

Oleksandr Kruglov

PhD in Geology

NSC "Institute for Soil Science and Agrochemistry Research named after O.N. Sokolovsky"

61024, 4 Chaikovska Str., Kharkiv, Ukraine

<https://orcid.org/0000-0003-2663-0935>

Oleksandr Menshov*

Doctor of Geological Sciences, Senior Researcher

Institute of Geology Taras Shevchenko National University of Kyiv

03022, 90 Vasylykivska Str., Kyiv, Ukraine

<https://orcid.org/0000-0001-7280-8453>

Lidiia Horoshkova

Doctor of Economic Sciences, Professor

National University of Kyiv-Mohyla Academy

04655, 2 Skovorody Str., Kyiv, Ukraine

<https://orcid.org/0000-0002-7142-4308>

Bohdan Kruhlov

Student

Institute of Geology Taras Shevchenko National University of Kyiv

03022, 90 Vasylykivska Str., Kyiv, Ukraine

<https://orcid.org/0000-0002-7899-2957>

Magnetic susceptibility of inclined soils and its relationship with some agronomic indicators

Abstract. The modern agricultural complex requires the use of new methods for determining soil characteristics for adequate information support of the latest technologies, which is often impossible to provide using conventional methods. The purpose of the study is to identify the informative value of magnetometric methods in determining slope processes that regulate the use of certain measures to increase soil fertility and protect soils from erosion. The study was conducted on inclined agricultural landscapes of the Kharkiv region. This study used a KLY-2 Kappabridge (Czech Republic) and an Ohaus

Suggested Citation:

Kruglov, O., Menshov, O., Horoshkova, L., & Kruhlov, B. (2023). Magnetic susceptibility of inclined soils and its relationship with some agronomic indicators. *Plant and Soil Science*, 14(1), 39-50. doi: 10.31548/plant1.2023.39.

*Corresponding author



Copyright © The Author(s). This is an open access article distributed under the terms of the Creative Commons Attribution License 4.0 (<https://creativecommons.org/licenses/by/4.0/>)

403 laboratory scale to determine magnetic susceptibility. The selected soil samples, in accordance with the accepted methods, were brought to an air-dry state under normal conditions. Soil sampling was conducted from a layer of 0-20 cm. Visualisation of the study results and determination of potential soil losses (USLE model) was performed in the QGIS programme. The correlation of magnetic susceptibility on simple and complex slopes was analysed. It was established that on simple slopes, the value of the magnetic susceptibility of the soil has a high value of this indicator with the content of physical clay and organic carbon. Therewith, there is a high degree of connection of this indicator with the results of mathematical modelling of erosion processes (USLE). For complex sections of slopes, the method is correct only for transeuvial landscapes, while for accumulative landscapes, the mentioned connection disappears. The correlation coefficient in the humus content – magnetic susceptibility pair also decreases. This is due to the alternation of washout–accumulation zones and exits of soil-forming rocks in runoff basins, the existence of which is not provided for by the procedure for applying the USLE model of potential soil losses. The use of soil MS data has a high potential for the localisation of soil inhomogeneities associated with the differentiation of humus content and granulometric composition

Keywords: soil; magnetic properties; chernozems; organic carbon; slope

INTRODUCTION

Global climate changes and unbalanced economic use lead to the spread of a number of negative phenomena in the soil cover, one of the manifestations of which is an increase in the degree of spatial differentiation of soil values, and, consequently, the heterogeneity of agronomic properties of the soil.

Modern agricultural technologies are now increasingly striving to apply the concept of precision farming, which is an adequate response to the soil and climatic conditions of each of the individual parts of agricultural allotments. The methodological basis of this approach is the localisation of soil cover heterogeneities, which require expanding the differentiation of agrotechnological measures for a more complete implementation of potential fertility. This is especially important on sloping lands, where the additional permanent impact is caused by water erosion.

Under these conditions, there are new increased requirements for the density of the soil testing network and their frequency, which can

not always be ensured by using conventional agrochemical methods for determining soil characteristics. One consequence of this is that the list of such studies is constantly expanding, mainly due to non-contact non-destructive methods, which are characterised by high detection rates and low cost (Byndych, 2017). Among such methods, the use of applied magnetometry, in particular, the determination of soil magnetic susceptibility (MS), occupies a prominent place (Jordanova, 2016). However, the use of the method has certain geographical and technological limitations and reservations that reduce its effectiveness, first of all, this is about the origin of iron minerals in soils, differences in agrotechnical and agrochemical nature.

