# GEOPHYSICAL MAPPING OF SOILS. NEW DATA ON ROMANIAN SOILS BASED ON MAGNETIC SUSCEPTIBILITY

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The geophysical investigation of soils is based on a number of physical parameters, the magnetic susceptibility being usually employed for studying past climate changes on loess and paleosols or topsoil pollution with heavy metals. The magnetic susceptibility of non-polluted soils is mostly influenced by the mineralogical composition of parental rocks and the pedogenetic processes. The recent advent of a new domain of Geophysics, Agricultural Geophysics, opened new ways of research and offered new scientific and professional objectives. Studies of *in situ* soil magnetic susceptibility, supported by the analysis of other magnetic and/or chemical properties, are used in the soil type determination and in-depth location of soil horizons. The study of soils situated in several regions located in the south-eastern part of Romania (Prahova county, Tulcea county, Danube river and Danube Delta) revealed good possibilities of this method to discriminate between soil types and precisely illustrate in-depth horizon boundaries.

*Key words*: geophysical mapping, soil types, magnetic susceptibility, horizon boundary, SE Romania.

## 1. INTRODUCTION

Magnetic properties in soils are usually a consequence of the presence of mineral compounds that include iron. Specific types of iron oxides, iron and titanium oxides and iron sulfides are the main causes of magnetic soil properties. The soil iron oxides are magnetic minerals, primary or secondary ones, inherited from the rocks or geological formations, formed during pedogenesis or from products of anthropogenic activities.

Soil magnetic properties are generally controlled by the presence of magnetite and maghemite. The occurrence of maghemite is due to the conversion of iron oxides from antiferromagnetic form like hematite ($\alpha$ $Fe_2O_3$) or goethite ($\alpha$ FeOOH ), into the ferromagnetic form, maghemite ($\gamma$ $Fe_2O_3$). The formation of maghemite in topsoils is attributed to the dehydration of goethite and lepidocrocite, in the presence of organic matter. Aeolian deposition of mineral grains may significantly enhance soil magnetic properties.

The concentration of iron oxides in soils is influenced by the parental material, biological activity, age of soil, pedogenetic processes, soil temperature, physico-chemical properties and anthropic activities. The magnetic susceptibility can vary on the soil profile due to a considerable number of factors, but the most important is the mineralogical composition. The magnetic susceptibility depends also on the direction and the form of magnetic particles spatially distributed in soil.

The magnetic susceptibility of soils is many times based on the mineralogical composition of parental rocks, but most of soil samples display higher magnetic properties than the geological background. Studies of *in situ* soil magnetic susceptibility, supported by the analysis of other magnetic and/or chemical properties, may be used in the soil diagnosis for determination of its genesis and identification of soil forming processes. Chemical and magnetic data on soils horizons are closely studied in order to better understand the relationships between soil chemistry and magnetic properties during pedogenetic processes (Spassov *et al.*, 2004).

Magnetic susceptibility mapping of soils represents nowadays one of the most important tools for estimating the anthropogenic pollution on industrial areas when probing the topsoil or road dust (Hoffman *et al.*, 2004; Lu *et al.*, 2007; Sangode *et al.*, 2010). An interesting approach, able to rapidly illustrate the degree of pollution with heavy minerals in industrial urban areas, is represented by the simultaneous study of mean magnetic susceptibility of neighboring agricultural and urban land areas (Hu *et al.*, 2010).

Important advances in the study of magnetic susceptibility of soils are presently observed in regions affected by military conflicts, due to the need of locating buried explosive objects such as mines or aviation bombs, since the natural variation of the soil magnetic properties is able to generate similar magnetic anomalies (Preetz *et al.*, 2009).

An actual research direction in geophysical soil mapping is the investigation of magnetic properties of both topsoil and subsoil in areas with different geological and environmental conditions, for a better understanding of soil spatial variability and regional dependence on particular lithogenic and/or anthropogenic processes (Fialova *et al.*, 2004).

A recent application of magnetic susceptibility measurements on soils is included in a new domain of Geophysics, Agricultural Geophysics. In this field, the spatial variability of magnetic properties may be related to the soil type based on its mineralogical content (Petrovsky *et al.*, 2004), and hence, the possibility of precisely locating in-depth soil horizons boundaries (Ioane *et al.*, 2010). Future development of magnetic investigations for precision farming is envisaged within the Agricultural Geophysics techniques (Allred, 2010).

The magnetic susceptibility studies on soils in Romania were mainly devoted so far to climate and environmental changes during Quaternary and to soil pollution with heavy metals due to anthropogenic activities.

Significant information on climate and paleoenvironmental changes in the south-eastern part of Romania were obtained in the Mostiştea lake area (Panaiotu *et al.*, 2001; Necula *et al.*, 2005) on a sequence of four loess and three paleosol layers, illustrating by variations of magnetic properties the alternations of dry and wet time intervals in Quaternary. The magnetic properties of loess layers are lower as compared to those measured on paleosols, the latter preserving during time a part of their magnetic signature.

Evaluation of soil pollution using magnetic susceptibility data was carried out within large cities in Romania, such as Bucharest, or smaller towns as Baia Mare, long time affected by industrial pollution with heavy metals (Panaiotu *et al.*, 2006). In Baia Mare, the soil content in heavy minerals was found to be statistically linked with variations in magnetic susceptibility.

## 2. SOIL MAGNETIC SUSCEPTIBILITY MEASUREMENTS AND SAMPLING

### 2.1. Location of studied areas

A soil magnetic susceptibility study was recently carried out in several areas located in the south-eastern part of Romania in view of better understanding the magnetic spatial variability of soils under different pedo-climatic conditions.

The soil magnetic and chemical sampling was performed in areas situated in the Moesian Platform and the North Dobrogean Orogen (Fig. 1), the soil geologic background offering sufficient rock variability. A large part of the analyzed soil profile locations follows the Danube river towards the Danube Delta, zones with obvious particular pedologic and climatic features.

The location of investigated soil profiles is the following (Fig. 1):

a) soil profiles in the Prahova county represented by red dots;

b) soil profiles in the Tulcea county (North Dobrogea) marked by blue dots;

c) soil profiles along Danube river represented by yellow dots.

On the soil profiles situated within the three studied areas magnetic susceptibility measurements were carried out and soil samples were collected for chemical analyses, the latter corresponding to the main soil horizons.

### 2.2. Magnetic susceptibility measurements

The horizontal or vertical mapping of magnetic susceptibility of soils offers important information about soil properties, as result of pedogenetic or anthropogenic processes.

