadanov (Illinetskyi district), and near Kitay-gorod it widens to 10 km, in some places the sand is piled up. Between Dashev and Gaisyn in the Sobi valley there are significant wetlands. There are large ponds in the Sobi basin (for example, Dashivsky), smaller ponds are found every 7-8 km along the river valley.

Through the Khmilnytskyi and Kalinivskyi districts, the Snyvoda River carries its waters to the Southern Bug, on which there are large reservoirs near Stariy and Novy Pykov. The river terraces are well exposed northwest of Ivanovo.

The Postolova River flows into the South Bug from the left. Its length is 38 km. There are marshy areas in the mouth of this river. Ponds were formed in the valley near the villages of Glynska, Guliivets, and Hrushkivka (Kalynivskyi district).

Near the village Stryzhavky (Vinnytsia district) Desna River flows into the Southern Bug from the left (length – 81 km). Its valley is wide and swampy; the small slope and slow current contribute to the accumulation of silt in the river. The banks of the river are overgrown with swamp vegetation. There are large ponds near Novaya Hrebla (Kalynivskyi district) and Turbova (Lipovetskyi district). This leads to the slowing down of the flow and siltation of the riverbed, as a result of which there is a need to systematically clean the ponds and eliminate the appearance of swamps along the banks.

In the southwest, on the border with the Chernivtsi region and Moldova, flows the second largest river of Ukraine – the Dniester. Within the boundaries of Podillia, this river, delving into the layers of sedimentary rocks, forms a winding bed. In some places, it penetrated to the native rocks, which is why rapids were formed here on the river (for example, near the village of Porogiv, Yampil district). The Dniester valley is not wide, sometimes steep rocks rise above the water at 60-80 m (near the villages of Lyadova and Bronnytsia, Mogilev-Podilsky District). On the Dniester, there are two floods – spring, caused by melting snow, and summer – during the period of rains in the Carpathians.

Flowing from the Dniester-Buz watershed, the left tributaries of the Dniester have a fast current, their narrow and deep canyon-like valleys are completely devoid of terraces, and the steep banks, composed of sandstones and limestones, form cliffs of amazing shapes.

The rivers of the extreme northeast of the region belong to the Dnipro basin. They only partially flow through the territory of the region.

On the slopes of the Dnieper Highlands, between the villages of Levkivka and Ordyntsy (Pogrebyshchensky district), the Ros – the right tributary of the Dnieper – originates. In the far north-east of the region, the Orikhova and Rostavitsa rivers flow – the left tributaries of the Rosi, Roska – the right tributary. In the north of the region, Hnylopyat and Guiva (in the Kozyatyn district) originate. Both of them are right tributaries of the Teterev (tributaries of the Dnieper).

Groundwater in Vinnytsia region has a significant influence on soil formation, mainly in river floodplains (Figure 1). In these places, they lie close to the surface (0.5-1.0 m), or (seasonally) come out, causing the formation of meadow, marshy soils and peatlands. Common sources. The creation of a wide network of ponds contributes to raising the level of ground water in the floodplains and, therefore, to waterlogging of the soil.

Groundwater in the region is characterized by the absence of a noticeable amount of easily soluble salts. The main place among the mineral residue is occupied by calcium carbonates. Only in groundwater formed on Sarmatian, Baltic, and red-brown clays, an increased amount of mineral salts is sometimes observed.

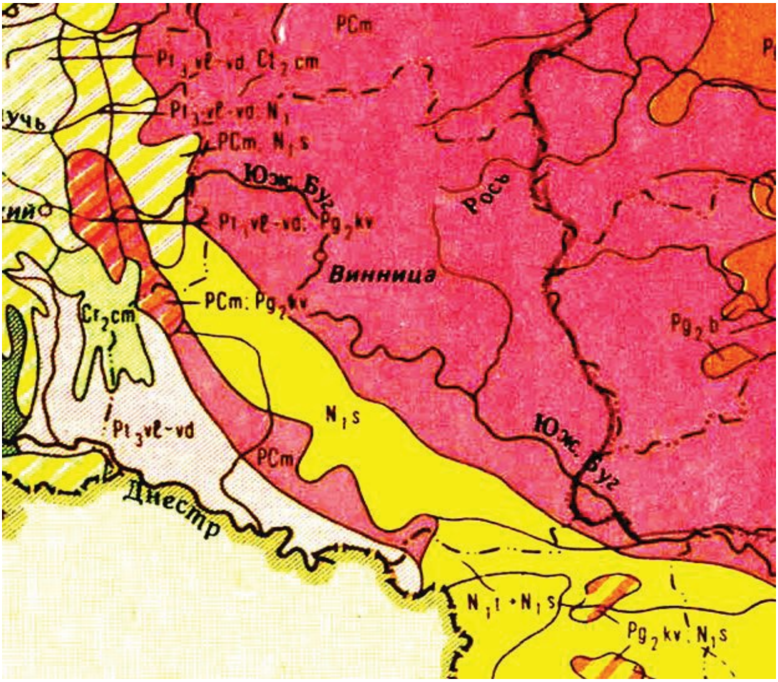


Figure 1. The main aquifers and their forming rocks in Vinnytsia region (in the original language)

Source: [47]

5. Ponds and lakes of the Vinnytsia region

The inland waters of the region include numerous ponds. There are about 2,500 ponds here, their total area exceeds 20,000 hectares.

The saturation of ponds in the Southern Bug basin is very high and occupies one of the first places in the republic; it is 4-5 times higher than on the Polish rivers of Ukraine.

The largest man-made reservoirs are in the valley of the South Bug River. First of all, the Ladyzhyn reservoir (popularly known as the Ladyzhyn sea) covers an area of 2,200 hectares and spilled 50 km upstream. In this reservoir, the water level near the dam has been raised by 17 m. Its volume can be judged from the fact that one centimeter of the level contains

170 cubic meters. m of water 20 thousand cubic m of water contains the Hlybochytsky Reservoir. The Sandratsky and Sutyske reservoirs, as well as the Dmytrenkivske reservoir on the Sobi River, should also be included among the large artificial reservoirs on the South Buza.

Swamp Swamps on the territory of Vinnytsia are located along river valleys. Most of them are in the northern and central parts of the region. The largest areas of swamps are along Zgar (7.4 thousand ha), Rovu (6.2 thousand ha), Rivets (5.4 thousand ha), Sobi (5.0 thousand ha), Sovran (4.6 thousand ha), Postolova (3.8 thousand ha), Desna (3.1 thousand ha).

Soil moisture conditions. The level of groundwater availability depends primarily on climatic conditions and the degree of dismemberment of the locality. The nature of the lithological composition of parent and underlying rocks also has a significant influence on the formation of the groundwater horizon and the degree of their mineralization.

Since fragmentation is significant in most of the territory of the region, and water-resistant rocks usually lie deep, the level of groundwater on the plateau and slopes covered with loess rocks is at a considerable distance from the surface (more than 10-15 m) and therefore, they do not affect soil formation.

On areas of the plateau and slopes in the southern part of the region, where waterproof clays are close to the surface, atmospheric precipitation is delayed, forming a horizon of the so-called "head water", which contributes to the formation of marshy soils.

On the terraces of the Southern Bug, Dniester and many of their tributaries, groundwater lies at a shallow depth (5-10 m), and in flat depressions it approaches the surface (2.5-3.0 m). This is connected with the formation of semi-hydromorphic and even hydromorphic soils.

6. Problems of using water resources

The territory of Ukraine is covered by a network of river valleys, gullies, ravines with numerous watercourses: starting from small intermittent streams to large rivers such as the Dnipro, Siversky Donets, Dniester, Southern Bug, Ingulets, Tisza, etc. However, recently the quality of their water has been constantly deteriorating, many of them are threatened with complete disappearance. It is often not only about the unsuitability of small rivers as sources of drinking water, but also about the impossibility of using their basins by society as a whole. And all because they are all subject to significant (very often catastrophic) anthropogenic pollution through the discharge of untreated sewage, planar washing of toxic compounds from the surface of agro-landscapes, excessive recreational load, littering, etc. Therefore, at such rates of pollution, the country's population may find itself without sources of drinking water in the coming years [23].

One of the main problems of using water resources is its contamination with various toxic chemicals, chemical agents, etc. Today, Vinnytsia is full of examples of the construction of warehouses for the storage of similar products under the open sky without compliance with environmental requirements. Warehouses leak and harmful substances from the soil enter the underground water, which feeds surface water. Improper application of mineral fertilizers into the soil also leads to the entry of harmful substances in surface and underground water. Considerable damage to the hydrographic network is caused by large enterprises that throw out tons of garbage, chemicals, detergents, etc. every year. The biggest polluters of water are sugar factories, which dump thousands of cubic meters of polluted effluent into the water [3]. The problem of drinking water is very acute, especially in cities. There is a great shortage of water in the south of the Cherkasy region [42].

The reason for this, in addition to natural factors, is irrational human use of natural resources. Yes, due to unreasonable human intervention in nature, rivers become thinner, and some even dry up. As a result, the level of ground water drops, the supply of drinking water even in villages becomes problematic [23].

The issue of protection, integrated use and restoration of the balance of the natural environment occupies one of the leading places in the ecological, economic, political and social life not only of individual states, but also of entire continents. Natural landscapes changed under the influence of economic activity, progressive pollution of the human habitat caused the deterioration of the quality of life, and negatively affected demographic characteristics [34].

The development of the water management complex must meet certain socio-economic and environmental requirements. The socio-economic aspect of these requirements involves the implementation of measures aimed at improving the territorial and sectoral structure and technologies of water use, providing quality water and preserving the health of the population, promoting the stable development of regions; international cooperation in the field of water fund use and protection; taking into account environmental restrictions and requirements when making social and economic decisions [37].

In recent years, the nature of the effect of public production on water bodies has intensified: changes in the conditions of formation of surface runoff as a result of processes of urbanization, industrialization of landscapes, intensification of rural and forestry; increasing the polluting effect of air transport of harmful emissions of industrial production for many kilometers, which leads to acid rain [14–22].

