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Soil magnetic properties of the landslide site in O.V Fomin Botanical Garden

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SUMMARY

To perform landslide susceptibility prediction, it is important to select appropriate mapping unit and landslide-related conditioning factors. Magnetic method is low cost and rapid instrument for the landslide and soil erosion identification. An example of the application of the magnetic methods for the local prediction of possible landslide activation was performed at the territory of the Alpine hill of O. V. Fomin Botanical Garden of Taras Shevchenko National university of Kyiv. The results of the soil magnetic studies demonstrated the redistribution of the soil genetic horizons. The confirmation is the visible difference from the normal natural conditions according to the magnetic susceptibility (MS, χ) values. The anthropogenic pollution was registered too. The values of MS are 1.5-2 times higher comparing with the natural chernozems of Kyiv region.

Introduction

Landslides are ubiquitous in sloping environments and can be driven by tectonic, climatic, or human activities. Landslide disasters arise when the hazardous movement of soil and rocks directly or indirectly impacts vulnerable human settlements and infrastructure, sometimes causing widespread damage (*Casagli et al., 2023*). Landslides forecasting is based on various approaches and methodology. Mathematical modelling is important (*Khlobystov et al., 2021; Vyzhva et al., 2013; Maslov et al., 2001*) as well as understanding of the geological nature with attracting of the geophysical methods (*Pigulevskiy et al., 2019; Pihulevskyi et al., 2019*). Forecasting at the regional scale can be both qualitative and quantitative and can be carried out using both stochastic and deterministic methods (*Ivanik and Lave, 2023; Ivanik et al., 2021*). Landslides are related to the accelerated linear erosion and hydromorphism of the soil. Water erosion is one of the major threats to soils in the European Union, with a negative impact on ecosystem services, crop production, drinking water and carbon stocks (*Panagos et al., 2015*). Slow-moving landslides and soil erosion depict the challenge that small process rates and changes in surface height can occur yet over a larger area and, respectively or on different parts of an affected area or mass. While changes in the order of only millimetres per observation period are common for soil erosion, changes in surface height in the order of a few centimetres per observation period or year are observable for complex, slow-moving landslides.

To perform landslide susceptibility prediction, it is important to select appropriate mapping unit and landslide-related conditioning factors. Magnetic method is low cost and rapid instrument for the soil erosion identification (*Wang et al. 2019*). *Ding et al. 2020* suggested magnetic susceptibility (MS, χ) to be applied to the study of soil erosion induced by both wind and water to provide a supplementary tool for the spatial analysis. *Yue et al. (2019)* assessed soil erosion and its distribution on cultivated slopes using magnetic susceptibility. Soil loss is a global environmental problem resulting from the erosion process caused by many factors, including land use and slope position. The results (*Bouhlassa and Bouhsane, 2023*) confirm that the χ enhancement of soils selected in calcareous parent material is related to the pedogenic processes with the formation of superparamagnetic particles distributed along the slope positions.

Hence, accurate cartography of the phenomenon, magnitude, and extent of erosion in the area needs a simple, rapid, and economical method such as magnetic susceptibility (*Ouallali et al., 2023; Menshov, 2018; Menshov et al., 2018*).

Methods

The experimental design of the soil magnetic properties studies includes both field and laboratory experiments. Vertical profiles are important to assume the redistribution of the soil horizons according to the soil movement within the slope as well as related to the local landslides.

In the field, the volume magnetic susceptibility (κ) of soils was measured with the PIMV-M portable MS meter. The field measurements were accompanying by soil sampling for further laboratory analyzes. Magnetic susceptibility was measured using a laboratory Kappabridge KLY (Agico, Chezh Republic). Mass-specific magnetic susceptibility (χ, MS) was calculated by normalizing the value to the mass of the sample. To measure and calculate the frequency dependence of MS (χfd) we used a dual frequency magnetometer MS2 (Bartington). For both KLY and MS2 measurements, the same material was used. Before measurements, the material was air-dried in natural conditions. Each measurement was repeated three times to increase the accuracy of the experiment. MS was measured at two frequencies (0.47 and 4.7 kHz). The values are expressed as low-frequency MS χlf and high-frequency MS χhf, respectively. The frequency-dependent magnetic susceptibility χfd was calculated as:

