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Толочик Инна, Мельник Вера. Современное состояние качества воды в р. Стырь в пределах Ровенской области. В работе исследуется современное состояние качества воды р. Стырь. Исследуются основные причины загрязнения воды в пределах Волынской возвышенности и Волынского Полесья на территории Ровенской области. Определяются основные загрязнители и загрязняющие вещества воды речки. Проводится подробный анализ динамики изменений, экологическая оценка современного состояния качества воды р. Стырь. Характеристика качества воды осуществляется на основании экологической классификации качества поверхностных вод суши и эстуариев Украины, которая включает широкий набор гидрофизических, гидрохимических, гидробиологических показателей, которые отражают особенности абиотической и биотической составляющих водных экосистем. Исследованиями установлено, что вода р. Стырь в пределах Волынской возвышенности значительно чище, чем в пределах Волынского Полесья, интегральный экологический индекс средних значений составляет 2,2 и 2,5, а максимальных значений – 2,5 и 3,0.

Ключевые слова: оценка качества воды, загрязняющие вещества, индекс загрязнения, класс качества воды, речка Стырь, Ровенская область.

Tolochyk Inna, Vira Melnyk. The Current State of Water Quality in the Styr River Within Rivnenska Region. The work is devoted to the study of the current state of water quality in the Styr river. The main causes of water pollution within the Volyn Upland and Volyn Polissya in the territory of Rivne region were investigated. The main pollutants and pollutant agents of the river water were identified. The detailed analysis of the dynamics of changes, the ecological assessment of the current state of the water quality of the Styr river were carried out. Characteristics of water quality are based on the ecological classification of the quality of surface waters of land and estuaries of Ukraine, which includes a wide range of hydrophysical, hydrochemical, hydrobiological indicators that reflect the peculiarities of the abiotic and biotic components of aquatic ecosystems. The studies have shown that the water of the Styr river in the Volyn Upland is much cleaner than in Volyn Polissya, the integral ecological index of the mean values is 2,2 and 2,5, and the maximum values are 2,5 and 3,0, respectively.

Key words: water quality assessment, pollutant agents, pollution index, water quality class, river Styr, Rivne region.

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Soil Ecomorphs as a Form of Adaptation to the Conditions of Biogeocenosis

The spatial variability of the mechanical impedance of ordinary chernozem have been investigated within a regular grid (105 points). Ecomorphic analysis of the vegetation in each cell of the grid has been done. Cluster analysis, conducted on the basis of the statistical data allowed to distribute the existing changes in soil mechanical profiles in three clusters with characteristic for them, relative to the same type of dynamic properties. Environmental separation content of the soil plots on clusters studied using discriminant and variance analyzes. Statistical significance of variations of external properties associated with the spatial heterogeneity within soil plots belonging to different clusters allows them to be meaningfully interpreted and confirms the formation of ecological nature of the identified soil structures-ecomorphs.

Key words: soil penetration resistance, morphological features, environmental factors.

Formulation of Scientific Problem and its Significance. The core problem of biogeocenology is the study of the nature and depth of interaction between the living and bone components of the biogeocoenosis. Connections between the components of biogeocenosis determine its structural and functional organization. Among the regulatory mechanisms, the intraspecific and interspecies interconnections of plants, which are associated with trophic dependencies and transformation of environmental conditions, are of fundamental importance [2]. As a component of biogeocenosis, vegetation appears for a system of eco-morphs which are certain adaptations of individual species to the biocenosis taken as a whole and to each of its building blocks. The system of ecomorphs for the steppe of Ukraine, in which cenomorphs, adaptations of species to phytocenosis taken as a whole, appear for ecology-cenotic groups, was developed by A. L. Bel'gard in details [2; 18]. One of the branches of the development of this doctrine is the research workon the biotope phytoindication method, which is based on the fact that phytocenosis forms in a certain biotope as a result of adaptation to a complex of environmental effects, and the amplitude and frequency of certain species reflects adaptation to environmental factors that determine this cenosis. The referring of the species to a particular cenomorph is determined expertly on the ground of an analysis of their frequency in different types of phytocenosis. So, for example, plant species, which living conditions are optimal in the steppe, are called steppe species, those ones on the meadow are calledmeadow species, those ones in the forest are calledsilvants etc. Unified phytoindication scales [8; 18], one of which is the working system of cenomorphs, which was proposed in a report of the flora of the Dnepropetrovsk and Zaporozhye regions, are used as a matter of practice [22]. Phytoindication scales based on data for plant species preferences for climatic and edaphic characteristics of the growing area (temperature, light intensity, occurrence of nutrients, humidity, etc.) are a convenient tool for environmental evaluation, since they require far fewer labor contribution than a direct measurement of its climatic and edaphic parameters.

