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ECOSYSTEM - REPRODUCTION OF SUSTAINABLE STRUCTURE IN AGRICULTURE AS A FACTOR OF SOIL FERTILITY

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Abstract

The paper presents the results of a long study of the ordinary cernozems structure of natural ecosystems and field agrocenoses. Structure is the most important indicator of soil fertility. The change of the structure under the influence of factors of intensification of farming is shown, its ecosystem essence (determinism) is highlighted. On the basis of modern (orheological) studies, the parameters of the strength characteristics of the structure are presented - plastic strength and ultimate load of destruction of structural bonds, which is of great importance when using soil as a means of production. The basis of fertility is the relationship between the content in the soil of organic matter and the formation of agronomically valuable aggregates (Cojocaru, 2016). Structural soil is more resistant to machine deformations, less energy is expended on its processing, it provides more efficient use of environmental factors of the habitat and anthropogenic energy spent on fertilizers, processing, pesticides, and other cultivated plants. Strong structure - the basis of erosion resistance of the soil. The purpose of the aggregate analysis is to establish the relative content of aggregates of various sizes in the soil.

Key words*: agriculture, ecosystem, soil, sustainable structure, fertility.*

INTRODUCTION

In modern agriculture, the role of soil, as an indispensable natural resource and, at the same time, the main means of production is steadily increasing.

The soil is the most important component - the "focus" of the biosphere, combining the characteristics of the parent rocks and the long history of the functioning of living matter (Dokuchaev, 1949). As a complex heterogeneous system, it has diverse properties, the most important of which for a farmer is fertility. Fertility is an emergent property of the soil, which is not found separately either in living organisms or in rocks. The measure of fertility potential is considered to be the content in the soil of organic matter (humus). It holds the greatest amount of high-quality free energy accumulated as a result of a long biogeochemical process (Vernadsky, 1965). Such a powerful effect of the biochemical process in the creation of soil fertility is possible due to the special energetic structural organization of the soil.

The structure of eroded soils is characterized by poor water resistance and, as a result, unfavorable agrophysical properties: high density, low porosity, weak water holding capacity. For this reason, crop yields and the efficiency of agricultural production are reduced. Therefore, the study of the nature of structure formation, the mechanisms of formation of a sustainable agronomically valuable structure and the agricultural technologies of its reproduction is an important point in the preparation of a creatively thinking agronomic specialist (Friedland, 1972).

Structural aggregates, as a unique form of organization of matter, are the main property of the soil not only in the industrial, agronomical point of view, but also ecological, biospheric. The structure is a spatial organization of the solid matter of the soil, due to the interaction of the solid, liquid, gaseous and living phases, ensuring the functioning of the soil as an ecological environment and the object of technological impacts and determining its specific morphological structure (Berezin et al., 1985).

However, the soil is not only the environmental factor surrounding the organisms, but also the product of their vital activity (Bulygin, 1993). The structure, composition and porosity of the soil are the most important characteristics that determine the availability of nutrients to plants

and soil animals, affecting aeration, water and air permeability, distribution of roots, soil animals and microorganisms (Westman, 1978; Kachinsky, 1965; Barber, 1988).
The soil structure determines the porosity, which regulates the flow of water and the diffusion of ions to the roots of plants (Bakhtin, 1969).
The density and hardness of the soil depends on the structural state of the soil, determining the conditions for the development of plant roots. The increase in density is accompanied by a sharp restriction of root growth. Root systems of grain, leguminous crops are located mainly at the depth of seed embedding, at high density the main root twists in a spiral, the number of root hairs decreases (Krivenkov, 1967; Sudakov, 1974; Filimonova, 1973). Increasing the soil density above 1.4 g/cm^3 makes it difficult to nitrify and assimilate nitrogen from the soil, resulting in reduced plant density, productive tillering, and spike graininess. The crop shortage is 23-37% (Viter, 1982; Sheptukhov, 1993).
Increasing soil density slows the rate at which water and nutrients enter the plant. At a density of 1.5-1.6 g/cm^3, the share of available moisture accounts for only 5-10% of the soil volume. With an increase in density of 0.1 g/cm^3, the content of inaccessible moisture increases by 10%. At the same time, diffusion of air and gas exchange between the soil and the atmosphere is suppressed, anaerobiosis begins to manifest itself, the oxygen content in the soil decreases, the direction of biological transformation of substances changes, and decomposition of organic matter is suppressed (Bakhtin, 1969; Vasilyevskaya, 1994).
The soil structure determines all the life support processes of plants and microorganisms: water, air and nutrient regimes, and the speed of biogeochemical processes. On the other hand, physical, chemical, biological, physical and mechanical processes significantly affect the structural state of the soil. Consequently, the knowledge of the mechanisms of structure formation and self-organization of soils, as bio-axial systems, opens up the possibility of targeted agrotechnical impact in order to optimize soil regimes.
T.A. Zubkova (1998); E.Yu. Milanovsky (2002) consider the soil as a matrix and associate the nature of the structure formation of different types of soil with the formation of active acid sites.
According to the matrix theory, the mechanical elements and structural units of the soil are the matrix on which all physicochemical processes take place, the root systems of plants develop, and the nutrients are absorbed.

