Mon23-126

Magnetic properties of sloping soils: methodological challenges

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SUMMARY

The application of magnetometry in service provision of agricultural production is a very promising market. However, a number of methodical tasks stand in the way of active introduction of soil magnetometry. One of them is taking into account the impact of anomaly-forming processes, among which there is the alternation of washout - washout zones under the action of erosion processes. This paper investigates the spatial distribution of magnetic susceptibility of the soils of the sloping agricultural landscape and its relationship with key agronomic characteristics. The most significant deviations are characteristic of the first third of the range of organic carbon content values. Such values are characteristic of the lower parts of the landscape, with the most pronounced manifestations of washout.

Introduction

The market of services for the needs of the agrarian sector of the economy is a dynamically developing market. First of all, this applies to the main means of production - the soil cover of agricultural lands. Among the requirements for modern research methods are efficiency, mass, low cost (*Khlobystov et al., 2021*). Such requirements are met by a number of geophysical methods, among which the application of magnetometry methods appears to be the most promising. It is believed that pedomagnetic developments are developing in several methodological directions: increasing the productivity of field measurements, reducing the cost of determining soil properties (due to automation and the introduction of new methods and techniques), and the development of new methods of interpolation of data from reference sections (*Kruglov et al., 2022*). Their application allows you to fully use the potential of methodical approaches united under the name "precision agriculture, i.e. adequate response to the soil and climatic conditions of each of the individual parts of agricultural plots (fields). Such approaches include the differentiation of agrotechnological measures (variable rates of sowing seeds of agricultural crops, rates of fertilizers, plant protection agents, depth and type of main tillage). At the same tame of the great importance is joint geophysical interpretation of methods (*Pihulevskyi et al., 2021; Pihulevskyi et al., 2019; Vyzhva et al., 2010*).
In the world, it is magnetometry that is considered the main means of solving such problems. The physical basis of this application is the differentiation of soil cover properties by the content and form of iron compounds *(Jordanova, 2016; Menshov and Sukhorada, 2012).* Thus, there are known successful cases of indication by magnetic methods of anomalies in humus content, soil density, and granulometric composition (*de Jong et al., 1998*). The use of both a set of directly magnetic methods and their integration with more traditional for soil science agrophysical and agrochemical methods is being developed (*Maher et al., 2003*).
The content and mineral form of iron compounds that is an indicator of several indicators related to soil organic carbon. Such compounds participate, directly or indirectly, in the carbon oxidation-reduction cycle, perform a transport function (*Cornell and Schwertmann, 2003*). In many cases, there is a close relationship between the content of soil carbon (C) and the magnetic characteristics of the soil. Thus, researchers from the Czech Republic recorded a high degree of connection between C and the specific magnetic susceptibility of the soil, R^2=0.971 (*Jakšík et al., 2016*). High values of the correlation coefficient were also obtained by us on the example of a site on chernozem soils (*Menshov et al., 2012*).
However, despite the success of using the method, it also has some problems of a methodical and methodological nature, and requires additional research, especially in areas related to the most massive analytical works. The most promising, in our opinion, are the determination of soil erosion, precise studies of the distribution of organic carbon content, and the forecast of the accumulation of productive moisture in the agricultural landscape. Among the main problems, we can mention soil inhomogeneities caused by the alternation of washout and washout zones. The purpose of this work is to study the characteristics of the spatial distribution of the content of C and MS, including their dependence on other factors.

Methods

During the research, the soil cover was sampled with the determination of the specific magnetic susceptibility with the help of a KLY-2 capameter, in some cases the in-situ volume MS was determined with a KT-5 capameter. Sampling was carried out from the arable layer using an irregular network. To determine the statistical characteristics, the standard software product Statistica® was used. Methods of soil sampling according to DSTU 4287:2004 and determination of humus content according to DSTU 4289:2004 were used. The work was carried out at the experimental field of DBTU (Kharkiv district, Kharkiv region). Soil moisture was determined by the thermostatic weight method.

