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Dynamics of soil fertility indicators in the Chernivtsi region

Abstract. Agrochemical assessment of soils is important for the development of measures for the rational use of soils. The purpose of the study was to establish the dynamics of changes in soil fertility indicators in the Chernivtsi region during 2011-2020. Laboratory and field methods, analysis, and generalisation were used. The reaction of the soil, humus content, the nitrogen content of easily hydrolysed compounds, mobile phosphates, and exchangeable potassium were determined in soil samples. It was identified that the acidity of the soil solution in the region is dominated by soils close to neutral (31.8%) and neutral (36.5%). The weighted average salt pH is 5.8, which corresponds to a close to the neutral reaction of the soil solution. Compared to the previous round of the examination (2011-2015), the weighted average pH indicator did not change in terms of the level of humus supply, soils with an average humus content (66.7%) predominate, and the weighted average humus content in the region is 2.7%. Compared to the previous round of the examination, the weighted average humus content increased by 0.1% in terms of nitrogen content, which is easily hydrolysed, most lands have very low (48.3%) and low (48.7%) indicators. The weighted average content of easily hydrolysed nitrogen for the reporting period is 106.4 mg/kg of soil, which corresponds to the low availability of this element. Compared to the previous round of the examination, the weighted average content of easily hydrolysed nitrogen increased by 0.9 mg/kg of soil. The region is dominated by land with an average content of mobile phosphorus compounds (31.5%), and the weighted average content of mobile phosphorus compounds is 56 mg/kg, which corresponds to the average availability. Compared to the previous round of the examination, the weighted average phosphorus content increased by 4.0 mg/kg. The content of mobile potassium compounds is dominated by soils with a very high content of potassium (51.5%), although the weighted average content of mobile potassium compounds is 78 mg/kg, which corresponds to the average availability of this macronutrient. Compared to the previous round of the examination, the weighted average phosphorus content increased by 15.4 mg/kg. The results of the paper can be used in the process of training specialists in soil science and agronomy, and will also be useful for land users of the Chernivtsi region when planning measures for the rational use of soils

Keywords: soil reaction, soil humus content, easily hydrolysed nitrogen compounds, mobile phosphorus, exchangeable potassium, agrochemical examination

INTRODUCTION

The rational use and protection of land resources are one of the most important socio-economic issues of the present time. Its multidimensional nature determines a systematic approach to solving practical problems of organising the effective and integrated use of the main national wealth – land. For practical solutions to problems of preserving soil fertility, it is necessary to have objective and reliable information about their ecological-agrochemical state (Bandurovych *et al.*, 2017; Hryshchenko *et al.*, 2019). That is why in Ukraine, to

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timely establish the nature and dynamics of changes in the soils of agricultural land, protect them, and restore fertility in accordance with the Law of Ukraine "On Land Protection" (2003), it is necessary to conduct their ecological-agrochemical certification. Ultimately, the data obtained allow for establishing the state of soil fertility and its changes and developing agrotechnical, agrochemical, technological, and economically justified measures to preserve and restore soil fertility.

Bulygin *et al.* (2020) note that the quality of soils can be assessed by the totality of their properties, which can be both positive and negative, which is associated with the specific features of their use.

Balyuk *et al.* (2018) indicate that the most pressing issues of modern times are those that ensure an increase in the level of the information content of data on the soil cover of Ukraine, its formation under the influence of both natural and anthropogenic factors.

Soil degradation processes are developing over large areas and the current state of land resources in Ukraine is of concern. The main reasons are non-compliance with an ecologically balanced ratio of agricultural land, forest-covered areas, reservoirs, and a substantial increase in anthropogenic load on soil cover in recent decades, which has negatively affected the sustainability of agricultural landscapes (Berezhniak *et al.*, 2020). Losses of humus and nutrients in Ukraine were recorded in 43% of all areas (Truskavets'kyy & Tsapko, 2016). The importance of soils is noted in supporting food production and providing ecosystem services, but the soils are under pressure due to population growth, higher demand for food, and competition in land use. For the sustainable use of soil resources, there is a growing demand for up-to-date soil information (Chen *et al.*, 2022).