At the initial stage of the study on the magnetic properties of soils, work, that mainly concerned the difference in the values of the volume magnetic susceptibility of different genetic horizons of the soil profile was conducted to identify them, and pioneering work concerned

the differences between horizons A and C of the soil profile (Borgne, 1955, 1960). The informative value of pedomagnetic data turned out to be suitable for predicting the natural conditions of soil formation and the course of pedogenesis in general. The presence of highly crystallised forms of iron is accepted as an indicator (Jones and Beaver, 1964). In the future, areas related to the research on natural magnetic characteristics, mainly various types of residual magnetisation and mass-specific MS, began to develop. This is due to the high degree of association between them and soil factors used in erosion models, such as factor K in the RUSLE model (Gurka-Kostrubiec *et al.*, 2015). More diverse tasks, including determining soil contamination, were implemented using multi-frequency devices (Dearing, 1999).

The value of MS in soils depends on the content and shape of iron minerals in them, which, in turn, depend on the geography and ecology of their formation, and even on the implementation of tillage activities (Maher, 1986). The physical basis for using these methods is the state of the most magnetic compounds of the soil, these include hydroxides (lepidocrocite, ferrihydrite) and oxides (hematite, magnetite, maghemite). The share in the values of magnetic characteristics in grey forest soils and chernozems provided by the magnetite-maghemite pair is about 90%. Bulgarian researchers demonstrated that the contribution of iron carbonates (siderite) to the overall magnetism of soils is insubstantial (Jordanova, 2016). There is a constant transformation of iron minerals in the soil depending on redox conditions, and the value of magnetic characteristics changes accordingly (Menshov *et al.*, 2012). A group of Japanese researchers concluded that, thus, the current state of iron compounds corresponds to the current ecological state of the soil (Moritsuka *et al.*, 2021). It is believed that the methodological

basis for the use of MS in studies of inclined soils is its relationship with the stability of soil aggregates (Alekseeva *et al.*, 2009), the content of the clay fraction (Peluco *et al.*, 2011), and organic matter content (Wang *et al.*, 2008). Such patterns in the future will allow predicting (interpolate or extrapolate data) the numerical values of soil factors of commonly used mathematical models of erosion. For several decades, information about the magnetic properties of the soil cover has been used to solve such problems. Pedomagnetic studies provide a number of economic and technical advantages over conventional methods: increasing the productivity of measuring equipment, reducing the cost of measurements (due to automation and the use of new methods and techniques), and introducing new methods of interpolation of these reference definitions.

The purpose of the study is to identify the informative value of magnetometric methods in determining slope processes that regulate the use of certain measures to increase soil fertility and protect soils from erosion.

MATERIALS AND METHODS

Various types of magnetic susceptibility were used: volume, determined in natural occurrence, in situ (instruments: KT-5, PIMV-M, KM-7) and mass-specific, determined in laboratory conditions (instruments: KLY-2, MS2B, KLY-3) (Dearing *et al.*, 1996).

The process of determining MS through modern measuring equipment is characterised by high efficiency (the determination time for the volume MS does not exceed several seconds) and accuracy (for the mass-specific MS, the measurement error does not exceed 0.5%) of definitions, which is the main factor in its spread. The most commonly used method for determining soil MS in recent years is according to Evans & Heller (2003).

The KLY-2 Kappabridge (Czech Republic) and the Ohaus 403 laboratory scale were used to perform this study. The analysed samples, according to the mentioned Deering method, were brought to an air-dry state under normal conditions. Soil sampling was conducted from a layer of 0-20 cm. Determination of organic carbon content (followed by conversion to humus) was conducted according to DSTU ISO 14235:2005 (2007). Visualisation of the study results was performed in the QGIS programme. The Universal Soil Loss Equation (USLE) was used to determine potential soil losses.

The experimental data described in the paper were obtained on the territory of experimental sites of the Educational and Scientific Centre "Institute of Soil Science and Agrochemistry Research named after O.N. Sokolovsky", located in the northern, western, and southern parts of the Kharkiv district of the Kharkiv region. Typical medium-humus chernozems and podzolic chernozems of varying degrees of washout represent the soil cover. The plots are located on slopes of 1-5° and are used as arable land, the slope length is up to 700 m.

RESULTS AND DISCUSSION

Agronomic unevenness of the soil cover is formed due to a number of factors, including the difference in environmental conditions of soil formation (insolation isomerism, slope mode of precipitation assimilation) and the redistribution of soil substance due to the development of slope processes, primarily water erosion. That is why the objects of this study were inclined land plots. However, the existence of such irregularities is explained not only by force processes but also the action of other factors of pedogenesis. The informative value of pedomagnetic data in predicting such conditions is reported on the example of many soils in the world (Jordanova, 2016). A study by

researchers from the UK showed differences in the magnetic properties of soils in different natural and climatic zones. According to the authors, the features of the formation of pedogenic oxides are described by the ratio of pedogenic iron minerals hematite/goethite (Long *et al.*, 2011). The existence of a relationship between mass-specific MS and annual precipitation ($R = 0.81$) and average annual temperature ($R = 0.58$) was shown on the example of Serbian soils (Radaković *et al.*, 2019).

