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Integration of magnetic and hydrogeological studies for landslides and soil erosion assessment. Case study from area Lake Glinka (Kyiv, Ukraine)

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SUMMARY

The results of magnetic soil and underlying rocks studies at the area near Lake Glinka (Kyiv, Ukraine) are considered. This study was performed as a part of the landslide investigation of the urban environment of the agglomeration. The aim was to detect the natural and man-made processes affecting critical infrastructure. The soil of the study area is grey forest (Greyic Phaeozems Albic in WRB) with signs of urban soil. Magnetic studies were conducted at two points at the high landslide bank of the Lake Glinka, as well as at the opposite low bank. The classification of the polygons is made by the attracting the magnetic susceptibility and its frequency dependence. The magnetic properties of soils are important for the joint interpretation with electric tomography, GPR measurements, and GIS analysis of the national landslide database of Ukraine. The results are useful for the development of the algorithm for the environmental monitoring of the critical infrastructure at the urban area. The exogenous processes on the slopes various depending of the moisture and composition of the rocks. The gravity and hydrodynamic processes plays important role. The optimal algorithm of the application the hydrogeology studies to identify landslide processes is considered.

Introduction

Landslides and soil erosion are one of the most dangerous processes for the urbanized environment and farmlands of Ukraine (*Menshov et al., 2018*). At the present study, we consider the results of the application of the magnetic soil measurements and hydrogeological investigation for the assessment of the landslide and water erosion risk at the area of Lake Glinka in Kyiv urbanized environment. This study performed as a part of the landslide investigation of the urban environment of the agglomeration. The aim was to detect the natural and anthropogenic processes affecting critical infrastructure. The results of magnetic soil and underlying rocks studies at the area near Lake Glinka (Kyiv, Ukraine) demonstrated close correlation with erosion processes and heavy metal pollution of soil. The algorithm of the hydrogeological studies related to the landslide activities is considered.

State of the art

Magnetic method is low cost and rapid instrument for the soil erosion identification (*Kruglov and Menshov, 2017*). There are several cases of the application of the magnetic data for landslides assessment. Soil erosion is on deep genetic relation to landslides. Many areas are influenced by both wind erosion and water erosion, and the overlap of wind and water erosive forces results in serious land degradation (*Ding et al., 2020*). Magnetic susceptibility (MS) is an effective tool for quantifying soil redistribution. A new in situ technique, called the magnetic layer detection method, is introduced in (*Liu et al., 2019*). The study of (*Barbosa et al., 2019)* aims to assess the efficiency of magnetic susceptibility as a predictor of soil erodibility factors (K for USLE model; Ki and Kr for WEPP model) fora detailed mapping of oxisols with different iron contents in northeastern São Paulo State, Brazil. The erosion, redistribution of soil, deposition of sediment play important geomorphological and ecological roles. *Ravi et al. (2019)* tested the applicability of a novel metal tracer-based methodology, using spatial-temporal measurements of low-field magnetic susceptibility. *Eso et al.* (*2019*) studied the trends of variations of the magnetic properties and chemical elements on soil profile in landslide area. Knowledge of soil erosion during exceptional rainfalls is required to support mitigation measures for areas with intense climate change. The "Rzhyshchev" section and the "Grebeni" site were used as testing objects of the landslide critical infrastructure investigation (*Menshov, 2019*).

Methods and Theory

Under the field condition, we measured the volume magnetic susceptibility of soil κ (10^{-3} SI), and sampling was performed according to the methodology described in (*Menshov et al., 2014*). Under the laboratory conditions we measured and then calculated the mass-specific magnetic susceptibility χ (10^{-8} m^3/kg), and its frequency dependence χFD (%). The soil of the study area is grey forest (Greyic Phaeozems Albic in WRB) with signs of urban soil. Magnetic studies were conducted at two points at the high landslide bank of the Lake Glinka, as well as at the opposite low bank. At the low bank, we organized measurements and sampling along the micro-catena and at the vertical soil section to study the soil genetic horizons. Magnetic polygons were constructed based on cosmography downloaded by ArcGIS. The classification of the polygons is made by the attracting the magnetic susceptibility and its frequency dependence. The overview of the area with magnetic polygons is presented in Fig. 1.