With the introduction of Soil Day (World Soil Day..., 2021) in December 2013, the term soil health is gaining popularity. Healthy soil is a dynamic living system that can ensure the cultivation of plants, breeding of animals, maintain their health, improve water and air quality, control the availability of nutrients, accumulate carbon in the soil, etc. Soil health is considered the foundation of plant health and productivity, and the basis of sustainable agricultural production (Handayani & Hale, 2022). The fact that land use should be conducted based on land use stabilisation by optimising natural components, introducing adaptive farming systems, and the latest technologies for realising the high biological potential of modern crop varieties is also mentioned by Novakovs'kyy & Novakovs'ka, (2017).

Dem'yanyuk & Boyko (2019) note that the issue of soil condition for various reasons on the land territories of Ukraine is currently being considered insufficiently. Soils need a comprehensive assessment of their condition for forecasting and timely prevention of degradation processes, protection, and rational use of land (Balyuk *et al.*, 2017; Graham, 2021; Hunchak, 2022;).

Cherlinka V. et al. (2019) indicate that in the current conditions, there is a growing need for updated land taxation methods based on accurate information about the ground cover. Ukraine has a large area of land, so field examinations often do not cover the entire territory, which can lead to errors in determining soil varieties and their properties. That is why the examination of indicators of effective soil fertility in a particular territory is relevant, which is what the paper is devoted to.

Smaha & Kazimir (2013) note that various genetic soil types are common in the Chernivtsi region. Sod-brown-earth and podzolic brown-earth soils were formed on eluvial-diluvial deposits, and in foothill areas, 25 thousand hectares are occupied by brownish-podzolic soils. In the forest-steppe districts of the region, 68.3 thousand hectares are occupied by light grey and grey forest soils, 90.8 thousand hectares – by dark grey forest soils. Podzolic chernozems cover an area of 41.9 thousand hectares and are confined to plateaus and shallow slopes of slightly hilly terrain. Such soils as light grey, grey, dark grey forest, podzolic chernozems, semi-hydromorphic meadow-chernozem and hydromorphic meadow-swamp are common in all administrative regions with the exception of Vyzhnytsia and Putyla districts. Brown mountain-forest soils are common in Storozhynets, Vyzhnytsia, and Putyla districts, sod-brown-earth and brown-earth-podzolic soils are typical for the Putyla district, and brown-earth-podzolic soils are common for Hertsa, Storozhynets, and Vyzhnytsia districts.

The purpose of the study – examine agricultural land, assess the state of the main indicators of soil fertility in the Chernivtsi region, and determine the dynamics of changes in these indicators for 2011-2020.

MATERIALS AND METHODS

The Chernivtsi branch of the state institution "Institute of Soil Protection of Ukraine" researched soils to determine the main indicators of soil fertility. The study was conducted in 2016-2020 according to the methods described in the methodology for agrochemical certification of agricultural land (Yatsuk *et al.*, 2019).

Soil samples were taken from a depth of 0-30 cm in accordance with DSTU 4287:2004 (2005). The combined sample consisted of 20-25 point samples weighing about 500 g. If there are two soil types or agricultural production groups of soils within the same basic site, point samples were taken from the type that prevailed in terms of area. If the areas of the two types were equivalent, then two samples were taken. When taking soil samples on agricultural land, a distance of at least thirty meters from buildings, forests, forest belts, warehouses of organic and mineral fertilisers, roads, and other linear objects was observed. In addition, when selecting combined samples, agricultural crops that were grown in the fields were considered: combined samples were taken for each crop. The average sample is made from an area of 50 hectares, provided that

the granulometric composition is uniform. If the granulometric composition was different, two or more averaged samples were taken for each soil type. Soil samples were dried for analysis. An average sample from at least 5 different locations was taken with a spatula from the dried soil sample. They determined the humus content by the Tyurin method (DSTU 4289:2004, 2005), the reaction of the soil medium according to DSTU ISO 10390:2007 (2007), the content of easily hydrolysed nitrogen compounds according to DSTU 7863:2015 (2015), mobile phosphates and exchangeable potassium according to DSTU 4115-2002 (2003).

During the period from 2016 to 2020, the Chernivtsi branch of the state institution "Institute of soil protection of Ukraine" examined 182.4 thousand hectares of agricultural land in Vyzhnytsia, Hertsa, Hlyboka, Zastavna, Kelmentsi, Kitsman, Novoselytsia, Putyla, Sokyriany, Storozhynets, and Khotyn districts.

RESULTS AND DISCUSSION

Figure 1 shows that in the Chernivtsi region, the largest areas are occupied by soils with a neutral and close to neutral reaction of the soil environment.

