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QUALITATIVE AND QUANTITATIVE ASSESSMENT OF SOILS IN THE WESTERN FOREST-STEPPE OF UKRAINE

The results of an agrochemical survey of the soils in the Yamnytsia Village Council, Ivano-Frankivsk region, are presented. An agro-industrial classification of all soils in the surveyed area was conducted. The current state and agrochemical properties of the soils in the Yamnytsia Village Council, particularly swampy and drained lands, were studied. It was established that the total land area in 2024 is 1,233.2 hectares, of which 1,049.9 hectares are agricultural lands. The agro-industrial classification of soils identified 11 soil groups with varying degrees of waterlogging. A significant impact of land reclamation measures was observed: 436.4 hectares of drained land, including 357.4 hectares of waterlogged and 76.6 hectares of slightly swampy land. Analysis of the soil quality showed that meadow-bog soils have the highest humus content (3.42%), while sod-podzolic soils exhibit increased acidity (pH 5.1–5.5). Patterns of agrochemical soil transformation under the influence of drainage were identified, confirming the necessity of balanced land reclamation measures to maintain soil fertility.

Keywords: soil, agro-industrial groups, drained soils, waterlogging, land reclamation, agrochemical properties.

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INTRODUCTION

Ukraine experiences a high level of agricultural development and significant land plowing. Extensive farming practices have led to severe degradation of agricultural lands, resulting in very low productivity (Hryhoriv *et al.*, 2024a; Hryhoriv *et al.*, 2024b; Kovalzhy *et al.*, 2024). In recent years, the average gross agricultural output per hectare of agricultural land in Ukraine has been approximately 375 euros, whereas in EU countries, this figure exceeds 2,000 euros (Medvedev, 2015a; Achasov & Medvedev, 2019a).

In modern conditions, land, like the entire biosphere, is significantly influenced not only by natural factors but also by human activity. In regions of intensive agriculture, soil changes not only correspond to the intensity of natural soil formation processes but often exceed them (Medvedev, 2011; Polupan *et al.,* 2015; Radchenko *et al.,* 2023).

The ongoing land reform in Ukraine is accompanied by an active transition of agricultural production to market conditions. According to legislation, land reform is an integral part of economic reforms aimed at transitioning the country to a market economy. The goal of this reform is to redistribute agricultural land by transferring it into private and collective ownership, creating conditions for the equitable use of land of various ownership forms by enterprises, institutions, and organizations, as well as ensuring the rational use and protection of land resources.

Therefore, modern scientific research dedicated to soil monitoring pays special attention to the characteristics of soil as a bio-lithogenic body. In this context, monitoring involves observing the dynamics of soil properties in space and time on specially designated plots that have state status and represent natural diversity and all types of economic land use (Tsapko, 2004; Gobat *et al.,* 2004; Heger *et al.*, 2012; Truskavetskiy & Tsapko, 2016; Karbivska *et al.,* 2022a).

The soils of the Western Forest-Steppe are genetically unique and attract significant attention from scientists. The studies of their qualitative characteristics, fertility restoration, and conservation measures have been the focus of works by Ukrainian scientists such as Pozniak, Andrushchenko, Vernarder, Yamelynets, Kit, and others (Pozniak, 2018; Andrushchenko, 2020; Kvitko *et al.*, 2021).

In the 1950s, in accordance with a resolution of the Ukrainian government, a large-scale soil survey of the country was conducted. For this purpose, an expedition was organized under the leadership of Kozhukhar, which included prominent soil scientists such as Humeniuk, Kulchytskyi, Panteleymonov, Tkachuk, Pasulko, Truskavetskyi, Aronets, and other specialists from Chernivtsi and Lviv universities (Kozhukhar, 1960a). The results of these studies included the compilation of soil maps for farms at a scale of 1:10,000 and for administrative districts of the region at a scale of 1:25,000, agro-soil zoning, as well as the determination of quantitative and qualitative soil characteristics, which were reflected in cartograms.

