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SOIL-FORMING PROCESSES IN THE RAVINE ECOSYSTEMS

The research paper presents the results of the researcher’s investigation on the complex ecological properties of native ravine forests in the Dnipropetrovsk Oblast. The results of soil sciencein different countries were reviewed. The structure of the ravine was studied, the macro- and micromorphological structure of the soil was described, the soil aggregate composition, water resistance of soil structural aggregates, and the humus state of forest chernozem were established. The benefit effect of native ravine forests on the soil-forming processes in the Steppe zone was revealed.
Keywords*: environmental properties; soil; aggregate composition; water resistance; humus state; soil-forming processes.*

У роботі наведено результати дослідження комплексу екологічних властивостей природних байрачних лісів Дніпропетровської області. Проаналізовано результати досліджень ґрунтів вченими різних країн. Досліджено структуру байраку, наведено опис макро- та мікроморфологічної будови ґрунту, встановлено агрегатний склад ґрунтів, водостійкість структурних агрегатів, гумусовий стан чорнозему лісового. Доведено позитивний вплив природних байрачних лісів на ґрунтотворні процеси в степовій зоні.
Ключові слова*: екологічні властивості; ґрунт; агрегатний склад; водостійкість; гумусовий стан; ґрунтотворні процеси.*

Problem’s formulation

Forest stands are extremely important for improving the state of the environment in Ukraine. The multifunctional properties of forests contribute to a significant improvement of quality characteristics by turning surface water runoff into deep water runoff. Forest stands prevent soil erosion by stopping the harmful effects of dry hot winds (the “sukhoveys”).

The characteristics of interaction between forest stands and chernozem soils in the Steppe zone were studied by many scientists and were definitely controversial in nature.

Since the late 19th century, there has been hypothesized that chernozem soils are degraded under the forests in the steppe zone. The hypothesis states that chernozem soils turn into podzols after passing a series of changes. Many scientists have supported such views on soil formation processes without taking into account their zonal characterization. These discussions were continued and, given the lack and imperfection of methodological developments, there were doubts about the unambiguous interpretation of this theory. Hence, a number of scientists considered the divergence between pedogenesis conditions to be the main reason for the difference between gray forest soils and chernozem in the unforested and the forested steppe instead of the degradation of chernozem. These forests are mainly represented by oakeries, and the author calls these soil as “black forest soil”.

The forest stands perform multiple functions. They stop or reduce the impact of dry easterly and north-easterly winds, turn surface water runoff into groundwaters, improve soil fertility, create the conditions favorable for harvesting higher and stable yields, and increase the meadow and pasture productivity. To preserve a certain ecosystem, it is necessary to begin with thoroughly study all its components.

Soil is the major, resulting unit of the forest ecosystem functioning. For a clearer understanding of the interaction principle between soil and forest biogeocenosis in steppe conditions, it is necessary to investigate a number of issues, including complex soil properties and the nature of soil-formation processes.

In Dnipro city, soil scientists has been studying for many years the complex of soil properties, the nature of pedogenesis and the soil genesis in the south-east of Ukraine. Monitoring studies of a complex of soil properties are being conducted.

Analysis of recent research and publications

Conservation and restoration of native forests is possible only with a thorough study of the complex soil characteristics. So far, complex soil properties and soil-forming processes have been widely studied by scientists worldwide. Brazilian scientists investigate the soil-formational role of earthworms [1], the impact of microelement-contaminated soils on plant productivity [2]; morphological, mineralogical and micromorphological properties of the soils in the coastal north-eastern plains of Brazil [3]; and earthworms as soil quality indicators in Brazilian tillage systems [4]. German scientists studied the relationship between soil macropores and its hydrological properties [5, 6]. Slovak scientists conducted a number of studies related to the soil physical properties under introduced tree species [7], the development of groundwater regime [8], the determination of organic fractions and enzymatic activity in the soil under spruce forest in Tatra National Park [9], the fluctuations of available elements in the upper layer of soil under the litter of different woody species [10], the organic matter assessment in soils of different ecosystems in regards to carbon parameters [11], the unpredictability of soil microorganisms and selected biotic and abiotic parameters of the soil under different land use types [12]. French researchers study quantitative aggregate analysis of undisturbed soil samples in the early pedogenesis stages with scanning soil micro-slides [13]; secondary accumulation of $CaCO_3$ in the soils of the European loess belt [14]; calcium-magnesium liming and acidification of forest soils: influence on humus, morphology and functioning [15]. Belgian scientists use the method of soil micromorphology in paleo-geological studies [16]. The conclusions of Spanish and French scientists coincide with our beliefs that phytostabilization is the most successful solution to chemical, toxicological and environmental challenges associated with soil pollution [17]. Australian scientists identify the role of the soil micromorphology method as key in studies on the describing the genesis of clay minerals [18].