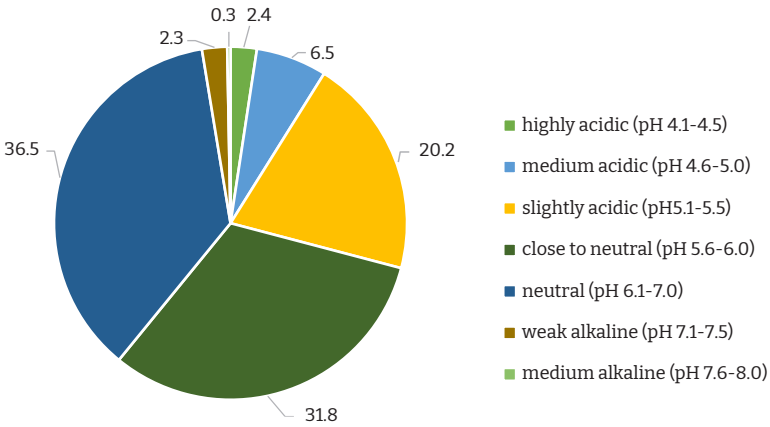

Figure 1. Distribution of the area of agricultural land in Chernivtsi region by the reaction of soil solution, %

Based on the results of the analysis of the reaction of the soil medium (salt pH), the areas under study were distributed as follows (Fig. 1): very highly acidic soils with a pH of less than 4.0 are absent in the area, highly acidic lands with a pH of 4.1-4.5 occupy 4.5 thousand hectares, which is 2.4% of the land area under study, medium acidic with pH 4.6-5.0 – 11.9 thousand hectares (6.5%), slightly acidic (pH 5.1-5.5) – 36.8 thousand hectares (20.2%), close to neutral (pH 5.6-6.0) – 57.9 thousand hectares (31.8%), neutral (pH 6.1-7.0) – 66.6 thousand hectares (36.5%), weak and medium alkaline (water pH 7.1-8.0) – 4.6 thousand hectares (2.6%). The weighted average pH of salt in the 11th round of examinations was 5.8, which corresponds to a close to neutral reaction of the soil solution.

Compared to the previous round of the examination (20112015), the weighted average pH value did not change (Fig. 2). However, there was a decrease in the area of acidic soils by 6%. The area of land with a close to neutral reaction of the soil environment increased by 3.7%, and neutral land decreased by 0.2%. Analysing the results of the study of the reaction of the soil environment in the context of districts, it was identified that in the Hertsa district, the weighted average pH indicator decreased by 0.2 compared to the previous round of the examination, and in the Kitsman and Hlyboka districts – by 0.1 units. This is due to the lack of measures for liming acidic soils. As for Kelmentsi, Zastavna, Storozhynets, and Putyla districts, their weighted average pH indicator remained at the level of the previous round. In Novoselytsia, Vyzhnytsia, Sokyriany, and Khotyn districts, there is a slight increase in the pH value.

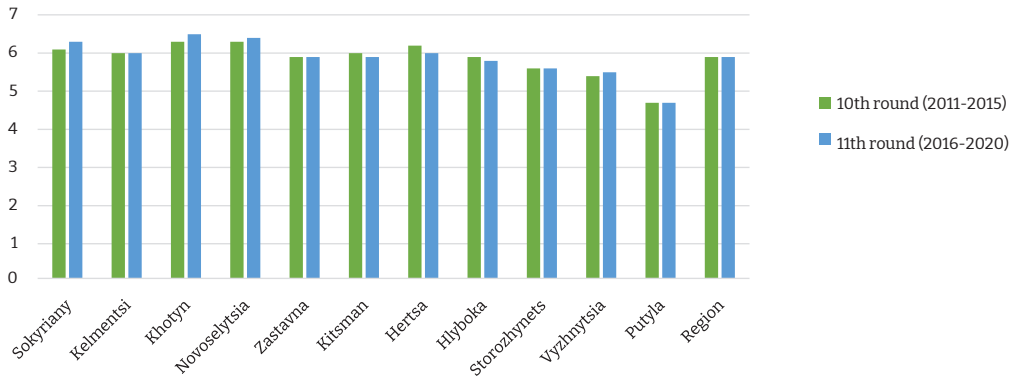

Figure 2. Dynamics of changes in the reaction of the soil (salt pH) of the lands of the Chernivtsi region for the 10th-11th round of agroecological examinations