Currently, land degradation processes and desertification are frequently observed, arising from exhausting and irrational soil exploitation, excessive deforestation, and active military actions. This leads to the active development of landslides, karst formation, and flooding of territories. The study of erosion processes in the Ivano-Frankivsk region has been the focus of works by Prykhodko, Tararika, and Shykula. They have developed theoretical and methodological foundations for anti-erosion measures, improving existing methods and creating new water-regulating techniques. Their works scientifically substantiate the advantages of the proposed technologies, taking into account the regional and environmental features of the Carpathian region (Prykhodko, 2017; Hryhoriv *et al.*, 2021; Tykhonova *et al.*, 2021).

According to the materials of the Department of Agro-Industrial Development, Ecology, and Natural Resources of the Ivano-Frankivsk region, agricultural land accounts for 75.3% of the total land area, while in certain administrative units, this figure varies from 65.5% to 85.7%. The arable land ratio in relation to all agricultural lands in the region is 65.3%, with district variations ranging from 54.7% to 78.6%. At the same time, approximately 24% (675.8 thousand hectares) of agricultural land is affected by water erosion, 8% (178.7 thousand hectares) by wind erosion, and 68% (1,711.0 thousand hectares) of soils are acidic.

Given the significant degradation of soils worldwide, particularly in Ukraine, there is a need for a comprehensive assessment of their condition. The morphological complexity of the region and its high level of forestation necessitate a detailed analysis of available lands, especially lowland areas, regarding potential changes under the influence of geological and technogenic factors (Kasiianchuk, 2020a; Masoero *et al.*, 2021; Radchenko *et al.*, 2024).

Research on the qualitative state of soils in the Ivano-Frankivsk region is a crucial scientific direction aimed at assessing fertility, identifying degradation processes, and developing soil resource conservation measures. Danyliv notes that the region is characterized by diverse soil cover, including gray forest soils, podzolized chernozems, sod-podzolic, and brown mountain-forest soils. The main degradation processes include water erosion, humus loss, and soil acidification (Danyliv, 2022; Dindaroglu *et al.*, 2022; Karbivska *et al.*, 2023). Kasiianchuk has found that anthropogenic pressure leads to changes in soil structure and properties, negatively affecting their ecological condition (Kasiianchuk 2020a, Hryhoriv *et al.*, 2022; Yatsenko *et al.*, 2025).

For 55 years, the Ivano-Frankivsk branch of the state institution "Institute for Soil Protection of Ukraine" has been monitoring the qualitative state of soils in the region. The institution conducts comprehensive scientific research and provides agrochemical field and land parcel passports containing indicators of soil fertility and environmental safety (Institute for Soil Protection of Ukraine, 2023).

Zorin (2025) assessed the ecological state of soil cover and the design of ecological monitoring within the Ivano-Frankivsk urban community and its surroundings. This article emphasizes the importance of using geographic information systems (GIS) for ecological monitoring and forecasting, emphasizing their relevance in modern ecological assessments (Figure 1).

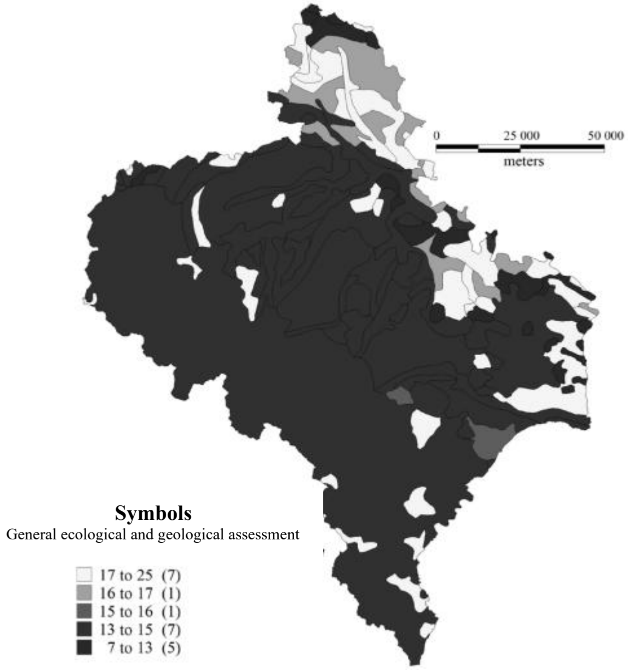

Figure 1. Map of ecological and geological assessment of the state of soils of Ivano-Frankivsk region

