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Magnetic susceptibility of soils of the chernozem zone of the left bank of Ukraine and its informativity in the agrochemical aspect

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Goal. To study the distribution of values of magnetic susceptibility (MS) of soils of agricultural lands of the chernozem zone of the Left Bank of Ukraine and to evaluate their informativeness for control of organic carbon (Corg) of soils at the regional level. **Methods.** Methods of soil sampling according to DSTU 4287:2004 were used and the humus content was determined according to DSTU 4289:2004. The standard software product Statistica® was used to establish the statistical indicators, and the results of the research were visualized in the environment of MapInfo and Surfer. **Results.** 90 samples were taken from the upper soil horizon (0 – 30 cm) of lands of different types (arable land, pastures, forest), their ratio roughly corresponded to the current structure of agricultural lands. For all samples, the specific MS was determined using a kappa-containing KLY2 according to the Evans method. **Conclusions.** The degree of relationship between the content of sorghum in the soils of the study area did not allow making unambiguous recommendations for the use of MS by interpolation or extrapolation of values at the regional level. This is due to differences in pedogenesis and soil use. The scattering graph of MS and Corg can identify areas that meet different conditions of soil formation: steppe, meadow, gray forest. They did not find regularities in the spatial distribution of soil MS (except for the growth of values with increasing hydrothermal coefficient) and Corg content.
Key words: *carbon, humus, study area, statistics, chernozem.*
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The issue of preserving soil fertility is the basis of human food security. The role of agricultural science in this its preservation, protection and rational use. This is due to the need for continuous monitoring of soil conditions. The monitoring process is characterized by a high level of material and labor costs - the object of the study is about 7 million plots of land. To obtain large arrays of regular and accurate information, traditional methods of determining soil properties need to be modified and supplemented by other, cheaper and faster. One of the most studied properties of the soil cover at present is its magnetic susceptibility (MS). It differs from other characteristics by the efficiency of determination and low cost of measurements. That is why this indicator is increasingly used in addressing soil genesis, in erosion research, land reclamation, determination of heavy metal pollution [1]. Next up is its use to control organic carbon in soils, especially since quite encouraging preliminary results have been obtained [2].

Research A.H. Sheudzhen co-authored we testify that MS is of automorphic soils

the highest in the horizon of humus accumulation [3]. L. Quijano et al. also revealed a close relationship brain between soil organic carbon finely divided material and ferro-magnetic minerals in arable soils [4].

In general, pedogenesis in forest species accompanied by the transformation of ultra-thin ferromagnetic minerals, which is stored in the "memory" of the soil and can be used for quantitative indication of simple location of certain types of modern soils and paleosoils [5]. Application modern digital soil technologies mapping, such as Split Moving Window, allows you to identify simple structure of the soil cover on the new MS data [6]. Moreover, the comparison degraded and non-degraded chernozems indicates the prospect of the application of the CU for diagnosing and monitoring degradation mineralization phenomena organic matter, plant combustion- or the use of fertilizers containing ash or other industrial pollutants [7]. Due to the high content of organic carbon fly in the upper humus horizon chernozems are characterized by the highest the value of MS compared to cambisols and wet soils [8]. At the same time, given the accumulated MS of organic carbon in soils formed were on forest deposits, left there are debatable issues. R. Yang et al. on-reported that on loess and alluvial soils of northern China spatial vari the ability of organic carbon is significant

even in the absence of MS variability [9]. The mechanisms are also unclear. we are caused by agrogenesis decline MS detected on old arable soils povoy zone of Ukraine [10].

The purpose of the work is to study the distribution of MS values of agricultural soils of the agricultural land of the chernozem zone of the Left Bank of Ukraine and to assess their informativeness for the control of soil organic carbon at the regional level.

Research methods and territory. Methods of soil sampling according to DSTU 4287:2004 and determination of humus content according to DSTU 4289:2004 were used, which determines statistical indicators, user of the standard software product Statistica®, visualization of research results was performed in MapInfo and Surfer.