Similar results were obtained by Iranian researchers on the example of soils in the northern part of the country: the correlation coefficient between soil MS and precipitation reaches $R = 0.80$ (Pourmasoumi *et al.*, 2019). A higher bond value was obtained by Chinese researchers on feralite soils of Hainan Island – $R = 0.90$ (Long *et al.*, 2011). Moreover, there is a connection not only with the precipitation regime but also with the drainage regime (Gholamzadeh *et al.*, 2019). The relationship between soil MS and moisture was noted on the example of slope areas of the central part of the Kharkiv region (Menshov *et al.*, 2021). Complexing of magnetic indicators was used to identify megacatena soils in France (the Mediterranean coast is the foot of the Alps), complicated by the influence of low anthropogenic factors: pollution, agriculture. The advantage of using a complex of magnetic methods over the use of conventional agrochemical methods is shown (Lecoanet *et al.*, 2003).

More informative at the local level of management is the possibility of indicating the manifestation of erosion processes, when the main factor of variability in the values of agronomic characteristics of the soil are inclined processes of substance movement (Peluco *et al.*, 2013). Thus, anomalies of humus content, granulometric composition, and soil density are formed (de Jong *et al.*, 1998). These soil characteristics have been successfully examined using

magnetometry on the example of the soils in Brazil (de Souza Bahia *et al.*, 2017) and the Czech Republic (Jakšík *et al.*, 2016). The concentration of strong magnetic iron minerals in the clay fraction of the soil (CF) also determines the relationship between the content of physical clay and MS. Thus, Brazilian researchers identified a high degree of association between MS and FG content in the slope soils of southern Brazil (Barbosa *et al.*, 2019). On the territory of Ukraine, the value of this indicator was established at

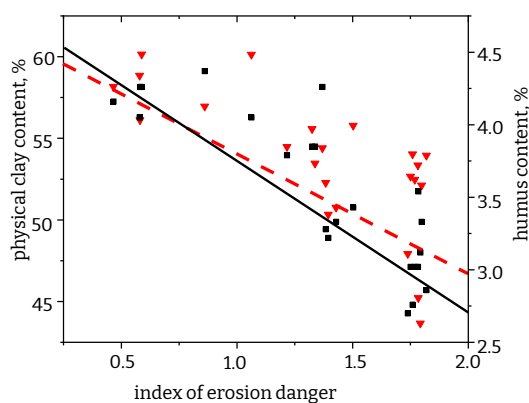


Figure 1. Graph of the dependence of the values of the erosion hazard index and the content of humus and physical clay on the example of a slope section of podzolic chernozem (Kharkiv region)

As shown in Figure 1, the calculated erosion hazard index is informative about the properties of the soil cover on slopes: there is a high degree of correlation of indicators (humus content and physical clay) and the requirements for homoscedasticity of the sample are met. A similar trend is also typical for the use of magnetometric methods instead of erosion modeling.

These results were obtained on a gentle slope, without complications. As the degree of terrain differentiation increases, dependencies arise that are not explained in simple models. Such results include detailed statistical studies

$R^2 = 0.83$ for podzolic chernozems in the north of the Kharkiv region (Menshov *et al.*, 2018).

Modern models of erosion are one of the means of parameterisation of slope processes, they give a fairly clear idea of the redistribution of soil matter, including its organic part. Such studies on the example of a site of podzolic chernozem showed a high degree of association – coefficients of correlation with MS are more than 0.9 (Menshov *et al.*, 2018). An example of such a connection is shown in the graphs of Fig. 1 and 2.

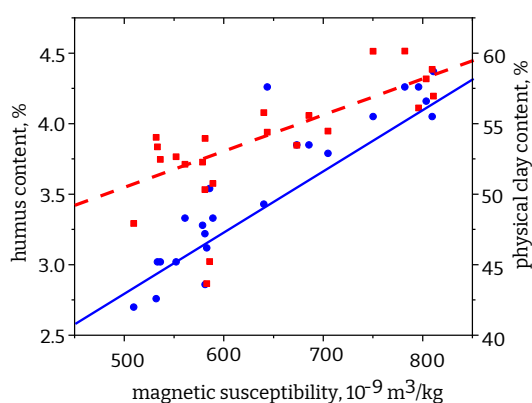


Figure 2. Graph of the dependence of the values of the mass-specific magnetic susceptibility of soil and the content of humus and physical clay on the example of a slope section of podzolic chernozem (Kharkiv region)

that showed a low level of reliability of the results and correlations obtained (Kruglov *et al.*, 2018). A similar trend was observed by Chinese researchers (Liu *et al.*, 2015). Therefore, the logical step is to expand research using a differential approach.