Figure 1 presents a general map characterizing the state of soils based on GIS analysis. Soils within the region have different assessments, which is explained by the uneven load on their qualitative state. As can be seen from the map, the overall assessment varies from 7 to 25. The assessment is the physical content of the influence of factors on the state of soils. Meadow-marsh soils, sod-brown gleyed soils, dark gray podzolized gleyed soils are most exposed to negative factors and require further study.

Thus, scientific research indicates a significant diversity of soil cover in the Ivano-Frankivsk region and the presence of degradation processes caused by both natural and anthropogenic factors. It is recommended to implement comprehensive measures for soil conservation and restoration, as well as systematic monitoring of their condition using modern technologies.

MATERIAL AND METHODS

The aim of our study was to survey agricultural lands, assess the nutrient regime of soils, summarize the results of ecological and agrochemical analysis, and conduct a comprehensive evaluation of the agroecological condition of soils in the Yamnytsia Village Council of Ivano-Frankivsk Oblast (Figure 2).

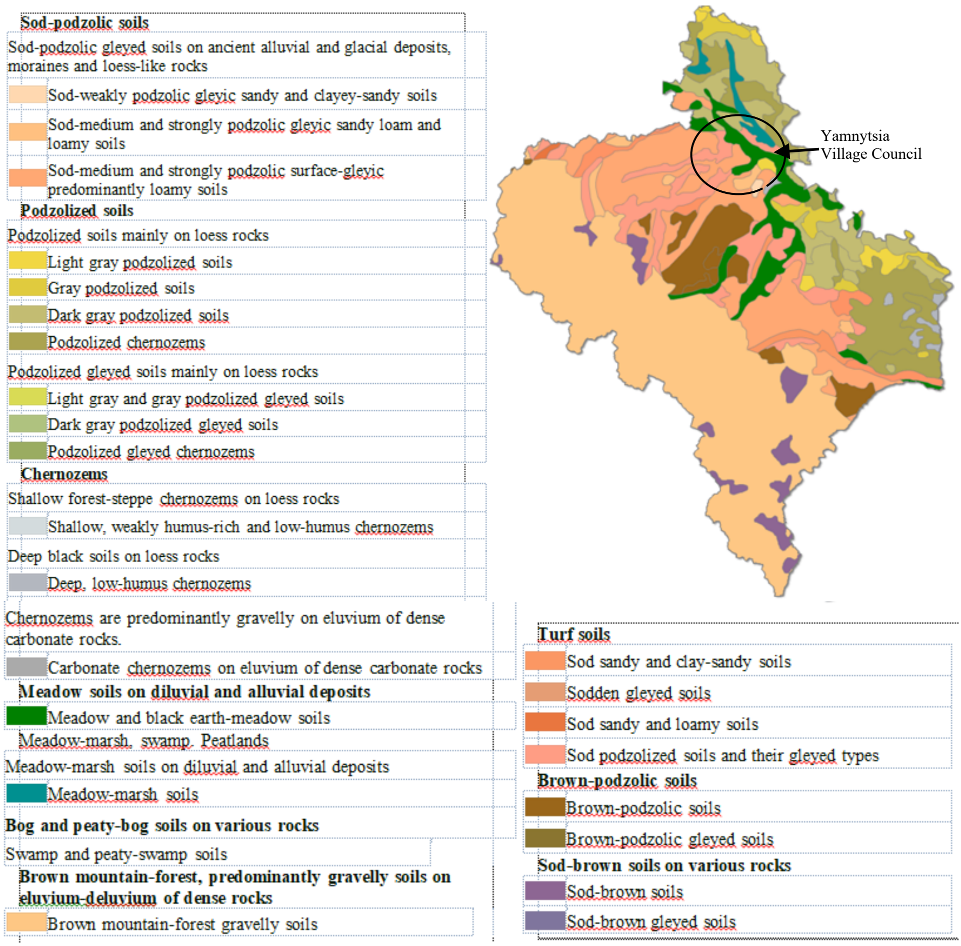

Figure 2. Soil map of Ivano-Frankivsk region

The object of research is the agricultural soils of the Yamnytsia Village Council of Ivano-Frankivsk Oblast and their qualitative state based on ecological and agrochemical characteristics.