Results

Determination of soil erosion of agricultural plots by magnetic methods is primarily related to information on the spatial distribution of humus content (*Menshov and Kruglov, 2023*) and the distribution of the granulometric composition of the soil (*Peluco et al., 2013*), which is due to the course of slope processes. However, our observations on the territory of the Kharkiv region indicate the spatial framework of the application of the method, which is related to the features of the topography of the site. Soil samples were taken on a site with a complex topography, for which some agrochemical indicators and soil MC were determined. The correlation coefficient between the content of humus and MC of the soil was recorded ρ=0.84 (Fig. 1)

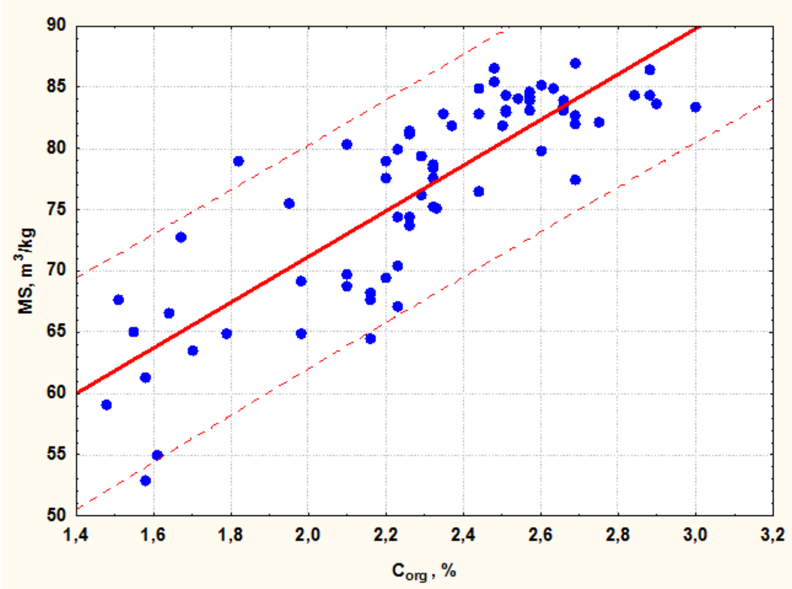

Figure 1 *Graph of dependence between the content of organic carbon and MS of the soil*

As shown in Fig. 1, the most significant deviations are characteristic of the first third of the range of organic carbon content values. Such values are characteristic of the lower parts of the landscape, with the most pronounced manifestations of washout.

To characterize the relief, the value of the LS topographic factor of the USLE model was chosen, which, according to its values, was divided into 7 groups (Figure 2). Statistical investigations showed the presence of a high degree of connection between LS and MC values, ρ=0.78.

In this case, deviations from the expected MC values are observed in the center of the range of topographic factor values. In practice, this corresponds to the transeluvial zone without manifestations of areas of alluvium. Similar results were obtained in other areas of chernozem soils of the region (*Khomenko et al, 2021*).

At the same time, the results of Figure 2 show an increase in the range and, therefore, the dispersion of the MC values with the increase in the values of the LS factor. Moreover, in groups 1-4, the range of MS values is almost the same. We explain this situation by the presence of intensive washing (very low MS values) and accumulation (increased MS values). Such information is relevant not only for land users, but also for soil protection works.

In addition, the content of productive moisture was determined. Its relationship with the topographic factor, ρ=0.70, is noted (Figure 3).

