Mon22-165

Soil sampling and magnetic susceptibility determination in soil science: methodological aspect

O. Kruglov *(NSC "Institute of Soil Science and Agrochemistry Research named after O.N. Sokolovsky")*, ****O. Menshov*** *(Taras Shevchenko National University of Kyiv)*, ***L. Horoshkova*** *(National University of Kyiv-Mohyla Academy)*, ***O. Tonkha*** *(National University of Life and Environmental Sciences of Ukraine)*, ***O. Andreeva*** *(Taras Shevchenko National University of Kyiv)*, ***B. Kruhlov*** *(Taras Shevchenko National University of Kyiv)*, ***O. Zhuravel*** *(State Biotechnology University)*

SUMMARY

The study is dedicated to the numerous methodological problems that arise when applying the magnetic susceptibility measurements of soils for the agrarian application. The experiment was carried out for the chernozem soils of the Kharkiv and Poltava regions. Problems in the sampling planning are related to the main tillage processes. The temporal and spatial parameters as well as the sampling depth were analyzed. It has been shown that the use of soil magnetic susceptibility (MS) has a high potential in determining soil inhomogeneities. The first of all, MS is relevant in the implementation of the concept of precision agriculture, where it has market advantages over traditional methods.

Introduction

The modern agrarian complex develops technologies that provide precise and targeted implementation of optimal agro technique and agrochemical measures. This approach requires the attraction of the precision agriculture measurements. Currently, this concept is fully or partially implemented in Ukraine at the area of more than 5 million hectares. The methodological basis for the implementation of precision agriculture is the localization of agronomic inhomogeneities of the soil, which require the differentiation of agrotechnical measures to determine potential fertility. Now days, the crop production is based on the use of the potential of the "soil-plant" system. The task of farmers is to optimize the links of this system to obtain the maximum amount of agricultural harvest using the necessary minimum of resources.

Often, the term "precision farming" refers to the geographical positioning of agricultural technique, the accuracy of movement of agricultural machines and tools on the surface of the land. The accuracy is only few centimetres. The increase of the set of techniques do not the change of the priority of the most basic indicators. Precise information about soil characteristics is the main component of such agricultural technologies. This makes it possible to maximally satisfy the needs of the growth and development of agricultural plants at every point of the medium at the studied areas. With the growth of the capabilities of agricultural machinery, there was a need to localize such inhomogeneities with high resolution. However, the determination of the main soil characteristics is important for creating sufficiently informative cartograms. This involve a large volume (hundreds of millions of determinations) of field measurements, processing and interpretation.

There is a gap in the effectiveness of the existing agrotechnique. In this study we consider the possible ways to optimize the methodological algorithm. To develop the optimal magnetic methodology, we attracted the previous geophysical evidence (*Ivanik et al., 2020; Onanko et al., 2011; Pihulevskyi et al., 2021; Tiapkin et al., 2019; Vyzhva et al., 2019*).

Methods and Theory

The various proximal and remote methods have been used to solve problems in precision agriculture several last decades. Among the, the magnetic studies demonstrated stable effectiveness. The magnetic susceptibility (MS, χ) is currently considered as the most commonly used in magnetic assessment of soils. The volumetric MS is usually measured in the field in situ with portative magnetometers like KT series. The mass-specific MS normally is measured and determined in laboratory conditions with kappabridges like KLY series or Bartington MS. These methods are characterized by high expressivity, low cost of determination, and the absence of physical or chemical influence on the sample. As a result, the studied sample corresponds to the natural conditions. However, the methodological gap is the sampling processes and the formation of the survey network. The problem arises according to the inhomogeneity of the magnetic characteristics of the arable horizon of the soil (topsoil) at the depth of the 0-30 cm. This horizon is the most important object of the precision soil survey. The nature of such heterogeneities can be both of pedogenic and lithogenic origin (*Suhorada & Kruglov, 2019*).

The soil magnetic studies require the improvement of the methodology. This means the increasing of the productivity of field measurements, reducing the cost of determinations (due to automation and the introduction of new methods and techniques), and the development of new methods of interpolation of data at the reference sections.

The magnetic susceptibility can be used to determine many agronomic characteristics of the soil. The most common reports are about the links to the stability of structural aggregates, particle size composition, in particular the content of the clay fraction, and finally the content of organic carbon (*Wang et al., 2008*). The promising results regarding the assessment of soil erosion due to water erosion and the distribution of humus content were obtained for the podzolized chernozem plot (*Menshov et al., 2018; Menshov, 2018*). The high correlation between the MS of the soil and the results of the application of the well-known mathematical models of soil erosion WEPP and USLE was considered by (*Barbosa et al., 2019*). Soil magnetic studies perfectly complements the traditional methods in their joint use (*Kruglov et al., 2020*).