Soil organic matter (SOM) is an important indicator of its fertility since changes in its content can indicate the presence or absence of soil degradation processes. SOM directly or indirectly improves soil health. That is why efforts must be made to persuade farmers or other land users to increase resource efficiency and the ability to preserve soil to maximise the benefits of agriculture (Sharma *et al.*, 2021; Yu *et al.*, 2022). Humus is the main component of SOM and its importance, first of all, lies in the fact that it serves as a reserve fund of the soil in relation to nitrogen, which, as is known, is not part of mineral compounds. In addition, 40-80% of all phosphorus is also located in its organic matter. Humus also affects the physico-chemical, biological, agrochemical properties of soils, and their water and air regimes, on which the productivity of agricultural crops depends. The weighted average humus content in the region is 2.7%, which corresponds to reserves of 81 tons per 1 ha (Fig. 3).

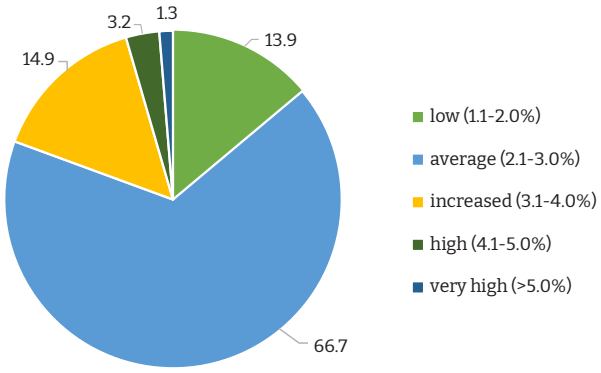

Figure 3. Distribution of the area of agricultural land in Chernivtsi region by humus content, %

In terms of humus content, the soils of the Chernivtsi region were distributed as follows: soils with a very low humus content in the region are absent, with a low content occupy 25.3 thousand hectares (13.9%), with an average – 121.5 thousand hectares (66.7%), with increased content – 27.2 thousand hectares (14.9%), with a high content – 5.9 thousand hectares (3.2%), with a very high content – 2.4 thousand hectares (1.3%). Thus, the region is dominated by soils with an average humus content. Thus, two-thirds of the soils of the region have an average potential fertility in terms of humus content, which is why it is necessary to pay special attention to the preservation of organic matter in the soil and prevent the development of dehumification processes in the soils. Therewith, 19.4% of the land is characterised by a humus content of more than 3%.

In general, the weighted average humus content in the region increased by 0.1%, which indicates effective land use and ɜrevention of losses of organic matter in soils (Fig. 4).

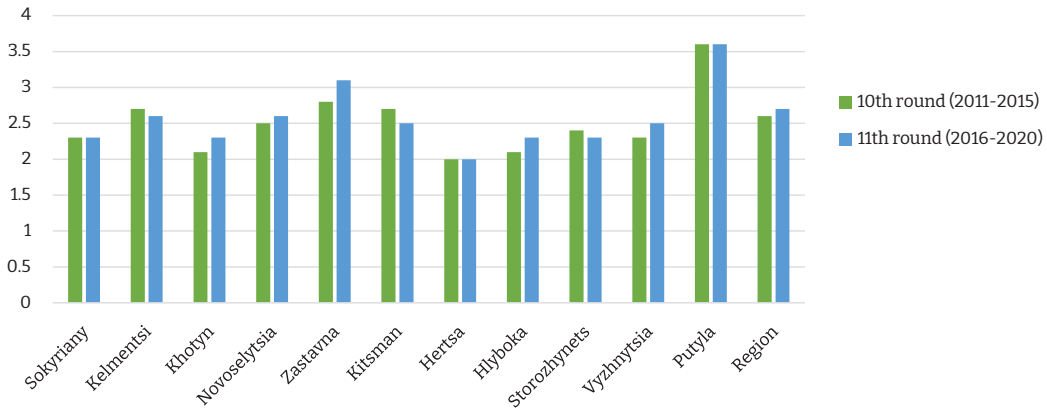

Figure 4. Dynamics of changes in humus content indicators of the examined lands of the Chernivtsi region for the 10th-11th round of agroecological examinations, %

The largest increases in humus content were observed in Zastavna (+0.3%), Hlyboka, Vyzhnytsia, and Khotyn (+0.2%) districts. However, there are areas where a decrease in the weighted average humus content was recorded: in Kitsman district, the decrease was 0.2%, and in Kelmentsi and Storozhynets districts – 0.1%. This indicates an irrational use of soil. Yatskiv (2008) indicates a decrease in the humus content in the soils of the