MATERIALS AND METHODS

The soil structure determines all the life support processes of plants and microorganisms: water, air and nutrient regimes, and the speed of biogeochemical processes. On the other hand, physical, chemical, biological, physical and mechanical processes significantly affect the structural state of the soil.
The structure of the soil is largely determined by its mechanical composition. If the soil consists of lumps up to 10 mm in diameter, then it is lumpy or granular. These lumps include mineral particles glued together with humus. In these types of soil a lot of water and air.
To assess soil structuring spend their structure (aggregate) analysis.
Structures soils consist of very small particles up to 0.001 mm in diameter. When water is absorbed, such soils form a continuous sticky mass. Units with a diameter of more than 0.25 mm are called macroaggregates, and smaller than 0.25 mm are called microaggregates.
To determine the structural composition used method dry and wet sieving of soil on the screens with holes of various diameters. Usually used a column of 7 sieves with holes: 10; 7; 5; 3; 2; 1; 0.5 and 0.25 mm. Sieves are put one on another. This allows you to sift the soil at once through all the sieves.
Consider samples of various types and varieties of soil structure, mark the shape, size of structural units. Using the table the determinant of the types and varieties of the soil structure, as well as reference samples, establish the type and type of the structure of the issued sample from any soil horizon. It should be borne in mind that most often the structure is mixed. Perform structural and water analysis of aggregates.
Construct the bar graphs of the structural state of the soil separately for each horizon, in which

horizontally mark fractions of aggregates, and vertically reflect their percentage, including the water-resistant part. Make a conclusion about the agronomic value of the structure of the studied soil.
Consider the soil and note the presence or absence of the structure in it, then add a little water and mix the soil. What is the mass formed? Solid viscous or not? Make a conclusion about the structure of the soil and make similar experiments with other soil samples.
Consequently, the knowledge of the mechanisms of structure formation and self-organization of soils, as bio-axial systems, opens up the possibility of targeted agrotechnical impact in order to optimize soil regimes.
The formation of the structure and its water resistance depends on three factors: humic substances, minerals and absorbed cations (Snakin et al., 1995). The most active role in creating aggregates belongs to the first fraction of humic acids associated with iron, the newly formed humic substance.

RESULTS AND DISCUSSIONS

The ecological functions of the soil are primarily determined by the type of matrix characteristic of the soil. The diverse biospheric and biocenotic functions of soils are associated, first of all, with its agrophysical and physicomechanical properties, a complex indicator of which is structure.
Equally important in the formation of soil structure belongs to the representatives of the soil fauna (earthworms, termites, ants) and root systems of plants (Hadas, 1990; Lee et al., 1991; Oades, 1991; Reid et al., 1981). The root system of plants together with soil microorganisms, being distributed in large pores and around large aggregates, form them.
Formation of the ecological concept was laid V.V. Dokuchaev (1949), who relied on the fundamental idea of nature as a single integral system, considered it as an object of the highest hierarchical level of the biosphere. In the future, attempts were made to separate factors - soil formers according to degree of importance into direct and indirect, active and passive, but it was the biological factor that almost always turned out to be the main factor (Rode, 1947).
It has been established that the formation of an agronomically valuable structure is associated with the irreversible coagulation of colloidal substances involving calcium and iron cations.
In eroded soils with a low content of organic matter, the prevailing acid sites determine the weak degree of consolidation of humus, its low resistance to destruction, the insignificant thickness of the adsorption layer and the weak stability of the aggregate level structures formed from such fragments. This explains the adverse physical properties of arable ordinary chernozem.
The study of the agrophysical properties of ordinary chernozem meadows of various types and arable chernozem at the monitoring sites of the village Negrea in 2012-2015 (Figure 1), makes it possible to state that in natural ecosystems not eroded ordinary chernozems, the state of structure, porosity, density, water strength is mainly determined by biotic factors - botanical composition and herbal density, nature and power of root systems of plants, root microorganisms, number of plants residues falling into the soil.
Annually flooded central floodplain of the Prut River is characterized by agrophysical properties favorable for meadow vegetation.
Eroded ordinary chernozems on which soils are formed with unfavorable agrophysical properties and the absence of flooding of these areas leads to compaction of the upper layers, reducing porosity.
Studies of recent years have found that soils (ordinary chernozem), in which aggregates from 0.25 to 3 mm prevail in the topsoil, evaporate moisture significantly less than if they are 5-10 mm in size. According to our data, soils with aggregates of 0.05–0.25 mm are distinguished by significant water permeability. But microaggregates are blown harder by wind than macroaggregates. The top layer (ordinry chernozem) of a normal dry meadow area in the absence of intensive grazing has generally favorable agrophysical properties. However, it is underlain by a compacted podzolic horizon, which reduces the permeability of the soil. During periods of intense precipitation, a temporary excess of moisture is created.