In this matter, the works of domestic and foreign ecologists, economists, who are devoted to the problems of the economy of nature use and environmental protection in the conditions of reforming land, water, and forest relations, and the formation of a market economy, are of significant scientific interest. In particular, a number of scientific works by S. Doroguntsov, B. Danylyshyn, L. Horev, R. Ivanukha, V. Mishchenko, N. Kovshun, M. Palamarchuk, V. Palamarchuk, M. Reimers, Yu. Tunitsa, M. Khvesyk, V. Shevchuk, E. Khlobistova, V. Tsemka, O. Yarotska is dedicated to the study of water conservation activities aimed at the rational use, preservation and reproduction of water resources in the general complex of environmental protection measures.

In the conditions of a market economy, the need to actively use economic tools to improve the process of water use is becoming more and more important. The urgency of introducing market incentives for its rationalization is reinforced by Ukraine's chronic budget deficit and a significant reduction in state investments in water protection activities. But precisely thanks to the implementation of reliable economic and legal mechanisms for the improvement of water systems, such conditions of production activity would be created, under which it would be beneficial for business entities to comply with water protection requirements, reduce the amount of pollution and prevent their occurrence.

The ecological aspect of the development of VHC involves a set of measures that ensure the protection of water resources and the rational use of water resources; increasing safety when using chemical substances; solving the waste problem. Therefore, today the need to actively use ecological and economic tools to improve the process of water use is gaining more and more importance.

Long-term forecasting of water consumption in many countries is based on the use of various mathematical models and methods using data on regional economic development and taking into account environmental, cultural and social factors. In many countries, there is a process of reduction in the number of the rural population and expansion of cities with the development of industry, which determines the creation of centralized water supply systems for 95% of the population in 2015–2025. As a result of increasing the level of water supply, many experts express the opinion of a possible increase in the rate of specific water consumption to 400-500 l/day per person.

Therefore, the need to ensure the optimal use of water resources determines the long-term forecasting of water management measures for a period of 15-30 years, taking into account environmental, social and radioactive pollution factors, as well as the implementation of broad programs of replenishment and stabilization of operational resources of underground water [7].

Special attention should be paid to the quality of water sources in drainage areas. Although the presence of pesticides and herbicides in the water sources of the drained territories is not registered by official reporting, however, there is a real danger of contamination by these ingredients when expanding the areas of irrigation and irrigation. That is why it is necessary to carry out preventive measures to protect water bodies from pollution, which would include a complex of agromelioration works, the creation of water protection zones and strips, impermeable screens around pollution zones, hydraulic watersheds in plan and vertically between local areas of pollution and aquifers. At the same time, it is expedient to organize small rivers with a complex of works on the decontamination of the territory.

In order to increase the economic efficiency of water supply and solve the issues of protection and reproduction of water resource potential, it is necessary to introduce an economic cadastral calculation of underground and surface waters according to their value and to determine the economically optimal parameters of water supply and water consumption from a public perspective. And installation the same tariffs for all water consumers will make it possible to economically interest enterprises and the population in saving water, which will result in huge cost savings in the region.

Implementation can be the solution to such problems new technological production processes, transition to closed ones (sewageless) water supply cycles, where treated wastewater is not discharged, but reused. An effective method of drastically reducing the use of water is the transfer of production to water-free and low-water technological processes, the introduction of air cooling. Among the radical measures in the "future" is a ban on the use of underground water for non-drinking purposes. The proven method of developed countries is the construction of new, more efficient water treatment facilities, reducing the waste of enterprises, but such a prospect is illusory in "crisis" Ukraine.

Water economics is vital to achieving sustainable development goals and other relevant social, environmental and economic goals. The article discusses the importance of complex water control, with an important component of which is work from the public, this is ecologically educated education and education on the preservation of healthy ecosystems and strengthening of human well-being.

7. Practical value and conclusions

Therefore, taking into account the great importance of water resources in the development of the national economy not only in the Vinnytsia region, but also in the country as a whole, the problem of balanced, scientifically based, ecologically safe water use and dynamic development of water management is extremely relevant. complex of Ukraine. To protect the natural environment and land in the Vinnytsia region, it is necessary to ban the use of pesticides, developing biological, agrotechnical and mechanical (machine) methods of pest control agricultural crops: reduce nitrogen fertilizer rates; organize control over the level of pollution of the environment and food products.

The problem of ensuring the proper ecological state of the water resource potential remains relevant for all regions of Ukraine. Practically all surface and a significant part of underground water resources, especially in the areas where powerful industrial and agricultural complexes are located, experience anthropogenic influence, which is manifested in pollution, depletion and degradation of these objects. Economically developed catchment areas are subject to significant transformations, which significantly changed the nature of the formation of runoff and the water regime of many water bodies. It was established that the largest river that flows through the territory of the region for a considerable length (317 km) and divides it into two almost equal parts is the Southern Bug. The length of the Southern Bug is 792 km, the area of the basin (together with Ingul) is 63,700 square meters. km The Southern Bug is the third largest river in Ukraine. It originates on the Volyn-Podilsky upland near the village. Kupela in the Khmelnytskyi region at an altitude of 340 m above sea level. After receiving the Buzhok, Vovk, and Ikva tributaries, the Southern Bug near the villages of Guli and Dumenka (Khmilnytskyi district) enters the territory of the Vinnytsia region.

References:

1. Arao, T., Kawasaki, A., Baba, K., Matsumoto, S. (2011). Effects of arsenic compound amendment on arsenic speciation in rice grain. *Environ. Sci. Technol.*, 45, 1291–1297.
2. A. Hudzevych, L. Nikitchenko, L. Hudzevych, L. Bronnikova, R. Demets (2021). Approaches to organize the econetwork of the Transnistria region in the conditions of urban landscape. *Journal of Geology, Geography and Geoecology,* 30 (3), 449–459.
3. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank ForestSteppe in Ukraine. *Ukrainian Journal of Ecology*, 10(5), 54–61.
4. Didur I., Pantsyreva H., Telekalo N. (2020). Agroecological rationale of technological methods of growing legumes. *The scientific heritage*, 52, 3–14.
5. Dong, D.T., Yamaguchi, N., Makino, T., Amachi, S. (2014). Effect of soil microorganisms on arsenite oxidation in paddy soils under oxic conditions. *Soil Sci. Plant Nutr.*, 60, 377–383.
6. Frommer, J., Voegelin, A., Dittmar, J., Marcus, M.A., Kretzschmar, R. (2011). Biogeochemical processes and arsenic enrichment around rice roots in paddy soil: Results from micro-focused X-ray spectroscopy. *Eur. J. Soil Sci.*, 62, 305–317.
7. Garnier, J.M., Travassac, F., Lenoble, V., Rose, J., Zheng, Y., Hossain, M.S., Chowdhury, S.H., Biswas, A.K., Ahmed, K.M., Cheng, Z. (2010). Temporal variations in arsenic uptake by rice plants in Bangladesh: The role of iron plaque in paddy fields irrigated with groundwater. *Sci. Total Environ.*, 408, 4185–4193.
8. Hashimoto, Y., Furuya, M., Yamaguchi, N., Makino, T. (2016). Zerovalent iron with high sulfur content enhances the formation of cadmium sulfide in reduced paddy soils. *Soil Sci. Soc. Am. J.*, 80, 55–63.
9. Hudzevich A., Liubchenko V., Bronnikova L., Hudzevich L. (2020). Landscape approach to take into account regional features organization of environ-

mental management of the protected area. *Visnyk Kharkivskoho natsionalnoho universytetu V.N. Karazina. Seriia "Heolohiia. Heohrafiia. Ekolohiia",* 52, 103–119. DOI: https://doi.org/10.26565/2410-7360-2020-52-09

10. Hryb, Y.V. (2010). Kontseptualni osnovy vidrodzhennia transformovanykh ekosystem malykh richok rivnynnoi chastyny terytorii Ukrainy. Zbirnyk materialiv II Vseukrainskoho zizdu ekolohiv z mizhnarodnoiu uchastiu. Vinnytsia,

11. Jia, Y., Bao, P., Zhu, Y.G. (2015). Arsenic bioavailability to rice plant in paddy soil: Influence of microbial sulfate reduction. *J. Soils Sediments*, 15, 1960–1967.

12. 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

13. Khan, N., Seshadri, B., Bolan, N., Saint, C.P., Kirkham, M.B., Chowdhury, S., Yamaguchi, N., Lee, D.Y., Li, G., Kunhikrishnan, A., et al. (2016). Root iron plaque on wetland plants as a dynamic pool of nutrients and contaminants. In Advances in Agronomy; Sparks, D.L., Ed.; Elsevier: Amsterdam, The Netherlands, vol. 138, pp. 1–96.

14. Khimko, R.V. (2003). Mali richky – doslidzhennia, okhorona, vidnovlennia. Kyiv: Instytut ekolohii, 378 p.

15. Klymenko, M.O. (2010). Okhorona vodnykh obiektiv vid antropohennoho vplyvu. *Visnyk KNU imeni Mykhaila Ostrohradskoho*, 6 (65), part 1, 177–181.

16. Klymenko, M.O. (2007). Shliakhy pokrashchennia ekolohichnoho stanu vodnykh ekosystem. *Visnyk Natsionalnoho universytetu vodnoho hospodarstva ta pryrodokorystuvannia*, 3 (39), part 1, 64–70.

17. Kyryliuk, O.V. (2007). Istoriia vstanovlennia baseinovoho pidkhodu u heohrafii ta ekolohichnomu rusloznavstvi. *Nauk. vypysky Vinnytsk. derzh. ped. un-tu im. Mykhaila Kotsiubynskoho. Seriia: Heohrafiia*, 14, 40–47.

18. Likho, O.A. (2010). Udoskonalennia metodyky otsinky ekolohichnoho stanu baseiniv malykh richok. Zbirnyk materialiv II Vseukrainskoho zizdu ekolohiv z mizhnarodnoiu uchastiu. Vinnytsia.

19. Manning, B.A., Goldberg, S. (1997). Arsenic(III) and arsenic(V) absorption on three California soils. *Soil Sci.,* 162, 886–895.

20. Matsumoto, S., Kasuga, J., Makino, T., Arao, T. (2016). Evaluation of the effects of application of iron materials on the accumulation and speciation of arsenic in rice grain grown on uncontaminated soil with relatively high levels of arsenic. *Environ. Exp. Bot*., 125, 42–51.

21. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. (2020). The productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. *Ukrainian Journal of Ecology*, 10(1), 101–105.

22. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons,* 24(7), 53–60. DOI: https://doi.org/10.48077/scihor.24(7).2021.53-60

23. Mazur V.A., Didur I.M., Pantsyreva H.V., Telekalo N.V. (2018). Energy-economic efficiency of growth of grain-crop cultures in conditions of Right-Bank Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 8(4), 26–33.

24. Mazur V.A., Mazur K.V., Pantsyreva H.V. (2019). 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*, 9, 50–55. Available at: https://www.ujecology.com/archive.html

25. 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, 148–153.

26. Mazur V.A., Pantsyreva H.V. (2020). Rid Lupinus L. v Ukraini: henofond, introduktsiia, napriamy doslidzhen ta perspektyvy vykorystannia. VNAU, p. 235.

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

28. 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

29. 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

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

31. Mazur V.A., Zabarna T.A. (2018). Changes in individual physical and chemical properties of soils in the biologization system of agricultural technologies. *Agriculture and forestry*, 2(9), 5–17.

32. 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.

33. 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.

34. 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

35. 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.

36. 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 Journal of Ecology*, 8(4), 26–33.

37. 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.

38. 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.

39. Moreno-Jimenez, E., Meharg, A.A., Smolders, E., Manzano, R., Becerra, D., Sanchez-Llerena, J., Albarran, A., Lopez-Pinero, A. (2014). Sprinkler irrigation of rice fields reduces grain arsenic but enhances cadmium. *Sci. Total Environ*., 485, 468–473.

40. Nakamura, K., Katou, H. (2012). Arsenic and cadmium solubilization and immobilization in paddy soils in response to alternate submergence and drainage. In Competitive Sorption and Transport of Heavy Metals in Soils and Geological Media; Selim, H.M., Ed.; CRC Press: Boca Raton, FL, USA, pp. 379–404.

41. Natsional'na dopovid' "Pro stan rodyuchosti gruntiv Ukrayiny" (2010) / Redkol. Balyuk S.A., Medvyedyev V.V., Tarariko O.H., Hrekov V.O., Balayev A.D. Kyiv, 111 p.

42. Neiko I.S. (2009). Forest genetic component as the basis of key territories of the ecological network of Eastern Podillia. *Bulletin of the Zhytomyr National Agroecological University*. Zhytomyr, issue 2 (25), pp. 170–174.

43. Nickson, R.T., McArthur, J.M., Ravenscroft, P., Burgess, W.G., Ahmed, K.M. (2000) Mechanism of arsenic release to groundwater, Bangladesh and west Bengal. *Appl. Geochem*., 15, 403–413.

44. Nosko B.S. (2006). Antropohenna evolyutsiya chornozemiv. NNTs IHA im. O.N. Sokolovs'koho. Kharkiv: Vyd "13 typohrafiya", 239 p.

45. Pantsyreva H., Stroyanovskiy V., Mazur K., Chynchyk O., Myalkovsky R. (2021). The influence of bio-organic growing technology on the productivity of legumins. *Ukrainian Journal of Ecology,* 11 (3), 35–39. DOI: https://doi.org/10.15421/2021_139

46. Pantsyreva, H.V. (2016). Doslidzhennia sortovykh resursiv liupynu biloho (Lupinus albus L.) v Ukraini. *Silske hospodarstvo i lisivnytstvo*, 4, 88–93.

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., 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.

49. Pantsyreva, H.V. (2019). Technological aspects of biogas production from organic raw materials. *Bulletin of KhNTUSG*. Kharkiv, pp. 276–290.

50. Pysarenko V.N. (2009). Ahroekolohiya. Stan rodyuchosti gruntiv Ukrayiny (za danymy VIII turu ahrokhimichnoyi pasportyzatsiyi zemel' sil's'kohospodars'koho pryznachennya / Za red. k.s.-h.n. Hrekova V.O, k.s.-h.n. Panasenko V.M. Kyiv, 47 p.

51. Scheidegger A.E. (1967). On the topologic of river nets. *Water, Res*., vol. 3, no. 1, pp. 103–106.

52. Schmidt, H., Eickhorst, T., Tippkötter, R. (2010). Monitoring of root growth and redox conditions in paddy soil rhizotrons by redox electrodes and image analysis. *Plant Soil*, 341, 221–232.

53. Schumm S.A. (1956). Evolution of drainage systems and slopes in bedlands of Perth Amboy – New Jersey. *Geol. Soc. Amer. Bull*., vol. 67, no. 5, pp. 597–646.

54. Seyfferth, A.L., Ross, J., Webb, S.M. (2017). Evidence for the root-uptake of arsenite at lateral root junctions and root apices in rice (Oryza sativa L.). *Soils*, 1, 3.

55. Seyfferth, A.L., Webb, S.M., Andrews, J.C., Fendorf, S. (2010). Arsenic localization, speciation, and co-occurrence with iron on rice (Oryza sativa L.) roots having variable Fe coatings. *Environ. Sci. Technol*., 44, 8108–8113.

56. Shimizu, M., Arai, Y., Sparks, D.L. (2011). Multiscale assessment of methylarsenic reactivity in soil. 2. Distribution and speciation in soil. *Environ. Sci. Technol*., 45, 4300–4306.

57. Shimizu, M., Arai, Y., Sparks, D.L. (2011). Multiscale assessment of methylarsenic reactivity in soil. 1. Sorption and desorption on soils. *Environ. Sci. Technol*., 45, 4293–4299.

58. Srive R.I. (1966). Statistical law of stream of numbers. *Journal of Geology*, 74, 17–37.

59. Strahler A.N. (1952). Hipsometrie (area-altitude) – analysys of erosial topography. *Geol. Soc. Amer.Bull*., 63, 1117–1142.

60. Suda, A., Baba, K., Akahane, I., Makino, T. (2016). Use of water-treatment residue containing polysilicate-iron to stabilize arsenic in flooded soils and attenuate arsenic uptake by rice (Oryza sativa L.) plants. *Soil Sci. Plant Nutr*., 62, 111–116.

61. Suda, A., Baba, K., Yamaguchi, N., Akahane, I., Makino, T. (2015). The effects of soil amendments on arsenic concentrations in soil solutions after long-term flooded incubation. *Soil Sci. Plant Nutr*., 61, 592–602.

62. Syu, C.-H., Lee, C.-H., Jiang, P.-Y., Chen, M.-K., Lee, D.-Y. (2014) Comparison of as sequestration in iron plaque and uptake by different genotypes of rice plants grown in as-contaminated paddy soils. *Plant Soil*, 374, 411–422.

63. Takahashi, Y., Minamikawa, R., Hattori, K.H., Kurishima, K., Kihou, N. (2004). Arsenic behavior in paddy fields during the cycle of flooded and non-flooded periods. *Environ. Sci. Technol*., 38, 1038–1044.

64. Ultra, V.U., Nakayama, A., Tanaka, S., Kang, Y.M., Sakurai, K., Iwasaki, K. (2009) Potential for the alleviation of arsenic toxicity in paddy rice using amorphous iron-(hydr)oxide amendments. *Soil Sci. Plant Nutr*., 55, 160–169.

65. 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.

66. 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.

67. Violante, A., Barberis, E., Pigna, M., Boero, V. (2003). Factors affecting the formation, nature, and properties of iron precipitation products at the soil-root interface. *J. Plant Nutr*., 26, 1889–1908.

68. Xu, X.Y., McGrath, S.P., Meharg, A.A., Zhao, F.J. (2008). Growing rice aerobically markedly decreases arsenic accumulation. *Environ. Sci. Technol*., 42, 5574–5579.

69. Yamaguchi, N., Nakamura, T., Dong, D., Takahashi, Y., Amachi, S., Makino, T. (2011). Arsenic release from flooded paddy soils is influenced by speciation, Eh, pH, and iron dissolution. *Chemosphere*, 83, 925–932.

70. Yamaguchi, N., Ohkura, T., Takahashi, Y., Maejima, Y., Arao, T. (2014). Arsenic distribution and speciation near rice roots influenced by iron plaques and redox conditions of the soil matrix. *Environ. Sci. Technol*., 48, 1549–1556.

71. Yhoshyn N.Y. (2009). Problemy vosstanovlenyia y okhrany malykh rek y vodoemov. Hydroekolohycheskye aspekty. Uchebnoe posobye. Kharkov: Burun Knyha, 240 p.

72. Yu, H.Y., Wang, X.Q., Li, F.B., Li, B., Liu, C.P., Wang, Q., Lei, J. (2017) Arsenic mobility and bioavailability in paddy soil under iron compound amendments at different growth stages of rice. Environ. Pollut., 224, 136–147.

73. Zhu, L., Gao, K.T., Jin, J., Lin, H.Z., Xu, X.Y. (2014) Analysis of ZVI corrosion products and their functions in the combined ZVI and anaerobic sludge system. *Environ. Sci. Pollut. Res*., 21, 12747–12756.

INFLUENCE OF SIDERATES ON THE AGRO-ECOLOGICAL CONDITION OF THE SOIL

Oleksandr Tkachuk[1]
Oleksiy Alieksieiev[2]

DOI: https://doi.org/10.30525/978-9934-26-290-6-9

Abstract. The work is devoted to the study of the expediency of using siderates for indicators of the agro-ecological state of the soil in the conditions of modern intensive crop rotation. Fertility indicators and soil contamination with heavy metals were studied. Correlation-regression dependencies between the studied factors were established and calculated. *The purpose.* Study of the siderates on the agro-ecological condition of the soil. *Result*. It was established that the biological mass of siderates, worked into the soil, helps to increase the content of humus by 0.11-0.14%, alkaline hydrolyzed nitrogen – by 1.7-7.1%, exchangeable potassium – by 27.4-32.2%. The highest content of humus in the soil is provided by siderates of peas and winter rapeseed – 2.44% each, alkaline hydrolyzed nitrogen – 127 mg/kg – peas, mobile phosphorus – 520 mg/kg – winter wheat, exchangeable potassium – 230 mg/kg – winter rapeseed, the largest amount of absorbed bases – 16.8 mg-eq./100 g – peas, the lowest hydrolytic acidity – 1.60 mg-eq./100 g – winter wheat, the highest pH value 5.85 – spring barley. *Value/originality.* It was determined that the cultivation of siderates leads to an increase in the content of mobile heavy metals in the soil by 17.2-24.3%, cadmium – by 10.0-14.3%, copper – by 17.6-22.2%, zinc – by 34.7-39.9%, compared to the version without siderates. Among the studied siderates, the lowest content of lead in the soil – 1.28 mg/kg and cadmium – 0.20 mg/kg is provided by winter rapeseed; copper – 0.51 mg/kg – peas and winter rapeseed; zinc – 1.73 mg/kg – spring barley.