Zoologists, in their turn, developed a method of zoological diagnostics of soils. Taxonomic groups of large soil invertebrates are used in it as reliable indicators of the condition of natural communities [1; 11; 14; 27]. The ecomorphic approach, both in phytodiagnostics and in zoodiagnostics, is based on the frequency of species in biogeocenoses of various typesand uses information on the population requirements for environmental parameters.

In accordance withthe doctrine of biogeocenosis, the soil is a fullfledged component of it. Moreover, the soil has a special status of the bio-inert body. Many characteristics (for example, metabolism and exchange of energy), which are found in living beings, characterize the soil. G. M. Minkovskysuggests multi-level morphoelements of the soil to be considered as parts of the living organism, which are a functional whole: their functioning is consolidated ina single process. The scientist believes that the division of objects into «living» and «lifeless» does not matterin structural problems, the concept of «living» has a moral meaning. Authors [17; 19] suggest to search for new forms of soil material activity at the morphological level of the organization. We believe that the heterogeneity of soil properties is a phenomenon, while studying which it is possible to come to grips with the objective laws of the existence of soil as a component of biogeocenosis. The above-mentionedmakes it necessary to develop an eco-morphological approach in the study of soil as a component of biogeocenosis. In addition to the above, it is important to select the criteria against which the changesintervening in the soil caused by soil formation factors in the time dimension,which is typical for the variability of the bi-cenotic components, could be measured. Mechanical impedance of the soil is such a criterion. Spatial and temporal dynamics of impedance correlates with variations of the majority of soil characteristics which create conditions for plant growth and habitat for soil fauna [1; 16; 28; 32]. Therefore, impedance is anadequate diagnostic sign that can act as an integrated index of the state of the soil body [6; 20].

The objective of this paper is to evaluate the relationship between the spatial variation of the mechanical impedance of chernozem and environmental factors by means of the use of phytoindicator scales.

Materials and Methods. The collection of mechanicalimpedance data and the description of the vegetation was carried out on April 19, 2013 at a steppe site located on the upper part of the South-East slope of the ravine Kamyanistaya exposure (southern suburb of the Dniprocity, 48°38'67" south latitude, 35°09'05"western longitude). The plot is located along the slope with an angle of 15°, from above it is bounded by a wood line and agricultural field adjacent to the range. The study was carried out on a regular gridwith 7×15 sample points, the distance between which is 3 m. Accordingly, the size of the range is 42 m × 18 m.

Studied soil was typical eroded high-carbonate mediumheavy-loamy on loess-like clayschernozem. This area is not used for economic operations.

Mechanical impedance of the soil was recorded using a cone-penetrometer Eijkelkamp. The average error of device measurement results was ± 8 %. Measurements of the mechanical impedance of the soil were made by a cone of cross-section 2 of cm² in each cell of range to a depth of 50 cm at intervals of 5 cm (10 impedance indices in each of the 105 points of the plot).

To assess the environmental conditions, phytoindication scales were used [8]. They are based on a description of the abundanceof vegetation and provide an opportunity to assess the environmental conditions according to both climatic and edaphic characteristics. The phytoindication method uses the data of the species representation in the plant cover within the plot and the scope of species tolerance to particular environmental factors, in other words, the range of ecological minima and maxima scope. The group of edaphic factors were presented by such soil hydration indexesas Hd – soil humidity, fH – variability of moisture, which takes is sensitive to the amplitude of change in the soil moisture index, Ae – aeration of soil, Rc – acidity, Sl – total salt regime, Ca – carbonate content in soil and Nt – nitrogen content. The group of climatic factors were presented by such parameters of thermal characteristics of the soil as Tm – thermal climate, Om – humidity, Cr – cryoclimate and Kn – climate continentality, which is considered asthe value of the function of annual amplitude of air temperature. Besides these specified factors, Lc – light in plant community was considered as a microclimatic scale.