To achieve the set goal, field and laboratory methods of soil analysis were applied. The qualitative and quantitative assessment of soils in the Yamnytsia Village Council of Ivano-Frankivsk Oblast was conducted using generally accepted methodologies for soil diagnostics and agrochemical analysis.

Soil survey routes within the respective village council territory were developed under laboratory conditions based on topographic maps at a scale of 1:10,000. Cartographic materials were used to precisely determine the initial, intermediate, and final points for soil sampling. Route planning was carried out considering the morphological and morphometric characteristics of all landscape elements and landforms – from watersheds to river valleys. This ensured the identification of patterns in the distribution of different soil types and varieties and the selection of samples in key relief zones.

Sampling points were geodetically referenced concerning the state geodetic network using GPS receivers. During the soil survey of agricultural lands that had previously been insufficiently studied, the standard Methodology of Large-Scale Soil Research and generally accepted analysis methods were applied (Sazonova, 1994). All planned studies were carried out following the requirements outlined in the Guidelines for Agrochemical Certification of Agricultural Lands (Yatsuk & Baliuk, 2013; Karbivska *et al.*, 2022b). The statistical analysis was performed using Microsoft Excel and Python software.

RESULTS AND DISCUSSION

To study the soil cover, we selected and examined the territory of the Yamnytsia Village Council. During the soil survey, we clarified the areas of land use (Table 1).

Table 1. Land Areas of Yamnytsia Village Council, 2024

Purpose	Area, ha	Area, %
Agricultural lands purpose	1049.9	85.1
forest	5.9	0.5
shrubs	28.9	2.3
stony places	47.4	3.9
ravines	0.2	0.1
others	100.9	8.1
Total	1233.2	100

It has been established that the total area of land within the Yamnytsia Village Council in 2024 is 1,233.2 hectares, with the majority being agricultural land (1,049.9 ha). Other land categories include 5.9 ha of forest, 28.9 ha of shrubland, 47.4 ha of rocky terrain, 0.2 ha of ravines, and 100.9 ha of other land types.

According to data from the Ivano-Frankivsk branch of the State Institution "Institute for Soil Protection of Ukraine," the area of agricultural land in 2014 was 1,042.5 ha, which differs from previous figures due to changes in land use, agricultural intensification, or natural factors. Other land categories remained unchanged (Institute for Soil Protection of Ukraine, 2023).

A comparison with data from previous years allows for an assessment of trends in land changes, such as the reduction or expansion of certain land categories, which may be linked to anthropogenic influences, natural processes, or shifts in land use.

The Ivano-Frankivsk region is characterized by significant soil diversity, including the presence of wetland and drained soils, which play a crucial role in regional ecosystems and agricultural production. The Yamnytsia Village Council area is located in the valley of the Bystrytsia River, on its left bank, where floodplains and the first and second above-floodplain terraces are well-defined. As a result, the surveyed area contains waterlogged and swampy soils that have formed and developed under conditions of permanent or seasonal excess moisture. The wetland soils of Ivano-Frankivsk are formed under excessive moisture conditions in lowland and foothill areas. They are characterized by a high content of organic matter but have low aeration and significant acidity (Knysh, 2017).

According to Andrushchenko (2020), swamp formation processes in the region largely depend on climatic factors, groundwater levels, and the composition of soil-forming rocks.

Within the study area, 535.1 ha of waterlogged and swampy agricultural lands were identified, of which 440.7 ha have been drained using tile drainage (Table 2). Additionally, 344.6 ha of gleyic soils have been drained.