---

[1] Doctor of Agricultural Sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine

[2] Candidate of Agricultural Sciences, Associate Professor, Vinnytsia National Agrarian University, Ukraine

1. Introduction

Soil, as a natural resource, is constantly subject to natural and anthropogenic influences. The influence of natural factors occurs continuously, but mineral and organic substances are in balance, thanks to which the natural course of geological processes is not disturbed.

Anthropogenic influence on soils causes their degradation, leads to a decrease in the productivity of agricultural lands. In Ukraine, the ecological consequences of soil degradation and deterioration of their quality have become particularly acute in the modern period due to the use of land as the only means of subsistence in conditions of survival at the expense of natural soil fertility, without compensation for its costs. High productivity of land in this case is ensured by applying high rates of mineral fertilizers and pesticides.

This leads to a merciless depletion of the natural fertility of soils, which is called degradation. Soil degradation leads to the deterioration of soil properties, fertility and quality, its contamination with chemical toxic substances, which is caused by a change in the conditions of soil formation due to the influence of natural or anthropogenic factors. Degradation of soils, and often their complete exclusion from agricultural use, occurs as a result of the processes of water and wind erosion, dehumification, decalcification, over-compaction by agricultural machinery, irrational operation of irrigation systems, which leads to flooding and waterlogging, secondary salinization and salinization of soils; due to violations of agricultural technology, overgrowth with weeds and shrubs, unbalanced application of mineral fertilizers, pollution with toxic substances, radionuclides, unregulated livestock grazing, etc.

As a result of such anthropogenic intervention, soils lose their natural stability, which leads not only to a decrease in their productivity, but also to a complete loss of soils and their removal from cultivation. The consequence of this can be not only a decrease in the productivity of crops, but also a significant deterioration in the quality of the grown products, which not only reduces their nutrition, but also accumulates toxic substances: heavy metals, pesticides, radionuclides, salts and acids, oil products.

The degree of soil resistance to chemical pollution is characterized by such indicators as the humus composition of the soil, acid-base properties, oxidation-reduction properties, cation-exchange properties, biological activity, the level of groundwater, the proportion of substances in a dissolved state, etc.

A situation has arisen where the intensive use of heavy machinery in soil cultivation, the application of pesticides and mineral fertilizers, and chemical preparations violate the natural laws of evolution. Self-regulation in living nature was broken, which weakened the self-defense of plants, animals, and humans.

For a long time, the application of organic fertilizers in the form of manure was a factor in restoring and stabilizing the agro-ecological condition of soils, and therefore a factor in improving the quality of products grown on them. In modern conditions, due to the lack of animal husbandry, it is impossible to solve this problem by adding manure. Therefore, one of the most important ways to restore such soils can be the maximum return to the soil of the plant mass of crops that are not used for economic production and their waste. Such substances can be siderates, as well as by-products of crop production in the form of stubble, straw, stalks, tops, etc. The question of the influence of these organic substances on the productivity of crops of the following crops in crop rotation has been studied at a sufficient level by Artemenko V. (2003), Berdnikov O.M. (2004), Makarova G.A. (2008), Gospodarenko H.M. (2012–2016), Razanov S.F. (2020), Pantsyreva H.V. (2020) and others.

At the same time, the change in indicators of the agro-ecological state of the soil, in particular the content of nutrients, acidity, heavy metals and other toxicants in it, as well as the influence of siderates and plant waste on the quality and ecological safety of the grown products, has not been studied enough, which determines the relevance of the chosen topic.

2. Analysis of recent research and publications

The relevance and significance of the problem of reproduction of soil fertility in agricultural production is due to the sharp contradiction between the need to ensure sustainable development of the agricultural sector of the economy and the intensive development of soil degradation processes that make it impossible to sustainably reproduce soil fertility. The main reason for this situation is the dominance of an unbalanced deficit system of agriculture in Ukraine, due to which the most fertile chernozems in the world have turned into soils with an average level of fertility and continue to deteriorate, and the harvests of recent years are mostly the result of a decrease in natural fertility and the impoverishment of its potential part [1–3].

In the agriculture of Ukraine, 79% of profit is obtained due to natural fertility and only 21% is the result of the introduction of technologies. At the same time, there is an "ecological eating away" of profit, since the losses from the decrease in soil fertility are close to, and in some years higher than, the profit from the sale of products by agricultural enterprises of Ukraine. Thus, in 2010, from 18.5 million hectares of arable land, on which the main groups of crops were grown, 2.38 million tons of nitrogen, phosphorus, and potassium were irretrievably lost, amounting to more than UAH 16.3 billion. However, this is only the cost of fertilizers, and the costs of their application are not taken into account. According to other data, the annual economic costs from the shortage of products due to soil erosion in Ukraine in general are estimated at 1.5 billion US dollars, and together with the incurred costs – about 2 billion dollars [4; 5].

In order to stop these negative processes, it is necessary to make wider use of natural ways of restoring and replenishing the reserves of organic matter in the soil, thanks to which not only the degradation processes in the soil will stop, but also the yield of plants grown on them will increase and the costs of their cultivation will decrease. In conditions of shortage of organic fertilizers in the form of manure, emphasis should be placed on green fertilizers – siderates [6; 23].

Green fertilizers (siderates) are fresh plant mass of specially grown crops, partially or completely worked into the soil to increase its fertility and improve the nutrition of subsequent plants with nitrogen and other elements. These cultures are called siderates, and the practice itself is called sideration, green manure is understood as the application of not yet dead green juicy biomass of plants, rich in sugars, starch, protein and nitrogen, to the soil, as well as their roots, which were still functioning at the time of tillage. This fundamentally distinguishes green manure from the application of other organic fertilizers to the soil, both dry (straw) and partially decomposed (manure) [7–10].

The production of siderates, like any other organic fertilizers, enriches the soil with organic substances, reduces its acidity, weediness of fields, increases buffering, improves the structure of the soil, and activates the vital activity of soil microorganisms. Their cultivation prevents the loss of nutrients due to erosion and migration along the soil profile. Sideration is used in fields far from farms, where it is economically unprofitable to bring manure, as well as in farms with small production of organic fertilizers, in specialized farms without animal husbandry. Green fertilizers are of great importance during the reclamation of produced quarries of non-metallic minerals and contaminated soils. For example, clover grows well on areas contaminated with motor oils. To detoxify the soil, trefoil, burgun and sweet clover are sown [18–21; 37].

The organic substance of green fertilizer can be considered as a reserve of all nutrients necessary for plants, which are created in the soil and which are not immediately transformed into an assimilated form, but gradually, throughout the growing season, ensuring continuous growth and development of plants. Especially valuable is green manure from leguminous crops, capable of enriching the soil with nitrogen by fixing it from the atmosphere with nodule bacteria. In this sense, the planting of leguminous green-fertilized plants can be called a living factory of nitrogen fertilizers, which without complex machines, but only thanks to the work of nitrogen-fixing microorganisms, bind a large amount of free nitrogen in the air into a useful form of soil organic matter. So, when 10 tons of green mass of lupine is harvested, the soil is enriched with nitrogen by 54-56 kg/ha, clover – by 62, peas and fodder beans – by 52, and cornflower – by 59 kg/ha. It is also important that the soil fertilized with nitrogen accumulated by leguminous plants does not require additional costs [22–25].

Siderates mobilize nutrients from the lower layers of the soil and move them into the arable layer. If the application of manure is the return to the soil of nutrients that were used by plants to create a crop, then the use of green manure is the mobilization of nutrients from solar energy, the atmosphere, and the lower layers of the soil, which are not used much [26; 27].

Green fertilizers help restore the normal cycle of organic matter and nitrogen in the soil. The results of research using labeled isotopes showed that when white mustard is used in the form of a harvest siderate, the nitrogen nutrition of barley plants and winter grain crops improved significantly, mainly due to an increase in the nitrogen utilization rate of mineral fertilizers by 40-60%. Increasing the resources of additional forms of nitrogen not only creates more favorable conditions for the growth and development of agricultural crops, but also reduces the contamination of the soil and plant products with nitrates and other harmful substances that can come with mineral fertilizers [28–32].

The diversity and specificity of sidereal crops requires theoretical and technological substantiation of their cultivation and fertilization in order to reduce the anthropogenic load on the surrounding natural environment, increase the productivity of crop rotations with the reproduction of the organic component of soils [37; 38].

Depending on the amount of heat, precipitation, local conditions, the granulometric composition of the soil, the presence of fertilizers and seeds, the following crops can be sown on siderates: legumes – perennial and annual lupins, white and yellow burdock, seradella, winter vetch and mountain vetch, diaper, peas, etc.; cereals – winter rye, wheat, barley, ryegrass, as well as sown cereal and leguminous perennial grasses, using the first cut for cattle feed, and the fallow – for fertilizer. In the presence of nitrogen fertilizers, it is promising to use cabbage crops (winter and spring rapeseed, winter and spring turnip, oil radish, white mustard, perko), phacelia, fodder peas and other fast-growing crops and their mixtures for sideration. Astragalus, mung bean, quinoa, fenugreek, alfalfa, asparagus, lentils, horse beans, gorse, sabdar, bers, soybean, rye, paiza, Sudan grass and many others can be used as side crops [39–43].

The rapid dynamics of the climate in the direction of warming significantly changes the usual ideas about the diversity of the biological set and the technological capabilities of some long-known cultures. Previously well-known cultures can manifest themselves under these conditions from previously unknown sides and demonstrate excellent productivity. It is advisable to test new crops that tolerate dry periods well, are undemanding to the soil, and are adapted to growing in deserts. These are plants from the leguminous family (woolly astragalus; naked, rough and Ural licorice; small-hairy, mouse and thin-leaved peas; tuberous and meadow plantain; Don and large safflower; large-flowered fenugreek; false or ordinary camel thorn), slender-legged (Karelina reed, multi-stemmed hairy and giant sedge, sedge and Colchis) and many other cultures. The main thing is that the soil is not empty, but is covered with green cover [44].

