UDC 631.46

EVALUATING THE AGGREGATE PROPERTIES OF PODZOLIZED CHERNOZEM IN AGRICULTURAL AND ABANDONED LAND

Pascuzzi Simone[1], проф.,
Ігнатьєв Є.І.[2], к.т.н.,
Фокіна Я.Є.[2]
[1]*University of Bari Aldo Moro*
[2]*Таврійський державний агротехнологічний університет імені Дмитра Моторного, м. Запоріжжя, Україна.*

Introduction. Prolonged intensive use of Chernozems in the Central Forest-Steppe of Ukraine leads to the degradation of agroecosystems, particularly affecting Chernozems. This results in the depletion of humus content and the overall deterioration of agrophysical properties of these valuable zonal soils. This degradation process leads to the destruction of soil structure, compaction, and the development of erosion processes. A necessary measure for the rehabilitation of degraded Chernozems is the restoration of their structural-aggregate state. Soil structure influences the global carbon cycle, fertility, environmental conditions, and the humus regime in arable Chernozems. Soil structure refers to the form and size of structural units and water-stable aggregates that soil breaks down into under agrogenic loads, characterized by the shape and degree of aggregation. One of the most important indicators of structure is its water stability – the ability to withstand disintegration when moistened.

Methods. Soil structure is quantitatively assessed based on the distribution of aggregate contents (air-dry and water-stable) by their size. The primary quantitative indicator of structure is the content of air-dry aggregates of different sizes. Another indicator of structure is its resistance to external influences, among which the most important is the effect of moisture. The simplest rapid method for quantitative assessment of structure involves sieving air-dry soil through a set of sieves of different sizes or shaking sieves in water during wet sieving. However, the adopted procedures for evaluating the results of wet and dry sieving typically aim to reduce all data to a single indicator. The structure coefficient is often used – the ratio of aggregates from dry sieving with sizes 10(7)-0.25 mm to the sum of structural units > 10 mm and < 1 mm. For a quantitative characterization of structure, the content of agronomically valuable aggregates in the soil is also used, with different sources defining different size limits for this fraction: most consider aggregates of 7-0.25 mm or 10-0.25 mm to be agronomically valuable. Additionally, average aggregate size indicators such as mean weighted diameter and mean geometric diameter are used. According to these approaches, from a fairly large array of data (size distribution), only one value is usually taken, complicating a detailed characterization of soil structure.

For a more detailed characterization of soil structure, additional data are often used alongside dry sieving results: concerning the water stability of aggregates, the size distribution of water-stable aggregates, microaggregates, and granulometric elements in the soil. The prospects for mathematically describing aggregate composition as a distribution, in this example – lognormal, have been previously shown.

In modern soil physics, soil structure is modeled using geometric models, which can generally be divided into two classes – regular and irregular models. In regular models of soil structure, the principle of complete similarity of parts of the pore space of capillary-porous bodies is implemented, and differential porosity calculations are based on geometry. The commonality of regular models is that they completely exclude the element of randomness, order disruption, and chaotic organization of soil units and their spatial arrangement. Irregular models of soil structure include models based on similarity concepts. These models extensively use concepts of fractal geometry and the fractal dimension of soil's porous space. Fractal models of soil structure are based on chaos theory, of which fractals are a part.

Effective assessment of the structural-aggregate state of Chernozems requires regular, comprehensive, interdisciplinary studies of the agroecological functions of soils and their closely related soil genetic and dynamic properties. Genetic, stable soil properties include: the degree of manifestation of the soil formation process, structural-aggregate composition, fractional and group composition of humus, granulometric and mineralogical composition, and soil profile thickness. These properties reflect the potential ability of soils to function within an agroecosystem. Dynamic, manageable soil properties include numerous agrochemical, physical, physicochemical, and biological parameters and processes.

Purpose. To identify the main patterns of transformation and establish normative parameters for changes in the structural-aggregate composition of low-humus podzolized Chernozem in the Central Forest-Steppe of Ukraine during the transitional period to No-till and minimum tillage systems in the agrocenosis of a 5-field grain-row crop rotation. This will be achieved by developing a comprehensive methodological approach that includes conventional soil structure assessment methods and modern statistical data analysis techniques. Existing modern statistical methods and approaches allow for maximum utilization of obtained data with minimal information loss. One of the most common approaches is the principal component analysis (PCA), cluster analysis, non-parametric statistics, and fractal analysis.