Table 2. Characteristics of Drained Lands, ha

Soil code	Soil name	Total area, ha	Drained	Needs to be drained
1	Sod-medium-podzolic, surface-gleyed, silty loam.	65.6	65.6	–
2	Podzolic-sod, surface-gleyed, silty loam.	203.5	202.2	1.3
3	Meadow leached, silty loam.	115.6	97.1	18.5
6	Turf-podzolic gleyic sandy-medium loamy soils	60.4	–	60.4
7	Turf-podzolic gleyic silty-medium loamy soils	27.3	15.1	12.2
8	Turf-podzolic gleyic silty-heavy loamy soils	62.7	60.7	2.0
Total		535.1	435.4	95.7

In the second half of the 20th century, large-scale land reclamation efforts were actively carried out in the Ivano-Frankivsk region, aimed at draining waterlogged lands and improving conditions for agriculture (Kozhukhar, 1960b). However, according to Medvedev's research (Medvedev, 2015b), excessive drainage can lead to secondary salinization, oxidation of peat horizons, and loss of humus.

Modern studies indicate the need for a comprehensive approach to managing drained soils, including regulated moisture control and agrotechnical measures to prevent degradation (Achasov & Medvedev, 2019b, Datsko *et al.*, 2024).

According to Kasiianchuk's findings (Kasiianchuk, 2020b), a significant portion of the drained lands in Ivano-Frankivsk region requires repeated reclamation due to the deterioration of the water regime and a decline in fertility. To enhance the efficiency of these soils, the application of organo-mineral fertilizers, green manure, and minimal mechanical tillage is recommended (Pozniak, 2018).

During soil surveys, we identified a considerable number of waterlogged soils formed in the floodplain of the Bystrytsia River. It was established that their waterlogging occurs due to the shallow groundwater table (Table 3).

From the analysis of land use distribution by category and degree of moisture on the studied territory, it was found that the total area of all land parcels is 534.3 hectares, with the largest portion occupied by arable land (489.2

hectares). Of this area, 379.5 hectares are classified as waterlogged, while 109.7 hectares belong to slightly swampy lands.

Table 3. Characteristics of Waterlogged Agricultural Lands

Name of the area	Total area, ha	Overhydrated	Wetlands
arable	489.2	379.5	109.7
including drained	436.2	357.2	76.6
hayfields	10.9	–	10.9
including drained	–	–	–
pastures	34.0	6.2	2.8
including drained	0.2	0.2	–
total	534.3	385.9	145.2
including drained	436.4	357.4	76.6

Among the arable land, 436.2 hectares have been drained, indicating a significant impact of reclamation measures. However, 357.2 hectares show signs of waterlogging, while 76.6 hectares exhibit slight swampiness. Hayfields cover 10.9 hectares and are exclusively represented by slightly swampy lands. Pastures occupy an area of 34.0 hectares, of which 6.2 hectares are waterlogged, and 2.8 hectares are slightly swampy.

The total area of drained land is 436.4 hectares, with 357.4 hectares classified as waterlogged and 76.6 hectares as slightly swampy. This indicates the effective use of reclamation; however, some lands still require additional measures for water regime regulation.

Scientific studies confirm that the swampy and drained soils of the Ivano-Frankivsk region have significant ecological and economic potential. However, their rational use requires balanced approaches. Further research should focus on adaptive water management technologies, fertility enhancement, and prevention of degradation processes.

Given the large number of settlements and extensive unexplored land areas, the solution to the problem lies in defining the main agro-industrial soil groups within the settlement using auxiliary materials such as topographic maps and agro-industrial soil maps of the study area.

According to data from the land resources department, the Yamnytsia village council contains 982.3 hectares of agricultural land.

Based on the obtained soil survey results within the Yamnytsia village council of the Ivano-Frankivsk region, agro-industrial soil grouping was conducted (Rishuk *et al.*, 2003). During the study, 11 agro-industrial soil groups were identified in the research area (Table 4).

So, based on the survey results, we see that soddy-podzolic soils (codes 18d, 28d) are present in the surveyed area. These soils are divided into non-drained and drained types, characterized by a medium-loamy mechanical composition and surface gleying .