In general, the magnetic indicators are related to a number of physical and chemical indicators of the land cover (*Moritsuka et al. 2021*). However, the practical application of the method on a specific field is often limited by the need to take into account the influence of different types of tillage, the depth of sampling, and the time that has passed since the main tillage.
In our study, the soil samples were collected to determine the mass-specific MS with KLY-2 kappameter. For the field measurements we used portable kappameter KT-5. The samples were collected from the soil horizons at the arable lands according to the profile system. The standard software product Statistica® was used to determine statistical indicators. The soil sampling was performed according to DSTU 4287:2004 and determination of humus content according to DSTU 4289:2004.

Examples

The pedogenic iron minerals are formed as a result of pedogenesis. This iron minerals are considered thermodynamically unstable, because under the influence of external factors (i.e. heating, moisture, pH conditions, and microbiological processes) they may change their magnetic phase (*Maxbauer et al., 2017*). The trigger of such processes is tillage: timing, depth, and the type of the implementation.
For the example of the determination of MS, we consider the ordinary chernozem soil of Kharkiv region. The experiment includes the depends of the time that has passed since the main processing. Four options were considered according to the time of the last ploughing: 1 – more than 12 months; 2 – in 15 days; 3 – in 100 days; 4 – virgin land (see Table 1). The analyses was performed at the end of the season of the vegetation in September.

Table 1 *Dependence of MS of ordinary chernozem soil and the time after the ploughing*

Option	Horizon, cm	MS, 10^{-8} м^3/kg
1	0 - 10	83.0
	10 - 20	79.0
	20 - 30	78.5
2	0 - 10	78.1
	10 - 20	80.2
	20 - 30	77.5
3	0 - 10	85.1
	10 - 20	85.3
	20 - 30	85.5
4	0 - 10	83.7
	10 - 20	79.2
	20 - 30	76.8

The data in Table 1 indicates a significant (about 8%) difference between the MS of individual horizons of the arable layer. The recent ploughing due to soil mixing levels leads to the difference between the layers of the arable horizon. Immediately after plowing, a decrease in the MS values is observed. The option after 100 days after cultivation demonstrated the increase in MS values up to 10%. The option a year after processing demonstrated that the MS of the soil horizons acquires values close to natural ones. The difference in values between layers 0-10 and 20-30 cm in the two options reaches 8%.
The influence of different types of main tillage was studied on the example of podzolized chernozem in Poltava region. The options of the experiment were: 1 – plowing, 2 – deep loosening, 3 – vertical tillage, 4 – shallow disking, 5 – no tillage. The options are the various depths, and the depth of cultivation decreases from 1 to 5 options, from 27 cm to 0 cm. The results of the determinations are presented in Table 2. The sampling was carried out during the vegetation season. The territory of the plot is a corn grain in the phase of the beginning of the flowering of the crop.

Table 2 *Soil MS under the different types of the cultivation*

Cultivation type	Horizon, cm	MS, 10^{-8} м^3/kg
Plowing	0 - 10	51.05
	10 - 20	50.20
	20 - 30	49.56
Deep loosening	0 - 10	51.04
	10 - 20	50.85
	20 - 30	48.11
Vertical tillage	0 - 10	51.99
	10 - 20	52.31
	20 - 30	51.66
Shallow disking	0 - 10	51.62
	10 - 20	51.38
	20 - 30	52.63
No tillage	0 - 10	51.89
	10 - 20	51.12
	20 - 30	50.62

The results presented in Table 2 demonstrated that the differentiation of MS of individual layers of the arable horizon occurs only under conditions of deep tillage with a significant degree of loosening. Thus, a significant difference between layers 0-10 and 20-30 cm is observed only in option with shelf plowing and deep loosening. The fact of such differentiation after plowing is also confirmed by the data presented in Table 1. However, these same data do not make it possible to assert the reliable identification of the type of main tillage using only data of the soil MS.

The influence of the depth of the soil sampling for determination of the MS was studied on the example of typical chernozems of Kharkiv region. The sampling was performed in layers of 0-10 cm and 20-30 cm. The volumetric MS was measured in the field conditions. The results are presented in Table 3. The analyzes were performed at the end of the growing season on the stubble of early ear crops.

Table 3 *Statistical indicators of MS of the ordinary chernozems in layers 0-10 and 20-30 cm (n=30)*

Indicator	Mass-specific MS, 10^{-8}м^3/kg		Volume MS, 10^{-3}	
	0-10 cm	**20-30 cm**	**0-10 cm**	**20-30 cm**
Mean	85.8	85.6	0.61	0.55
Coefficient of variation, %	2.99	2.40	11.33	5.79

The results presented in Table 3 show the absence of a significant difference between the mass-specific MS values in the 0-10 and 20-30 cm layers. There is a slight decrease in the variability of the trait. And in the option with volumetric MS, this phenomenon is more pronounced. A 2-fold decrease was noted. At the same time, the average arithmetic value of the sign decreased by 10%. The variability of the indicator of volumetric MS is much higher than the corresponding indicator of mass-specific MS. We assume, that this is explained by the presence of local soil compaction after the passage of heavy agricultural machinery. Such difference is balanced when determining the volume MS at the depth of the main tillage with agricultural tools of 0-30 cm comparing with the depth of 0-10 cm.