The magnetic susceptibility measurements on the soil profiles were performed with a SM 30 (Gf Instruments) digital portable susceptibility meter. This technique was applied in view of a fast mapping of the vertical and horizontal soil magnetic properties variability. The accuracy of magnetic susceptibility field measurements compared with similar observations made in laboratory on soil samples was previously found satisfactory (Kapick *et al.*, 1997).

The soil profiles were prepared with a spade at variable depths in order to observe the in-depth soil horizon structure.

The magnetic susceptibility profile mapping was carried out on grids with measurement points situated at 10 or 20 cm interval on the vertical profile of each studied soil profile. Prior of taking measurements the soil profile vertical surface was smoothed with the spade for a proper contact with the geophysical instrument. In each measurement point the magnetic susceptibility was observed four to five times, being recorded only its highest value.

The magnetic susceptibility data, measured in $10^{-3}$SI units, were mostly represented as contoured maps of the soil profile vertical walls. In view of a rapid comparison and data interpretation a common color code was employed.

In a single case the magnetic susceptibility measurements on a soil profile are presented as contoured data in a sequence of three horizontal soil layers.

### 2.3. Soil chemical analyses

Chemical analyses of soils are important for determining the soil type and assessing the nutrient status of soils for agricultural production and in determining the environmental hazards imposed on soils by industrial, municipal, and agricultural wastes.

The investigated soil profiles were sampled in view of enabling laboratory chemical analyses, each sample being taken from the middle part of soil horizons.

The chemical analyses included important soil chemical properties such as PH, carbonate concentration, Ht (total humus), Nt (total nitrogen), Sh (exchangeable hydrogen), Sb (the capacity for base exchange), Fe, K, Na, Mg, Ca, T (total exchange capacity), V (base saturation).

The soils PH was established electrochemically, the readings being taken with a PH–meter Thermo Orion 3. The carbonates concentration from soils probes were determined using gas volumetric method with Scheibler calcimeter. The total nitrogen (Nt) was determined using the wet oxidation method and titrimetric graduation – Kjeldahl method, with Gerhardt mineralizator and distiller. The determination of exchangeable hydrogen was made through percolation after the Cernescu method.

## 3. VERTICAL VARIABILITY OF MAGNETIC SUSCEPTIBILITY ON SOIL PROFILES

Magnetic susceptibility measurements on the soil profiles offer significant advantages as compared to measurements taken at the topographic surface.

Many times boundaries of the horizon structure of a particular soil type are illustrated by a fast increase or decrease of magnetic susceptibility allowing rapid and correct decisions for in-depth soil mapping.

Knowledge on the presence of soil layers bearing high magnetic properties, situated at different depths at the scale of a few meters may be useful for geophysicists when performing detailed magnetic surveys for near-surface geological structures (civil engineering, hydrogeology, environment), for archaeology or agriculture (Ioane *et al.*, 2010).

### 3.1. Prahova county

In the Prahova county the magnetic susceptibility measurements were carried out on three soil profiles situated at distances of 4 and 16 km. All three soil profiles exhibit different types of luvisols, a specific soil for this region.

For this soil type the pedogenetic processes of eluviation and illuviation are characteristic, leading in time to the formation of clay minerals in the *B* horizon.

The *in situ* observations of the Prahova county soil profiles are presented as follows:

– *P1, Stagnic preluvisol* with thickness of *Ao* horizon 0–10 cm, a loamy-sandy texture, glomerular structure and *Bt* (argic) horizon with thickness 10–70 cm and situated on a hilly relief at 300 m altitude;

– *P2, Epicalcari-gleyic luvisol* with thickness of *Ao* horizon 0–12 cm, a loamy-sandy texture and blocky structure; *Elka* horizon with thickness of 12–40 cm with sandy texture and glomerular structure; *Bt* horizon with thickness of 40–90 cm, loamy clay texture and prismatic structure. The profile is situated at 100 m altitude.

– *P3, Stagnic luvisol* with thickness of *A* horizon 0–10 cm, brown dark color, sandy-loamy texture, glomerular structure; *El* horizon with thickness of 10–30 cm, brown–yellow color, loamy texture and blocky structure; *Bt* horizon with thickness of 30–90 cm, brown with rusty spots, clay texture and prismatic structure. The soil profile is situated at 100 m altitude.

The magnetic susceptibility data for all three sites, presented as contoured maps of a vertical wall in the soil profile, are displayed in Fig. 2. The magnetic soil properties illustrate a clear vertical variability (Fig. 2a, 2b and 2c) and at higher depths, a horizontal variability (Fig. 2c).

The vertical variability of magnetic susceptibility in all three cases follows in good conditions the soil horizons structure.

The *Stagnic luvisol* and *Epicalcari-gleyic luvisol* (Fig. 2a and 2b) are characterized by the lowest values in magnetic susceptibility in the *E* horizon, showing that the horizon is depleted of iron oxides, as well as of colloids like organic matter. They were mostly accumulated in the *B* horizon, where higher values of magnetic susceptibility were obtained. The rise of magnetic susceptibility in *B luvisol* horizons can also be determined by pedogenetic processes of *gleying* (*Gr*) and *pseudogleying* (*w*); the difference is that the *BtkaGr* horizon (Fig. 2b) has lower values in magnetic properties due to a high concentration in carbonates (diamagnetic) that fill in places the soil pores.

The S*tagnic preluvisol* has higher magnetic susceptibility in the *A* horizon as compared to the *B* horizon and does not have an *E* eluviation horizon.

On the *Stagnic preluvisol* profile the horizontal distribution of magnetic susceptibility was measured in order to compare it with its vertical distribution. The measuring horizontal area was 80 cm long and 60 cm wide.

The horizontal distribution of magnetic susceptibility (Ka) for the *Stagnic preluvisol* profile presented in Fig. 3 depicts a similar variation alike its vertical distribution presented in Fig. 2c. However, a good picture of the horizontal variability is observed at the lowest measured level (50 cm depth), a feature that may be useful when analyzing soil cracks and water permeability.

### 3.2. Tulcea county

The studied soil profiles are situated in North Dobrogea, in contrasting areas as concerned the geological background. Four soil type profiles were investigated here on the magnetic susceptibility vertical variability.

The *in situ* observations of the Tulcea county soil profiles are presented as follows:

*D1 – Mollic preluvisol* with thickness of *Am* horizon of 0–40 cm, dark color, loamy texture and prismatic texture. *Bt* horizon between 40–70 cm, brown color, loamy clay structure and prismatic structure. *C* horizon from 70 cm depth. The soil profile is situated in a hilly area at 170 m altitude.

*D2 – Rendzic leptosol* with thickness of *Amka* (*A* mollic carbonatic) horizon between 0–40 cm, black color, sandy-loamy texture and glomerular structure. *AR/ka* horizon between 40–75 cm, dark brown color, loamy-sandy texture and glomerular structure. The soil profile is situated at 240 m altitude.