A large number of researchers have proved that plant communities are more accurate and better indicators than selected specieswhich are characterized by a wider ecological amplitude and, as a rule, belong to different types of communities. Therefore, for a more complete indication, the scales of the coenomorphs by A. L. Bel'gard [2] and V. V. Tarasov [22] were given in the paper. They provide an opportunity to estimate the biotopes as a whole [18, 23] and in regardto some of the environmental factors [13]. Cenomorphs are represented by steppe species, meadow species, psammophytes, plants which live in sand, silvants, which are forest species, ruderants, which are ruderal species. Steppe speciesand meadow species form the majority of the vegetation cover, therefore just these ecomorphs were used as predictors of the soil mechanical impedance (variables St and Pr represent the ecomorphs' projective cover, %).

Quantitative characteristics of the representation of ecological forms of plants with different preferences for humidity of environment are characterized by a hygromorph scale. Hygromorphs were represented by xerophytes (humidity level 1), mesoxerophytes (humidity level 2), xeromesophytes (humidity level 3), mesophytes (humidity level 4) and hygromesophytes (humidity level 5). The humidity index (Hygr) was estimated as:

$$Hygr = \frac{\sum_{i=1}^{i=N} (i \times P_i)}{100},$$

where *i* – humidity level; *Pi* – hygromorphs projective cover of corresponding humidity level.

Trophomorphs are ecomorphs, adapted to certain trophotopes. In the plant community within the plot, they were represented by oligotrophs (trophicity level 1), mesotrophs (trophicity level 2) and megatrophs (trophicity level 1). The trophicity index (Troph_B) was estimated as:

$$Troph\_B = \frac{\sum_{j=1}^{j=N} (j \times P_j)}{100},$$

where *j* – trophicity level; *Pj* – trophomorphs projective cover of corresponding trophicity level.

Plants may be classified ecologically, according to their requirement of light. Such ecological groups are named as heliomorphswhich were represented within the plot by heliosciophytes (solar radiation level 2), sciophytes (solar radiation level 3), and heliophytes (solar radiation level 4). The solar radiation index (Hel) was estimated as:

$$Hel = \frac{\sum_{z=1}^{z=N} (z \times P_z)}{100},$$

where *z* – solar radiation level; *Pz* – heliomorphs projective cover of corresponding solar radiation level.

In statistical calculations, descriptive statistics, geostatistical, cluster, dispersion and discriminant analyzes were used.

Results and its Discussion. Mean values of the mechanical impedance of studied soil increased with depth, from 1,34 ± 0,04 MPa to 1,60 ± 0,03 (table 1). The layer of 10−15 cm from the surface exhibits the lowest level of the mechanical impedance, the deepest studied layer of 45–50 cm exhibits the highest level of the mechanical impedance. When moving downwards on a profile, the mechanical impedance as a whole tends to increase. The coefficient variation of the indicators differs significantly in the layers of 5–10 and 10–15 cm downwards on a profile, where it is the highest (31,40 and 30,42 %). The parameters of the layers located above and below are less variable, the coefficient variation ranges from 17,89 to 22,77 %.

Table 1

Mechanical Impedance of Soil: Descriptive Statistics

Layers Depth, *cm*	**x ± SE, MPa**	**CV, *%***	**SDL, *%***	***R, m***
0–5	1,34 ± 0,03	22,77	20,00	8,04
5–10	1,35 ± 0,04	31,40	27,78	9,59
10–15	1,29 ± 0,04	30,42	31,25	10,50
15–20	1,32 ± 0,03	20,46	37,50	8,31
20–25	1,32 ± 0,03	17,89	33,33	7,42
25–30	1,36 ± 0,02	18,42	37,50	11,30
30–35	1,38 ± 0,03	19,69	50,00	10,80
35–40	1,45 ± 0,03	21,46	50,00	11,40
40–45	1,53 ± 0,03	21,83	83,33	10,66
45–50	1,60 ± 0,03	21,36	30,77	8,51

Explanation of Symbols. *x – mean (MPa), SE – standard error, CV – coefficient variation (%), SDL – spatial dependence level (%), R – radius of influence (m).*