Materials and Methods. The research was conducted in a field stationary experiment at the Cherkasy State Agricultural Research Station from 2016 to 2021. The soil is strongly degraded low-humus medium loam podzolized Chernozem on carbonate loess. In the plow layer, the humus content is 2.76-3.03% (according to Tyurin's method), the sum of absorbed bases is 24.5-28.1 mg-eq per 100 g of soil, hydrolytic acidity is 1.99-2.19 mg-eq/100 g of soil, and the pH of the salt extract is 5.56-6.31. The base saturation degree is 92.8-93.3%, the content of mobile phosphorus (according to Truog's method) is 9.0 mg per 100 g of soil, and exchangeable potassium (according to Brovkina's method) is 12 mg per 100 g of soil.

The research was conducted in a field stationary experiment studying the productivity of a 5-field grain-row crop rotation, which included peas, winter wheat, corn, soybeans, and barley. The cultivation system included:

1. Differentiated tillage based on plowing.
2. Differentiated tillage with deep chiseling in 2016 followed by surface tillage to a depth of 10-12 cm for all crops in the rotation over a period of 6 years.
3. Minimum tillage to a depth of 5-6 cm against the background of systematic plowing (transitional tillage).

The fertilization system used was $N_{75}P_{65}K_{82}$ + 6 t ha^{-1} of by-products.

Results and Discussion. The fractal assessment of the distribution of water-stable aggregates within the agronomically valuable interval revealed that during surface tillage, the fractal dimension (D) exceeded D>1.6, characterizing the soil system as unstable and capable of transitioning to a new state. Regardless of the tillage method, the correlation coefficient in the distribution series of water-stable aggregates ranged from C = -0.45 to -0.53, while the Hurst exponent was close to H = 0, indicating the unpredictability of the soil system's behavior.

During the summer period, the fractal dimension fell within the range of $1.4 \leq D \leq 1.6$, determining the stability of the distribution of components regardless of the soil cultivation method. However, towards the end of the crop vegetation in July, the fractal dimension of the distribution of components fell below $D < 1.4$, leading the soil system into an unstable state.

The analysis of the Hurst exponent showed that for surface tillage and plowing, H = 0.57-0.59, indicating the state of the distribution of structural components corresponding to "white" noise or chaotic behavior of the series, i.e., the lowest reliability of prediction. For transitional tillage, the Hurst exponent falls within the range of $0.6 \leq H < 1$, indicating trend persistence and a long-term memory effect. However, during the summer period, the state of the distribution of structural components falls within the range of chaotic behavior of the soil system ($0.5 < H < 0.6$) regardless of the soil cultivation method. The value of the Hurst exponent for the distribution of components in July, regardless of the cultivation method, reached values of $D > 1.6$, indicating the instability of the soil structure, with the soil as a system being "ready" to transition to a new state.

The calculations of correlation (C) in the series of distribution of fractions of structural components showed that the stronger the distribution stability according to the D and H parameters, the weaker the correlation between the fractions. Thus, during the spring period, the correlation coefficient C was at a low level (C = +0.10-0.20) both in spring and in the summer period. When the soil system enters a bifurcation state according to the D and H parameters, the correlation between the fractions of structural components strengthens. For instance, during surface tillage, the correlation coefficient (C) increases to +0.45, while for plowing and transitional tillage, it reaches correlation values of C = 0.35-0.39.

Conclusion. Based on the conducted studies, it can be concluded that the systematic application of surface tillage resulted in a better agrophysical state of the 0-30 cm layer of Chernozem in terms of structural state and water stability of the structure compared to plowing and transitional tillage. The main finding is that during surface tillage, the water stability of the soil structure in the 0-30 cm layer of Chernozem was in a better qualitative and quantitative state in seasonal measurements compared to systematic plowing and transitional tillage. This should be considered the completion of the transition period (6 years) to the application of the No-till system in continuous implementation within a 5-field crop rotation.

References

1. Olt J., Bulgakov V., Beloev H., Nadykto V., Ihnatiev, Ye., Dubrovina O., Arak M., Bondar M., Kutsenko A. A mathematical model of the rear-trailed top harvester and an evaluation of its motion stability. Agronomy Research 20(2), 2022, pp. 371–388.

2. Adamchuk V., Bulgakov V., Korenko M., Boris A., Boris M., Ihnatiev Y. Laboratory and field equipment workingout and the results of experimental studies of pre-harvesting sugar beet field conditions. Mechanization in agriculture. Sofia, Bulgaria, 2016. Issue 1. pp. 3–5.

3. Адамчук В.В., Булгаков В.М., Ігнатьєв Є.І. Теоретичне дослідження параметрів комбінованого гичкозбирального агрегату. Вісник аграрної науки 95 (3), С. 47–53.

4. Ihnatiev Y. Theoretical substantiation of topping parameters without sugar beet head copying. IV International scientific Congress “Agricultural machinery”. Varna. Issue 18 (181). Vol. 1, 22-25 june 2016. P. 55–58.