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# Integration of geophysical, soil science and geospatial methods in the study of eroded soil

**O. Kruglov** *(Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky)*, ***O. Menshov** *(Taras Shevchenko National University of Kyiv)*, **M. Miroshnychenko**, **M. Shevchenko** *(Institute for Soil Science and Agrochemistry Research named after O. N. Sokolovsky)*

## SUMMARY

Eroded soils require studies of their present condition, monitoring, and the development of the recommendations of their use. The aim of the present study is to show the prospects of applying of the combination of geophysical, geospatial, and soil science methods to assess eroded and erosion-hazardous lands. The result is expected to be the increase in the efficiency of their protection measures and land use management. At the presented results, there is a high correlation coefficient R2=0.87 between magnetic susceptibility (MS) and humus content. This makes it possible to bring the sampling density up to 2 pcs/ha, and obtain more detailed map of the soil erosion. The data on the spatial distribution of MS is the basis for the interpolation of values of humus content. The distribution of MS corresponds to the location of the main elements of the relief, the minimum values correspond to the beam mesh, the maximum to the undisturbed or redeposited soil. The integrating of the geophysical, optical, magnetic, electric, geospatial, and agrophysical methods to the algorithm of the eroded soil studies greatly extends the range of application fields. The obtained results are characterized by higher reliability, more accurate informative, and lower cost.

## Introduction

The main reason of soil degradation in Ukraine is accelerated water erosion. Estimated that up to 13 million hectares of the protection actions against the water flows is needed (Kutsenko, 2016). Eroded soils require studies of their present condition, monitoring, and recommendations for their use.

Soil erosion is a complex phenomenon. The nature lies in the geological, anthropogenic and soil planes. The geological filed is partly considered in (Mienasova et al., 2019; Ivanik et al., 2019). The effective tools for the study of erosion processes and for the development of measures to reduce their development must to attract all possible data (Tyapkin et al., 2014). The data requires to be statistically verified (Vyzhva et al., 2019; Vyzhva et al., 2018).

To develop the methodology of the erosion studies with geophysical, geospatial, and soil science methods, we can refer to the joint geophysical methods studies (Kruglov et al., 2018; Menshov et al., 2018). Reliable example is the joint study in geology, geophysics, electrical (Pigulevskiy et al., 2016) and chemistry methods (Alekseev et al., 2014). An exception is when one or more methods are applied with a probability of $p < 0.5$ (Ventzel and Ovcharov, 1988). Currently, reliability and integration are recognized as one of the key principles of ecological rating (Balyuk et al., 2008). However, the combination of methods results in increases of the cost of the study which requires justification of the theory.

The aim of the present study is to show the prospects of applying of the combination of geophysical, geospatial, and soil science methods to assess eroded and erosion-hazardous lands. The result is expected to be the increase in the efficiency of their protection measures and land use management.

## Method and Theory

In modern soil science, there are two main areas of studies: diagnosis of actual erodibility of soil and development of recommendations for increasing the stability of agro-landscapes to protect of the water flows. Soil science compares the humus profile of eroded soils with indelible counterparts (Tonkha et al., 2018).

Sustainable agricultural landscapes or separate anti-erosion measures are designed on the basis of the prediction of the development of erosion processes resulting from the use of mathematical models of erosion: USLE, RUSLE, WEPP (Wischmeier and Smith, 1978). In Ukraine, it is recommended to use the model of Mirzhulava (DSTU 7903). The alternative scenarios of agro-landscape reconstruction or the application of separate anti-erosion measures are proposed in (Kutsenko, 2016). The pollution level of the environment has to be considered under soil erosion studies (Melnyk and Kravchenko, 2019).

Magnetic methods were applied according to the technology described in (Evans and Heller, 2003). The main parameter to access soil erosion was magnetic susceptibility $\chi$ (MS).