*D3 – Tipic preluvisol* with thickness of *Ao* horizon 0–40 cm, dark brown color, loamy-sandy texture, glomerular structure. *Bt* between

40–120 cm, brown red color, loamy texture and prismatic structure. The soil profile is situated at 150 m altitude in hilly area.

*D4 – Eutri-calcaric cambisol* with thickness of Amka horizon 0–25 cm, dark brown color, sandy-loamy texture and glomerular structure. *Bvka* between 25–110 cm, brown yellow color, loamy-sandy texture and glomerular texture. The soil profile is situated at 80 m altitude.

The soil profile, determined as a *Eutri-calcaric cambisol*, is situated in the northern part of the Dobrogea county on Quaternary loess deposits (Fig. 4a). The major pedogenetic process that affected this soil profile is the *in situ* formation of clay. The highest values of magnetic susceptibility were recorded in the *A* horizon; the values decrease in the *B* horizon and even more in the loess parental deposit (*C*), which displays here the lowest magnetic susceptibility.

In the *Mollic preluvisol* and the *Renzic leptosol* (Figs. 4b and 4c), an important decrease with depth in magnetic susceptibility was observed, the highest values being recorded in the upper *Am* horizon.

On the contrary, the *Typical preluvisol* profile presented in Fig. 4d presents a significant increase in magnetic susceptibility with depth.

The decrease of magnetic susceptibility with depth within the first three soil profiles (Fig. 4a, 4b and 4c) is due to weathering soil processes, while the increase with depth in magnetic properties for the *Typical preluvisol* (Fig. 4d) is determined by the high magnetic properties of its parental material (magmatic rock).

It may be also interesting and useful to consider the parental material and the vertical distribution of magnetic susceptibility for both the *Rendzic leptosol* (limestone) and the *Typical preluvisol* (magmatic rock) (Fig. 4c and 4d). The *Renzic leptosol* displays a "normal" in-depth distribution of magnetic properties, with highest values in *A* and lowest in *C*, while the *Typical preluvisol* illustrates an "anomalous" in-depth distribution of magnetic susceptibility, the highly magnetic *C* horizon being responsible for this reversed vertical distribution.

### 3.3. Danube river and Danube Delta soil profiles

The studies areas are located in the Brăila and Tulcea counties, along the Danube river and within the Danube Delta, the analyzed soil profiles being developed on alluvial deposits.

The specific type of soil formed in seasonal flooded areas, where water is present long time intervals during the year. These soils are developed on the same parental material, so the major factor in spatial variability of magnetic susceptibility may be attributed to weathering conditions.

The soil profiles display generally the same horizon structure. There may be separated two soil types due to the vertical extension of an aerobic oxidation horizon (*Go*): a) soils which have a *Go* horizon at depths higher than 50 cm are *Fluvisol* soils type; b) soils which have *Go* horizon above 50 cm depth are *Gleysol* type soils.

The magnetic susceptibility varies with depth and display specific values associated with soil horizons. All these soil profiles are rich in carbonates and have a thin horizon rich in organic matter (*A*) because it is usually depleted during flooding episodes.

In the majority of the presented soil profiles (Figs. 5a, 5b, 5c, 5e and 5f) higher magnetic susceptibility values are recorded in the *Go* horizon, being noticed a substantial decrease in magnetic susceptibility in the *Gr* horizon.

## 4. CORRELATION OF CHEMICAL SOIL PROPERTIES AND MAGNETIC SUSCEPTIBILITY

Correlating results of magnetic susceptibility measurements and significant chemical soil proprieties in the soil profiles of the studied areas may lead to a better understanding of soil magnetism and the causes of its spatial variability. Soil pH, organic matter content (Ht) and cation exchange capacity (T) provide a general description for the chemical characteristics of soil, while the Fe content may be related to magnetic properties (Table 1).

*Table 1*

Chemical analyses and magnetic susceptibility data on soil samples

| **Soil type** | **Soil sub type** | **Soil horizon** | **Horizon depth** | **Ka (magnetic susceptibility) x $10^{-3}$ SI** | **Fe mg/kg** | **PH** | **Ht (%) Total humus** | **T (me/100g)** |
|---|---|---|---|---|---|---|---|---|
| **Prahova county** | | | | | | | | |
| Preluvisol | stagnic | Ao | 0–10 cm | 0.234 | | 5.57 | 5.71 | 26.31 |
| | | Btw | 10–70 cm | 0.116 | | 5.17 | 0.51 | 19.54 |
| Luvisol | gleic, epicalcaric | Aoka | 0–12 cm | 0.134 | | 7.73 | 5.95 | |
| | | Elka | 12–40 cm | 0.1 | | 8.22 | 1.55 | |
| | | BtkaGr | 40–90 cm | 0.14 | | 8.07 | 2.51 | |
| Luvisol | stagnic | Ao | 0–10 cm | 0.127 | | 5.69 | 9.26 | 37.16 |
| | | El | 10–30 cm | 0.096 | | 4.89 | 2.19 | 35.97 |
| | | Btw | 30–90 cm | 0.161 | | 4.85 | 0.57 | 37.2 |
| **North Dobrogea area** | | | | | | | | |
| Preluvisol | mollic | Am | 0–40 cm | 0.986 | 15090 | 6.88 | 2.64 | |
| | | Bt | 40–70 cm | 0.792 | 13940 | 7.61 | 1.15 | |
| Leptosol | rendzic | Amka | 0–40 cm | 0.797 | 20390 | 8.07 | 5.64 | |
| | | A/Rka | 40–75 cm | 0.261 | 11140 | 8.30 | 2.82 | |
| Preluvisol | tipic | Ao | 0–20 cm | 0.469 | 24520 | 6.83 | 7.19 | |
| | | Bt | 20–130 cm | 0.840 | 15450 | 5.92 | 0.90 | 77.90 |
| Eutri – cambisol | mollic, calcaric | Amka | 0–25 cm | 0.360 | 11560 | 7.89 | 3.59 | |
| | | Bvka | 25–110 cm | 0.194 | 10546 | 8.40 | 1.10 | |
| **Brăila and Tulcea counties** | | | | | | | | |
| Gleysol | Fluvic, proxicalcaric | Aoalka | 0–5 cm | 0.173 | | 7.64 | 6.63 | |
| | | Goalka | 5–30 cm | 0.246 | | 8.14 | 2.72 | |
| | | Gralka | 30–80 cm | 0.212 | | 8.34 | 0.39 | |
| Gleysol | Fluvic, proxicalcaric | Aoalka | 0–10 cm | 0.408 | 15632 | 7.47 | 8.95 | |
| | | Goalka | 10–30 cm | 0.365 | 15321 | 8.06 | 2.27 | |
| | | Gralka | 30–90 cm | 0.274 | 15001 | 8.32 | 0.75 | |
| Gleysol | Fluvic, proxicalcaric | Aoalka | 0–10 cm | 0.405 | 15542 | 7.38 | 7.04 | |
| | | Goalka | 10–30 cm | 0.516 | 15112 | 8.12 | 2.22 | |
| | | Gralka | 30–80 cm | 0.214 | 14996 | 8.20 | 2.15 | |
| Fluvisol | gleic, proxicalcaric | Aoka | 0–10 cm | 0.326 | 11230 | 7.51 | 5.88 | |
| | | Goka | 10–60 cm | 0.392 | 11321 | 8.22 | 1.50 | |
| | | Grka | 60–100 cm | 0.242 | 11169 | 8.49 | 1.18 | |
| Fluvisol | gleic, proxicalcaric | Aoka | 0–5 cm | 0.254 | 11289 | 7.44 | 7.65 | |
| | | Goka | 5–55 cm | 0.375 | 11351 | 8.02 | 2.67 | |
| | | Grka | 55–80 cm | 0.184 | 11301 | 8.08 | 2.64 | |
| Gleysol | Fluvic, epicalcaric | Aoalka | 0–10 cm | 0.288 | | 7.39 | 8.69 | |
| | | Goalka | 10–30 cm | 0.329 | | 7.44 | 5.13 | |
| | | Gralka | 30–80 cm | 0.208 | | 8.27 | 1.52 | |