Ukrainian scientists comprehensively and thoroughly investigate the properties of soils: forest chernozems as a special type of soil of chernozem type [19], selectivity of heavy metals absorption by soil and humic acids at different pH levels [20]; predict the levels of chemical elements in soils of different genesis to assess their ecological and energy status [21], soil factors of floodplain soils that limit the growth of energy crops [22], assess the anti-deflationary effectiveness of no-till technology in the conditions of the southern steppe in Ukraine [23].

In Dnipro city, soil scientists has been studying for many years the complex of soil properties, the nature of pedogenesis and the soil genesis in the south-east of Ukraine. Monitoring studies on structural and aggregate soil composition and macro- and micromorphology are being conducted [24, 25, 26, 27, 28].

We fully agree with the beliefs of prof. V. Medvedev who stated that one of the most important tasks of the state is to organize monitoring of soil cover on the basis of the latest software, mathematical, instrumental and cartographic principles, their harmonizing with European experience [29].

Formulation of the study purpose

The purpose of our scientific work was to continue monitoring comprehensive studies of the native forests characteristics on the example of ravine ecosystems in the Dnipropetrovsk Oblast and prove their benefit impact on pedogenic processes.

Presenting main material

The "Viyskove" ravine was chosen as the object of our research situated in Solonyansky District, the Dnipropetrovsk Oblast. The sample site was located in the middle third of 7° north-faced slope at a distance of 15 m from ravine talweg in a maple oakery with goutweed on the soils with slightly fresh class of moisture regime. The type of forest conditions was slightly fresh loam. Type of light structure was shadow, III age degree. Crown closeness was 0.8. Humidification conditions were atmospheric-transit inflow-outflowing.

In the first wooden sub-layers, common oak (*Quercus robur* L.) was represented: a): double-stemmed common oak trees with a trunk diameter of 45 cm, b) double-stemmed common oak trees with a trunk diameter of 30 cm, 15 cm, 14 m high, 55 years old, c) double-stemmed common oak trees with a trunk diameter of 55 cm, 60 cm, 18—20 m high; seed field maple (*Acer campestre* L.) with a trunk diameter of 13 cm. The undergrowth was comprised of *Acer campestre* L. *and Acer tataricum* L.

Shrubby undergrowth was comprised of *Euonymus europaea* L., self-seeding *Euonymus verrucosa Scop* 10 cm high, 1 % cover degree.

The total cover degree of the grass stand was 90 %.

The forest litter was solid, double-layered, comprised of *Quercus robur* leaves with a thickness of 3 cm.

The soil was medium-leached deep forest carbonate multi-humus loam chernozem on deluvial deposits.

Characterization of macro- and micromorphological structure of the soil profile

Upper horizon of the soil profile H_1 (0—8 cm) was represented by a solid forest litter from semi-decomposed, semi-glued leaves of common oak turned into a rotten mass of dark brown color, crumbly, poorly separated from the soil. It was almost black, fresh, humus-accumulative, moist, medium-leached, nutty-granular, loamy, very loose, multi-root, coarse-textured horizon, the transition in structure and color was low-observable. The microscopic slide was dark-brown, almost black, uniform over the entire slide area, due with the high number of organic compounds. There is a large number of plant residues at different stages of decomposition; medium-decomposed ones predominated. Zoogenic processing of soil mass was very significant. It is a well-aggregated horizon. Aggregates mostly of regular shape, usually represented by earthworm casts. In them, organic matter is represented by well-processed and decomposed plant residues. Small invertebrate casts occurred in interaggregate pores. Humus plasma is clayey, uniform over the entire slide plane. Small clumps of humic microforms are evenly dispersed in the plasma. Humus is represented by humons and collomorphic fresh brown humus. Finely dispersed humus is represented by a large number of evenly spaced clumps of humons. The humus form is mull. The area of the visible surface of the pore space is significant and amounts to 30—40 %, depending on the microzone on the slide. The pores are rounded and elongated, regular-shaped. Small invertebrate casts occurred in the pores. Microstructure is of loose and spongy type depending on the microzone on the soil slide. Elementary microstructure is plasmatic-pulverous. The mineral framework is represented by minerals of different sizes. The mineral framework is dominated by quartz and feldspar. Crystals of SiO_2 are visible on the edge of aggregates.