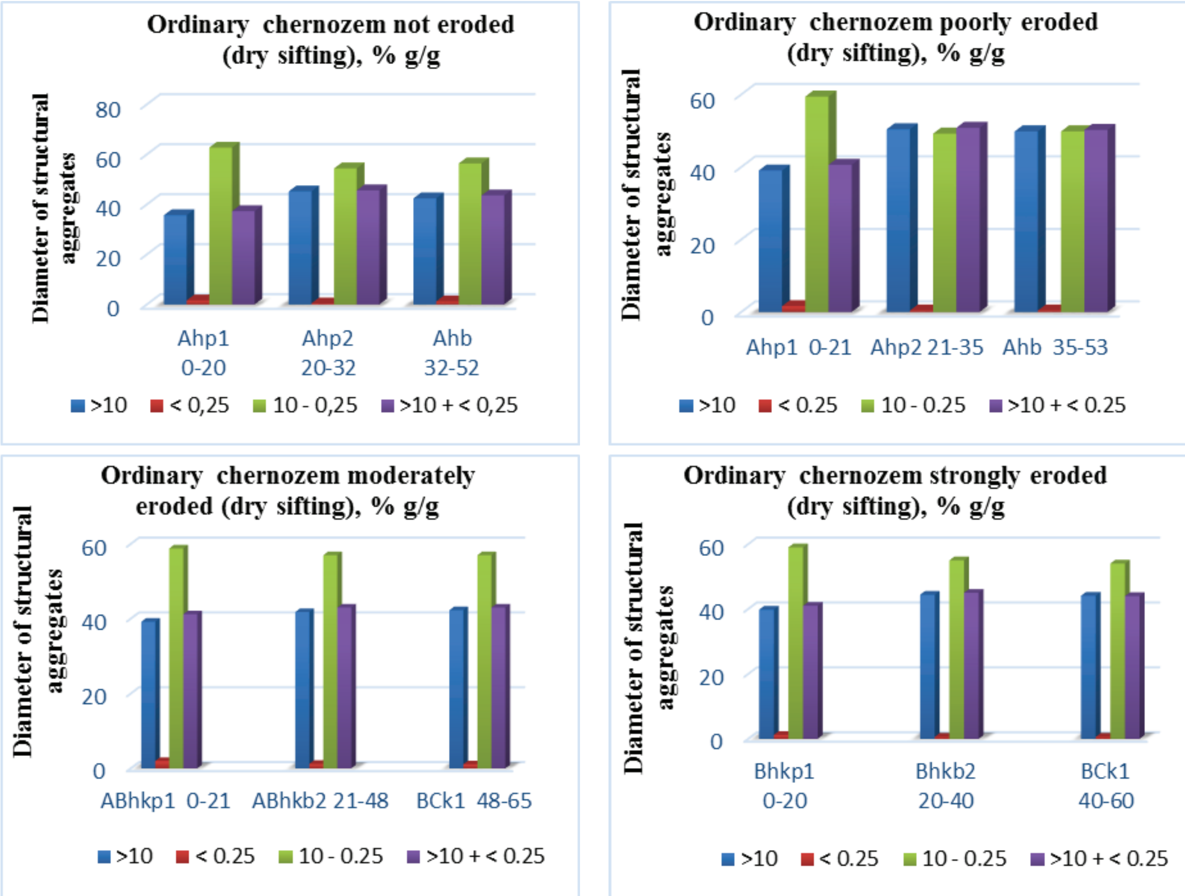

Figure 1. The structural composition of the aggregates of the ordinary chernozems (dry sifting)