The magnetic susceptibility vertical variation has the same trend as the total organic matter content and the cation exchange capacity in the studies soils, excepting the *Stagnic luvisol* in *Btw* horizon, were magnetic susceptibility is increasing from *El* horizon while the total organic matter is decreasing.

The increase in magnetic susceptibility in *Btw* horizon can be attributed to oxidation processes during lower water table intervals, being created conditions for converting hematite to maghemite. The *Stagnic luvisol* and *Preluvisol* have an acid reaction; while the *Epicalcari-gleyic luvisol* have an alkaline reaction because of high carbonates concentration (12.7% in *Aoka* horizon, 16% in *Elka* horizon and 17% in *BtkaGr* horizon) (Fig. 6). The carbonates soil content does not have in the case of these soil types an important effect in the distribution of magnetic susceptibility, because other pedogenetic processes play a major role in the magnetic susceptibility increase (bioaccumulation, eluviation, illuviation and gleying).

The vertical variability in magnetic susceptibility for the North Dobrogea and Danube river and Danube Delta studied areas illustrates a good correlation with soil chemical properties. There is a strong correlation between magnetic susceptibility and total iron content (Fe) on the studied soil profiles, with some exceptions in *Gleysols* and *Fluvisols* in the *Go* horizon (*Gleyic-oxidation* horizon), where an increase in magnetic susceptibility was noticed. The increase in magnetic susceptibility in *Go* horizon is due to iron oxides that result from the pedogenetic process of gleying (Fig. 7).

Even the majority of the soil profiles have the same trend of vertical variation in magnetic susceptibility and iron content, when we compare the analyzed soils we may notice that the soil profile with highest values in magnetic susceptibility does not have greatest iron content. This aspect is due to different mineralogical composition and mainly, to different types of iron oxides with specific magnetic properties.

The vertical variability in organic matter content displays the same trend as the magnetic susceptibility, with the exception of *Gleysols* and *Fluvisols,* where the *A* horizon presents higher values. These types of soil have a higher concentration of organic matter but are not characterized by high values of magnetic susceptibility. This lack of correlation is due to a different type of organic matter that is formed normally in flooding areas and does not have enough time to decompose because of flood cycles and does not form organic-mineral complexes that accumulate iron oxides.

Soil PH is mainly influenced by the soil carbonates content. All studied soil profiles have an alkaline reaction with the exception of the *Mollic preluvisol*.

## 5. CONCLUSIONS

This paper presents results obtained in a first stage of researches dedicated to soil geophysical investigation using the magnetic susceptibility spatial variability, being probably the first study of this kind carried out on Romanian soils.

The vertical magnetic susceptibility distribution, observed in soil profiles situated in analyzed geological, climate and vegetation conditions indicated a structured in-depth distribution of magnetic susceptibility that generally corresponds with the soil horizons.

The comparison of vertical variability of magnetic susceptibility with those of selected chemical compounds and properties showed correlations that were considered as natural (enhanced magnetic susceptibility with increased organic matter), or non-correlations which may arise presently interpretation problems (decreasing magnetic susceptibility and increasing PH).

Considering the correlation between magnetic susceptibility and organic matter content, high values were especially noticed at the upper part of the soil profiles, especially on the *mollic* type of organic matter.

*Acknowledgements.* The scientific researches were performed with financial support from the CNCSIS-UEFISCU 998/2009 scientific project. The authors acknowledge the support of “Forest Research and Management Institute”, Bucharest, Romania soil scientists in determining the studied soil types and their chemical characteristics.

REFERENCES

ALLRED, B.J. (2010), *Agricultural Geophysics: Past, Present and Future*. Proceedings of SAGEEP Conference, Keystone, CO.

FIALOVA, H., MEIER, G., KAPICKA, A., PETROVSKY, E., SCHOLGER, R. (2004), *Magnetic properties of soils from sites with different geological and environmental settings*. Geophys. Res. Abstr., Vol. **6**, EGU, Vienna.

HOFFMANN, V., ROSSLER, W., SCHIBLER, L. (2004), *Anomalous magnetic signature of top soils in Burghausen area, SE Germany*. Geophys. Res. Abstr., Vol. **6**, EGU, Vienna.

HU, X.F., ZHANG, G., WU, X-H., CAO, X., JIANG, Q., LI, S., LI, Y. (2010), *Vertical distributions of magnetic susceptibility of the urban soil profiles in Shanghai* *and their environmental implications*. Proceedings of the 19th World Congress of Soil Science, Brisbane.

IOANE, D., CHITEA, F., MEZINCESCU, M., GÂRBACEA, G. (2010), *Geophysical mapping and monitoring of variations in soil moisture in cultivated land: Buzău county, Romania*. Near Surface Geophysics, (submitted).

KAPICKA, A., PETROVSKY, E., JORDANOVA, N. (1997), *Comparison of in situ field measurements of soil magnetic susceptibility with laboratory data*. Studia Geoph. Geod., **41**, pp. 391–395.