Horizon H_2 (8—43 cm) is dark gray, almost black, fresh, nutty-granular fine-grained, loose loam. The transition in structure is gradual. Black-brown color of the micromorphological slide, uniform over the entire surface. The color is associated with high content of organic compounds. It is a well-aggregated horizon. Aggregates mostly of regular shape, usually represented by earthworm casts. In them, organic matter is represented by well-processed and decomposed plant residues. Microstructure mostly is of loose and spongy type depending on the microzone on the soil slide. Elementary microstructure is of the plasmatic-pulverous type. The mineral framework is represented by minerals of different sizes. The mineral framework is dominated by quartz and feldspar. The plasma is humic-clay, uniform over the entire plane of the slide, anisotropic with a speckled fluorescence. Plant remains of varying degrees of decomposition. Finely dispersed humus is represented by a large number of evenly spaced clumps of humons. The humus form is mull. The area of the visible pore surface is significant ly large and amounts to 40—65 %, depending on the microzone on the slide. The pores are rounded and elongated, regular-shaped. Small invertebrate casts occurred usually in the pores.

Horizon H_3 (43—68 cm) dark gray, fresh, nutty-fine-grained, loose, carbonate, loamy, denser. The soil boiling with HCl occurs at a depth of 45 cm. The color of the microscopic slide was dark brown, almost black, uniform over the entire area of the micromorphological slide. The color is associated with high content of organic compounds. Sponge-type microstructure. Elementary microstructure is plasmatic-pulverous. The mineral framework is represented by minerals of different sizes. The mineral framework is dominated by quartz and feldspar. The plasma is humic-clay, uniform over the entire plane of the slide, anisotropic with a speckled fluorescence. Plant remains of varying degrees of decomposition. The humus form is mull. The visible surface area is significantly smaller than the previous horizon.

Horizon Hpk (68—79 cm) dark gray, carbonate, fresh, fine-grained, loamy, denser structure, color gradually brightens with the depth of the soil profile. The color of the microscopic slide was brown, uniform over the entire slide area, organic compounds are significantly less than in the previous horizon. Elementary microstructure is plasmatic-pulverous. The mineral framework is dominated by quartz and feldspar. Minerals are mostly anisotropic. The form of minerals is angular, less often low-length. Humus plasma is clayey, uniform over the entire slide plane, anisotropic. Microstructure is of spongy type. There are significantly fewer organogenic components. The pores are narrow and elongated, irregular in shape. Visible porosity occupies a much smaller area.

Horizon Phk (79—120 cm) is gray, lighter than the previous one, gradually turning into loess-like loam high-dense horizon. The color of the microscopic slide was light brown. Elementary microstructure is plasmatic-pulverous. The mineral framework is dominated by quartz, less feldspar of various sizes, mainly isometric in shape, semi-rounded. Significantly less organic ingredients. There are dense opaque rounded organic clots with diffuse contours. The plasma is humic-carbonate-clay, heterogeneous, and anisotropic. The fluorescence is speckled over the entire slide surface. The soil aggregate composition is shown in Tabl. 1.

Table 1. Aggregate composition of forest chernozems

Horizon, cm	Size of aggregate fractions, mm							*J*,%	*C*,%	*B*,%	*K*
	16—8	8—4	4—2	2—1	1—0.5	0.5–0.25	<0.25				
0—10	24.39	9.36	23.12	32.19	6.60	2.51	1.85	61.91	73.77	26.23	2.81±0.96
10—20	8.48	4.74	21.09	38.86	12.62	7.26	6.94	70.59	84.59	15.42	5.49±0.18
20—30	3.15	3.66	24.71	41.96	12.75	7.80	6.99	69.41	89.87	10.14	8.87±1.10
30—40	13.34	7.96	22.95	31.36	10.99	6.26	7.15	65.30	79.51	20.49	3.88±0.77
40—50	9.77	5.76	18.93	37.46	12.92	8.03	7.14	69.31	83.10	16.91	4.92±1.02
50—60	20.96	5.36	16.76	35.47	1.10	5.72	14.65	53.32	64.40	35.61	1.81±0.43
60—70	8.74	4.91	24.94	44.32	10.08	3.93	5.11	59.33	86.16	13.84	6.23±0.28
70—80	9.53	7.95	17.09	37.01	13.96	8.26	6.21	68.10	84.26	15.74	5.35±1.17
80—90	12.35	4.58	15.1	33.86	13.27	9.26	11.57	62.25	76.10	23.92	3.18±0.54
90—100	10.63	4.52	13.44	40.74	14.53	8.63	7.52	68.71	81.86	18.14	4.51±0.87

Note: *J* — sum of soil aggregates 0.5—2.00 mm, *C* — sum of soil aggregates 0.25—8 mm, *B* — sum of ground aggregates smaller than 0.25 mm and larger than 8 mm, *K* — the structure rate expressed in *S/B*.