The soil and climatic conditions of Ukraine make it possible to sow a large number of crops on green manure. In regions with sufficient moisture, lupine, clover, vetch-oat mixtures, ryegrass, cabbage crops should be sown; in more arid conditions – vetch-rye, vetch-oat and pea-oat mixtures, peas, burdock, asparagus [24].

Seradella, lupine and phacelia, which are very demanding on moisture, grow well on poor sandy soils. Only white lupine and burkun tolerate carbonate soils well. Thin-legged – winter rye and its varieties (green-eared, perennial), oats, ryegrass are suitable for poor soils with excessive acidity. Cabbages need more compact and fertile soils (except for the relatively undemanding oil radish) [35].

In the first year of operation, the nitrogen utilization rate of green manure is usually higher than that of manure. In addition, leguminous siderates have a well-developed root system that penetrates deep into the soil, so they absorb nutrients from the lower layers of the soil, as well as phosphorus and other nutrients from poorly soluble compounds. In this regard, during the decomposition of the earned plant mass, the upper layer of the soil is enriched not only with organic substances and mobile nitrogen compounds, but also with phosphorus, potassium, calcium and other elements [13].

In terms of the degree of influence on crop yield, siderates are close to litter manure at the rate of 20-30 t/ha, and the costs of their production and application are 2-4 times lower [10].

Therefore, sideration, in addition to replenishing the content of organic substances and nitrogen in the soil, has such a versatile positive effect on the soil: the acidity of the soil is slightly reduced, the mobility of aluminum is reduced, and the buffering capacity and absorption capacity of cations is increased; soil erosion and degradation is eliminated; soil microbiological processes are regulated as a result of stimulation of the reproduction of microorganisms; the structure improves, the volumetric mass and density of the soil decrease; the water permeability and moisture capacity of the soil increases significantly; plant diseases are reduced; soil nutrients are mobilized; weediness of the fields decreases; the efficiency of fertilizers and liming increases.

In most literary sources, it is noted about the positive impact of growing siderates on the condition of the soil mainly in generalized phrases, without clear data on the improvement of certain indicators.

In particular, it is known that siderates replenish humus reserves in the surface layer of the soil, thus increasing the fertility of the arable horizon, enriching it with nitrogen, phosphorus, potassium and other macro- and microelements useful for cultivated plants. It has also been established that green fertilizers reduce soil acidity.

At the same time, the issue of reducing soil pollution with toxic elements remains relevant: heavy metals, pesticide residues, radionuclides, salts and acids, which, especially today, have increased their danger not only in relation to soils, but also to accumulation in plant products.

The agrosphere of Ukraine is characterized by intensive agriculture due to favorable conditions for the production of plant products, one of which is a large amount of chernozem compared to other countries of the world. Intensive farming on these soils leads to removal of biogenic elements with the harvest, which reduces the amount of humus and their fertility. Under such conditions, there is a need for their constant renewal, which increases the volume of use of mineral fertilizers. In the conditions of intensive agriculture, about 130 million tons of fertilizers are used annually, including 70 million tons of nitrogen, 39 million tons of phosphorus, and 26 million tons of potassium fertilizers [17; 46].

The use of high doses of mineral fertilizers along with the renewal of soils with nitrogen, potassium, phosphorus and other nutrients increases various toxicants in them, particularly heavy metals. It is known that with each kg of ammonium nitrate, 0.5 mg of lead and 0.05 mg of cadmium enters the soil, with double superphosphate 4.4 mg of lead and 0.05 mg of cadmium, and with potassium chloride 3.0 mg lead and 3.0 mg of cadmium [19; 40].

Analyzing the safety of food products in Ukraine in recent years, it was found that they exceeded the hygienic standards regarding the content of lead, cadmium and mercury. It was established that about 10% of food samples contain salts of heavy metals, half of which exceed the MPC [36; 45].

3. Conditions and methods of research

The research was intended to study the influence of siderates, which spontaneously sprouted after the loss of crop yields and disking of the field, on indicators of fertility and agro-ecological condition of soils.

The following observations, records and measurements were carried out: the determination of soil pollution by mobile forms of heavy metals, soil fertility indicators was carried out in the certified and accredited laboratory of the Zhytomyr branch of the State Institution "State Soil

Protection" of the Ministry of Agrarian Policy and Food of Ukraine. Soil samples were taken from the 0–20 cm layer in accordance with DSTU ISO 10381-1:2004 [1; 7; 30–33]; determination of the content of humus in the soil – according to the Tyurin method in accordance with DSTU 4289:2004 [10–13; 22–24]; determination of the content of mobile forms (after extraction with an acetate-ammonium buffer solution pH 4.8) of heavy metals in the soil: lead, cadmium, copper and zinc – by the method of atomic absorption spectrophotometry in accordance with DSTU 4362:2004, DSTU 4770 (2, 3, 9): 2007 [14–18]; determination of the reaction of soil pH saline – ionometrically in accordance with DSTU ISO 10390-2001 [19; 20]; determination of hydrolytic acidity – by the Kappen method in accordance with DSTU 7537:2014 [21; 22]; determination of the content of hydrolyzed nitrogen in the soil – by the Kornfield method according to DSTU 7863:2015 [13; 23]; determination of the content of mobile forms of phosphorus and potassium in the soil – by Chirikov's methods according to DSTU 4115-2002 [12; 19; 24]; determination of the amount of absorbed bases in the soil – according to Kappen-Hilkovits.

Research was conducted during 2018–2021 on gray podzolized medium loamy soils of FG "Zorya Vasylivka" of Tyvriv district, Vinnytsia region. The experimental field of FG "Zorya Vasylivka", where the field research was carried out, is located in the central part of Vinnytsia region in the Central Forest Steppe and is located almost on the border of two geomorphological regions: the Letychiv-Lytyna ancient alluvial and water-glacial depression and the Vinnytsia denudation-accumulative undulating plain of the Dnieper Highlands.

4. Research results

The use of siderates of the main agricultural crops: winter wheat, spring barley, winter peas and rapeseed, grown under conditions of intensive agriculture, had a positive effect on the change in soil fertility indicators, compared to the option without growing siderates during the crop rotation period. The main indicators of soil fertility include: the content of humus, easily hydrolyzable nitrogen, mobile phosphorus, exchangeable potassium, soil pH reaction, hydrolytic acidity, the sum of absorbed bases, and others.

In particular, the humus content was 2.30% in the variant without growing siderates. Cultivation of siderates during the crop rotation period contributed to an increase in the humus content of the soil by 0.11-0.14%. The humus content increased the most in the option of growing siderates of winter peas and rapeseed, and the least – in spring barley. In general, the highest content of humus was found in the option of growing winter pea and rapeseed – 2.44% each, and the lowest – in the case of growing spring barley siderate – 2.41% (Table 1). According to the content of humus, all studied options were in the range of "average content" (2.1-3.0%).

The content of alkaline hydrolyzed nitrogen in the version without growing siderates was 118 mg/kg. When growing siderates, the content of alkaline hydrolyzed nitrogen in the soil increased by 1.7-7.1%. The content of alkaline hydrolyzed nitrogen in the soil increased most significantly after the cultivation of pea siderate, and the least – after spring barley and winter rape. The highest content of alkaline hydrolyzed nitrogen was found in the soil where pea siderate was grown – 127 mg/kg, and the lowest – after growing spring barley siderate and winter rapeseed – 120 mg/kg each. According to the content of alkaline hydrolyzed nitrogen in the soil, all the tested options were in the "low content" range (100-150 mg/kg).

Table 1

The influence of siderates on soil fertility indicators, 2021, M±m

Agrochemical indicators of the soil	**Siderates**				
	wheat winter	**barley is hot**	**pea**	**winter rape**	**without siderates**
Humus, %	2,42±0,02	2,41±0,02	2,44±0,01	2,44±0,01	2,30±0,03
Alkaline hydrolyzed nitrogen, mg/kg	125±2	120±3	127±2	120±3	118±3
Mobile phosphorus, mg/kg	520±4	510±2	515±3	517±3	622±3
Exchangeable potassium, mg/kg	215±2	218±2	220±1	230±1	156±4
Soil reaction, pH	5,75±0,02	5,85±0,03	5,65±0,01	5,55±0,02	6,05±0,03
Hydrolytic acidity, mg-eq./100 g	1,60±0,04	1,65±0,04	1,70±0,03	1,72±0,03	1,60±0,02
Sum of absorbed bases, mgeq./100 g	16,2±0,4	16,4±0,2	16,8±0,3	16,4±0,2	17,5±0,2

The concentration of mobile phosphorus in the control variant without growing siderats was 622 mg/kg and was the highest among all studied options where siderats were grown. On the variants with the cultivation of sideral crops, the content of mobile phosphorus in the soil decreased by 16.4-18.0%. The smallest decrease in the content of mobile phosphorus in the soil, compared to the option without the use of siderates, was found in the option of growing siderates of winter wheat, and the largest decrease was found in the option of growing siderates of spring barley. In general, the lowest content of mobile phosphorus in the soil was found after growing spring barley siderate – 510 mg/kg, and the highest – after growing winter wheat siderate – 520 mg/kg. According to the content of mobile phosphorus in the soil, all the studied variants are in the "average content" category (51-100 mg/kg).

The soil of the variant without siderate cultivation contained exchangeable potassium of 156 mg/kg. Cultivation of siderates helped to increase the content of exchangeable potassium in the soil by 27.4-32.2%. The greatest increase in the content of exchangeable potassium in the soil was found in the option of growing winter rapeseed, and the least – growing winter wheat. The highest content of exchangeable potassium in the soil was established on the option of growing winter rapeseed – 230 mg/kg, and the lowest – after winter wheat siderate – 215 mg/kg. In the control option, without growing siderate, the content of exchangeable potassium in the soil corresponded to the "high content" indicator (120-180 mg/kg), and in the remaining options, where siderates were grown, to the "very high" indicator (over 180 mg/kg).