It is shown that in different sections of the complicated slope, the degree of relation between the values of MS, potential flushing, and humus content decreases. Thus, the almost complete absence of such a connection in the eluvial parts of the agricultural landscape is proved, while in the transeluvial areas, it is reliable. In the

range of values of the topographic coefficient LS of the USLE model 0...0.30, the correlation coefficient p between the humus content and soil MS

is 0.25, in the range 0.26...0.99, respectively, 0.82, and close to 0 in accumulative elements (Fig. 3). The total for the sample is $p = 0.49$.

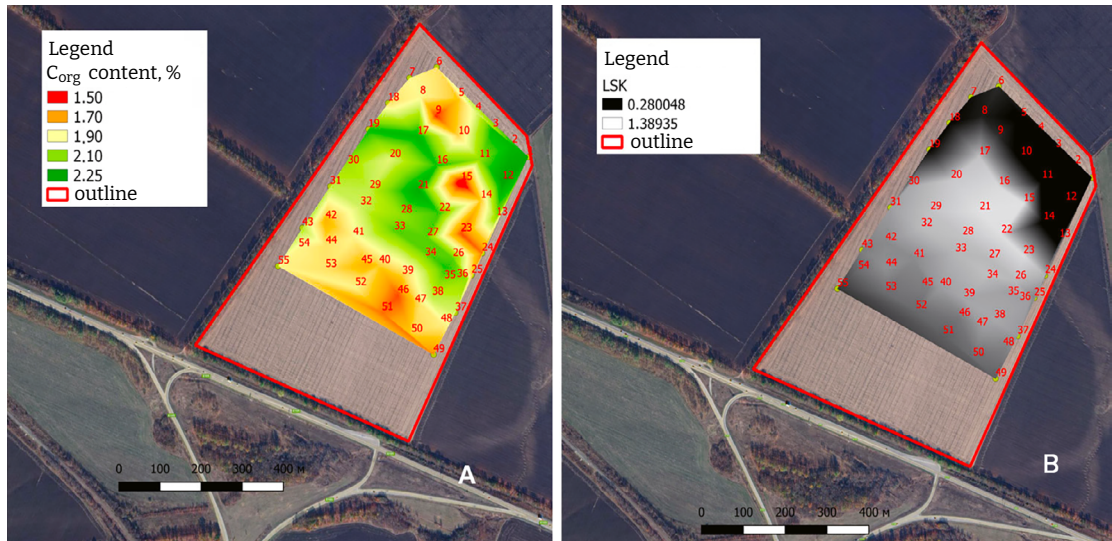


Figure 3. Features of the spatial distribution of Corg content (A) and values of the topographic factor LSK of the USLE model (B)

Figure 3 shows the case when the humus content in the soil in general increases with increasing values of potential erosion, but there are substantial deviations in the central and north-eastern parts of the site, which explains the relatively low value of the correlation coefficient between them. MS of the soil here has a high degree of association with the humus content ($p = 0.63$). Figure 4 clearly shows a decrease in MS in the northern part of the field – this corresponds to the territory of the basin with washed-out soils, and, accordingly, with low values of humus content (Fig. 3 A). The maximum MS values are located in the centre of the field and correspond to one of the humus content maxima.

The low level of correlation between topographic indicators and humus content is associated with the existence of numerous washout-accumulation zones, the existence of which is

not provided for by the procedure for applying the USLE model of potential soil losses. Additional complications, such as a developed network of runoff basins or a large proportion of non-eroded land, reduce the level of this connection, which partially echoes the results of Brazilian researchers (Barbosa *et al.*, 2019).

High values of the MS correlation coefficient and humus content were also shown on the example of slope areas of chernozem soils in the southern part of the Kharkiv region. In this study, Spearman's p between the humus – MS content is in the range of 0.75-0.81 and depends on the frequency of MS determination (Kruglov *et al.*, 2021). This is also confirmed by the results of an international team of specialists who showed the patterns of transformation of pedogenic magnetite under the influence of the main factors of the current stage of pedogenesis

(Lyons *et al.*, 2010; Maxbauer *et al.*, 2017; Ramos *et al.* 2017). The magnetic parameters of the soil have even been proposed to be used as one of the criteria for its conservation (Quijano *et al.*, 2014) and determination of the degree of its degradation (Sadiki *et al.*, 2009).