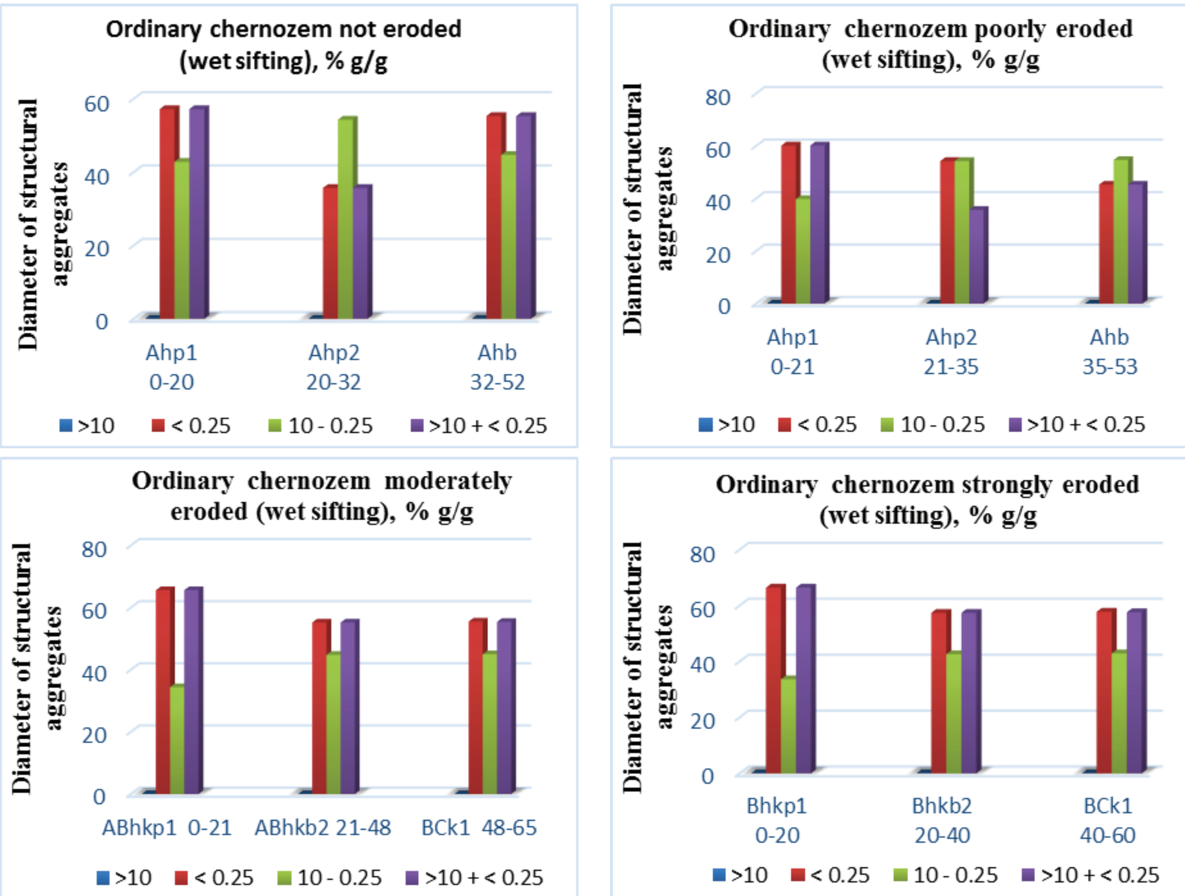

Figure 2. The structural composition of the aggregates of the ordinary chernozems (wet sifting)