Chernivtsi region from 2003 to 2008 by 0.1% from 2.5 to 2.4. Poznyak *et al.* (2020) note that the most productive soils with a high content and reserves of humus, a sufficient level of supply of nutrients, and favourable physical properties are used as arable land, the share of which in the Chernivtsi region is 60.2%. The reasons for the decrease in humus content are an increase in the area of row crops sown against the background of an insufficient number of perennial grasses, etc. In addition, the removal of crop by-products from the fields and an unbalanced crop fertilisation system lead to soil dehumification. Therewith, the introduction of straw provides an increase in the stability of soil aggregates and bacterial diversity (Tonkha *et al.*, 2019). A decrease in the percentage of areas with low humus content and an increase in areas with medium and very high humus content is present in the region.

Nitrogen is one of the main elements of plant nutrition, which is necessary for their growth and development. The level of nitrogen nutrition determines the size and intensity of the synthesis of proteins and other nitrogenous organic compounds in the plant, which substantially affect the growth processes. Insufficient nitrogen supply delays plant growth, reduces the size of the assimilation surface of leaves, the duration of their functioning in the active state, and the level of yield and worsens its quality (Tonkha *et al.*, 2019; Tsentylo & Tsyuk, 2019). According to the nitrogen content of compounds that are easily hydrolysed, the area of the examined land is distributed as follows: land with a very low nitrogen content – 88.1 thousand hectares (48.3%), with a low – 88.7 thousand hectares (48.7%), with an average – 2.0 thousand hectares (1.1%), and with an increased nitrogen content – 3.5 thousand hectares (1.9%) (Fig. 5).

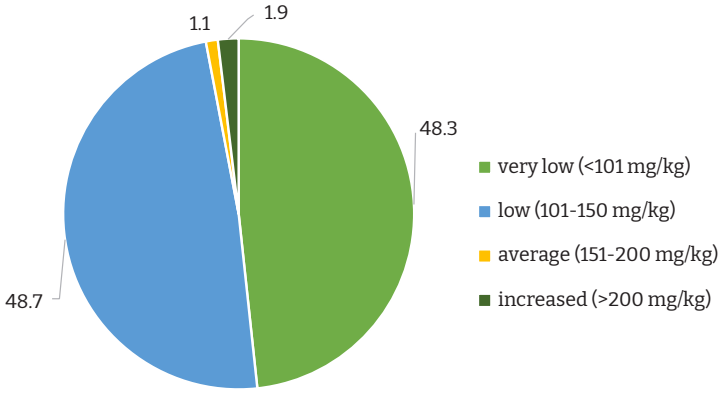

Figure 5. Distribution of the area of agricultural land in Chernivtsi region by nitrogen content, which is easily hydrolysed, %

The weighted average content of easily hydrolysed nitrogen for the period of 2016-2020 is 106.4 mg/kg of soil, which corresponds to reserves of 319 kg/ha. During the two rounds of examinations, the weighted average content of easily hydrolysed nitrogen increased by 0.9 mg/kg (Fig. 6). The greatest increase in easily hydrolysed nitrogen content was observed in Kelmentsi (+14 mg/kg), Hlyboka (+12 mg/kg), and Novoselytsia (+11 mg/kg) districts. A decrease in the weighted average indicator was identified in Putyla (-18 mg/kg), Khotyn (-14 mg/kg), and Vyzhnytsia (-9 mg/kg) districts.