The pH reaction of the soil on the option without growing siderates was 6.05 pH. Variants with the cultivation of siderates were marked by a decrease in the reaction value of the soil solution by 0.2-0.5 pH. This indicates acidification of the soil when growing siderats. The greatest acidification of the soil is observed after the cultivation of winter rape seed extract, and the least – after spring barley seed extract. In general, the highest pH value of the reaction of the soil solution on the variants with the cultivation of siderates was found after spring barley – 5.85 pH, and the lowest – after winter rape – 5.55 pH. According to the reaction of the pH of the soil solution, the version with siderate cultivation of winter rapeseed had a slightly acidic reaction (5.10-5.55 pH), the other options with siderate cultivation were close to neutral (5.6-6.0 pH), while as an option without growing siderates, it had a neutral pH reaction (6.05-7.00 pH).

The hydrolytic acidity of the soil in the variant without growing siderates and when growing siderates of winter wheat was the same and amounted to 1.60 mg-eq./100 g. In other variants of growing siderates, the value of hydrolytic acidity of the soil increased by 3.0-7.0%. The largest increase in hydrolytic acidity was found in the variant of growing winter rapeseed, where the actual hydrolytic acidity of the soil was the highest and amounted to 1.72 mg-eq./100 g.

The amount of absorbed soil bases in the variant without growing siderates was the highest and amounted to 17.5 mg-equiv./100 g. When growing siderates, the amount of absorbed soil bases decreased by 4.0-7.4%. The amount of absorbed bases in the soil, where siderate winter wheat was grown, decreased most significantly, and peas the least. The largest value of the amount of absorbed soil bases was found in the variant where pea siderate was grown – 16.8 mg-equiv./100 g, and the lowest – when growing winter wheat siderate – 16.2 mg-equiv./100 g.

Therefore, the conducted research established that the cultivation of winter wheat, spring barley, winter pea and winter rapeseeds had a positive effect on increasing the humus content in the soil by 0.11-0.14%, which is due to the accumulation of organic matter in the soil formed by siderates and its gradual transformation into humus. The same regularity is observed in the content of alkaline hydrolyzed nitrogen and exchangeable potassium in the soil, which are formed from the organic mass of siderates.

At the same time, the content of mobile phosphorus in the soil when growing siderates was lower than in the version without siderates. This can be explained by the fact that siderates removed mobile phosphorus from the soil for their growth and development, but did not return it in a form available to plants.

The reaction of the pH of the soil solution and the hydrolytic acidity of the soil during the cultivation of siderates moves in the direction of soil acidification, which can be explained by the extraction of calcium siderates from the soil. This statement is substantiated by the fact of a decrease in the amount of absorbed soil bases when growing siderates.

Thus, the cultivation of siderates of winter wheat, spring barley, peas and winter rape helps to increase the content of humus in the soil by 0.11-0.14%, alkaline hydrolyzed nitrogen – by 1.7-7.1%, exchangeable potassium – by 27, 4-32.2%, but a decrease in the content of mobile phosphorus – by 16,418.0%, acidification of the reaction of the soil solution – by 0.2-0.5 pH, an increase in hydrolytic acidity to 7.0% and a decrease in the amount of absorbed bases by 4, 0-7.4%.

In particular, the cultivation of pea siderate, compared to other studied siderates, contributes to the greatest increase in the content of humus and alkaline hydrolytic nitrogen in the soil and the formation of the highest amount of absorbed bases. Cultivation of siderate of winter rapeseed allows the greatest increase in the content of humus in the soil, exchangeable potassium, but causes the least increase in the content of alkaline hydrolyzable nitrogen, the greatest acidification of the reaction of the soil pH solution and increases hydrolytic acidity. Cultivation of siderate of winter wheat provides the greatest increase in the content of mobile phosphorus in the soil, the greatest decrease in the value of hydrolytic acidity, but allows to obtain the smallest increase in exchangeable potassium in the soil and the lowest value of the sum of absorbed bases. Spring barley, as a siderate, provides the smallest increase in the content of humus in the soil and alkaline hydrolyzed nitrogen, the lowest content of mobile phosphorus, but the most neutral reaction of the soil pH, compared to other studied sideral crops.

A strong positive correlation r = 0.988 was established between the biological mass of siderate plants and their influence on the growth of humus content in the soil. The diagram of the correlation-regression dependence of the studied factors is shown in Figure 1.

The coefficient of determination $R^2 = 0.976$ shows that the increase in humus content in the soil depends on the yield of siderates by 98%.

An average positive correlation of r = 0.534 was established between the biological mass of siderate plants and their influence on the growth of alkaline hydrolyzed nitrogen content in the soil. The reason for this is the increase in nitrogen content in the soil on the variant where siderate peas grew due to its symbiotic nitrogen fixation.

A strong positive correlation r = 0.984 was established between the biological mass of siderate plants and their influence on the growth of exchangeable potassium content in the soil. The diagram of the correlation-regression dependence of the studied factors is shown in Figure 2.

The coefficient of determination $R^2 = 0.968$ shows that the increase in the content of exchangeable potassium in the soil depends on the yield of siderates by 97%.

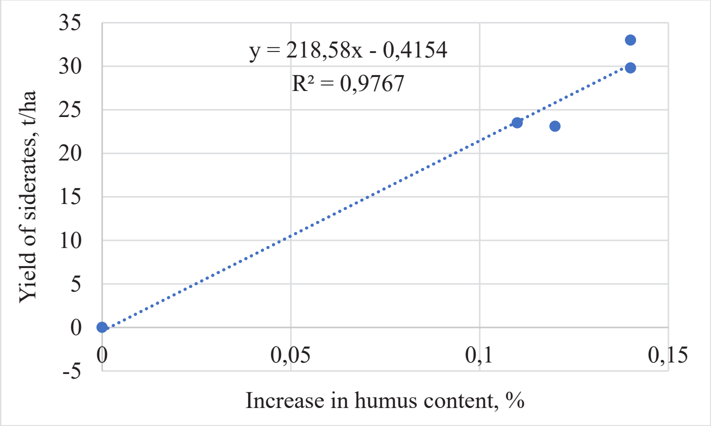


Figure 1. Correlation-regression relationship between the increase in humus content in the soil (x) and the yield of siderates (y)

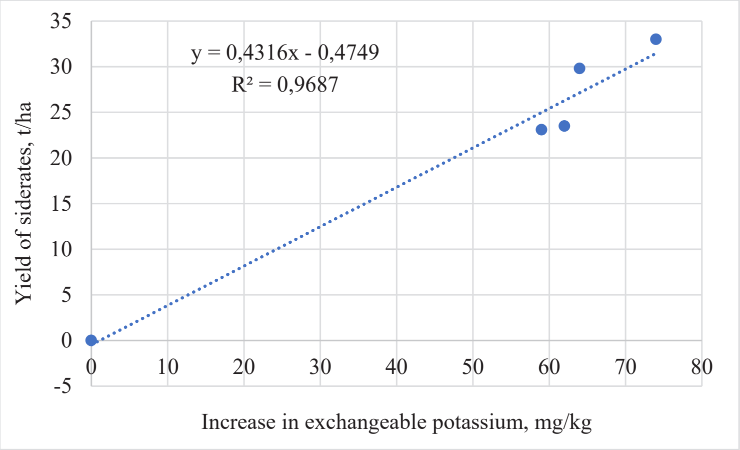


Figure 2. Correlation-regression relationship between the increase in the content of exchangeable potassium in the soil (x) and the yield of siderates (y)

The concentration of mobile forms of heavy metals: lead, cadmium, copper and zinc during the cultivation of siderates also underwent changes. In particular, the lead content in the soil for growing siderats was 1.28-1.40 mg/kg. The lowest content of mobile forms of lead in the soil was found in the variant of growing winter rapeseed, and the highest – when growing spring barley. Compared to the site where siderates were not grown, the content of mobile forms of lead in the soil on the version with siderates increased by 17.2-24.3%. However, the maximum allowable concentration of mobile forms of lead in the soil (6.0 mg/kg) is significantly higher than the actual content in the soil of the experimental sites, which does not pose a danger (Table 2).

Table 2

The influence of siderates on the content of mobile forms of heavy metals in the soil, 2021 mg/kg, M±m

Heavy metals	MPC of heavy metals	Siderates				
		wheat winter	**wheat winter**	**wheat winter**	**wheat winter**	**wheat winter**
Pb	6,0	1,35±0,04	1,40±0,03	1,38±0,03	1,28±0,02	1,06±0,02
Cd	0,7	0,21±0,01	0,21±0,01	0,21±0,01	0,20±0,01	0,18±0,01
Cu	3,0	0,54±0,03	0,53±0,03	0,51±0,02	0,51±0,02	0,42±0,02
Zn	23,0	1,82±0,05	1,73±0,03	1,88±0,05	1,82±0,04	1,13±0,02

The concentration of cadmium in the soil during the cultivation of siderates was 0.20-0.21 mg/kg. The lowest cadmium content was found in the winter rapeseed siderate cultivation option, and in the remaining siderates – 0.21 mg/kg. In the variant without growing siderates, the concentration of mobile forms of cadmium was 10.0-14.3% lower and amounted to 0.18 mg/kg. The maximum permissible concentration of mobile forms of cadmium in the soil is 0.7 mg/kg, which is much higher than the actual concentration of cadmium in the soil of the tested options, so there is no danger.

The content of mobile forms of copper in the soil where siderates were grown was 0.51-0.54 mg/kg. The lowest copper content was found in the option of growing siderates of winter peas and rapeseed, and the highest – in the option of growing siderates of winter wheat. In the variant without growing siderates, the copper content in the soil was 17.6-22.2% lower and amounted to 0.42 mg/kg. Maximum permissible limit for copper in soil is 3.0 mg/kg. The actual content of copper in the soil of the experimental variants was much lower.

The concentration of mobile forms of zinc in the soil where siderates were grown was 1.73-1.88 mg/kg. The lowest content of mobile forms of zinc was found in the soil where spring barley siderate was grown, and the highest – where pea siderate was grown. The concentration of zinc on the control option without growing siderats was 1.13 mg/kg, which was 34.7-39.9% less than on the options for growing siderats. The maximum allowable concentration of zinc in the soil is 23.0 mg/kg, which was significantly less than in the experimental variants.