The descriptive stage of the study gives an idea of average profile, the characteristics of which are too approximate, as evidenced by the difference in the coefficients variation related to the data of different soil layers. For deeper analysis of the regimentation of soil mechanical impedance indicators, geostatistics tools were used. With their help, the degree of spatial dependence of the mechanical impedance data was determined layer-by-layer, that is, spatial relation of SDL. When interpreting it, it should be taken into account that if its level is within the range from 0 to 25 %, then it is a case of strong spatial dependence; if it is within the range from 25 to 75 %, the dependence of the variable is moderate; if it is greater than 75 %, the variable is considered to be weakly spatially dependent [22; 25]. According to the results of our studies, the mechanical impedance of chernozem comes with a high degree of spatial dependence in the surface layer, a weak one in the layer of 40–45 cm from the surface and the middle one in all other layers of the studied soil depth.

Cluster analysis based on the obtained geostatistical data provided an opportunity to sort conditionally provided profiles of the soil mechanical impedance (105 points) into four clusters with relatively single-type dynamics of characteristics which is specific to them (fig. 1). The proximity of sites was measured in the Euclidean distance. As a merge rule, the Ward's Method was used.

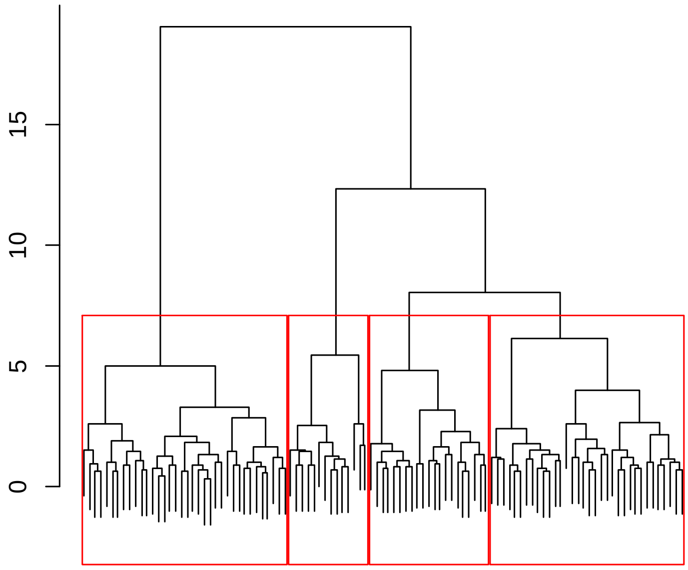

Fig. 1. *Clusteranalysison Mechanical Impedance, Ward's Method, the Euclidean Distance*

Note. *The Rectangles Indicate the Amount of Clusters For a Solution of 4 Clusters.*

Division into clusters provided an opportunity to organize the observed data into demonstrative structures, for a meaningful description of the differences between them. Sites belonging to the same cluster are characterized by the same change in the mechanical impedance with a penetration. Figure 2 shows the dynamics of the soil mechanical impedance along the profile for each of the selected clusters.