LU, S.G., BAI, S.Q., XUE, Q.F. (2007), *Magnetic properties as indicators of heavy metals pollution in urban topsoils: a case study from the city of Luoyang, China*. Geophys. J. Int., **171**, pp. 568–580.

NECULA, C., PANAIOTU, C., PANAIOTU, C.E., GRAMA, A. (2005), *Magnetic properties of a loess-paleosol sequence at Mostiştea (Romania).* Romanian Reports in Physics, Vol. **57**, No. 3, pp. 453–461.

PANAIOTU, C.G., PANAIOTU, E.C., GRAMA, A., NECULA, C. (2001), *Paleoclimatic Record from a Loess-Paleosol Profile in Southeastern Romania*. Phys. Chem. Earth (A), Vol. **26**, no. 11–12, pp. 893–898.

PANAIOTU, C.G., DUMITRESCU, L., BILAL, L. (2006), *Magnetic and geochemical measurements on top soil and street dust in Baia Mare town (Romania).* Geophys. Res. Abstr., Vol. **8**, EGU, Vienna.

PETROVSKY, E., KAPICKA, A., FIALOVA, H., DOLECKOVA, T., CERMAK, P., PROVAZNIK, K. (2004), *Magnetic properties of agricultural soils in dependence of land use.* Geophys. Res. Abstr., Vol. **6**, EGU, Vienna.

PREETZ, H., ALTFELDER, S., HENNINGS, V., IGEL, J. (2009), *Classification of soil magnetic susceptibility and prediction of metal detector performance – case study from Angola*. Detection and Sensing of Mines, Explosive Objects and Obscured Targets. Proceedings of SPIE, Vol. **7303**.

SANGODE, S.J., VHATKAR, K., PATIL, S.K., MESHRAM, D.C., PAWAR, N.J., GUDADHE, S.S., BADEKAR, A.G., KUMARAVEL, N.J. (2010), *Magnetic susceptibility distribution in the soils of Pune Metropolitan Region: implications to soil magnetometry of anthropogenic loading*. Current Science, Vol. **98**, no. 4, 25, pp. 516–527.

SPASSOV, S., EGLI, R., ZANANIRI, I., DE MARCO, E., LUSCHER, P., KRETZSCHMAR, R. (2004), *A detailed chemical and rock magnetic investigation of a soil profile in Switzerland formed on loess*. Geophys. Res. Abstr., Vol. **6**, EGU, Vienna.

*Received: November 19, 2010*
*Accepted for publication: January 12, 2011*

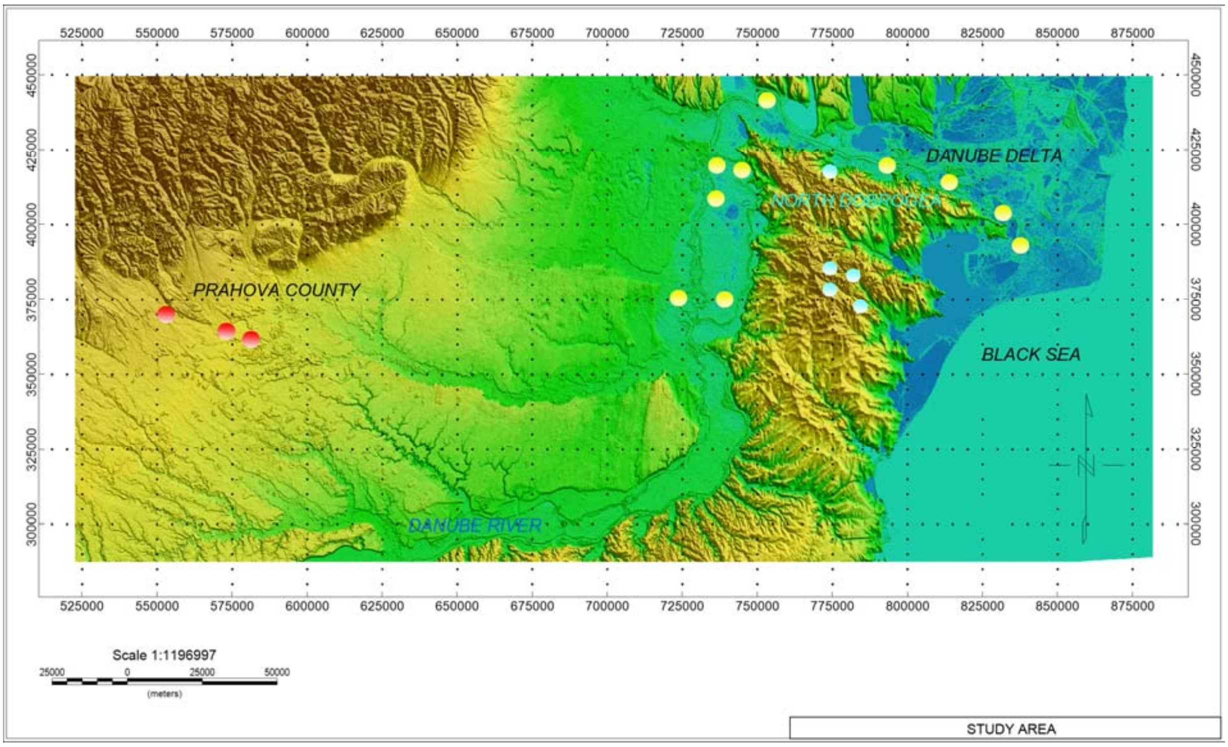


Fig. 1 – Location of studied soil profiles in the south-eastern part of Romania.