90 samples were taken from the upper soil horizon (0-30 cm) of different types of land (arable land, pastures, forest), their ratio is approximately equal to the current structure of agricultural land. For all samples, the specific MS was determined using a kapabridgeKLY-2 according to the method of Evans [11].

The research was carried out on chernozem soils of the Left Bank of Ukraine (Kharkiv, Dnipropetrovsk and Zaporizhzhya. The sampling area is about 45,000 km^2, ie 1 sampling per 500 km^2. Kharkiv and Dnipropetrovsk regions) and southern chernozems (Zaporizhzhya region), as well as alluvial and meadow soils of river valleys.

The relationship between the magnetic properties of the soil and the content of organic matter is one of the most frequently studied. If the first works on pedomagnetism considered the differences between the MS of soil-forming rocks and humus horizons of soils, the logical next step was their differentiation by organic matter content [12, 13].

For example, chernozem soils are characterized by 3-4.5 times the values of the MS of the upper horizons over the MS of forests [14]. This dependence is observed throughout the territory, where soils develop on forests, loess and alluvial deposits [15]. Known excesses of this ratio are due to ferromagnetic dust pollution in the area of influence of metallurgical enterprises (at high values of MS of the upper horizon) or flooding (at low values of MS of the soil rock) [8]. In this study, the relationship between magnetic parameters and S_{org} content was investigated at the regional and local local levels [16].

At the regional level, studies were conducted on chernozem soils of the Left Bank of Ukraine (Kharkiv, Dnipropetrovsk and Zaporizhia) (Fig. 1a and 1b), with a sampling area (n = 90) of about 45,000 km^2, ie 1 sampling per 500 km^2.

The study area is characterized by typical, podzolic chernozems (northern part of Kharkiv region), common chernozems (southern part of Kharkiv and Dnipropetrovsk regions) and southern chernozems (Zaporizhzhya region). Alluvial and meadow soils of river valleys were also selected.

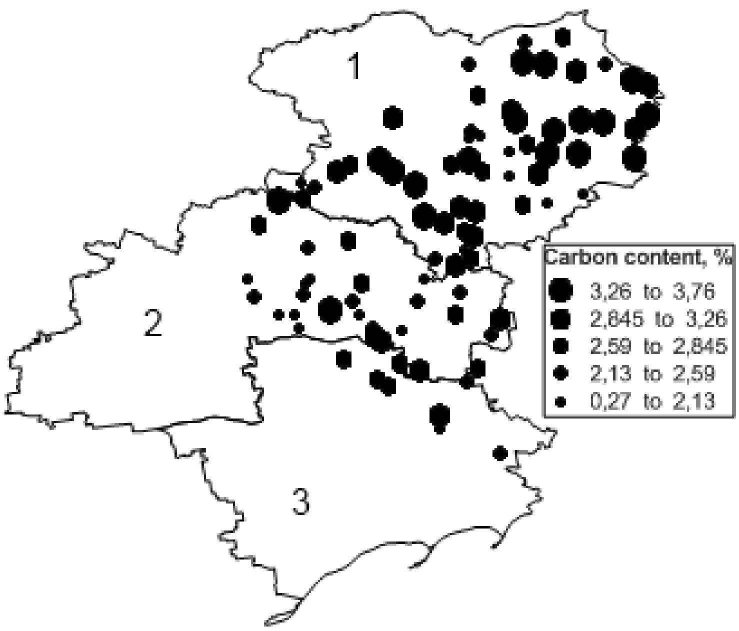

Fig. 1. Scheme of soil sampling points (in the format of values of the content of C org): 1 – Kharkiv region; 2 – Dnipropetrovsk region; 3 – Zaporozhye region

As we can see, regularities in the spatial distribution of C_{org} (Fig. 1) are not traceable. Values in the lower range are mainly characteristic of soils developed on alluvial deposits of large river valleys of the region (Dnieper, Seversky Dinets).