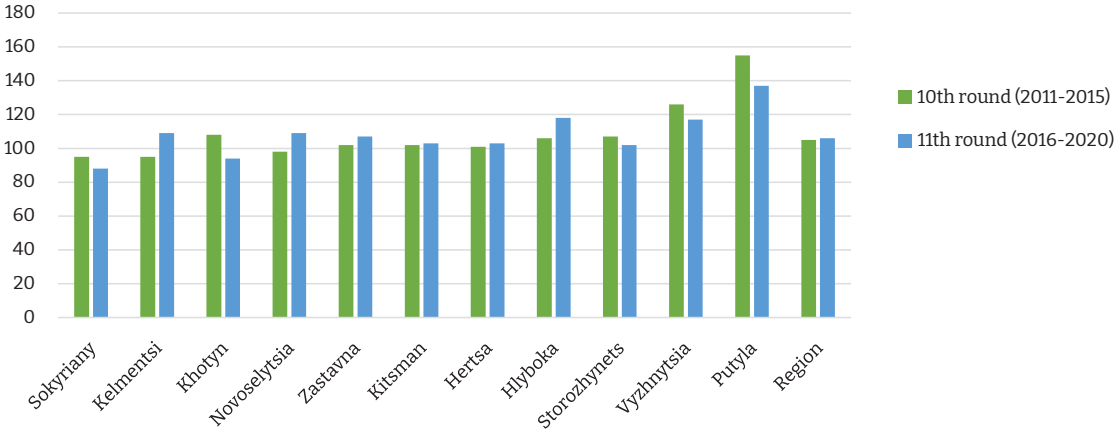

Figure 6. Dynamics of changes in the content of nitrogen, which is easily hydrolysed in the soils of Chernivtsi region according to the 10th–11th round of agroecological examinations, mg/kg

The effective fertility and effect of fertilisers are influenced by the phosphorous regime of the soil. The level of providing the soil with phosphorus mobile compounds is an important indicator of effective fertility since this element is involved in metabolic processes, and is part of DNA, RNA, and other substances, which is why its content in soils affects crop yields. A special feature of phosphorus is that in most varieties of soils, it is in poorly soluble mineral and organic forms inaccessible to plants (Yaliang *et al.*, 2022; Kramariov *et al.*, 2015).

According to the results of the agrochemical examination of agricultural land in the region, the content of mobile phosphorus compounds is distributed as follows: with a very low content – 4.5 thousand hectares (2.5%), with a low content – 21.9 thousand hectares (12.0%), with an average content – 57.5 thousand hectares (31.5%), with an increased content – 52.3 thousand hectares (28.7%), with a high content – 33.6 thousand hectares (18.4%), with a very high content – 12.5 thousand ha (6.9%) (Fig. 7) the weighted average content of mobile phosphorus compounds is 56 mg/kg. Compared to the previous round of the examination (2011-2015), the weighted average phosphorus content increased by 4.0 mg/kg (Fig. 8).

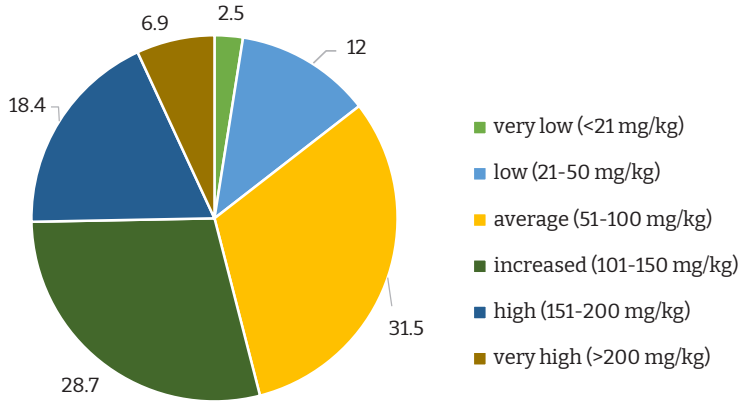

Figure 7. Distribution of the area of agricultural land in Chernivtsi region by the content of mobile phosphorus compounds, %