$$\chi fd\ (\%) = (\chi lf - \chi hf)/\chi lf \times 100$$

Magnetic mineralogical measurements were performed to study the thermomagnetic parameters, different types of the magnetization and magnetic susceptibility, and hysteresis loops with the Variable Field Translation Balance (VFTB) instrument. VFTB provide the possibility of the measurements of the magnetization and ma magnetic susceptibility, thermomagnetic curves at -180°C to 800°C (simultaneous measurement of magnetization and susceptibility), isothermal remanent magnetization IRM (full temperature range), backfield (full temperature range), hysteresis loops (full temperature range), and FORC diagrams. VFTB is a sensitive and versatile instrument for measurement of magnetic properties of

materials. Due to its high sensitivity, it is an ideal instrument for research in rock magnetism and environmental magnetism and can measure weakly magnetic materials, such as sandstone, limestone, soil etc. It can also be used for magnetic analysis in the field of material science e.g. analysis of synthetic materials, thermal behavior of permanent magnets etc. It is the only instrument on the market that can simultaneously measure the reversible and irreversible components of magnetization and their temperature dependence. This makes it an instrument that is particularly suited for discrimination of different magnetic phases in the sample. RockMag Analyzer software was used to interpret all this data.

Results

An example of the application of the magnetic methods for the local prediction of possible landslide activation was performed at the territory of the Alpine hill of O. V. Fomin Botanical Garden of Taras Shevchenko National university of Kyiv.

The technogenic constructions and buildings that located along T. Shevchenko Boulevard nearby had a negative effect on the hydraulic gradient and led to overwetting of the rocks of the Botanical Garden (*Kostyuchenko and Mokiyenko, 2015*). For these reasons, the northern slope of the hill is also prone to landslides, because low resistance is observed here, which indicates the overwetting of loess loams of the area. Waterlogging leads to changes in the loess structure, thus affecting mechanical properties and causing geohazards. However, at this stage, the presented interpretation is of a qualitative nature and characterizes the general patterns of the spread of landslide-hazardous processes in the geological environment.

Within the alpine hill in the Botanical Garden, two landslide-prone zones are distinguished, which cover the northern and southern slopes of the hill. In order to minimize the negative impact on the unique ecosystem of the Botanical Garden in the experimental area, immediate anti-slide measures are necessary.

Local landslides are related to changes of the structure of soil. First of all the erosion processes arises at the mentioned areas. Studies of the soil genetic horizons give the evidence of the redistribution of the soil matter. We used the magnetic susceptibility measurements to understand the landslide, anthropogenic, and man-made pollution at the Alpine hill. The lateral distribution of the magnetic susceptibility of top-soil is presented in figure 1. We performed a number of magnetic studies, but in fig. 1 we concentrated in volume (field) magnetic susceptibility measured in natural field conditions.