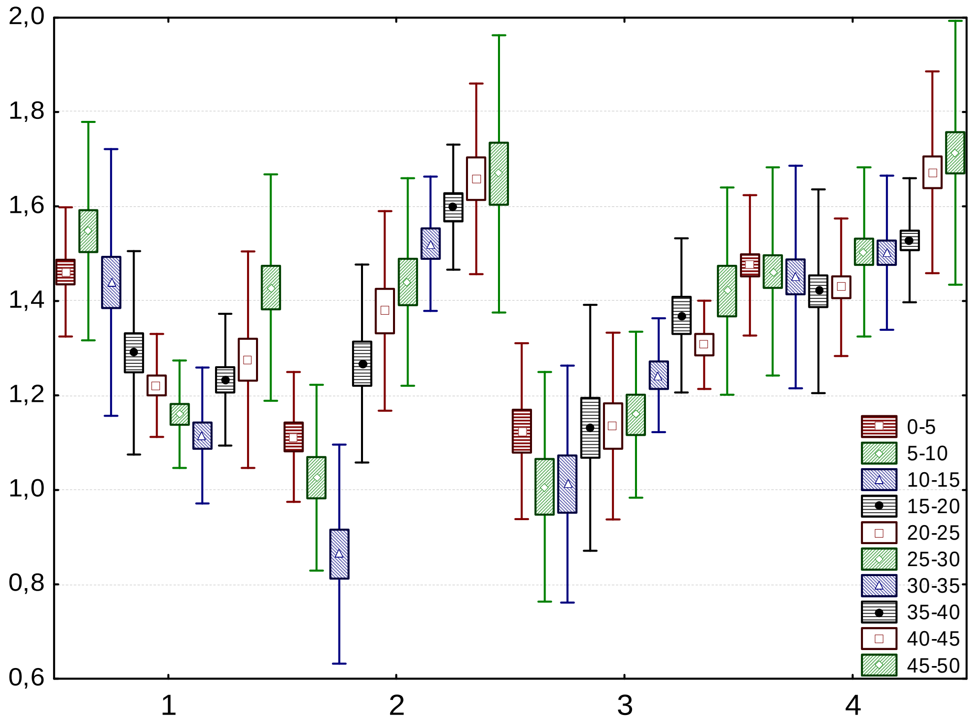

Fig. 2. *Changeinthe Mechanical Impedance with a Penetration Along the Profile Typical for the Different Clusters: by the Abscissa Axis, Clusters Numbers are Indicated, by the Ordinate Axis, Soil Mechanical Impedance, MPA is Indicated*

The time of the study (mid-April) makes impact on the results. The characteristic property means that the surface layers are harder than those located below. The greatest decrease is observed in clusters 1 and 2. The minimum indices in cluster 1 are observed at the level of 30–35 cm of the soil profile, in cluster 2 at a depth of 10–15 cm. For the dynamics of the soil mechanical impedance of clusters 3 and 4, a certain decrease in indices with the penetration is typical but less significant. The studied property acquires the greatest values at the level of 45–50 cm in clusters 2 and 4.

Soil clusters are located quite compactly. The fourth cluster occupies the largest area of the studied plot, the rest occupy substantially smaller part (figure 3).

The ecological content of the division of soil sites into clusters was studied using variance analysis. In our case, it is used to detect environmental factors associated with specific soil profiles which are typical for each of the four clusters. The environmental factors are expressed in terms of phytoindication scales, determined by the quantitative and qualitative analysis of the plant community of the investigated plot [8; 22]. The validity of this approach is discussed in a number of papers [8; 18; 30]. The results of the discriminant analysis are presented in table 2.

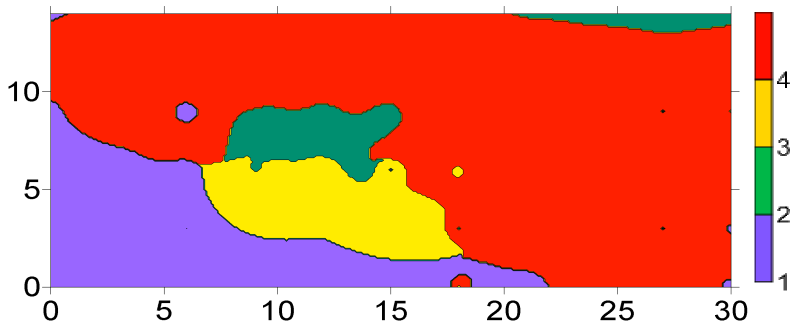

Fig. 3. *Spatial Distribution of Clusters of the Soil Mechanical Impedance on the Studied Plot*

Table 2

Variance Analysis of Data on the Ecomorphic Characteristics of Vegetation on Clusters of Chernozem

Scales	SS	MS	F-value	p-level
Phytoindication Scales				
Hd	0,24	0,08	2,53	0,06
ffl	0,08	0,03	1,05	0,37
Rc	**0,24**	**0,08**	**4,79**	**0,00**
Sl	**0,16**	**0,05**	**3,26**	**0,02**
Ca	**0,16**	**0,05**	**6,37**	**0,00**
Nt	0,04	0,01	0,47	0,70
Ae	0,02	0,01	1,90	0,13
Tm	**0,03**	**0,01**	**3,53**	**0,02**
Om	**0,03**	**0,01**	**3,71**	**0,01**
Kn	0,11	0,04	2,58	0,06
Cr	0,00	0,00	0,51	0,68
Lc	0,00	0,00	1,15	0,33
Plantsecomorphsindexes				
Hygr	**2,05**	**0,68**	**8,55**	**0,00**
Troph_B	**0,11**	**0,04**	**3,08**	**0,03**
St	0,44	0,15	2,42	0,07
Pr	0,41	0,14	2,29	0,08
Hel	**0,54**	**0,18**	**10,25**	**0,00**