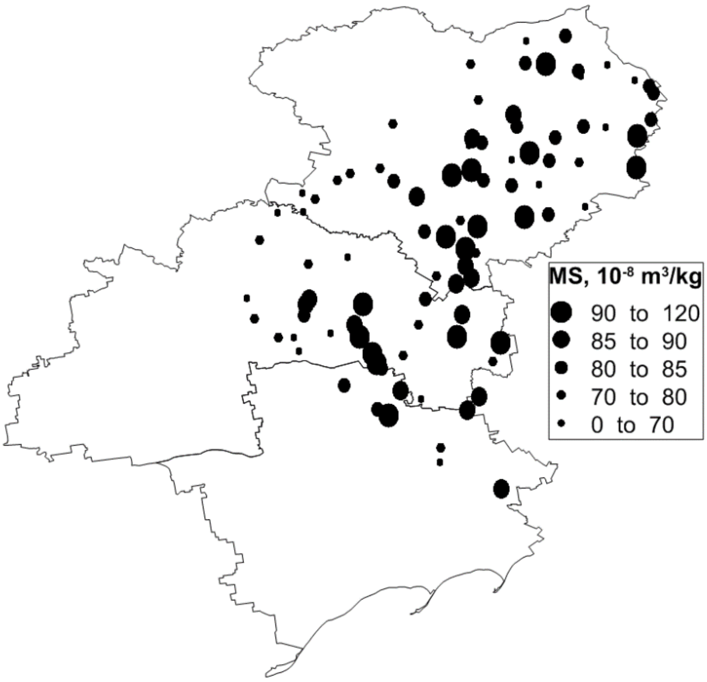

Fig. 2. The value of the MS of the soil of the study area

In contrast to the spatial distribution of sorghum, there is a certain dependence in the distribution of MS values: growth in the south-eastern direction, which roughly corresponds to the growth of НТК. We have not confirmed the known relationship between soil MS and the amount of annual precipitation [17, 18]. The main statistical characteristics of the distribution of MS values and Sorghum content are given in Table.

The main statistical characteristics of the distribution of MS values and the content of C_{org} soils in the study area

Indicator	Mean	Mediana	Range	St. deviation	Coef. Variation, варіат. %	Skewness	Kurtosis	Variance
Content C_{org} .%	2,62	2,74	0,27 –3,76	0,664	25,3	-0,93	1,44	0,441
MS, 10^{-8} m^3/кг	76,37	82,75	5,72 - 110,44	19,963	26,1	-1,68	2,89	398,5

As you can see, the descriptive statistics of the samples (Table 1) does not allow to accept the hypothesis of a normal distribution of values of the studied indicators. The median is shifted to the right from the arithmetic mean by 4.3% and 7.7%, respectively. Indicators of asymmetry and excess also differ from the values characteristic of the Gaussian distribution. The coefficients of variability are almost the same, quite significant, but do not exceed the average [19].

More informative is the scatter diagram of the studied indicators, shown in Figure 3. There are three groups of soils associated with differences in pedogenesis, namely the predominance of steppe (fields, fallows), forest (forest, edge) or meadow-swamp (soil valleys) conditions.