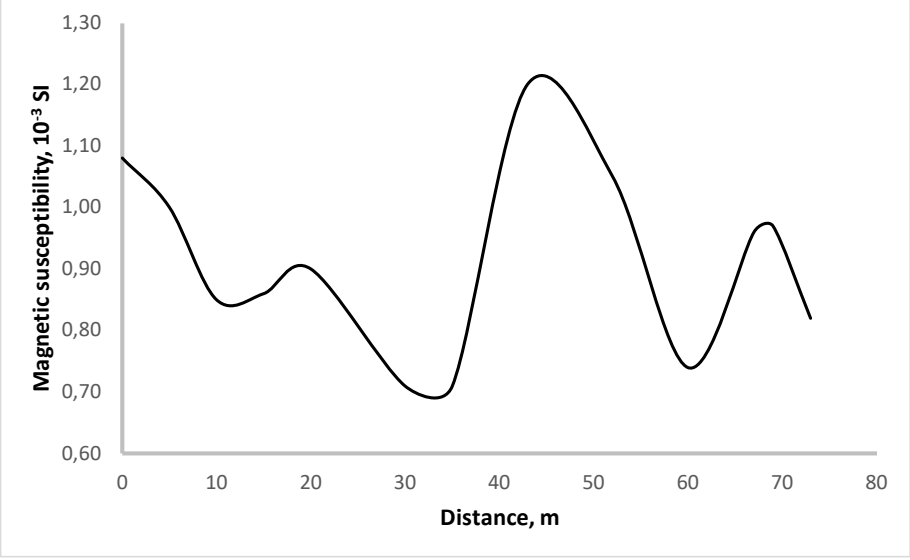

Figure 1 *Volume magnetic susceptibility of soil within transect crossing landslide activation zones at the territory of the Alpine hill of O. V. Fomin Botanical Garden*

The absolute maximum of MS was registered at the distance of 40-50 m at the end of watershed and at the slope. Soil is black, close to chernozem but with visible anthropogenic impact (even admixtures of the

anthropogenic particles). The slope processes related to the landslide and erosion processes play the predominant role. At the same time for natural soil – maximums of MS are common for watersheds. In our case the watershed at the distance of 30 m demonstrated the minimums of MS. The registered values confirmed the redistribution of the soil matter and mixtures of the soil genetic horizons.
To deeper understanding of the redistribution of the soil genetic horizons we organized three soil profiles. The first one is located at the landslide cliff. The vertical distribution of the MS is given in fig. 2. The maximums related to rich with organic matter horizon A. At the same time poor with humus underlaying horizon C demonstrated MS, which is slightly higher than in transition horizon B. Such situation is related to landslide redistribution as well as to the anthropogenic pollution. The soil contamination confirmed with absolute values of MS which are higher than for natural chernozem soil of Kyiv region.

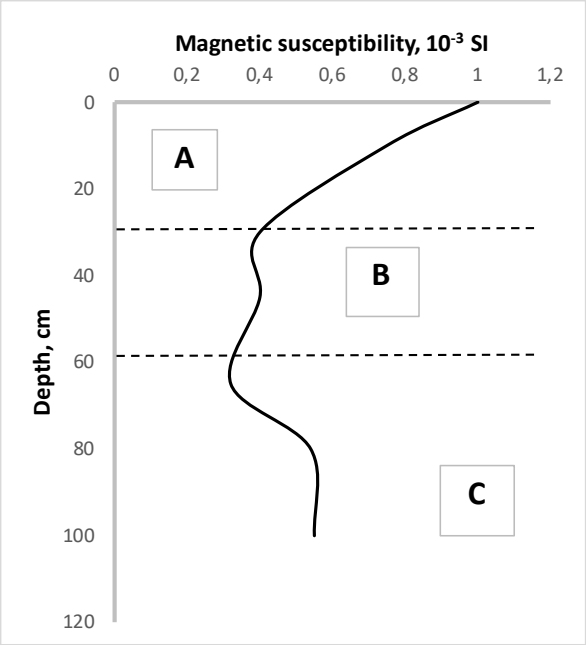

Figure 2 *Volume magnetic susceptibility of soil profile (genetic horizons) located at the landslide cliff at the territory of the Alpine hill of O. V. Fomin Botanical Garden*

More precision interpretation will be given during the presentation. The results of the laboratory magnetic studies of the thermomagnetic parameters, hysteresis and backfield curves expected to clarify the genesis of the magnetic signal of the soils collected at the study landslide and erosion area of O.V. Fomin Botanical Garden

Conclusions

The results of the soil magnetic studies at the territory of the Alpine hill of O. V. Fomin Botanical Garden of Taras Shevchenko National University of Kyiv demonstrated the redistribution of the soil genetic horizons. The confirmation is the visible difference from the normal natural conditions according to the magnetic susceptibility values. The anthropogenic pollution was registered too. The values of MS are 1.5-2 times higher comparing with the natural chernozems of Kyiv region.

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