## Results

Soil and organic carbon losses can be related to conventional agricultural practices that result in erosion values between 0.2 and 1.67 mm per yr. This is far in excess of the rate of soil formation which is estimated between 0.06-0.8 mm per yr. (Montgomery, 2007). The increase of the organic matter concentrations in soils is recognized as the most effective way to restore soil health and stability (Doran, 2002; Lal et al., 2007). The determination of actual soil erosion is often based on studies of regular changes in the humus/organic (C) content in the topsoil, which is traditionally determined by the sulfochromic oxidation method. But such kind of the analysis is quite long and costly. Currently the express-methods of soil analysis are being developed. The reflectance spectroscopy and different optical techniques provide a possible alternative to conventional laboratory methods of soil analysis. Combining two or more methods is aimed at cheapening and improving the accuracy of the results through a denser network of samples. We consider joint application of the optical and magnetic methods. Optical methods, despite of their high cost, have a number of disadvantages that limit their use. First of all, the study area must be without vegetation and with homogeneous machining. Therefore, other methods are being developed, especially the measuring of different types of magnetic susceptibility. A close correlation between humus content and MS is recorded for all soil types, except only those that are developed directly on the weathering bark or are polluted with heavy metals. The correlation $R^2$=0.971 was obtained for Czech soils (Jakšík at al, 2016), and $R^2$=0.89 for Moravian-Silesian soils (Kapicka at al, 2013). Brazilian researchers found in the dry subtropics soils that there was a high degree of correlation between MS and physical clay content $R^2$=0.83, with total carbon $R^2$=0.85, and total nitrogen $R^2$=0.77 (de Souza Bahia, 2017). We obtained (see Fig. 1) the high degree of association of MS with humus content and erosion modeling results in Ukraine (Menshov et al., 2018).

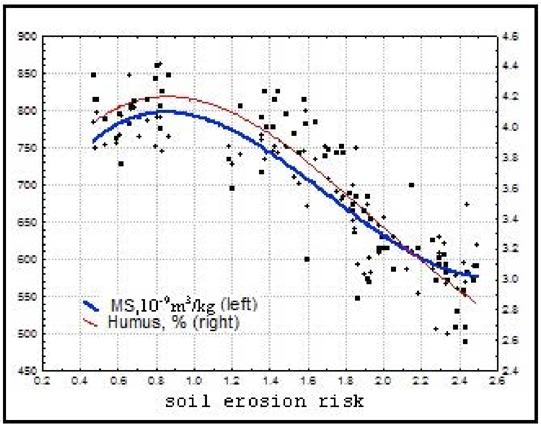


***Figure 1*** *Correlations between soil magnetic susceptibility and humus content (Menshov et al., 2018)*

At the presented results in Fig. 1, there is a high correlation coefficient $R^2$=0.87 between MS and humus content. This makes it possible (by an order of magnitude lower inspection costs) to bring the sampling density up to 2 pcs/ha, and obtain more detailed map of the soil erosion. The data on the spatial distribution of MS is the basis for the interpolation of values of humus content. Comparing the map of the humus content (actual erosion) and potential soil loss, we are able to identify anomalous areas caused by insufficient functionality of the shelter infrastructure (Fig. 2), and finally to make the correction (Kruglov, 2020). Thus, the combination of agrochemical, geophysical methods and mathematical modeling make it possible to obtain more accurate results and extend their scope.