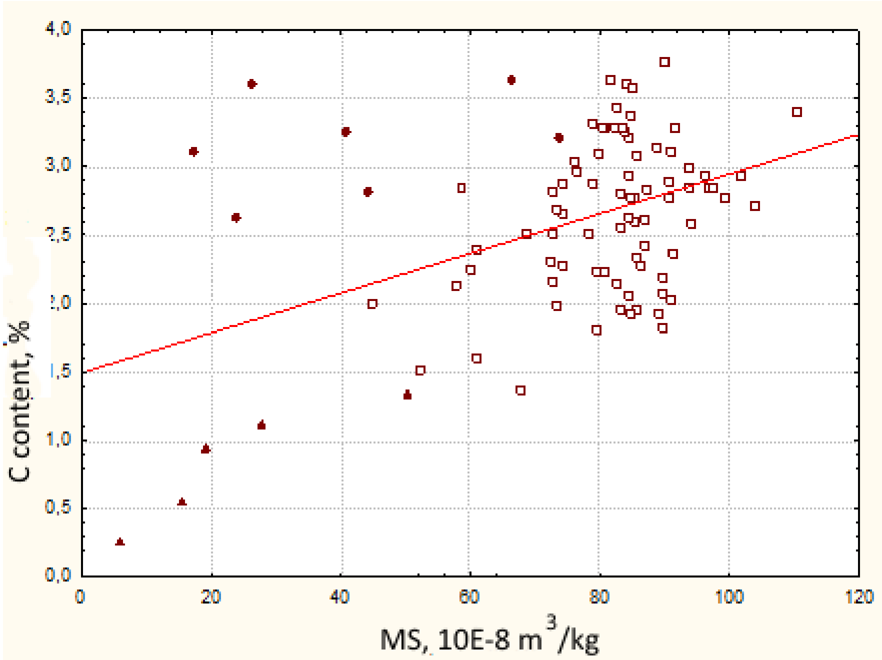

Fig. 3. Diagram of scattering of MS values and Sorghum content: ● – meadow soils; ○ – steppe soils; ▲ – forest soils

The absence of a confirmed normal distribution (Kolmogorov-Smirnov criterion) does not allow Pearson's correlation to be used to study the relationship between the studied indicators. In such cases, it is advisable to use non-parametric methods, primarily to determine the Spearman coefficient ρ.

The application of this approach allowed to record the average level of relationship between MS and Sorghum content: $\rho = 0.45$ at $p \leq 0.05$. This does not allow to make unambiguous recommendations for the use of MS in forecasting Corg at the regional level.

The recorded tendency to allocate in separate sectors (Fig. 3) soils with different directions of pedogenesis allowed us to analyze the ratio of the two studied indicators MS / Corg, ie to determine the contribution of a unit of soil organic carbon in the magnetic properties. The spatial distribution of the obtained result is shown in Figure 4. Dimension 10^{-7} for convenience is not taken into account.

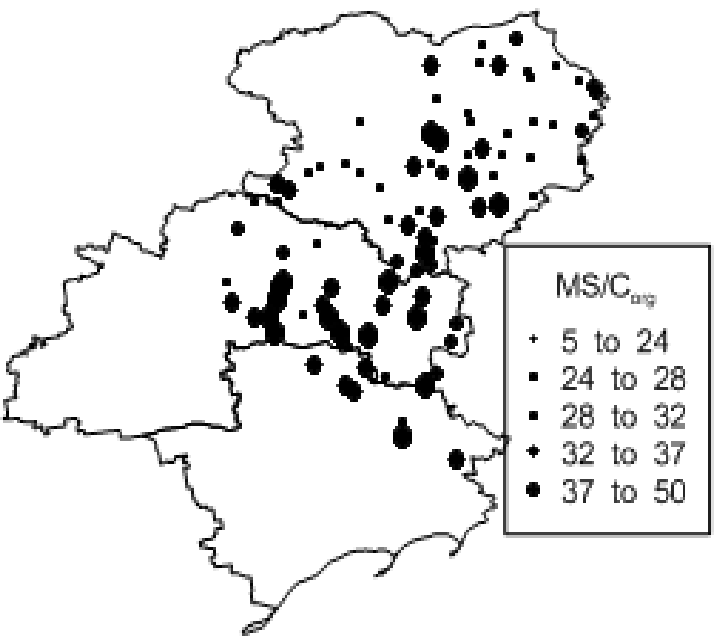

Fig. 4. Spatial distribution of MS / C_{org}

As shown in Fig. 4, there is a clear tendency to increase the coefficient of MS / C_{org} in the study area in the south-western direction. In our opinion, this is due to a similar increase in the content of Fe_2O_3 as the main source for the formation of highly crystallized iron compounds.

Conclusions

The degree of connection of MS with C_{org} content in the soils of the study area does not allow to make unambiguous recommendations for the use of MS in the interpolation or extrapolation of values at the regional level. In our opinion, this is due to differences in pedogenesis and soil use. In the scattering schedule of MS and Corg, we can note the zones that meet different conditions of soil formation: steppe, meadow-swamp, forest. We did not find any patterns in the spatial distribution of soil MS (except for the increase in values with increasing HTC) and C_{org} content. Instead, there is a tendency to increase the values of the MS / C_{org} coefficient in the study area in the south-western direction, which we associate with an increase in the content of Fe_2O_3 in the soil.

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