An important indicator that determines the ecological danger of the content of heavy metals in the soil relative to the maximum permissible concentration is the danger coefficient, which is determined by the ratio of the actual concentration of heavy metals in the soil to their MPC. The obtained value should be less than one, this indicates satisfactory environmental conditions. The smaller the indicator, the safer the ecological situation.

The hazard ratio of lead in the soil when growing siderats was 0.21-0.23. It was the smallest when growing winter rapeseed. On the option without growing siderats, the hazard ratio was slightly lower and amounted to 0.18 (Figure 3).

The lowest cadmium hazard ratio when growing siderates was on the winter rapeseed variant – 0.29, and on the remaining variants – the same – 0.3. This is slightly more than in the option without growing siderates – 0.26 (Figure 4).

The lowest coefficient of danger of copper in the soil during the cultivation of siderats was established on the version of peas and winter rape – 0.17 each.

The highest risk factor was established for the siderate cultivation option of winter wheat and spring barley – 0.18 each. The hazard ratio of copper in the option without growing siderates was the lowest and amounted to 0.14 (Figure 5).

The lowest zinc hazard ratio was found on the variant without siderate cultivation – 0.05. In the remaining experimental variants, it was the same after growing all siderates and amounted to 0.08 (Figure 6).

Since soil contamination with several heavy metals was determined at the same time (lead, cadmium, copper and zinc), it is necessary to calculate the total pollution index, which takes into account the complex impact of

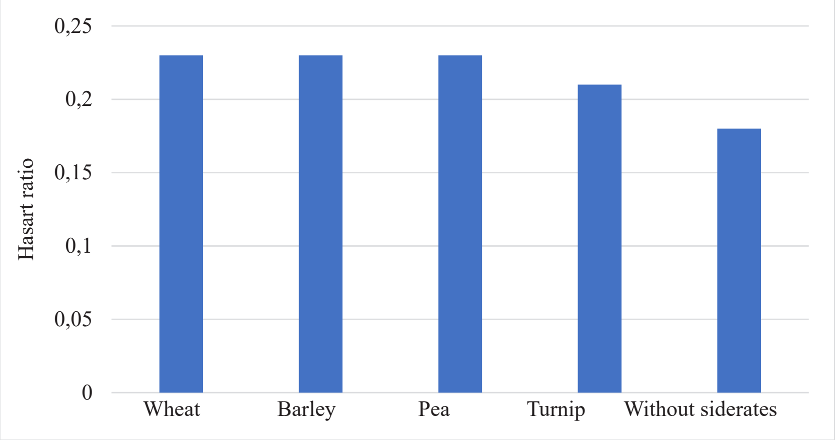


Figure 3. The risk factor of lead in the soil when growing siderats

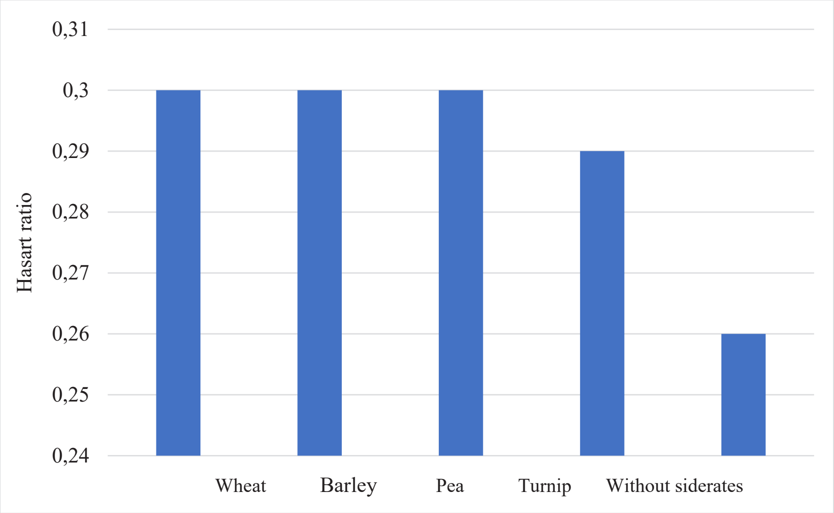


Figure 4. The hazard ratio of cadmium in the soil when growing siderats

all heavy metals on the ecological state of the soil environment, according to the formula:

$$Zc = (Kc1 + Kc2 + Kc3 + Kc4) - (n - 1),$$

where: Zc is the total indicator of soil pollution; Kc is the hazard ratio of a heavy metal; n is the number of heavy metals taken into account.

Such a calculation will show which siderate has the most positive effect on reducing the concentration of several heavy metals at the same time. The lower the obtained number, the more favorable the environmental impact of siderate on reducing the danger of heavy metals in the soil.

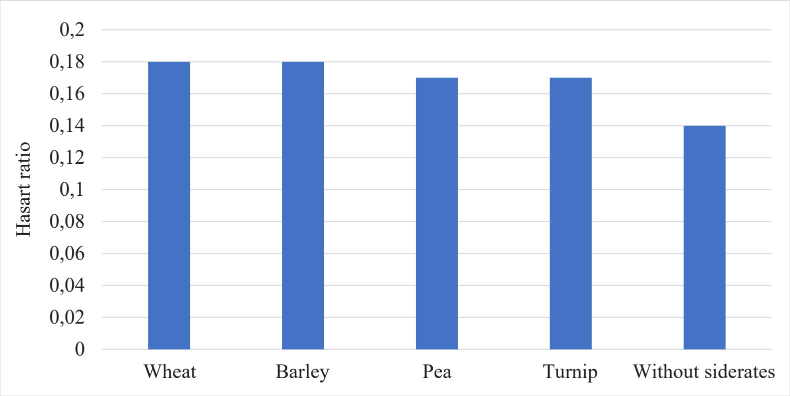


Figure 5. The danger coefficient of copper in the soil when growing siderats

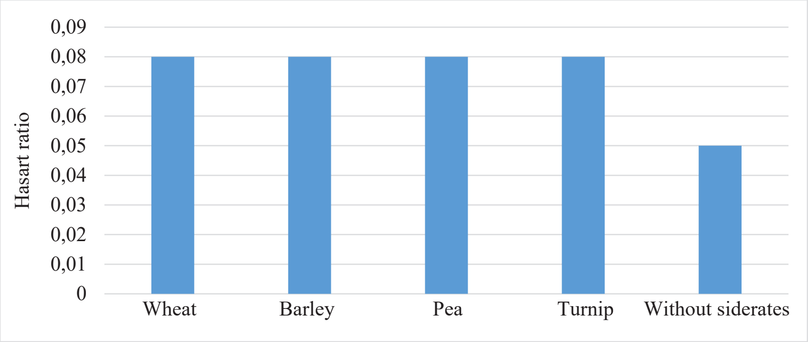


Figure 6. The hazard ratio of zinc in the soil when growing siderates

All studied siderates provided very low values of the total indicator of soil contamination with several heavy metals with negative values. The lowest total indicator was provided by the siderate of winter rape – minus 2.25, and the highest – b y the siderates of winter wheat and spring barley – minus 2.21 each. In the variant without growing siderates, the total indicator of soil contamination by several heavy metals was even lower – minus 2.37 (Figure 7).

On the basis of research conducted on the effectiveness of growing siderates for reducing the content of mobile forms of heavy metals in the soil, it can be stated that the cultivation of siderates of winter wheat, spring barley, peas and winter rape leads to an increase in the content of lead in the soil by 17.2-24.3%. cadmium – by 10.0-14.3%, copper – by 17.6-22.2% and zinc – by 34.7-39.9%, compared to the option without growing siderates, which is explained by the conversion of hard-to-reach substances into soil in easily soluble mobile compounds, which also applies to heavy metals. That is, difficult-to-dissolve compounds of heavy metals that were in the soil are transformed into easily-soluble ones – available to plants when growing siderates, but there is no harm to plants at such concentrations.

Among the investigated siderates, the lowest content of lead, cadmium and copper in the soil is provided by winter rapeseed. Also, this option allows you to get the lowest amount of total soil contamination with four

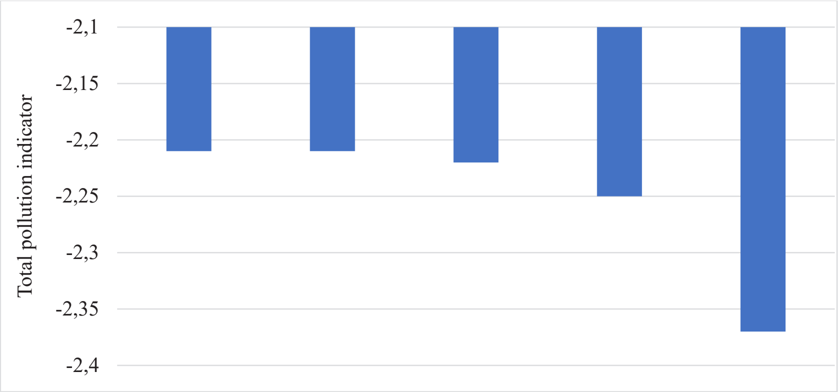


Figure 7. Total indicator of soil contamination with several heavy metals during the cultivation of siderats

types of heavy metals. Siderate peas provide the lowest copper content in the soil, but the highest zinc content. Spring barley siderate provides the highest content of lead in the soil, but the lowest – of zinc, as well as the highest amount of total contamination of the soil with all heavy metals. Siderate winter wheat provides the highest content of copper in the soil and the highest total indicator of soil contamination with all heavy metals.

5. Conclusions

The most positive effect of the investigated siderates on soil fertility indicators was exerted by peas, which increased the content of humus by 0.14%, easily hydrolyzed nitrogen by 7% compared to the control; winter rape – increased the content of humus by 0.14%, exchangeable potassium – by 32.2% compared to the control; winter wheat – increased the content of mobile phosphorus among all siderates. The most positive effect on the reduction of the content of mobile forms of heavy metals in the soil was exerted by winter rapeseed crops for lead, cadmium and copper; spring barley – for zinc; peas – for copper.

References:

1. Bondarenko V., Havrylianchik R., Ovcharuk O., Pantsyreva H., Krusheknyckiy V., Tkach O. and Niemec M. (2022) Features of the soybean photosynthetic productivity indicators formation depending on the foliar nutrition. *Ecology, Environment and Conservation*, 28, 20–26. DOI: https://doi.org/10.53550/EEC.2022.v28i04s.004

2. Didur I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank Forest-Steppe in Ukraine. *Ukrainian Journal of Ecology*, 10(5), 54–61.