Results of magnetic studies

We identified (see Fig. 1) the polygon with the highest values of magnetic susceptibility ($\chi=54\times10^{-8}$ m^3/kg, red color) and the lowest value of frequency dependence (χFD = 3.6%). This is the soil with man-made pollution. Two polygons with similar values of magnetic parameters were identified: χ=25-35$\times10^{-8}$ m^3/kg, χFD = 8-10%. Such values are related to the natural soils (green color). Three polygons (two at the low bank and one at the high landslide bank of Glinka) have the average in intensity values of magnetic parameters: χ=35-40$\times10^{-8}$ m^3/kg, χFD = 6-7% (yellow color).
The vertical distribution of soil magnetic parameters in genetic horizons was observed and the redistribution of magnetic material was detected. In Fig. 2, the vertical distribution of the magnetic

susceptibility is presented. The maximum values are related to the depth of 100 cm. The soil is mixed, so the classification of the genetic horizons was difficult.

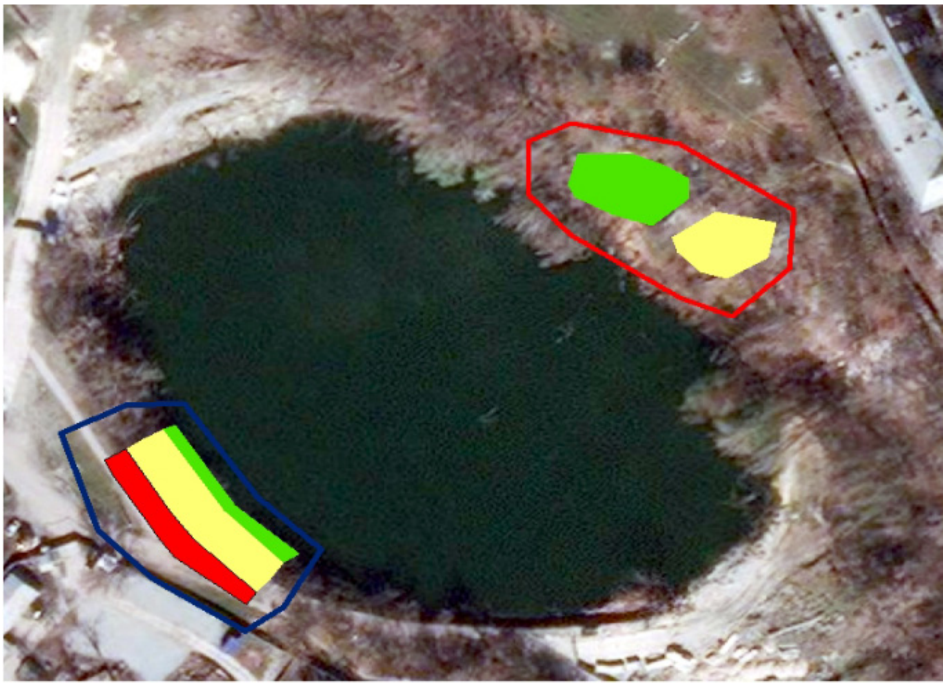

Figure 1 *Magnetic GIS model of the Glinka study area: blue outline - polygon 1, red outline - polygon 2*

The distribution with the depth of the frequency dependence of the magnetic susceptibility is presented in Fig. 3. The values from 0 to 4 % indicates the presence of the magnetic material of the man-made origin. Such values were detected at the depth of 50 and 150 cm. Other part of the samples indicated the values from 6 to 8 which are common for the pedogenic (natural) soil magnetics formation.
The magnetic properties of Ukraine soil considered in (*Menshov and Sukhorada, 2010*). The obtained results in the present abstract identified the redistribution of the soil and underlying rock material. This indicates the erosion processes as the initial process of the landslide activity. At the same time, of the great importance is attracting data about possible anthropogenic pollution of soil by heavy metals.