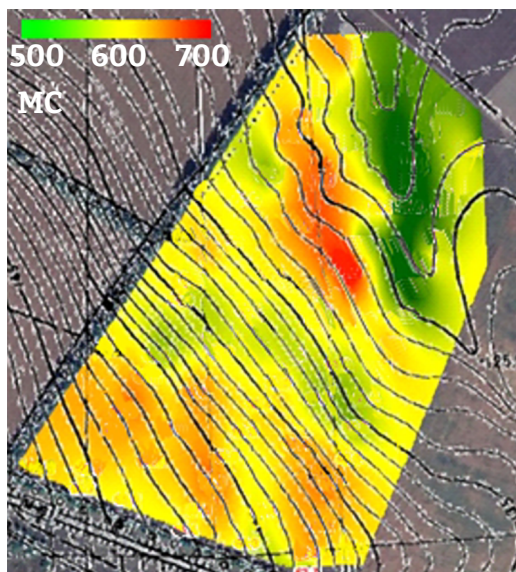


Figure 4. Cartogram of the mass-specific magnetic susceptibility of the soil of the experimental site

Thus, a high level of the information content of pedomagnetic data for transeleuvial areas of the agricultural landscape, i.e. inclined areas can be stated. The obtained correlation coefficients between the MS of inclined soils and the values of mathematical modelling of erosion are close to the values obtained on the example of USLE and WEPP. This allows stating the prospects of research considering options for replacing the most resource-intensive methods of agrophysics and agrochemistry with magnetic exploration methods, in particular, the determination of MS (Jimenez *et al.*, 2017)

The use of the method in accumulative areas is difficult, this is not provided for in the most

common versions of the USLE. (Santos, 2013). The correlation coefficient between the examined indicators is low here (0.1..0.3), which was also noted on the example of various landscapes in Brazil.

CONCLUSIONS

The application of data on the magnetic susceptibility of soils has a high potential for localisation of inhomogeneities of the values of agronomic indicators associated with the differentiation of the humus content of granulometric composition, and, accordingly, some other related fertility indicators, which is especially important in the implementation of precision farming technologies. This method of assessing the agricultural landscape has an order of substantially lower cost and labour intensity indicators compared to using any agrophysical or agrochemical method with a similar configuration of the soil characteristics testing network.

This application is based on a high degree of correlation between the values of the mass-specific magnetic susceptibility of the soil and the content of organic matter (humus), physical clay (0.01 mm particles) and the results of mathematical modelling of erosion processes. On the example of chernozem soils of the Kharkiv region, high correlation values are shown, both between the mass-specific magnetic susceptibility and organic carbon content, and the values of the topographic factor (LS) of the USLE.

However, the use of magnetometry methods for the needs of agronomic soil science and in agronomic practice faces a number of methodological problems, including methods and methods of conducting field measurements, and the reliability of the results obtained. In particular, the method shows unsatisfactory results in areas with complicated terrain with alternating washout-accumulation zones and existing active foci of linear erosion. There is also a low level of correlation between the values of magnetic

susceptibility and humus content in eluvial landscapes with low values of the topographic factor of the USLE model, and non-eroded soils are developed in such landscapes. The method demonstrates the highest efficiency in uncomplicated agricultural landscapes (with a flat slope without runoff basins) and in transeluvial (slope) areas with a pronounced effect of erosion processes. More promising is the integration of pedomagnetic methods with the

results of applying more modern mathematical models of erosion, considering the existence of washout-alluvial zones and foci of accelerated water erosion.

None.

None.