Note. *SS – the sum of squares, MS – the standard deviation. Hd – hydromorph scale, ffl – the variability of moisture, Rc – acidity regime, Sl – total salt regime, Ca – carbonate content in the soil, Nt – content of assimilable nitrogen forms, Ae – aeration, Tm – thermal regime, Om – humidity, Kn – climate continentality, Cr – cryoclimate, Lc – light scale, Hyg – hygromorphs, Troph_B – trophomorphs, St – steppe species, Pr – meadow species, Hel – heliomorphs. Statistically significant values are provided in bold.*

According to the data presented in table 2, the difference in clusters is reliably significant for the variable scales of the soil solution acidity, total salt and termal regimes, humidity and carbonate content in the soil. Indices based on plant ecomorphs show that clusters are reliably identifiable by the presence of hydro-, tropho- and heliomorphs.

On the territory located closer to the bottom left corner on the map, the dynamics of the soil mechanical impedance along the profile is marked by a significant decrease in the parameters to a depth of 35 cm. Such soil ecomorphs are associated with the relatively low acidity of the soil solution and the low content of carbonate salts in the soil (fig. 5). For the cenomorphic structure of the plant community which is located on this territory, decreased number of plants requiring humid living conditions, and an increased representation of those demanding for soil nutrition and greater light, is typical.

On the territory where the mechanical impedance of the surface layer of soil is the highest (4 cluster), the edaphotope is characterized by high acidity, the concentration of carbonate with a high ratio of heat and moisture. The characteristics of the plant community are averaged.

Relatively small areas of the second and third clusters are characterized by the highest soil temperature, high content of carbonate salts and a decrease in the representation of plants with high requirements for soil nutrition and light in the plant community. The territory of the second cluster (with the lowest values of the soil mechanical impedance) is also characterized by an increased representation of plants of humid ecotopes.