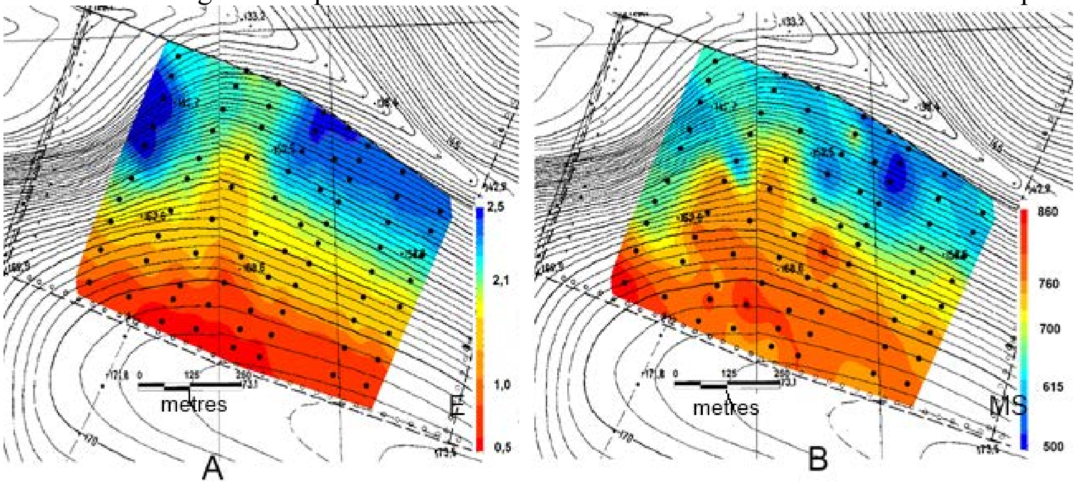


***Figure 2*** *Cartogram of spatial distribution: A – potential erosion, E; B – soil MS of the experimental area (Kruglov and Menshov, 2017)*

The combination of the magnetic measurements indicates the erosion structure of the land. The MS map of the soil and altitudes are presented in Fig. 3. The distribution of MS corresponds to the location of the main elements of the relief, the minimum values correspond to the element of the beam mesh, the maximum – to the elements with undisturbed or redeposited soils.

For the proper interpretation, we need the information about agriculture activities. Changes in soil properties caused by its cultivation are considered as one of the factors of accelerated erosion. In table 1, we illustrated the differentiation of some soil erosion properties depending on the main tillage methods.

The experience of the attracting of the electric methods for the study of eroded soils seems to be promising. In conditions of arid climate, moisture is the main limiting factor in such lands. Combining agrophysical methods with electrometric methods allow to get more accurate soil moisture maps without system errors inherent in the use of portable moisture meters.

Integrating of the mentioned methods to the development of long-term prediction and programs for sustainable agro-landscapes is very important now. At the same time, the great attention should be paid to all factors of erosion: neotectonic changes of relief, properties of soil-forming rocks, hydrological characteristics of the territory.

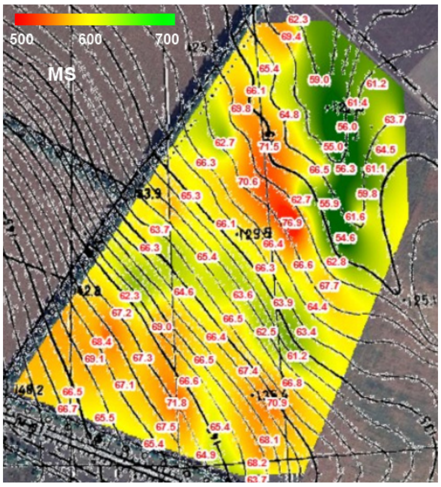


***Figure 3*** *Spatial distribution of MS values of the slope section soil*

***Table 1*** *Some parameters of physical properties of soil in sunflower crops, depending on the method of basic tillage (2017-2019) (Shevchenko, 2019)*

| Parameter | Horizon, см | Ploughing, 25-27 cm | Chiseling, 33-35 cm |
|---|---|---|---|
| **Density, g / cm³** | 0-10 | 1.05 | 1.11 |
| | 10-20 | 1.20 | 1.23 |
| | 20-30 | 1.23 | 1.27 |
| | 0-30 | 1.18 | 1.20 |
| **Hardness, kg /см²** | 0-10 | 7.7 | 9,5 |
| | 0-20 | 13.3 | 14.8 |
| | 0-30 | 19.2 | 20.6 |

To identify the heterogeneity of modern neotectonic movements, we use the method described in Philosophov, (1975). This method consists of the study of variations of equipotential basis or vertex surfaces of single-order elements of a hydrographic network. The significant deviations (from meters to the first tens of meters) indicate high vertical movements of individual parts of the territory (up to 1 cm per year), which is not use now at the current system of protection of lands from erosion. Such approach requires the adaptation of land management investigations (Khmelovskyi et al., 2019) and implementation of coordinated agroforestry activities.

The approximate composition of soil erosion can be obtained from data on beam density (Yermolaev, 2002) by the increase in the share of eroded soils. This parameter is obtained by analyzing STRM.

## Conclusions

The integrating of the geophysical, optical, magnetic, electric, geospatial, and agrophysical methods to the algorithm of the eroded soil studies greatly extends the range of application fields. The obtained results are characterized by higher reliability, more accurate informative, and lower cost.

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