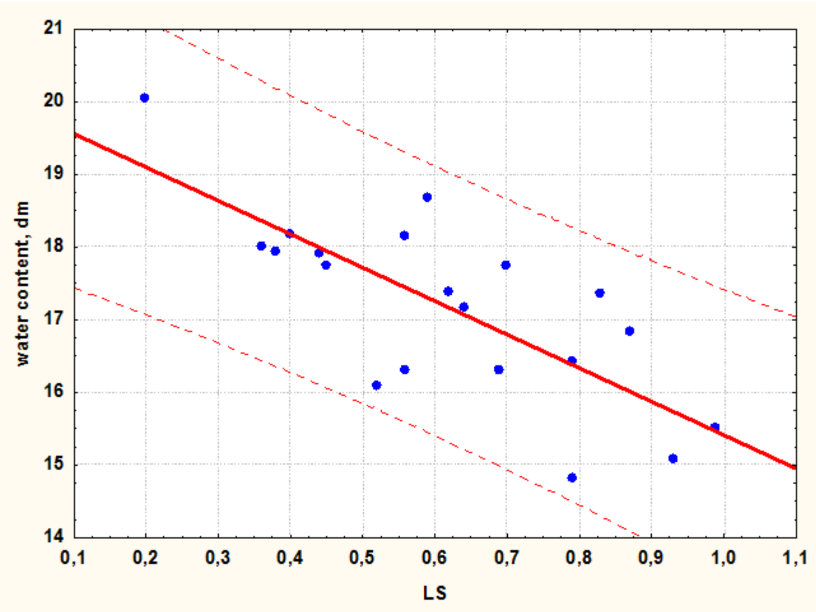

Figure 2 *Soil MS value depending on terrain characteristics*

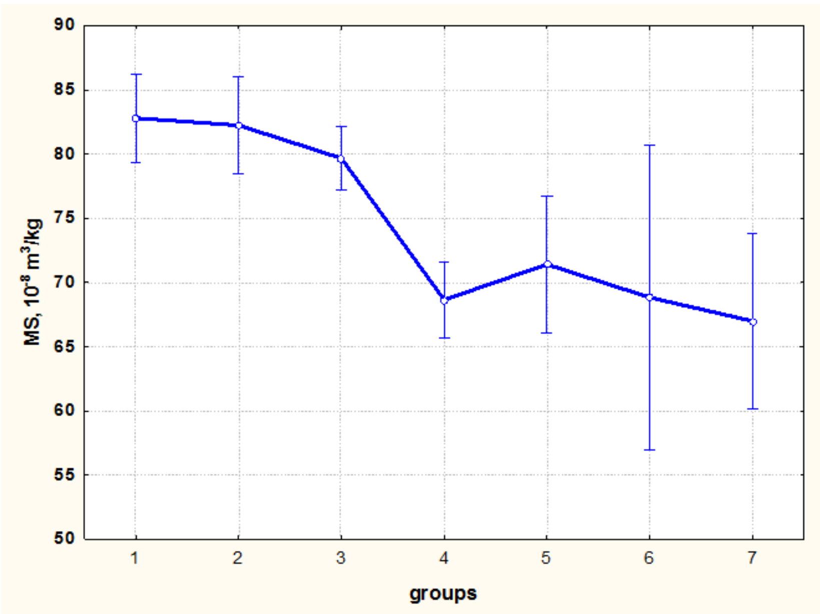

Figure 3 *Dependence of productive moisture content on the topographic factor*

As shown in Figure 3, the largest deviations of the values of productive moisture from the expected values are in the middle of the range of values of the LS factor, that is, in the trans-eluvial section. Taking into account the deviation recorded in Fig. 2, for the same values in the center of the range, we can conclude about the low prospects of using MS in forecasting the spatial distribution of productive moisture in this part of the agricultural landscape. The joint application of magnetic reconnaissance and erosion modeling will allow to more fully reveal the potential of the methods.

Conclusions

The application of soil magnetometry data has a high potential in determining agronomic heterogeneities, it is relevant both in the implementation of the concept of "precision agriculture", where it has market advantages over traditional methods, and in the creation of a soil protection system.

Thus, based on the results of the experiment, it is possible to conclude about the significant potential of using magnetometry in determining soil erosion, humus content, and water-physical properties. At the same time, it should be noted the limitations associated with the uncertainty of the results in transeluvial areas and the possibility of errors in the zones of soil substance deposits. Combining the results of magnetometry and terrain characteristics will reduce the total error and expand the application of the method

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