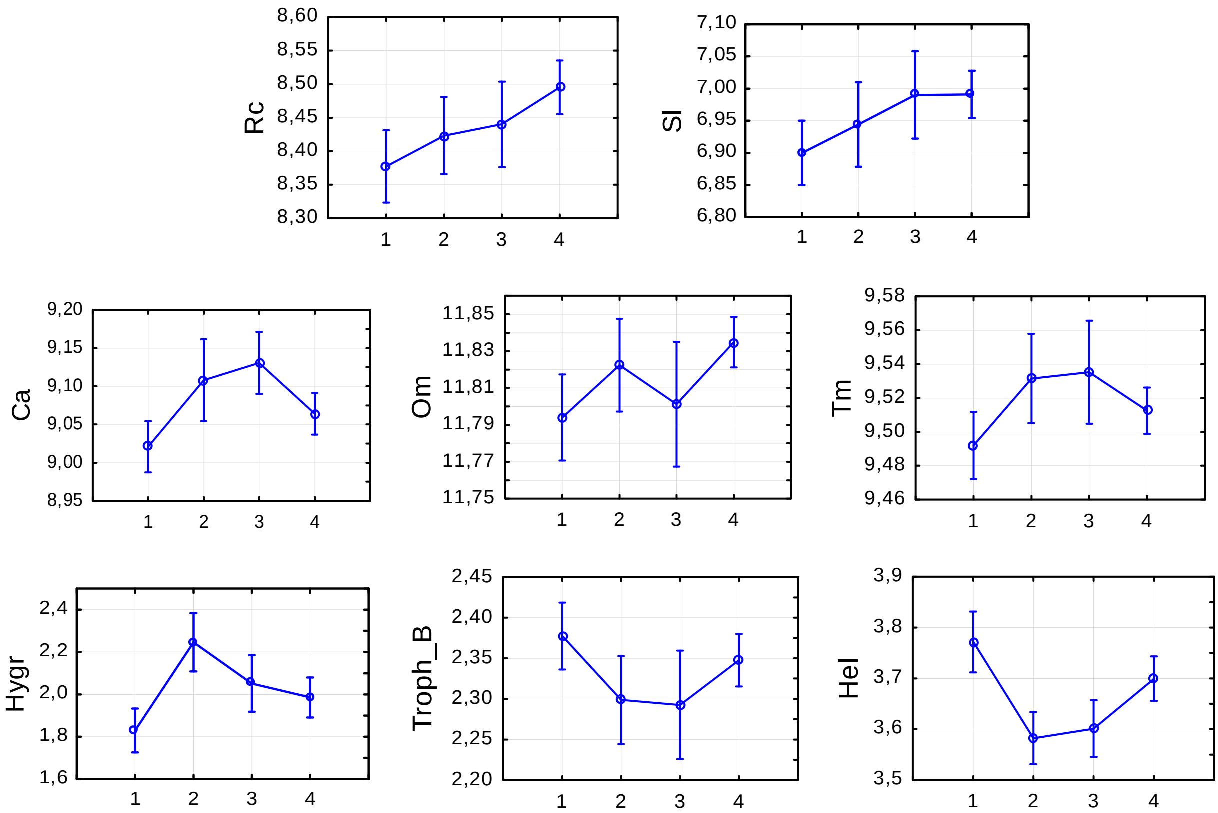

Fig. 5. *Values of Ectomorph Scales of Acidity Regime, Total salt Regime, Carbonate Content in the Soil, Humidity, Thermal Regime, Hygromorphs, Trophomorphs, Heliomorphs on Chernozem Clusters*

Note. *By the abscissa axis, value of the corresponding scale is indicated, by the ordinate axis, numbers of clusters are indicated.*

The results of the study show that the dynamics of the soil mechanical impedance down the profile at different points of the experimental site is significantly different. Points in which the behavior of the soil mechanical impedance is similar to the penetration, are related to certain characteristics of the environment and have reliable different characteristics from points where the nature of the change in the soil mechanical impedance is diverse. Furthermore, these changes are associated with the distribution of species with differing preferences for moisture, trophicity and light conditions in the plant community. Profiles with the single-type of soil mechanical impedance change are located quite compactly, merging into clusters that occupy a certain territory and form demonstrative structures. The connection between the dynamics of soil mechanical impedance and specific ecological characteristics and ecological forms of plants speaks of the ecological character of the formation of the soil structure, and we propose to call the selected soil structures – clusters – soil ecomorphs.

Soil ecomorphs are elements of the spatial organization of the soil of the over-the-horizon level, which have their own sizes, shape, certain regularities of spatial distribution. Since the soil mechanical impedance strongly depends on the characteristics of the plant community [3; 12; 16], it can be expected that the plants themselves take an active part in the formation of soil ecomorphs. The different ability to desuction and split-level root systems model the soil space, drying out its layers nonuniformly and thereby contributing to the creation of heterogeneity of soil conditions.

The relationship of the soil ecomorphic structure with the environmental factors proves their functional dependence. We believe that the formation of the ecomorphicstructure is the way the soil, as a component of the biogeocoenosis, interacts with its other components. By ecomorphic structure we mean the features of the structure (in the broad sense of the word) of soil ecomorphs and their mutual arrangement in surrounding soil material as parts which form an integral unit – the soil body. Soil ecomorphs are found in different types of soils and differ in shape and structure [29–32]. They can be called elements of heterogeneity, since they differ by the criterion of the soil mechanical impedance from adjoining elements of the organization – the soil material where they are located. These morphological formations are natural elements of soil organization as a natural body, since they are separated from adjoining soil space by gradient boundaries, which are considered to be the most «natural» ones, since their position in soil space is conditioned by the position and views of the researcher least of all [9]. The detection of soil ecomorphs face the classification challenge of the hierarchy of morphological elements, indicated by a number of authors [19, 26]. Furthermore, soil ecomorphs may be one of the missing links in the diatropical system of the living world of the Earth [5], which elementary unit of organization is biogeocenosis.