Maximum value of the coefficient of structurality (*K*) in 20—30 cm horizon is equal to 8.87. In the horizon 10—20 cm it is equal to 5.49. Down the soil profile value of *K* decreased, and in 60—70 cm horizon it rises to 6.23, and to 5.35 in 70—80 cm horizon; deeper it fluctuates gradually decreasing.

The value of the sum of aggregate fractions 0.50—2.00 mm over the entire horizon is very high and almost does not change. The maximum value of the indicator is 79.41 % in 20—30 cm horizon and 72.59 % in 10—20 cm horizon. Then the indicator decreases to a minimum value of 53.32 % in the horizon of 50—60 cm and then, similar to the indicator of the structural coefficient, significantly increases in the horizon of 60—70 cm and is equal to 79.33 % and again decreases slightly with depth.

The water resistance value of all aggregates decreased with increasing horizon depth and was the highest in the horizon of 0—10 cm (fraction 0.25—0.50 mm) 87.41 % and the lowest in the horizon of 50—60 cm (fr. 0.25 mm) 16.65 %.

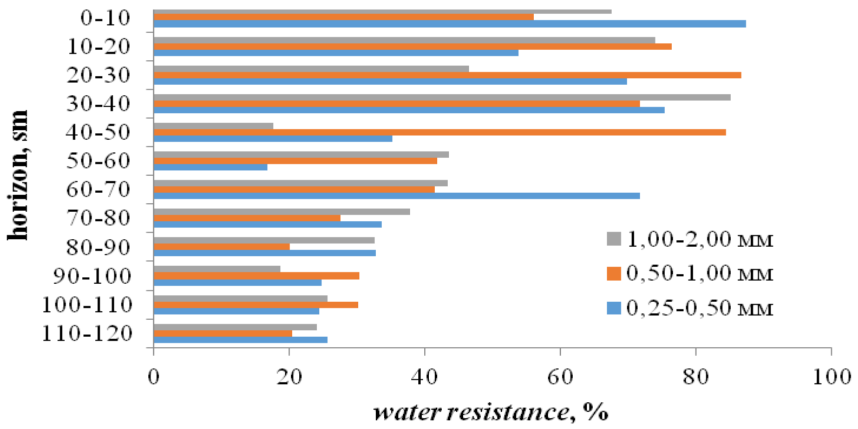

Fig. 1. Water resistance of structural aggregates

In the horizons of 0—10 and 10—20 cm the values of this indicator were close to the maximum and ranged 56.01 % to 87.41 %. Fraction of 0.50—1.00 mm of all horizons has the highest values compared to other values of fractions.

Studies of the humus state have shown that in the upper horizon of the soil profile, the total humus content was high 9.3 % (Tabl. 2).

Table 2. Indicators of the humus state in forest chernozem

Horizon, cm	Total humus content, %	C_{ga} / C_{total} × 100%	C_{ga} / C_{fa}	C residue to C_{total} × 100%
$H_1$0—8	9.30 ± 0.61	36.71 ± 2.11	2.33 ± 0.77	53.11 ± 1.07
H_2 8—43	8.76 ± 0.82	31.14 ± 1.73	2.18 ± 0.65	51.28 ± 1.43
H_3 43—68	6.40 ± 0.33	29.23 ± 1.05	2.04 ± 0.43	54.57 ± 2.49
Hpk 68—92	3.76 ± 0.46	29.09 ± 0.78	1.92 ± 0.67	55.83 ± 1.66

Humus reserves in the horizon of 0—20 cm (180 t/ha) are high in terms of humus state. The distribution of humussubstances in soilprofile is gradually decreasing, and the humus horizon is thick. Humus type was varied from humate to fulvate-humate (C_{ga}/C_{fa}= 2,3—1,9); humification degree was varied from high to medium (36.7—29.1) with the depth of the soil profile. The content of non-hydrolyzed residue was average (51.3—55.8 %).