3. Didur I., Chynchyk O., Pantsyreva H., Olifirovych S., Olifirovych V., Tkachuk O. (2021). Effect of fertilizers for Phaseolus vulgaris L. productivity in Western Forest-Steppe of Ukraine. *Ukrainian Journal of Ecology*, 11 (1), 419–424. DOI: https://doi.org/10.15421/2021_61

4. Didur, I., Bakhmat M., Chynchyk O., Pantsyreva H., Telekalo N., Tkachuk O. (2020). Substantiation of agroecological factors on soybean agrophytocenoses by analysis of variance of the Right-Bank Forest-Steppe in Ukraine. *Ukrainian Journal of Ecology*, 10(5), 54–61.

5. Didur, I.M., Prokopchuk, V.M., Pantsyreva H.V. (2019). Investigation of biomorphological and decorative characteristics of ornamental species of the genus Lupinus L. *Ukrainian Journal of Ecology*, 9(3), 287–290. DOI: https://doi.org/10.15421/2019_743

6. Honcharuk I., Matusyak M., Pantsyreva H., Kupchuk I., Prokopchuk V., Telekalo N. (2022). Peculiarities of reproduction of pinus nigra arn. in Ukraine. *Bulletin of the Transilvania University of Brasov. Series II: Forestry, Wood Industry, Agricultural Food Engineering,* 15 (64), 1, 33–42.

7. Honcharuk I., Pantsyreva H. (2020). Efficiency of growing legumes crops in Ukraine. Collective monograph. Riga, Latvia: Publishing House "Baltija Publishing", pp. 42–65.

8. Honcharuk I., Pantsyreva H., Mazur V., Didur I., Tkachuk O., Telekalo N. (2020). Integration of traditional and innovation processes of development of modern science. Collective monograph. Riga, Latvia: Publishing House "Baltija Publishing", pp. 42–108.

9. Matusyak M.V., Pantsyreva H.V., Prokopchuk V.M. (2021). Assessment of decorative value and prospects of the genus Magnolia compositional use on the territory of Vinnytsia. *Agriculture and forestry*, 4 (23), 137–147.

10. Mazur V.A., Myalkovsky R.O., Pantsyreva H.V., Didur I.M., Mazur K.V., Alekseev O.O. (2020). Photosynthetic productivity of potato plants depending on the location of rows placement in agrophytocenosis. *Eco. Env. & Cons*., 26 (2), 46–55.

11. Mazur V., Didur I. (2020). Legumes are strategic factor in regulating protein balance and soil fertility: collective monograph. Riga, Latvia: Publishing House "Baltija Publishing", pp. 66–90.

12. Mazur V., Didur I., Myalkovsky R., Pantsyreva H., Telekalo N., Tkach O. (2020). The Productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest- steppe Ukraine. *Ukrainian Journal of Ecology*, no. 10 (1), pp. 101–105. DOI: https://doi.org/10.15421/2020_16

13. Mazur V., Pantsyreva H., Mazur K., Myalkovsky R., Alekseev O. (2020). Agroecological prospects of using corn hybrids for biogas production. *Agronomy Research*, vol. 18, pp. 205–219.

14. Mazur V., Tkachuk O., Pantsyreva H., Demchuk O. (2021). Quality of pea seeds and agroecological condition of soil when using structured water. *Scientific Horizons,* 24(7), 53–60.

15. Mazur V.A., Didur I.M., Pantsyreva H.V., Telecalo N.V. (2018). Energy-economic efficiency of growth of grain-crop cultures in the conditions of right-bank Forest-Steppe zone of Ukraine. *Ukrainian Journal of Ecology*, vol. 8, no. 4, pp. 26–33.

16. Mazur V.A., Mazur K.V., Pantsyreva G.V. (2022). Production and export of grain and leguminous crops under martial law. *Agriculture and forestry*, 3 (26), 66–76. DOI: https://doi.org/10.37128/2707-5826-2022-3-5

17. 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, 148–153.

18. Mazur V.A., Myalkovsky R.O., Pantsyreva H.V., Didur I.M., Mazur K.V., Alekseev O.O. (2020). Photosynthetic productivity of potato plants depending on the location of rows placement in agrophytocenosis. *Ecology, Environment and Conservation*, vol. 26, no. 2, pp. 536–545.

19. 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. DOI: https://doi.org/10.15421/2019_807

20. 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

21. Mazur, V., Didur, I., Myalkovsky, R., Pantsyreva, H., Telekalo, N., Tkach, O. (2020). The Productivity of intensive pea varieties depending on the seeds treatment and foliar fertilizing under conditions of right-bank forest-steppe Ukraine. *Ukrainian Journal of Ecology,* 10(1), 101–105.

22. 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.

23. Mazur, V.A., Pantsyreva, H.V., Mazur, K.V., & Monarkh, V.V. (2019). Ecological and biological evaluation of varietal resources Paeonia L. in Ukraine. *Acta Biologica Sibirica*, 5 (1), 141–146. DOI: https://doi.org/10.14258/abs.v5.i1.5350

24. Monarkh V.V., Pantsyreva H.V. (2019). Stages of the Environmental Risk Assessment. *Ukrainian Journal of Ecology*, 9(4), 484–492. DOI: https://doi.org/10.15421/2019_779

25. Oleksandr Tkachuk, Myroslava Mordvanyuk (2022). Study of the influence of unfavorable vegetation conditions on agro-ecological resistance of bean varieties. Theoretical and practical aspects of the development of modern scientific research: Scientific monograph. Riga, Latvia: Publishing House "Baltija Publishing", pp. 109–125.

26. Olexander Tkachuk, Myroslava Mordvaniuk (2021). Research of technological indicators of grain quality of legumes as objects of storage and processing. Development of scientific, technological and innovation space in Ukraine and EU countries. Riga, Latvia: "Baltija Publishing", pp. 221–240.

27. Pantsyreva H., Stroyanovskiy V., Mazur K., Chynchyk O., Myalkovsky R. (2021). The influence of bio-organic growing technology on the productivity of legumins. *Ukrainian Journal of Ecology*, 11 (3), 35–39. DOI: https://doi.org/10.15421/2021_139

28. 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. DOI: https://doi.org/10.15421/2019_711

29. 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.

30. Puyu V., Bakhmat M., Pantsyreva H., Khmelianchyshyn Y., Stepanchenko V., Bakhmat O. (2021). Social-and-Ecological Aspects of Forage Production Reform in Ukraine in the Early 21st Century. *European Journal of Sustainable Development*, 10(1), 221–228.

31. Razanov S.F., Tkachuk O.P., Mazur V.A., Didur I.M. (2018). Effect of bean perennial plants growing on soil heavy metal concentrations. *Ukrainian Journal of Ecology*, 8(2), 294–300. DOI: https://doi.org/10.15421/2018_341

32. Razanov S.F., Tkachuk O.P., Bakhmat O.M., Razanova A.M. (2020). Reducing danger of heavy metals accumulation in winter wheat grain which is grown after leguminous perennial precursor. *Ukrainian Journal of Ecology*, 10(1), 254–260. DOI: https://doi.org/10.15421/2020_40

33. Razanov S.F., Tkachuk O.P., Ovcharuk V.V., Ovcharuk I.I. (2021). The effect of siderates on soil fertility. *Balanced environmental management*, 4, 144–152.

34. Razanov S.F., Tkachuk O.P., Razanova A.M., Bakhmat M.I., Bakhmat O.M. (2020). Intensity of heavy metal accumulation in plants of Silybum marianum L. in conditions of field rotation. *Ukrainian Journal of Ecology*, 10(2), 131–136. DOI: https://doi.org/10.15421/2020_75

35. Tkachuk O., Verhelis V. (2021) Intensity of soil pollution by toxic substances depending on the degree of its washout. *Scientific Horizons*, vol. 24, no. 3, pp. 52–57.

36. Tkachuk O.P. (2022). Prerequisites for the transition of agriculture in Ukraine to ecologically balanced principles. *Environmental sciences*, 5 (44), 144–149.

37. Tkachuk O.P., Vradiy O.I. (2022). The balance of nutrients in the soil during the cultivation of leguminous crops. *Environmental sciences*, 2 (41), 43–47.

38. Tkachuk O. (2021). Biological features of the distribution of root systems of perennial legume grasses in the context of climate change. *Scientific Horizons*, 24(2), 70–76.

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

40. V.A. Mazur, K.V. Mazur, H.V. Pantsyreva (2019). 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*, 9, 50–55.

41. Vdovenko S.A., Palamarchuk I.I., Pantsyreva H.V. and ets. (2018). Energy efficient growing of red beet in the conditions of central forest steppe of Ukraine. *Ukrainian Journal of Ecology*, 8, 34–40.

42. Vdovenko S.A., Pantsyreva H.V., Palamarchuk I.I., Lytvynuk H.V. (2018). Symbiotic potential of snap beans (Phaseolus vulgaris L.) depending on biological products in agrocoenosis of the RightBank Forest-steppe of Ukraine. *Ukrainian Journal of Ecology,* 8 (3), 270–274.

43. Vdovenko S.A., Procopchuk 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), 1–5.

44. Victor Mazur, Oleksandr Tkachuk, Hanna Pantsyreva, Ihor Kupchuk, Myroslava Mordvaniuk, Oleksandr Chynchyk (2021). Ecological suitability peas (Pisum sativum) varieties to climate change in Ukraine. Agraarteadus. *Journal of Agricultural Science*, no. 2, vol. XXXII, pp. 276–283.

45. Viktor Mazur, Ihor Didur, Oleksandr Tkachuk, Hanna Pantsyreva, Vitaliy Ovcharuk (2021). Agroecological stability of cultivars of sparsely distributed legumes in the context of climate change. *Scientific Horizons*, vol. 24, no. 1, pp. 54–60.

Izdevniecība “Baltija Publishing”
Valdeķu iela 62 – 156, Rīga, LV-1058
E-mail: office@baltijapublishing.lv

Iespiests tipogrāfijā SIA “Izdevniecība “Baltija Publishing”
Parakstīts iespiešanai: 2023. gada 10. marts
Tirāža 300 eks.