ACKNOWLEDGEMENTS

CONFLICT OF INTERESTS

REFERENCES

- [1] Alekseeva, T., Sokolowska, Z., Hajnos, M., Alekseev, A., & Kalinin, P. (2009). Water stability of aggregates in subtropical and tropical soils (Georgia and China) and its relationships with the mineralogy and chemical properties. *Eurasian Soil Science*, 42, 415-425. doi: [10.1134/S1064229309040085](https://doi.org/10.1134/S1064229309040085).
- [2] Barbosa, R.S., Marques Júnior, J., Barrón, V., Martins Filho, M.V., Siqueira, D.S., Peluco, R.G., Camargo, L.A., & 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. doi: [10.1007/s12665-018-8015-0](https://doi.org/10.1007/s12665-018-8015-0).
- [3] Borgne, E (1955). Susceptibilite Magnetique anormal du sol susperficiel. *Annales de Geophysique*, 4, 399-419.
- [4] Borgne, E (1960). [Influence du feu sur les proprettes magnetiques du sol et sur celles du schiste et du granite](#). *Annales de Geophysique*, 16, 159-195.
- [5] Byndych, T. (2017). Using Multispectral Satellite Imagery for Parameterisation of Eroded Chernozem. *Soil Science Working for a Living*, 57-65. doi: [10.1007/978-3-319-45417-7_5](https://doi.org/10.1007/978-3-319-45417-7_5).
- [6] de Jong, E., Nestor, P.A., & Pennock, D.J. (1998). The use of magnetic susceptibility to measure long-term soil redistribution. *Catena*, 32(1), 23-35. doi: [10.1016/S0341-8162\(97\)00051-9](https://doi.org/10.1016/S0341-8162(97)00051-9).
- [7] de Souza Bahia, A.S.R., Marques, J., La Scala, N., Pellegrino Cerri, C.E., & Camargo, L.A. (2017). [Prediction and mapping of soil attributes using diffuse reflectance spectroscopy and magnetic susceptibility](#). *Soil Science Society of America Journal*, 81(6), 1450-1462.
- [8] Dearing, J.A. (1999). *Environmental Magnetic Susceptibility, Using the Bartington MS2 System*. Second edition. London: Chi Publishing.
- [9] Dearing, J.A., Dann, R.J.L., Hay, K., Lees, J.A., Loveland, P.J., Maher, B. A., & O'Grady, K. (1996). Frequency-dependent susceptibility measurements of environmental materials. *Geophysical Journal International*, 124, 228-240. doi: [10.1111/j.1365-246X.1996.tb06366.x](https://doi.org/10.1111/j.1365-246X.1996.tb06366.x).
- [10] DSTU ISO 14235:2005. (2007). Soil quality – Determination of organic carbon in soil by sulfochromic oxidation. Kyiv: Derzhspozhyvstandart.
- [11] Evans, M., & Heller, F. (2007). *Environmental magnetism: principles and applications of enviromagnetics*. London: Academic Press.
- [12] Garbacea, G.F., & Ioane, D. (2010). Geophysical mapping of soils. New data on Romanian soils based on magnetic susceptibility. *The Journal of Geophysics*, 54, 83-95.

- [13] Gholamzadeh, M., Ayoubi, S., & Shahrivar, F.S. (2019). Using magnetic susceptibility measurements to differentiate soil drainage classes in central Iran. *Studia Geophysica et Geodaetica*, 63(3), 465-484. doi: [10.1007/s11200-018-0679-0](https://doi.org/10.1007/s11200-018-0679-0).
- [14] Gyrka-Kostrubiec, B., Teisseyre-Jeleńska, M., & Dytłow, S.K. (2016). Magnetic properties as indicators of Chernozem soil development. *Catena*, 138, 91-102. doi: [10.1016/j.catena.2015.11.014](https://doi.org/10.1016/j.catena.2015.11.014).
- [15] Jakšík O., Kodešová R., Kapička A., Klement A., Fer M., & Nikodem A. (2016) Using magnetic susceptibility mapping for assessing soil degradation due to water erosion. *Soil and Water Research*, 11(2), 105-113. doi: [10.17221/233/2015-SWR](https://doi.org/10.17221/233/2015-SWR).
- [16] Jimenez, A., Cristian, et al. (2017). [Relationship between physical properties and the magnetic susceptibility in two soils of Valle del Cauca](#). *Revista de Ciências Agrárias*, 34(2), 33-45.
- [17] Jones, R., Beaver, A.H. (1964). A technique for magnetic susceptibility determination of soil material. *Soil Science Society of America*, 28, 47-49. doi: [10.2136/sssaj1964](https://doi.org/10.2136/sssaj1964).
- [18] Jordanova, N. (2016). *Soil magnetism*. Cambridge: Academic Press.
- [19] Kruglov, O., Menshov, O., Kolada, V., Achasova, A., & Andreeva, O. (2021). Integrating of geophysical and agrochemical methods for slope lands studying. *Visnyk of Taras Shevchenko National University of Kyiv. Geology*, 3(94), 53-58. doi: [10.17721/1728-2713.94.06](https://doi.org/10.17721/1728-2713.94.06).
- [20] Kruglov, O., Menshov, O., Ulko, E., Kucher, A., & Nazarok, P. (2018). Soil erosion indication by magnetic methods in Kharkiv region. *Visnyk of Taras Shevchenko National University of Kyiv. Geology*, 3(82), 36-44. doi: [10.17721/1728-2713.82.05](https://doi.org/10.17721/1728-2713.82.05).
- [21] Lecoanet, H., Léveque, F., & Ambrosi, J.P. (2003) Combination of magnetic parameters: An efficient way to discriminate soil contamination sources (south France). *Environmental Pollution*, 122(2), 229-234. doi: [10.1016/S0269-7491\(02\)00299-3](https://doi.org/10.1016/S0269-7491(02)00299-3).
- [22] Liu, L., Zhang, K., Zhang, Z., & Qiu Q. (2015). Identifying soil redistribution patterns by magnetic susceptibility on the black soil farmland in Northeast China. *Catena*, 129, 103-111. doi: [10.1016/j.catena.2015.03.003](https://doi.org/10.1016/j.catena.2015.03.003).
- [23] Long, X., Ji, J., & Balsam W. (2011). Rainfall dependent transformations of iron oxides in a tropical saptrolite transect of Hainan Island, South China: Spectral and magnetic measurements. *Journal of Geophysical Research*, 116, article number F03015. doi: [10.1029/2010JF001712](https://doi.org/10.1029/2010JF001712). 2011.
- [24] Lyons, R., Oldfield, F., & Williams, E. (2010). Mineral magnetic properties of surface soils and sands across four North African transects and links to climatic gradients. *Geochemistry, Geophysics, Geosystems*, 11, article number Q08023. doi: [10.1029/2010GC003183](https://doi.org/10.1029/2010GC003183).
- [25] Maher, B.A. (1986). Characterisation of soils by mineral magnetic measurements. *Physics of the Earth and Planetary Interiors*, 42 (1-2), 76-92. doi: [10.1016/S0031-9201\(86\)80010-3](https://doi.org/10.1016/S0031-9201(86)80010-3).
- [26] 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. doi: [10.1038/s41598-017-17722-2](https://doi.org/10.1038/s41598-017-17722-2).
- [27] Menshov, O., Kruglov, O. & Sukhorada, A. (2012). Informational content of the soil magnetism indicators for solving agrogeophysical and soil science tasks. *Scientific Bulletin of National Mining University*, 3, 7-12.
- [28] Menshov, O., Kruglov, O., Vyzhva, S., Horoshkova, L., Pereira, P., Pastushenko, T., & Dindaroglu, T. (2021). Landscape Position Effects on Magnetic Properties of Soils in the Agricultural Land Pechenyg, Ukraine. *Earth Systems and Environment*, 5(3), 739-750. doi: [10.1007/s41748-021-00240-7](https://doi.org/10.1007/s41748-021-00240-7).

