RESEARCH OF LAND RESOURCES AND SOIL COVER OF VINNYTSIA REGION

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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

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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

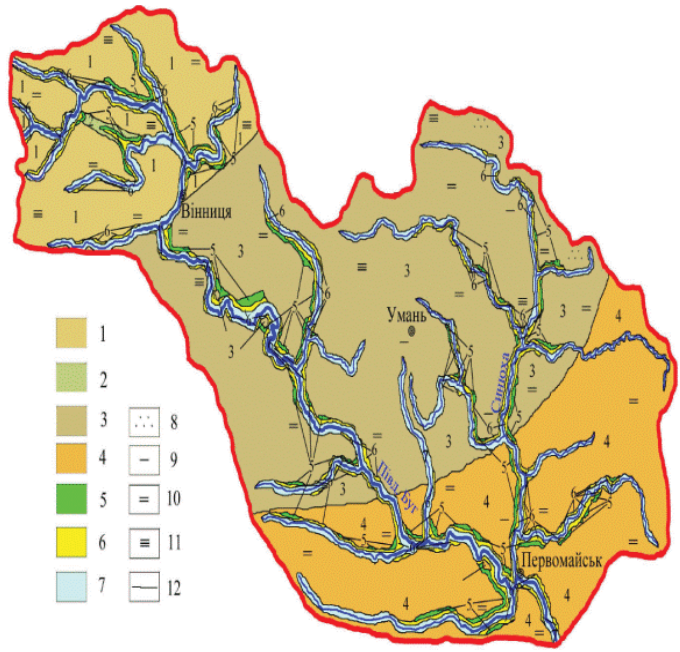

Figure 1. Soil cover of the Middle Pobuzhye in the Vytachev (Dubniv) stage (55-27 thousand of years)

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			
		Sod podzolic	Light gray forest	Dark gray	Black and green	Black soil	Lucni	Meadow – sod	Swampy	In total	Of them		
											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 Ecology*, 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.