Table 4. Agro-Industrial Soil Groups

Code	**Soil Name**
18d	Soddy-medium-podzolic and podzolic-soddy, surface-gleyed, medium-loamy, non-drained soils
28d	Soddy-medium-podzolic and podzolic-soddy, surface-gleyed, medium-loamy, drained soils
133d	Meadow medium-loamy soils
141	Meadow-bog soils
175g	Shallow soddy, gleyed, light-loamy soils
176d	Deep soddy, podzolized, gleyed, medium-loamy soils
178d	Deep soddy, podzolized, gleic, medium-loamy, non-drained soils
178e	Deep soddy, podzolized, gleic, heavy-loamy, non-drained soils
179e	Soddy, podzolized, gleic, heavy-loamy, drained soils
188vk	Weakly developed soddy, sandy loam soils
215	Eroded medium-loamy soils and outcrops of loose rocks

Meadow and meadow-bog soils (codes 133d, 141) have a medium-loamy texture and form under conditions of periodic waterlogging. Meanwhile, soddy-podzolic soils (codes 176d, 178d, 178e, 179e) are distinguished by gley and gleic processes, varying degrees of moisture, and different mechanical compositions. Weakly developed sandy loam and eroded soils (codes 188vk, 215) are affected by erosion processes or marked by outcrops of loose rocks.

This classification allows for the assessment of the agroecological properties of the soils and provides a basis for their effective use in agriculture.

The results of the agrochemical analysis of the soils in the Yamnytsia Village Council area are distributed by agro-industrial groups. The main research parameters include humus content, acidity level (pH in salt extract and aqueous suspension), hydrolytic acidity, the sum of absorbed bases (Ca^{2+}, Mg^{2+}), the degree of base saturation (BS), and soil moisture (Table 5).

It was established that the highest humus content (3.42%) was recorded in meadow-bog soils (agrogroup 141), which aligns with the characteristic accumulation of organic matter in such soils. The most acidic soils were observed in groups 215 (eroded medium-loamy) and 18d (soddy-podzolic, non-drained), where pH values range from 5.1 to 5.5. This corresponds to the findings of Shpak (2017), who also noted increased acidity in the soddy-podzolic soils of Prykarpattia.

The sum of absorbed bases varies from 0.68 mg-eq/100 g in group 178d (non-drained gleic soils) to 6.41 mg-eq/100 g in group 178e (heavy-loamy, non-drained soils), indicating significant differences in the soils' absorption capacity. Similar results were reported by Horovyi *et al.* (2020) for waterlogged and soddy-gleic soils of Prykarpattia.

Drained soils (groups 28d, 179e) have lower moisture content compared to their non-drained counterparts (18d, 178d, 178e), confirming the effectiveness of drainage measures in the region, consistent with the conclusions of Knysh *et al.* (2019).

Table 5. Results of agrochemical properties of soils of Yamnytsia village council