Conclusions

Our results show that the oakery studied has optimal complex environmental indicators. Micromorphological structure of the soils studied in “Viyskove” ravine indicates that the upper humus horizons were very well-structured and humified. The color of microscopic slides was dark brown, almost black, due to humus-clay plasma. The soil has quite high values of the coefficient of structurality and water resistance of structural aggregates, respectively. Our data confirmed the position of professors O.L. Belgard and A.P. Travleev that in the steppe zone the forests have a positive effect on the complex properties of the soil, in contrast to the forest zone. Ravine chernozems were characterized by active formation of biogenic microstructure, which results in significant aggregation and looseness of the soil microstructure.

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ГРУНТОТВІРНІ ПРОЦЕСИ В БАЙРАЧНИХ ЕКОСИСТЕМАХ

Реферат

У роботі розкриті особливості ґрунтотвірних процесів під лісовою рослинністю в умовах степу на прикладі байрачного біогеоценозу. Для поліпшення стану екологічного середовища України лісові насадження мають надзвичайно важливе значення. Багатофункціональні властивості лісів сприяють значному підвищенню якісної характеристики ґрунтів, перетворють поверхневий стік води на глибинний, припиняючи згубний вплив суховіїв, попереджають ерозію ґрунтів.

Щоб зберегти певну екосистему, треба, насамперед, досконально вивчити всі її компоненти. Ґрунт є основним, результуючим блоком функціонування лісової екосистеми. Для більш чіткого розуміння принципу взаємодії ґрунтів з лісовим біогеоценозом у степових умовах необхідно мати відповіді на ряд питань, серед яких комплексні властивості ґрунту та характер ґрунтотвірних процесів.

У роботі представлені результати визначення агрегатного складу, водостійкості структурних агрегатів, гумусовий стан лісових чорноземів під байрачною рослинністю.

Максимальне значення коефіцієнт структурності (*К*) має у гор. 20—30 см і дорівнює 8,87. У горизонті 10—20 см він становить 5,49. Вниз по ґрунтовому профілю значення *К* знижується, а в горизонті 60—70 підвищується до 6,23, та 5,35 у горизонті 70–80 см, далі коливається, поступово знижуючись.

Значення суми агрегатних фр.0,50—2,00 мм по всьому горизонту дуже високе і майже не змінюється. Максимальне значення показника 79,41 % у гор.і 20—30 см та 72,59 % у гор. 10—20 см. Далі показник знижується до мінімального значення 53,32 % у горизонті 50—60 см і потім, аналогічно показнику коефіцієнта структурності, значно підвищується в горизонті 60—70 і дорівнює 79,33 % і знову трохи знижується з глибиною.

Значення водостійкості всіх агрегатів зменшується із збільшенням глибини горизонту і має найбільше значення у горизонті 0—10 см (фракція 0,25—0,50 мм) — 87,41 % а найменше у

горизонті 50—60 см (фр. 0,25 мм) — 16,65 %. Значення даного показника у горизонтах 0—10 і 10—20 см приближені до максимальних і коливаються від 56,01 % до 87,41 %. Фракція 0,50—1,00 мм всіх горизонтів має найбільші показники, порівняно з іншими показниками фракцій.

Дослідження гумусового стану показали, що у верхньому горизонті ґрунтового профілю загальний вміст гумусу високий — 9,3 %

Запаси гумусу в горизонті 0—20 см (180 т/га) за показниками гумусового стану високі. Профільний розподіл гумусу поступово спадний, гумусовий горизонт потужний. Тип гумусу змінюється від гуматного до фульватно-гуматного ($С_{гк}/С_{фк} = 2,3—1,9$), ступінь гуміфікації з глибиною ґрунтового розрізу змінюється від високого до середнього (36,7—29,1). Вміст негідролізованого залишку середній (51,3—55,8 %).

Отримані нами результати свідчать, що досліджувана пакленова діброва має оптимальні комплексні екологічні показники. Мікроморфологічна структура досліджуваних ґрунтів байраку свідчить, що верхні гумусові горизонти дуже добре структуровані та гуміфіковані. Колір мікрошліфів темно-бурий майже чорний, обумовлений гумусо-глинистою плазмою. Ґрунт має досить високі показники коефіцієнта структурності та водостійкості структурних агрегатів відповідно. Отримані нами дані підтвердили положення професора А. П. Травлєєва, що ліси в степовій зоні, на відміну від лісової зони, позитивно впливають на комплексні властивості ґрунту. Байрачні лісові чорноземи характеризуються активним біогенним мікроструктуроутворенням, результатом якого є значна агрегованість та пухкість мікроструктури, тощо.

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