In arable poorly cultivated soil of field crop rotation, the mass of root residues is 3-7 times less than in natural biogeocenoses.
The level of application of organic and mineral fertilizers is insufficient to increase fertility, which affects the state of agro-physical properties.
The ecosystem essence of the agrophysical properties associated with the production process and the "humus farming" of the soil remains environmentally determined in agrocenoses. The change in the nature of the production process associated with the alienation of the crop, the decrease in the amount of plant residues, the impoverishment of the composition and species diversity of the soil microflora, causes a decrease in the content of organic matter and, moreover, leads to the ecologization of the soil agrophysical properties.
The highest individual productivity of microorganisms is characteristic of not eroded soils and, which is associated not only with a higher humus content and favorable agrophysical properties, but also with the species diversity of the microflora.
The processes of transformation of substances and energy in agrocenoses determine the state of agrophysical and physicomechanical properties.
Microaggregate analysis (Figure 2) showed that not eroded chernozems soil contains 8.7% more aggregates 1-0.25 mm in size than arable. In arable soil, by contrast, contains 8.35% more coarse dust.
The macroaggregate state of biogeocenoses reflects such indicators as the coefficient of structure (Ks) and the sum of water-reinforced aggregates. Structural analysis showed that not eroded soil is well structured, does not contain lumps and dust, the number of agronomically valuable aggregates 5-0.25 mm is 69%, and 30.8% is a fraction of 3-1 mm. Ks is 3.66.
Studies have shown a close correlation between the plastic strength of the soil structure and the content of organic matter in it.
At the humidity of the yield strength, this dependence is described by the equation

$$P_{h_1} = \frac{c}{0.01747 + 0.9545 * c - 0.06627 * c^2};$$

the correlation ratio μ = 0.99 ± 0.0001.
When the maximum swelling humidity functional relationship is linear

$$P_{h_2} = -0.455 + 0.3614 * c$$

the correlation coefficient is 0.765 ± 0.104.
It follows that a fertile soil with a high content of organic matter is able to withstand higher mechanical loads without destroying the structure.
Studying the dependence of fractions of microaggregates on the humus content in arable light loamy not eroded ordinary chernozem for 5 years of experience showed that only particles 0.01-0.005 and 0.005-0.001 mm in size tend to increase with increasing organic matter.
The dependency equations are:
- *for particles with a size of 0.01-0.005 mm*:

$$P_{h_1} = \frac{c}{0.03899 + 0.2112 * c - 0.0898 * c^2}$$

μ = 0.99 ± 0.0001.
- *for particles of size 0.005-0.001 mm:*

$$P_{h_2} = \frac{c}{0.0001499 + 0.3011 * c - 0.0310 * c^2}$$

μ=0.938±0.056.
The fraction of coarse dust (0.05-0.01 mm) with an increase in the humus content from 0.5 to 2.0% tends to decrease:

$$P_{h_2} = \frac{c}{-0.00007001 + 0.03194c + 0.003399c^2}$$

R=0.999±0.007
The alternation of annual crops in crop rotation with perennial grasses promoted the influx of plant residues in a larger quantity (31.1 q/ha) compared with permanent agrocenoses.
The saturation of crop rotations with tilled crops by 25, 50, 75 and 100% and the strengthening of the anthropogenic impact on the soil in connection with this leads to a decrease in the limit of physical ripeness and lengthening the soil ripening period.
The change in the macroaggregate composition from the content of organic matter can be judged by the coefficient of structurality (Ks).
In connection with the increased anthropogenic impact on the soil cover in the process of land use, it is necessary to determine the resistance of the soil to some form of human intervention in soil formation. The stability of soil as a natural resource in agriculture is of great interest when planning agrotechnologies, developing environmental standards, forecasting the

effects of degradation, improving soil valuation, conducting monitoring studies, and so on (French et al., 1979; Tansley, 1935).

The stability of the structural organization of soils and, due to it, water, heat, gas and food regimes are determined in the general result of their physico-mechanical properties. This circumstance reflects the importance of studying the physicomechanical properties of soils, which are the basis for predicting the effects of various kinds of anthropogenic stress on the soil and soil cover.

Such physical and mechanical characteristics of the soil as cohesion (s), angle of internal friction (φ), shear resistance (τ) have a decisive influence on the erosion resistance of the soil (Mirtskhulava, 1990).

CONCLUSIONS

It should be noted that with agricultural use, the soil is exposed to the most versatile (in terms of the number of disturbing factors) and intensive impacts, which affects the ecological situation of agricultural landscapes and ecosystems as a whole.

Soil structuring under the influence of grasses is most effective in areas with sufficient rainfall and on irrigated land.

An important task of modern agriculture is the development of areas of ecologization of agricultural technologies that increase the stability of soil fertility and the productivity of agroecosystems.

The results show that the annual intake of fresh plant residues into the soil in winter rye crops provides a significant increase in the swelling of the structure compared to potatoes and the crop rotation field.

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