- [29] Menshov, O., Kruglov, O., Vyzhva, S., Nazarok, P., Pereira, P., & Pastushenko, T. (2018) Magnetic methods in tracing soil erosion, Kharkov Region, Ukraine. *Studia Geophysica et Geodaetica*, 62(4), 681-696. doi: [10.1007/s11200-018-0803-1](https://doi.org/10.1007/s11200-018-0803-1).
- [30] 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, article number 115013. doi: [10.1016/j.geoderma.2021.115013](https://doi.org/10.1016/j.geoderma.2021.115013).
- [31] Peluco, R.G., Marques Junior, J., Siqueira, D.S., Pereira, G.T., Barbosa, R.S., Teixeira, D.B., Adame, C.R., & Cortez, L.A. (2013). Soil magnetic susceptibility and estimation of support capacity for vine application. *Pesquisa Agropecuária Brasileira*, 48, 661-672. doi: [1590/S0100-204X2013000600012](https://doi.org/1590/S0100-204X2013000600012).
- [32] Pourmasoumi, M., Khormali, F., Ayoubi, S., Kehl, M., & Kiani, F. (2019). Development and magnetic properties of loess-derived forest soils along a precipitation gradient in northern Iran. *Journal of Mountain Science*, 16, 1848-1868. doi: [10.1007/s11629-018-5288-4](https://doi.org/10.1007/s11629-018-5288-4).
- [33] Quijano, L., Chaparro, M. A. E., Marié, D. C., Gaspar, L., & Navas, A. (2014). Relevant magnetic and soil parameters as potential indicators of soil conservation status of Mediterranean agroecosystems. *Geophysical Journal International*, 198, 1805-1817. doi: [10.1093/gji/ggu239](https://doi.org/10.1093/gji/ggu239).
- [34] Radaković, M.G., Gavrilov, M.B., Hambach, U., Schaetzl, R.J., Tošić, I., Ninkov, J., & Marković, S.B. (2019). Quantitative relationships between climate and magnetic susceptibility of soils on the Bačka Loess Plateau (Vojvodina, Serbia). *Quaternary International*, 502, 85-94. doi: [org/10.1016/j.quaint.2018.04.040](https://doi.org/10.1016/j.quaint.2018.04.040).
- [35] Ramos, P.V., Siqueira, D.S., Dalmolin, R.S.D., Almeida, J.Ad, Júnior, J.M., & Moura Bueno, J.M. (2017). Magnetic susceptibility of soil to differentiate soil environments in southern Brazil. *Revista Brasileira de Ciência do Solo*, 41, article number e0160189. doi: [10.1590/18069657rbcs20160189](https://doi.org/10.1590/18069657rbcs20160189).
- [36] Sadiki, A., Faleh, A., Navas, & Bouhlassa, S. (2009). Using magnetic susceptibility to assess soil degradation in the Eastern Rif, Morocco. *Earth Surface Processes and Landforms*, 34, 2057-2069. doi: [10.1002/esp.1891](https://doi.org/10.1002/esp.1891).
- [37] Santos, H.L., Marques Júnior, J., Matias, S.S.R., Siqueira, D.S., & Martins Filho, M.V. (2013). Erosion factors and magnetic susceptibility in different compartments of a slope in Gilbués-PI, Brazil. *Engenharia, Agrícola*, 33(1), 64-74. doi: [10.1590/S0100-69162013000100008](https://doi.org/10.1590/S0100-69162013000100008).
- [38] 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. *Journal of Paleolimnology*, 40, 897-921. doi: [10.1007/s10933-008-9206-6](https://doi.org/10.1007/s10933-008-9206-6).
-