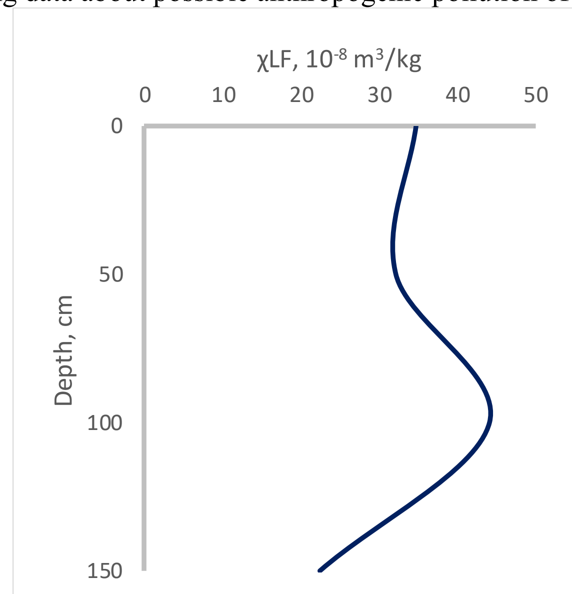

Figure 2 *Magnetic susceptibility distribution with depth*

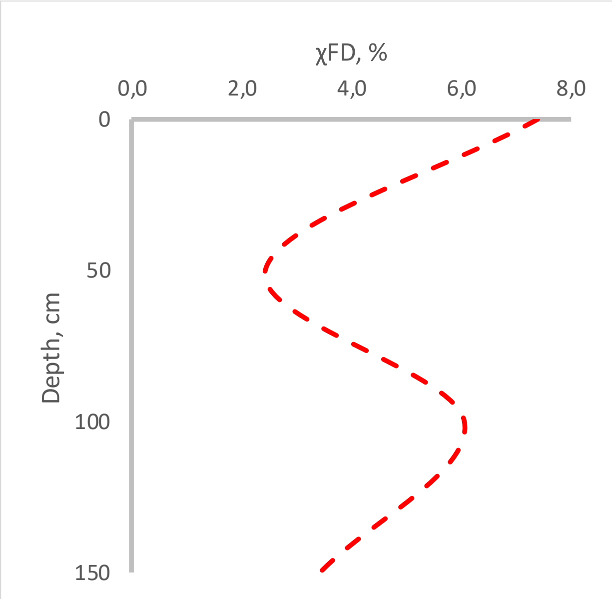

Figure 3 *Frequency dependence of the magnetic susceptibility distribution with depth*

Hydrogeology studies for landslides assessment

The combination of the magnetic and hydrogeological methods for the environmental studies in Ukraine are described in (*Shevchenko and Menshov, 2019; Menshov et al., 2019*).
The exogenous processes on the slopes various depending of the moisture and composition of the rocks. They are gravity and hydrodynamic processes. The processes of combined genesis are landslides. They are of the gravitational forces origin in the presence of a slip surface and a critically moistened amount of the rocks. The groundwater has the maximum impact on the stability of the slope in the case of the slope is composed by the low-permeable rocks. These rocks have high water-holding capacity and the low water output. As a result, the stability of the slopes is impaired according to the deterioration of the physical and mechanical properties of the sediments caused by the increase in filtration pressure and the tension after its moistening. The degree of humidity of the rocks of the aeration zone can be determined by the electric current with the non-polarized ceramic electrodes (located in the soil surface and at the depth). Between the change in the current and the humidity of the rocks, we registered the inverse relationship. When humidity is increasing, the currents decrease. The transfer of current with the vapor moisture can explain this. The filled capillaries with liquid moisture lead to the electric current significant reduce (*Shevchenko et al., 2016*). The prerequisites of the aeration zone create the negative electromagnetic fields, which generate a large number of negative ions in the atmosphere. The result of changes in temperature or cyclonic and anticyclonal fronts, we have quite significant oscillations of the ground water levels.
To determine the depth and condition of the sliding surface, we use manual drilling, which identify areas of wetting or seepage of pressure water from the clay sediments. To develop the optimal algorithm of the application the hydrogeology studies to identify landslide processes at the area of Lake Glinka, we attract the previous knowledge. In the study of landslides in the Carpathians, we found that the formation of the surface of sliding and the line of separation of the landslide is facilitated by the evacuation of groundwater at a depth (0.9-1.1 m). The clay deposits with small fragments of mudstones change the material that formed the shear body (*Kostyuchenko and Shevchenko, 2010*). The arrangement at these areas of the closed tubular drainage with inverted sand-gravel filter avoids the problems of wetting and sliding of the rock mass.

Conclusions

The magnetic properties of soils are important for the joint interpretation with electric tomography, GPR measurements, and GIS analysis of the national landslide database of Ukraine. For the improving of the interpretation, the hydrogeological data is required. The results are useful for the development of the algorithm for the environmental monitoring of the critical infrastructure at the urban area.

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