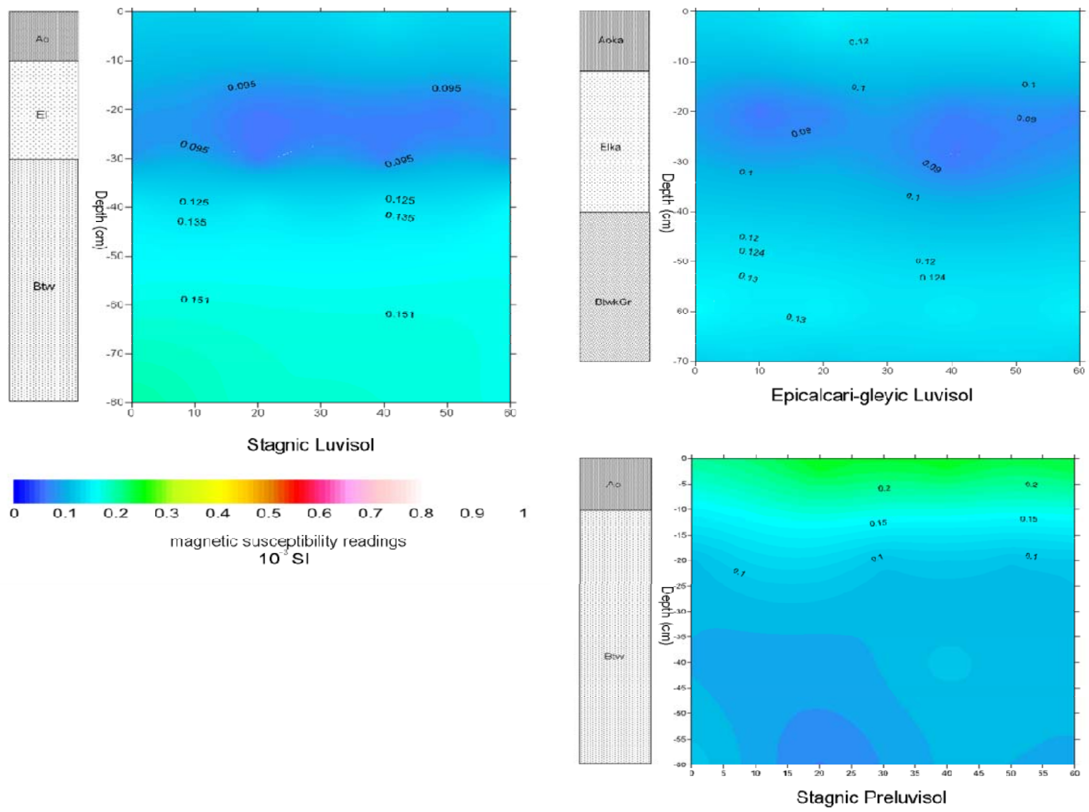


Fig. 2 – Vertical variability of magnetic susceptibility in Prahova county soil profiles:
a) *Stagnic luvisol*; b) *Epicalcari-gleyc luvisol;* c) *Stagnic preluvisol*.

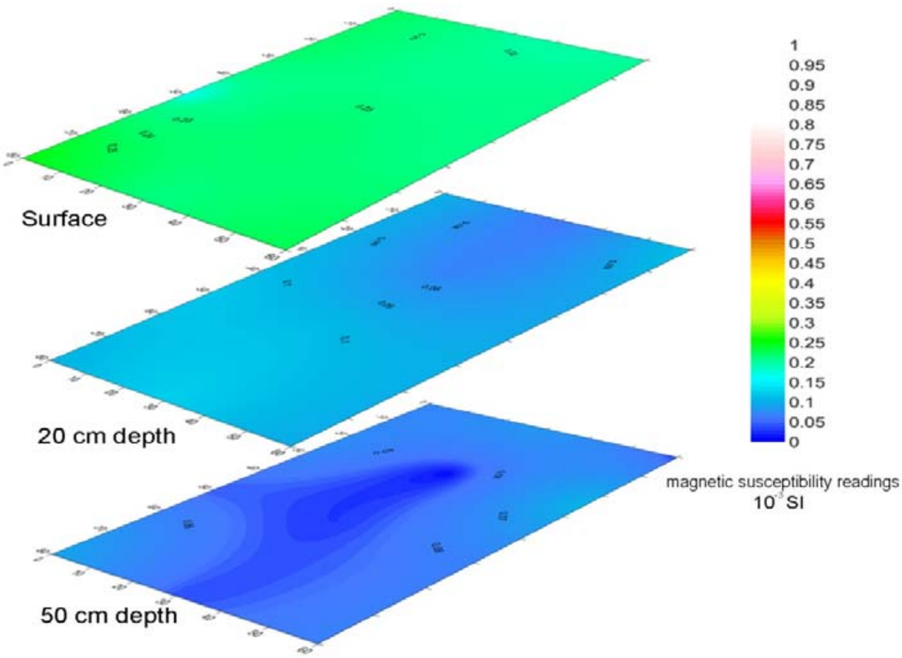


Fig. 3 – Horizontal variability of magnetic susceptibility at various depths
in the *Stagnic preluvisol* profile.