Олександр Вікторович Круглов

Кандидат геологічних наук

ННЦ «Інститут ґрунтознавства та агрохімії імені О.Н. Соколовського»

61024, вул. Чайковська, 4, м. Харків, Україна

<https://orcid.org/0000-0003-2663-0935>

Олександр Ігоревич Меньшов

Доктор геологічних наук, старший дослідник

ННІ «Інститут геології» КНУ імені Тараса Шевченка

03022, вул. Васильківська, 90, м. Київ, Україна

<https://orcid.org/0000-0001-7280-8453>

Лідія Анатоліївна Горошкова

Доктор економічних наук, професор

Національний університет «Кієво-Могилянська академія»

04655, вул. Григорія Сковороди, 2, м. Київ, Україна

<https://orcid.org/0000-0002-7142-4308>

Богдан Олександрович Круглов

Студент

ННІ «Інститут геології» КНУ імені Тараса Шевченка

03022, вул. Васильківська, 90, м. Київ, Україна

<https://orcid.org/0000-0002-7899-2957>

Магнітна сприйнятливість схилових ґрунтів та її зв'язок з деякими агрономічними показниками

Анотація. Сучасний аграрний комплекс вимагає застосування нових методів визначення характеристик ґрунтів для адекватного інформаційного забезпечення новітніх технологій, що часто неможливо забезпечити за допомогою традиційних методів. Мета роботи – розкрити інформативність магнітометричних методів при визначенні схилових процесів, що регламентують застосування тих чи інших заходів з підвищення родючості ґрунтового покриву та охорони ґрунтів від ерозії. Дослідження проведено на схилових агроландшафтах Харківської області. При виконанні даного дослідження для визначення магнітної сприйнятливості використовувався каппамісток KLY-2 (Чехія) та лабораторні ваги Ohaus 403. Відібрані проби ґрунту, відповідно до прийнятих методик, було доведено за нормальних умов до повітряно-сухого стану. Відбір проб ґрунту проводився з шару 0-20 см. Візуалізація результатів дослідження та визначення потенційних втрат ґрунту (модель USLE) проводилась у програмі QGIS. Було проаналізовано кореляційний зв'язок магнітної сприйнятливості на простих та ускладнених схилах. Встановлено, що на простих схилах значення магнітної сприйнятливості ґрунту має високе значення цього показника з вмістом фізичної глини та органічного вуглецю. Водночас відзначається високий ступінь зв'язку цього показника з результатами математичного моделювання ерозійних процесів (USLE). На ускладнених ділянках схилів метод коректний лише на транселювіальних ландшафтах, тоді як для акумулятивних ландшафтах згаданий зв'язок зникає. Знижується і коефіцієнт

кореляції у парі уміст гумусу – магнітна сприйнятливість. Це пов'язане з чергуванням зон змиву-намиву та виходами ґрунотворчих порід в улоговинах стоку, існування яких не передбачено процедурою застосування моделі потенційних втрат ґрунту USLE. Застосування даних про МС ґрунтів має високий потенціал при локалізації ґрунтових неоднорідностей, пов'язаних з диференціацією вмісту гумусу та гранулометричного складу

Ключові слова: ґрунтовий покрив; магнітні властивості; чорноземи; органічний вуглець; схили