The results of our study reveal some mechanisms of interaction of the soil, as a component of the biogeocoenosis, with its other components and outline an integral picture of the mediator processes occurring in it between the soil formation factors and soil characteristics. The soil characteristics determine its functions, the most important of which is its role in preserving of biodiversity. This is not about biodiversity, which is associated with a taxonomic diversity of the soils on a global scale, but about securing subsistence of a huge number of species in taxonomically identical soils. Even within a single biogeocenosis, predominantly, the number of species is commensurate to the number of soil types that are specificated by soil scientists [7; 9; 21]. And plants, animals, and microorganisms find an ecological niche for themselves, which is entirely or partially located in the soil space. The coexistence of species with different requirements to the soil environment is possible in consequence of the presence of the soil ecomorphic structure that provides favorable conditions for the life of organisms with different, sometimes conflicting, requirements for living conditions.

Conclusions. Dynamics of the soil mechanical impedance of typical chernozem down the profile is significantly different at different points of the experimental plot and forms characteristic profiles on the change in the soil mechanical impedance.

Sectors of the same type, on grounds of the vertical variation of the soil mechanical impedance, are integrated into clusters compactly enough and we called them soil ecomorphs.

The detected soil morphological formations reliably differ in related climatic and edaphic properties, as well as in the ecological structure of the plant community.

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Задорожная Галина. Почвенные экоморфы как форма адаптации к условиям биогеоценоза. Исследуется пространственная вариабельность твердости чернозема обыкновенного по регулярной сетке (105 точек). Произведен экоморфический анализ растительности в каждой ячейке полигона. Кластерный анализ, проведенный на основе полученных статистических данных, позволил распределить имеющиеся профили изменения твердости почвы в три кластера с характерной для них относительно однотипной динамикой свойства. Экологическое содержание разделения участков почвы на кластеры изучено с помощью дискриминантного и дисперсионного анализов. Статистическая значимость изменений внешних признаков, сопряженных с пространственной неоднородностью почвенных участков, принадлежащих к разным кластерам, дает возможность их содержательного описания и подтверждает формирование экологического характера выявленных почвенных структур – экоморф.

Ключевые слова: твердость почвы, морфологические элементы, экологические факторы.

Задорожна Галина. Ґрунтові екоморфи як форма адаптації до умов біогеоценозу. Досліджено просторову варіабельність твердості чорнозему звичайного за регулярною сіткою (105 точок). Проведено екоморфічний аналіз рослинності. Кластерний аналіз, виконаний на основі отриманих статистичних даних, дав підставу розподілити наявні профілі зміни твердості ґрунту в три кластери з характерною для них відносно однотипною динамікою властивості. Екологічний зміст поділу ділянок ґрунту на кластери вивчено за допомогою дискримінантного й дисперсійного аналізу Статистична значимість змін зовнішніх ознак, пов’язаних із просторовою неоднорідністю ґрунтових ділянок, що належать до різних кластерів, уможливлює їх змістовий опис та підтверджує формування екологічного характеру виявлених ґрунтових структур – екоморф.

Ключові слова: твердість ґрунту, морфологічні елементи, екологічні фактори.

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Нейтралізація фітотоксичності перегорілої породи відвалів кам’яновугільних шахт попелом ТЕС і гуматом калію

Досліджено вплив кам’яновугільного попелу з Добротвірської теплоелектростанції та гумату калію «ГКВ-45» на фітотоксичність субстрату перегорілої породи з відвалів кам’яновугільних шахт Червоноградського гірничопромислового району. Для біотестування використали суданську траву *Sorghum bicolor* subsp. *drummondii* (Nees ex Steud.).

Виявлено збільшення площі листкової поверхні, довжини й маси коренів зі зменшенням висоти стебла за додавання гумату до субстрату перегорілої породи. Застосування лише попелу не спричинило достовірного впливу на досліджені морфометричні параметри, але у варіанті з його внесенням разом із гуматом простежено підсилення стимуляційного впливу останнього на масу коренів і площу листкової поверхні.

Установлено, що внесення попелу призводить до підвищення вмісту хлорофілу *a* з одночасним зниженням умісту феофітину *a* у листках суданської трави. Додавання гумату призвело до підвищення вмісту хлорофілу *a* і зниження феофітину *a*. Застосування попелу разом із гуматом підвищило вміст хлорофілу *a* та знизило вміст феофітину *a* більшою мірою, ніж унесення лише попелу.

Збільшення розмірів листків і коренів *Sorghum bicolor* subsp. *drummondii*, підвищення вмісту хлорофілу *a* у поєднанні зі зменшенням висоти стебла, зниженням умісту феофітину *a* свідчить про зменшення стресового