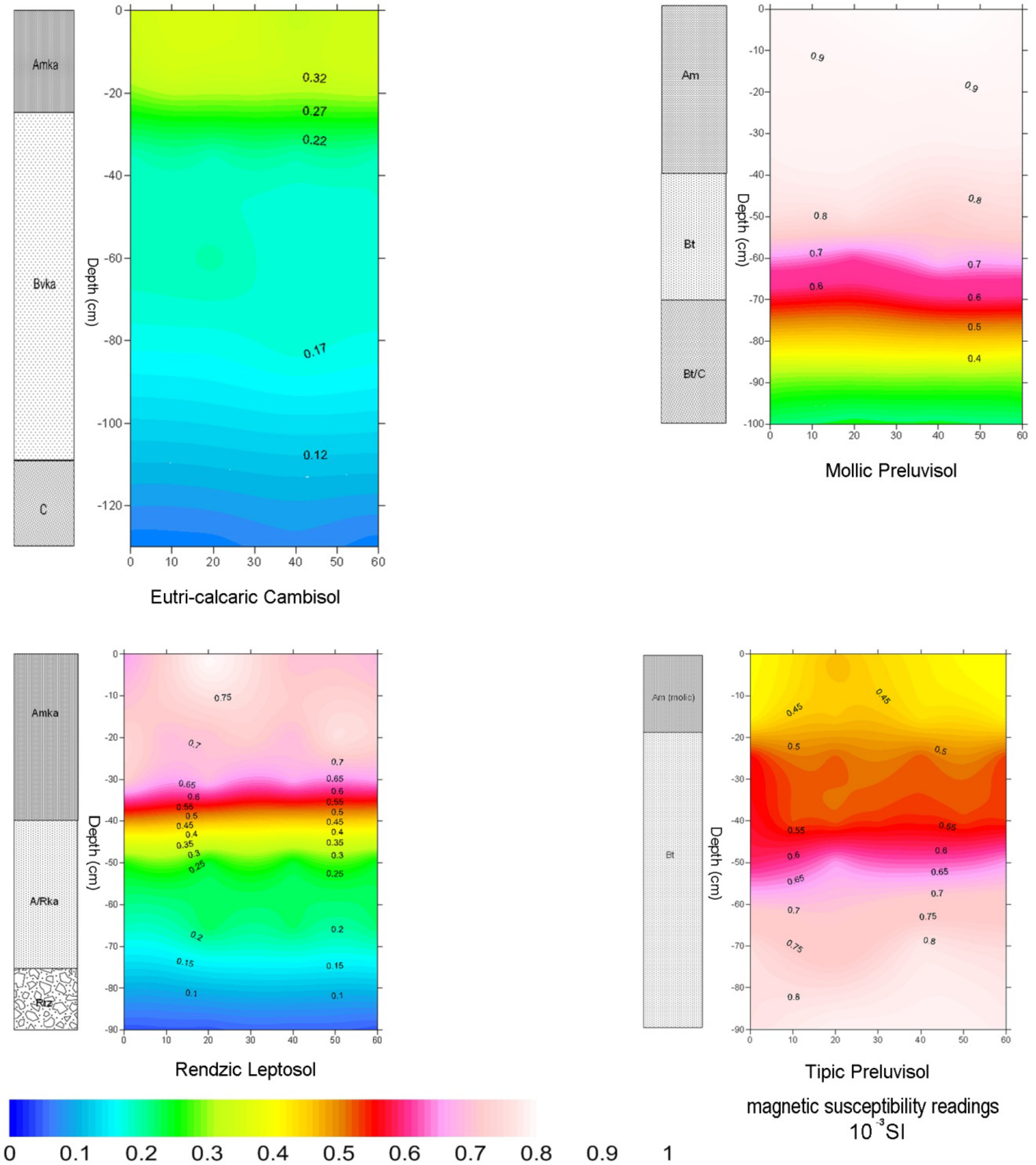


Fig. 4 – Spatial variability in magnetic susceptibility (Ka) on soil profiles in North Dobrogea.

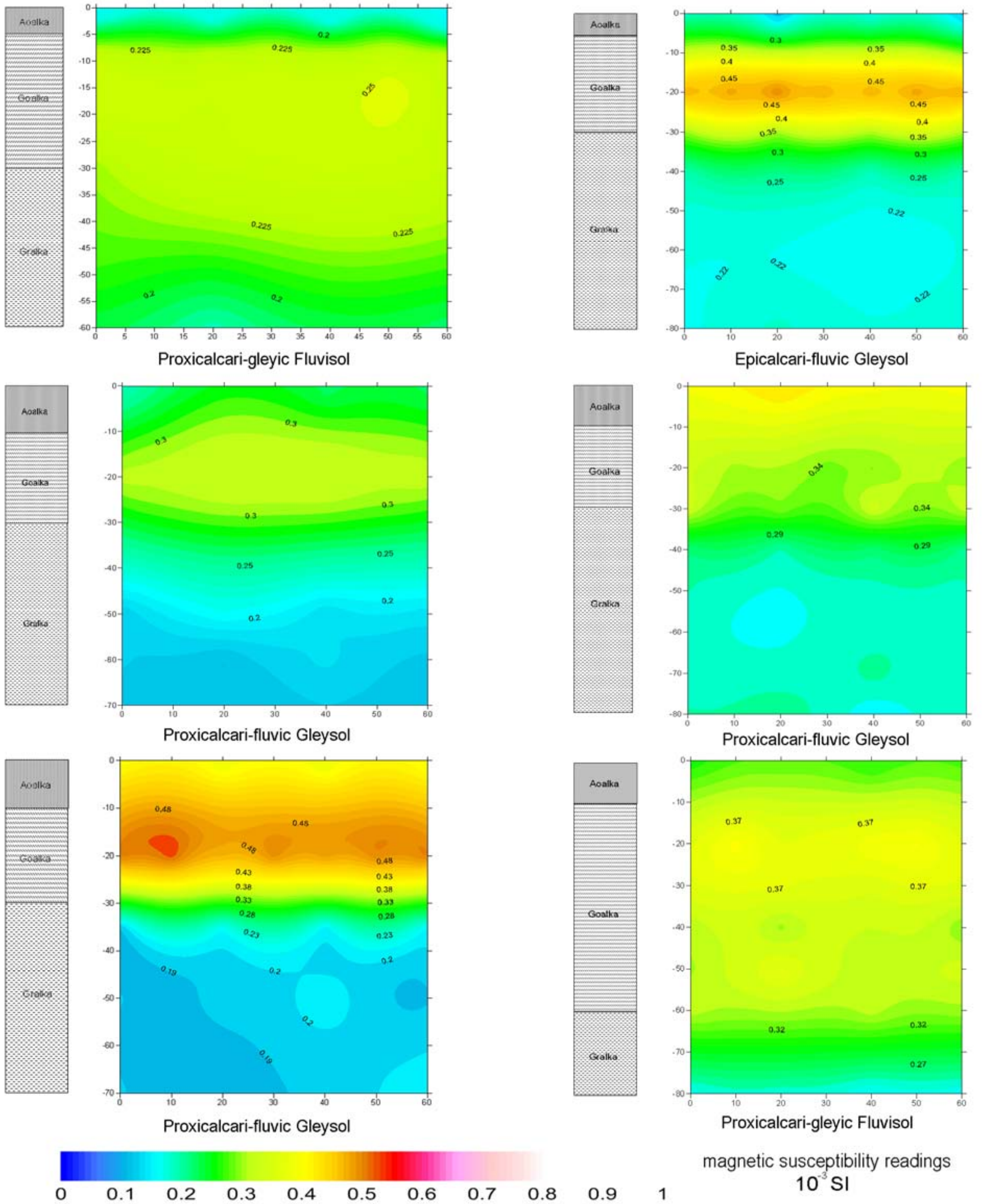


Fig. 5 – Vertical variability in magnetic susceptibility (Ka) on soil profiles along Danube river and within Danube Delta.