The Spearman's correlation of the two studied types of MS is weak, ρ=0.3, both for the 0-10 cm layer and for the 0-30 cm layer. Considering the lower level of variability of the mass-specific MS, the application of this magnetic parameter seems more reasonable comparing with the volumetric MS. The use of volumetric MS in the field condition provides an important operational tool for understanding the spatial inhomogeneities of the soil continuum, especially under the conditions of the occurrence of soil-forming rocks directly at the study area.

Conclusions

The application of soil MS data has a high potential in determining soil heterogeneities. The first of all, the MS is relevant in the implementation of the concept of "precision agriculture", where market advantages over traditional methods are obvious. However, when conducting soil magnetic studies, the important is to consider the identity of the cultivation of the main soil tillage at entire area. The use of mass-specific MS is more reliable, compared to the volumetric MS data attraction.

References

Barbosa, R. S., Marques Júnior, J., Barrón, V., Martins Filho, M. V., Siqueira, D. S., Peluco, R. G., ... & Silva, L. S. (2019). Prediction and mapping of erodibility factors (USLE and WEPP) by magnetic susceptibility in basalt-derived soils in northeastern São Paulo state, Brazil. *Environmental earth sciences*, 78(1), 1-12.

Ivanik, O. M., Kravchenko, D. V., Tustanovska, L. V., Mazko, A. E., Hadiatska, K. P. (2020). The main causes of landslide hazards in Kyiv region, Ukraine. *In XIV International Scientific Conference "Monitoring of Geological Processes and Ecological Condition of the Environment. European Association of Geoscientists & Engineers*.

Kruglov, O., Menshov, O., Miroshnychenko, M., & Shevchenko, M. (2020). Integration of geophysical, soil science and geospatial methods in the study of eroded soil. *In Geoinformatics: Theoretical and Applied Aspects. European Association of Geoscientists & Engineers.*

Maxbauer, D. P., Feinberg, J. M., Fox, D. L., Nater, E. A. (2017). Response of pedogenic magnetite to changing vegetation in soils developed under uniform climate, topography, and parent material. *Scientific reports*, 7(1), 1-10.

Menshov, O., Kuderavets, R., Chobotok, I. (2018). Magnetic and mineralogy analysis of soils of hydrocarbon prospective areas in Ukraine. *In 24th European Meeting of Environmental and Engineering Geophysics. European Association of Geoscientists & Engineers*.

Menshov, O. (2018). Theory and methodology of soil magnetism in geology, ecology and soil science. *In 12th International Scientific Conference on Monitoring of Geological Processes and Ecological Condition of the Environment*.

Moritsuka, N., Matsuoka, K., Katsura, K., Sano, S., Yanai, J. (2021). Laboratory and field measurement of magnetic susceptibility of Japanese agricultural soils for rapid soil assessment. *Geoderma*, 393, 115013.

Onanko, Y. A., Prodayvoda, G. T., Vyzhva, S. A., Onanho, A. P., & Kulish, M. P. (2011). The Computerized System of Processing of Measurements of Longitudinal and Transverse Velocities of Ultrasound. *Metallofizika i noveishie tekhnologii*, 33, 529-533.

Pihulevskyi, P., Tiapkin, O., Anisimova, L., Kalinichenko, O., Panteleeva, N. (2021). Geophysical and tectonic modernization of geoecological monitoring system of territories near nuclear fuel cycle objects of Ukrainian Southeast. *In 15th International Conference Monitoring of Geological Processes and Ecological Condition of the Environment. European Association of Geoscientists & Engineers.*

Suhorada, A.V., Kruglov, O.V. (2019). Classification of soils by their magnetic properties. *In 18th International Conference on Geoinformatics-Theoretical and Applied Aspects. European Association of Geoscientists & Engineers*.

Tiapkin, O., Kendzera, O., Pihulevskyi, P., Dovbnich, M. (2019). Complex geophysical research of near surface sustainability of mining waste-storages in Central Ukraine. *In 25th European Meeting of Environmental and Engineering Geophysics. European Association of Geoscientists & Engineers*.

Vyzhva, Z., Demidov, V., Vyzhva, A. (2019). About statistical simulation algorithm of dataset in 3-D area with spherical correlation function on Rivne NPP example. *In 18th International Conference on Geoinformatics-Theoretical and Applied Aspects. European Association of Geoscientists & Engineers.*

Wang, H., Huo, Y., Zeng L, Wu, X., Cai, Y. (2008). A 42-yr soil erosion record inferred from mineral magnetism of reservoir sediments in a small carbonate-rock catchment, Guizhou Plateau, southwest China. *J. Paleolimnol*, 40, 897-921.