Sampling Depth, cm	Humus, %	pH		Hydrolytic Acidity, mg-eq/100 g soil	Sum of Absorbed Bases (Ca^{2+}, Mg^{2+}), mg-eq/100 g	CHO, %	Moisture by Mass, %
		Salt Extract	*Water*				
Group 18d							
Soddy-medium-podzolic and podzolic-soddy, surface-gleyed, medium-loamy, non-drained soils							
0-20	1.60	5.5	5.7	3.1	12	79.2	10
20-40	1.52	5.4	5.6	2.8	17	80.0	15
Group 28 d							
Soddy-medium-podzolic and podzolic-soddy, surface-gleyed, medium-loamy, drained soils							
0-20	1.62	5.3	6.1	2.71	15.5	75	14
20-40	0.77	5.1	5.8	1.85	20.0	47	19
Group 133 d							
Meadow medium-loamy soils							
0-20	3.31	6.2	6.0	0.92	20.0	83	11
20-40	2.73	6.3	6.9	0.72	22.1	90	18
Group 141							
Meadow-bog soils							
0-20	3.42	6.00	6.88	0.97	21.00	95.58	12
20-40	2.75	6.19	7.03	0.70	24.40	97.21	20
Group 175 g							
Shallow soddy, gleyed, light-loamy soils							
0-20	1.75	5.5	6.2	2.54	10.8	76	11
20-40	1.34	5.3	6.0	1.21	15.0	80	16
Group 176d							
Deep soddy, podzolized, gleyed, medium-loamy soils							
0-20	1.78	5.5	5.9	2.01	13	77.5	11.9
20-40	1.40	5.4	5.7	1.84	19	84.5	15.0
Group 178d							
Deep soddy, podzolized, gleic, medium-loamy, non-drained soils							
0-20	1.84	5.78	6.51	0.68	11.00	94.25	12
20-40	0.77	5.75	6.57	1.75	16.00	90.20	20
Group 178e							
Deep soddy, podzolized, gleic, heavy-loamy, non-drained soils							
0-20	2.05	5.9	6.4	6.41	14.5	82	10
20-40	1.13	5.5	6.1	5.05	15.0	75	14
Group 179e							
Soddy, podzolized, gleic, heavy-loamy, drained soils							
0-20	1.97	5.50	6.77	2.12	18.00	89.50	12
20-40	1.17	5.15	6.25	2.21	11.00	83.25	18
Group 188vk							
Weakly developed soddy, sandy loam soils							
0-20	1.70	5.3	6.3	2.97	10.0	75	12
20-40	1.28	5.1	6.1	1.44	13.8	81	18
Group 215							
Eroded medium-loamy soils and outcrops of loose rocks							
0-20	0.65	5.10	6.08	1.90	11.20	85.49	12
0-20	0.92	5.17	6.21	1.82	12.40	87.20	17
X	1.7		5.54	6.23	2.17	15.58	14.45
S	0.77		0.38	0.41	1.38	4.13	3.31
V,%	45.17		6.78	6.52	63.75	26.51	22.90

A high level of moisture supply (over 90%) was recorded in meadow-bog and soddy-gleic soils, which is typical for waterlogged ecosystems.

For an in-depth analysis of the agrochemical properties of the soils within the Yamnytsia village council, methods of descriptive statistics, correlation analysis, and analysis of variance (ANOVA) were applied.

The correlation analysis revealed a strong positive relationship between humus content and soil pH ($r = 0.90$), as well as between humus and the sum of absorbed bases ($r = 0.80$). This indicates the important role of organic matter in shaping the chemical properties of soils. A moderate negative correlation was found between humus content and soil moisture ($r = -0.38$), which may be due to differences in soil types and the degree of drainage.

Thus, the strongest relationship is observed between humus content, soil acidity (pH), and base saturation. This confirms their role in the formation of soil fertility.

The obtained results align with the data of Smoliarchuk (2016), who studied the agrochemical indicators of drained lands in Prykarpattia. In particular, a similar trend of decreasing acidity and improving agrochemical properties after drainage was observed.

Research by Babych (2021) confirms that meadow-bog soils maintain high natural fertility, reflected in the elevated humus content (up to 3.42%) and high base saturation (BS) values.

Overall, the results indicate patterns of agrochemical soil transformation depending on natural and anthropogenic factors, consistent with widely recognized scientific approaches in soil research in Prykarpattia (Rishchuk, 2003; Horovyi *et al.*, 2020).

CONCLUSIONS

Based on the conducted research, it has been established that the territory of Yamnytsia Village Council is characterized by significant land-use diversity, with agricultural lands prevailing. A comparison with 2014 data indicates dynamic changes in land-use structure, which may be driven by both natural factors and anthropogenic influence.

The study of soil cover confirmed the presence of large areas of waterlogged and swampy lands, most of which have undergone reclamation measures. It was found that drainage significantly affected the agrochemical properties of the soils, improving their structure, reducing moisture content, and altering acidity levels.

The analysis of soil agro-production grouping revealed significant differences in mechanical composition, moisture levels, and fertility. The highest humus content is typical for meadow-bog soils, while soddy-podzolic and eroded soils exhibit increased acidity.

The obtained results confirm the need for an integrated approach to managing drained soils, including regulated moisture control, the application of organic-mineral fertilizers, and minimizing mechanical tillage. To preserve fertility and prevent degradation processes, the implementation of adaptive technologies and the re-melioration of certain land plots are recommended.

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