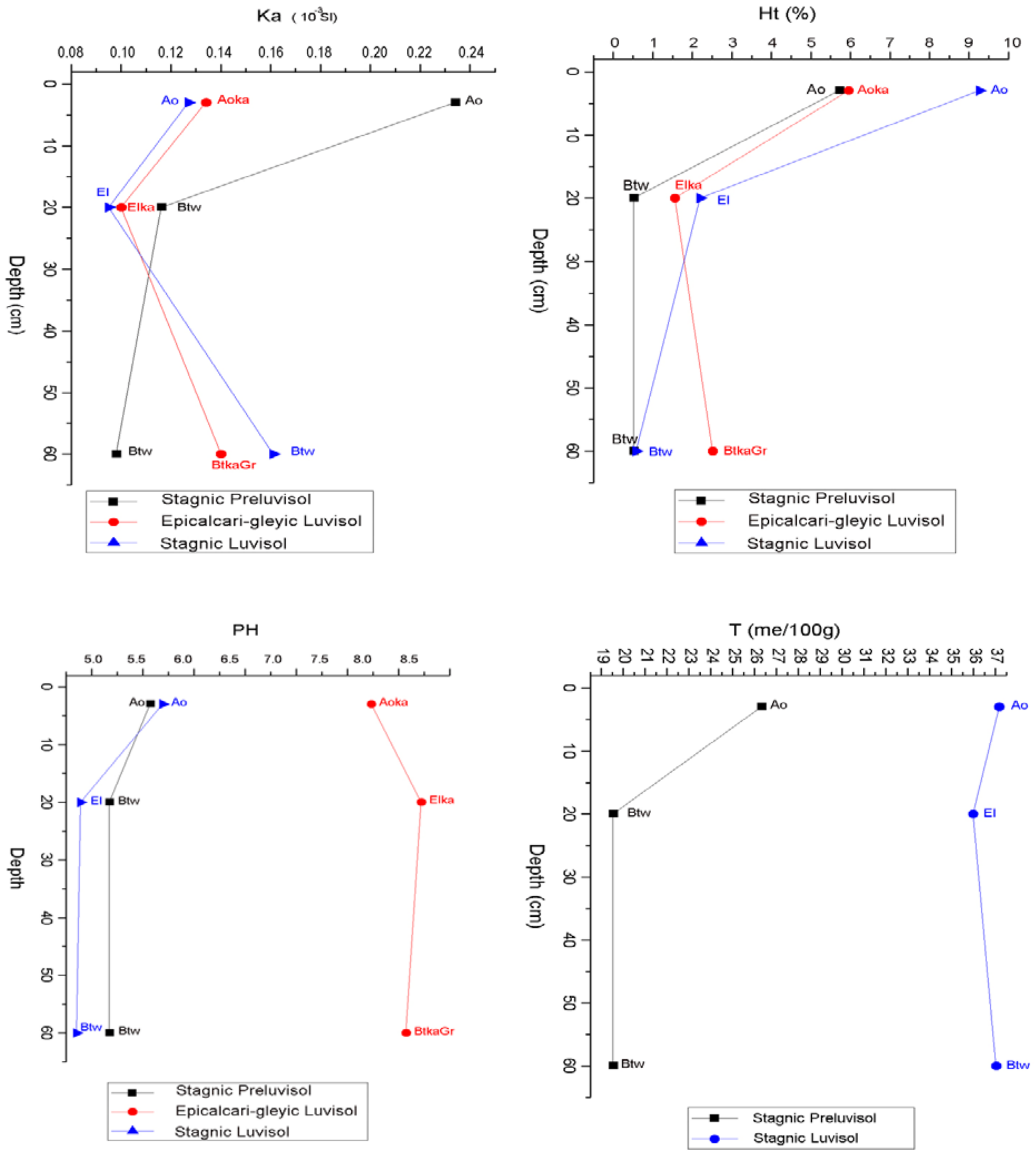


Fig. 6 – Vertical variability in magnetic susceptibility (Ka), total organic matter (Ht) and total cation exchange capacity (T) in studied soil profiles.

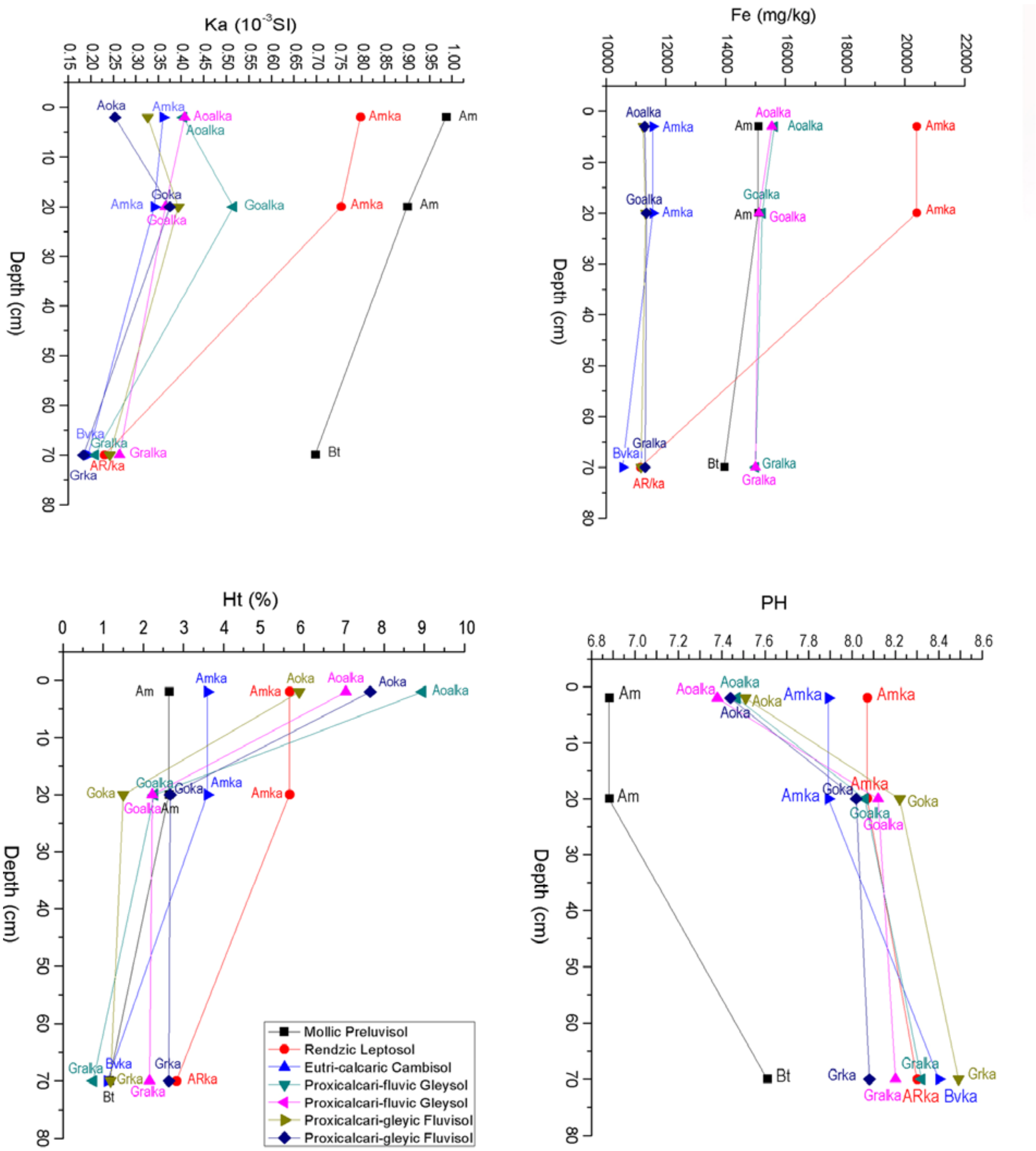


Fig. 7 – Vertical variability in magnetic susceptibility (Ka), total organic matter (Ht), Fe content and PH in studied soil profiles.