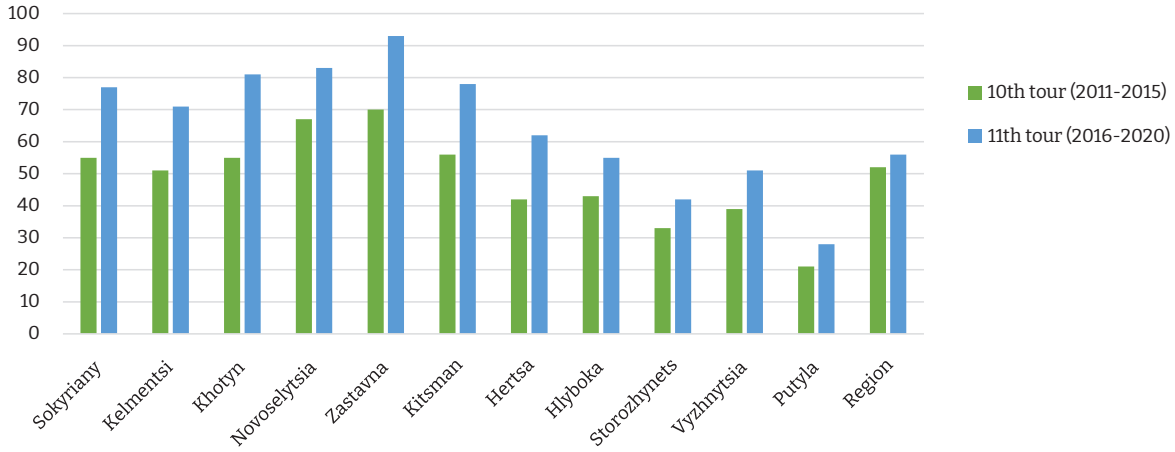

Figure 8. Dynamics of changes in the content of mobile phosphorus compounds in the soils of Chernivtsi region according to the 10th-11th round of agroecological examinations, mg/kg

In general, the content of mobile phosphorus compounds increased in all districts of the region, but most of all in Khotyn (+26 mg/kg), Zastavna (+23 mg/kg), Kitsman, and Sokyriany (+22 mg/kg) districts.

According to the results of an agrochemical examination, agricultural land in the region is distributed according to the content of exchangeable potassium compounds as follows: with very low content and low content – absent. With an average content – 12.2 thousand hectares (6.7%), with an increased content – 21.3 thousand hectares (11.7%), with a high content – 54.9 thousand hectares (30.1%), with a very high content – 93.9 thousand hectares (51.5%) (Fig. 9). The weighted average content of exchangeable potassium compounds is 78 mg/kg.

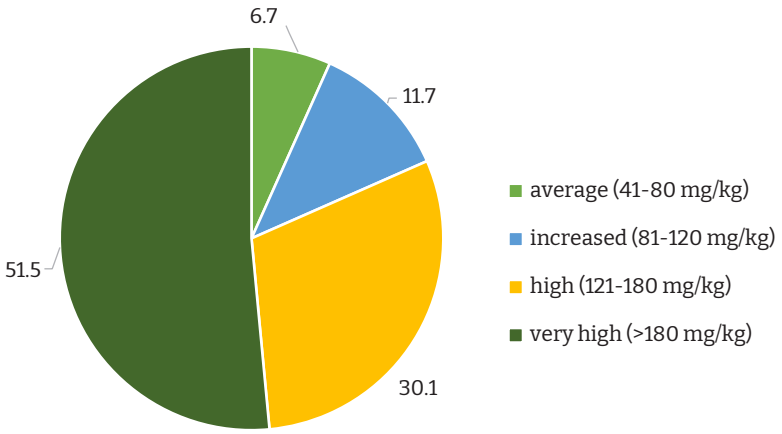

Figure 9. Distribution of the area of agricultural land in Chernivtsi region by the content of mobile potassium compounds, %

The weighted average potassium content increased by an average of 15.4 mg/kg in the region (Fig. 10). In general, the content of mobile potassium compounds increased in all districts of the region, but the largest increase is observed in Sokyriany (+21 mg/kg), Zastavna, Vyzhnytsia (+19 mg/kg), and Kelmentsi (+17 mg/kg) districts.

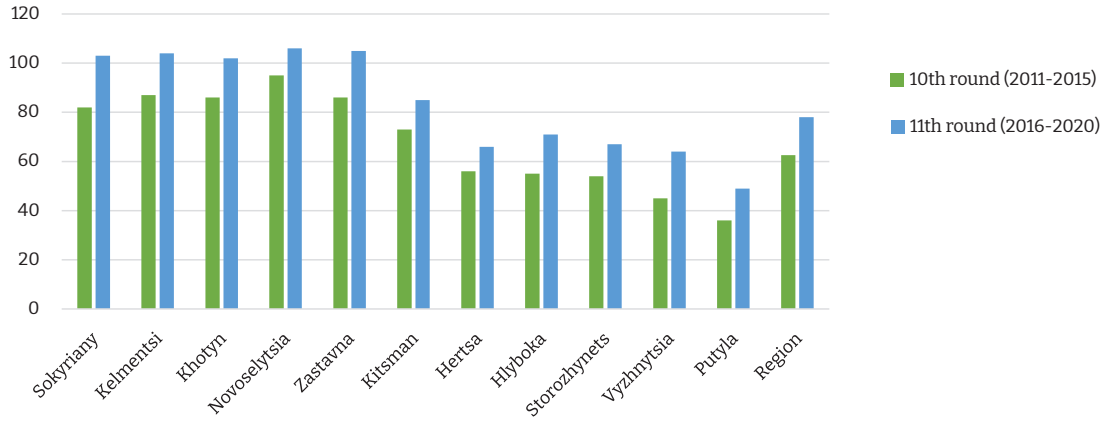

Figure 10. Dynamics of changes in the content of mobile potassium compounds in the soils of Chernivtsi region according to the 10th-11th round of agroecological examinations, mg/kg

