**MAGNETIC PROPERTIES OF TOPSOILS IN CROATIA**

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Magnetic susceptibility (MS) of soils and paleosols indicates the formation of secondary ferrimagnetic minerals (SFM) and pedogenic processes. MS measurements can relatively fast and non-destructively characterize the concentration, mineralogy, and grain size of magnetic minerals present in samples (HATFIELD, 2014; PETERS & DEKKERS, 2003). The soil characteristics are influenced by variations in iron mineral forms, and it can give clue to the processes of pedogenesis (DEARING, 1996). Topsoil has been identified as an environment in which ferrimagnetic materials are actively produced. Secondary magnetic minerals (magnetite/maghemite) are mostly ultrafine grained and contain a significant superparamagnetic (SP) component (<0.03 µm).

The analysis of surface (0-10 cm depth) and sub-surface soils (20-30 cm depths) in a dataset created from more than 750 locations in Croatia (MIKO et al., 2017) have been performed through measurements of low field mass specific MS (Xlf), mass specific and frequency-dependent MS (Xfd). The aim of the study was to determine the spatial distribution of MS. The MS data set is combined with data for geochemistry, geology and soil type in order to determine the main source of magnetic particles. Data can then be used for provenance studies of soil and erosional processes (HATFIELD & MAHER, 2008), climate reconstructions (MAHER, 2011; GEISS et al., 2008) as well as evaluation of historical landuse and anthropogenic soil pollution (HOFFMANN et al., 1999; MITCHELL et al., 2010). Measurements are also used in the landmine-affected regions because of the effect of soil MS on metal detectors (HANNAM & DEARING, 2008).

Maps created with the soil MS data set in Croatia show two clearly differentiated distributions – Pannonian region versus Dinaric area of Croatia (Figure). Differences exist due to the geological sub-division of Croatia and its associated main soil types: the Mesozoic carbonate rocks of the Dinaric-Coastal karstic region with dominant red soils and calcocambisols versus the Pannonian region with dominant cambisols, luvisols and gleysols mostly developed on clastic Neogene and Quaternary sediments (HGI, 2009, BOGUNOVIĆ et al., 1996). Summary data shows that soils developed on carbonate rocks have higher MS values compared to soils of the Pannonian region (Figure). Anthrosols also have elevated MS values.

Magnetic properties of soils in the karstic area are dominated by the presence of nanoscale SP SFM grains produced in situ. Soil-derived magnetite gives major contribution to the magnetic enhancement in red soils. Primary ferrimagnetic minerals derived from geological sources dominate magnetic properties in only a minority of localities (mountainous areas composed of magmatic and metamorphic rocks).

This is the first attempt to produce a soil magnetic susceptibility map of Croatia that covers all dominant soil types in Croatia.

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References:

BOGUNOVIĆ, M., VIDAČEK, Ž., RACZ, Z., HUSNJAK, S., SRAKA, M. (1996): Namjenska pedološka karta tala za obradu Republike Hrvatske M 1:300.000.

DEARING,J.A., HAY, K. L., BABAN, S. M. J., HUDDLESTON, A. S., WELLINGTON E. M. H., LOVELAND, P.J. (1996): Magnetic susceptibility of soil: an evaluation of conflicting theories using a national data set. Geophys. J. Int. 127,728-734

GEISS, C.E., EGLI, R., ZANNER, C.W. (2008): Direct estimates of pedogenic magnetite as a tool to reconstruct past climates from buried soils. J. Geophys. Res., 113, 1–15.

HANNAM J.A., DEARING, J.A. (2008): Mapping soil magnetic properties in Bosnia and Herzegovina for landmine clearance operations Earth and Planetary Science Letters 274 285–294

HATFIELD, R.G. (2014): Particle Size-Specific Magnetic Measurements as a Tool for Enhancing Our Understanding of the Bulk Magnetic Properties of Sediments. Minerals, 4, 758-787

HATFIELD, R.G. & MAHER, B.A. (2018): Suspended sediment characterization and tracing using a magnetic fingerprinting technique: Bassenthwaite Lake, Cumbria, UK. Holocene, 18, 105–115.

HOFFMANN, V., KNAB, M., APPEL, E. (1999): Magnetic susceptibility mapping of roadside pollution. J. Geochem. Explor., 66, 313–326.

HRVATSKI GEOLOŠKI INSTITUT, HGI (2009): Geološka karta Republike Hrvatske 1:300.000. Hrvatski geološki institut, Zagreb.

MAHER, B.A. (2011): The magnetic properties of Quaternary Aeolian dusts and sediments, and their palaeoclimatic significance, Aeolian Research 3/2, 87-144.

MIKO, S., HASAN, O., KOMESAROVIĆ, B., ILIJANIĆ, N., ŠPARICA MIKO M., ĐUMBIR, A.M., OSTROGOVIĆ SEVER, M.Z., PALADINIĆ, E., MARJANOVIĆ, H. (2017): Promjena zaliha ugljika u tlu i izračun trendova ukupnog dušika i organskog ugljika u tlu te odnosa C:N. Knjiga I: Izvješće o setu podataka za izradu izvješća prema Okvirnoj konvenciji UN-a o promjeni klime – UNFCCC (sektori LULUCF i poljoprivreda)

MITCHELL, R., MAHER, B.A., KINNERSLEY, R. (2010): Rates of particulate pollution deposition onto leaf surfaces: Temporal and inter-species analyses. Environ. Pollut. 2010, 158, 1472–1478

PETERS, C. & DEKKERS, M.J. (2003): Selected room temperature magnetic parameters as a function of mineralogy, concentration and grain size. Phys. Chem. Earth, 28, 659–667.

Figure caption: Interpolated Frequency Dependant Susceptibility Map of Soils (Xfd (10-7 m3kg-1)) in depth interval 0 to 10 cm. Soils from the Dinaric-coastal region, especially terra rossa soils, have elevated magnetic susceptibility values compared to the Pannonian region.