Khrystenko (2016) notes that the low availability of mobile phosphates in the arable land of the Chernivtsi region in 2016 amounted to 37 mg of P2O5/kg of soil and is due to the high acidity of brown-earth-podzolic soils. The researcher draws attention to the fact that often the assessment of soil fertility, due to under-examination of the least fertile soils, is somewhat overestimated. In the study, the weighted average value of mobile phosphates was 56 mg/kg for the period from 2016 to 2020, which indicates a positive trend.

CONCLUSIONS

1. According to the results of agrochemical examinations of agricultural land in the Chernivtsi region, it was identified that the reaction of the soil environment in the region is dominated by soils close to neutral (31.8%) and neutral (36.5%).

2. In terms of humus content soils with a humus content of 3.1-4% account for 66.7% of the total, and the weighted average for the region is 2.7%.

3. In terms of easily hydrolysed nitrogen content, most lands have very low (48.3%) and low (48.7%) nitrogen content. 31.5% of all lands have an average phosphorus content, and the weighted average content of this macronutrient is 56 mg/kg of soil. In terms of the content of exchange potassium, lands with a very high content of potassium (51.5%) predominate with a weighted average of 78 mg/kg of soil.

The research on a comprehensive assessment of land quality in the Chernivtsi region based on bonitet points and the development of measures to protect and restore soil fertility is considered promising.

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Динаміка показників родючості ґрунтів Чернівецької області

Анотація. Для розробки заходів з раціонального використання ґрунтів важливою є агрохімічна оцінка ґрунтів. Метою досліджень було встановлення динаміки змін показників родючості ґрунтів Чернівецької області протягом 2011-2020 рр. В роботі були використані лабораторні, польові методи, аналіз та узагальнення. У зразках ґрунту визначали реакцію ґрунтового середовища, вміст гумусу, вміст азоту сполук, що легко гідролізують, рухомих фосфатів та обмінного калію. Встановлено, що за кислотністю ґрунтового розчину в області переважають землі близькі до нейтральних (31,8 %) та нейтральні (36,5 %). Середньозважений показник pH сольове – 5,8, що відповідає близькій до нейтральної реакції ґрунтового розчину. В порівнянні із попереднім туром обстеження (2011-2015 рр.) середньозважений показник pH не змінився За рівнем забезпечення гумусу переважають ґрунти з середнім його вмістом (66,7 %), а середньозважений уміст гумусу по області становить 2,7 %. В порівнянні з попереднім туром обстеження середньозважений уміст гумусу збільшився на 0,1 % За вмістом азоту, що легко гідролізується найбільше земель мають дуже низький (48,3 %) та низький його вміст (48,7 %). Середньозважений показник умісту азоту, що легко гідролізується за звітний період становить 106,4 мг/кг ґрунту, що відповідає низькій забезпеченості даним елементом. При порівнянні з попереднім туром обстеження середньозважений показник умісту азоту, що легко гідролізується збільшився на 0,9 мг/кг ґрунту. В області переважають землі з середнім вмістом рухомих сполук фосфору (31,5 %), а середньозважений показник умісту рухомих сполук фосфору становить 56 мг/кг, що відповідає середній забезпеченості. В порівнянні з попереднім туром обстеження середньозважений показник умісту фосфору збільшився на 4,0 мг/кг. За вмістом обмінних сполук калію переважають землі з дуже високим його вмістом (51,5 %), хоча середньозважений показник їх вмісту складає 78 мг/кг, що відповідає середній забезпеченості макроелементом. В порівнянні з попереднім туром обстеження середньозважений показник умісту фосфору збільшився на 15,4 мг/кг. Результати роботи можуть бути використані у процесі підготовки фахівців з ґрунтознавства та агрономії, а також будуть корисними для землекористувачів Чернівецької області при плануванні заходів з раціонального використання ґрунтів

Ключові слова: реакція ґрунтового середовища, вміст гумусу у ґрунті, легкогідролізовані сполуки азоту, рухомий фосфор, обмінний калій, агрохімічне обстеження