Preliminary Data on the Magnetic Properties of Fallow Soils (Zelenodolsky District, Republic of Tatarstan)

L. A. Fattakhova, L. R. Kosareva, V. V. Antonenko, A. V. Fattakhov and R. D. Akhmerov

Abstract Over the last few years, there has been an expansion of fallow lands in Russia due to issues in agricultural economics. Soils become fallow when left uncultivated for a time after successive crops. The recovery process depends on the duration of continuous arable farming in the area, soil type, area size and preferred land use methodology. Therefore, the importance of a comprehensive study of the processes occurring in fallow soils is reflected in their enormous expansion. In the course of soil formation, the transformation and migration of iron compounds change the magnetic susceptibility of soil. This suggests that magnetic susceptibility reflects the process of soil formation and may be considered a diagnostic indicator. This article presents the research results on the magnetic properties of fallow soils in Zelenodolsky district (Kazan). Samples of fallow sod-podzolic soils were used in this work. The magnetic properties of fallow soils were studied, and changes in the magnetic characteristics of fallow sod-podzolic soils were analyzed. The soil is characterized by the eluvial/illuvial type of profile patterns of magnetic susceptibility distribution. Evaluation of the contribution of the dia- /paramagnetic, superparamagnetic and ferromagnetic components from the coercive spectra shows that the increase in the magnetic susceptibility of sod-podzolic soils is due to the contribution of the ferromagnetic component.

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1 Introduction

Today, arable lands are being taken out of production in most countries in accordance with common land management practices. This causes changes in soil formation processes and, subsequently, in the evolution of arable soils [1].

Plowing removes the vegetative cover and changes the composition and properties of soil. Soil becomes fallow as soon as it is left uncultivated for more than a year. The future plant succession and soil composition depend on the soil type, the duration of continuous arable farming in the area and the area size.

The importance of a comprehensive study of the processes occurring in fallow soils is reflected in their enormous expansion. They are the foundation of the agricultural land reserves.

In the past two decades, the study of environmental magnetism, including the magnetic characteristics of soils, had gained much ground worldwide [2–7]. Magnetic susceptibility patterns are unique for each soil type and depend on the magnetic susceptibility of parent rocks, weathering, and specific properties of the soil itself: organic content, mineral composition, grain size distribution, water and redox regime, composition of newly formed ferrous minerals, biogenic activity, etc. [2, 8]. Magnetic characteristics, such as magnetic susceptibility, are determined primarily by the content of iron compounds, their phase composition and dispersion. It was established that magnetic properties of zonal soils can regularly and continually change with depth, forming a magnetic profile that reflects type and intensity of the soil-forming process [2]. Also, it seems that the assumptions about soil being able to self-recover to its original state under naturally growing plant successions are unfounded. Therefore, it might be interesting to analyze the magnetic profiles of long-fallow (>10 years) sod-podzolic soils.

The purpose of this work is to study the magnetic properties of fallow soils, and to analyze received magnetic characteristics of fallow sod-podzolic soils.

2 Materials and Methods

For this study, long-fallow (11 and 12 years) loamy sod-podzolic soils of Zelenodolsky Municipal District (Republic of Tatarstan, Volga-Vyatsky region) were selected. The fallow vegetation is represented by fir and pine trees, grass and mixed herbs. The area belongs to the boreal (sub-taiga) type. Weathered dolomitized limestones and sandstones, clays, and marls (Upper Kazan stage of the Upper Permian) form flat and slightly wavy watersheds. The area under study is covered by unconsolidated Quaternary deposits represented by light and medium loam, sandy loam, and sand.

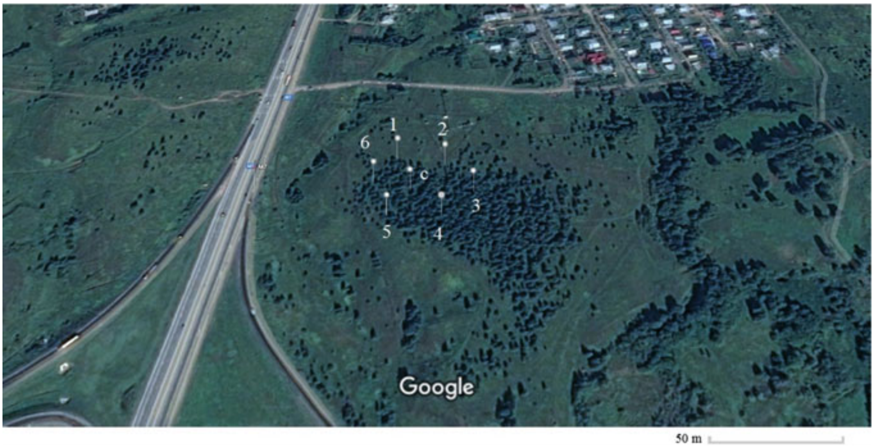

Fig. 1 Sampling procedure

Sampling sites formed a hexagonal grid. The distance between the central sampling point and each of the peripheral ones was 50 m (Fig. 1). The samples were taken every 10 cm to a depth of 70 cm (including sod). At the central point, sampling was conducted to a depth of 120 cm.

Preliminary sample preparation was performed in accordance with the guidelines provided by the International Organization for Standardization [9]. AGICO susceptibility bridge MFK1-FA was used to measure the magnetic susceptibility (χ). Prior to this, all samples were ground in an agate mortar.

Coercive spectra can be used to determine the contribution of the dia/paramagnetic (χ_p) and ferromagnetic (χ_f) components to the magnetic susceptibility. Coercive spectra of isothermal magnetization in the magnetic fields of up to 0.5 T were obtained using a coercive spectrometer ("J_meter") [10, 11], which allows separate recording of remanent and induced magnetization at room temperature. Samples were magnetized from their natural state. The following parameters were derived from the magnetization curves: saturation remanent magnetization (Jrs), saturation magnetization corrected for the paramagnetic component (Js), bulk coercive force corrected for the paramagnetic component (Bc), coercivity of remanence (Bcr).

3 Results and Discussions

In the course of soil formation, transformation and migration of iron compounds changes the magnetic susceptibility of soil. This suggests that magnetic susceptibility reflects the process of soil formation and may be considered a diagnostic indicator [2, 12–15]. Using the measured values of magnetic susceptibility, the curves of changes with depth were constructed. Figure 2 shows variations of different components of

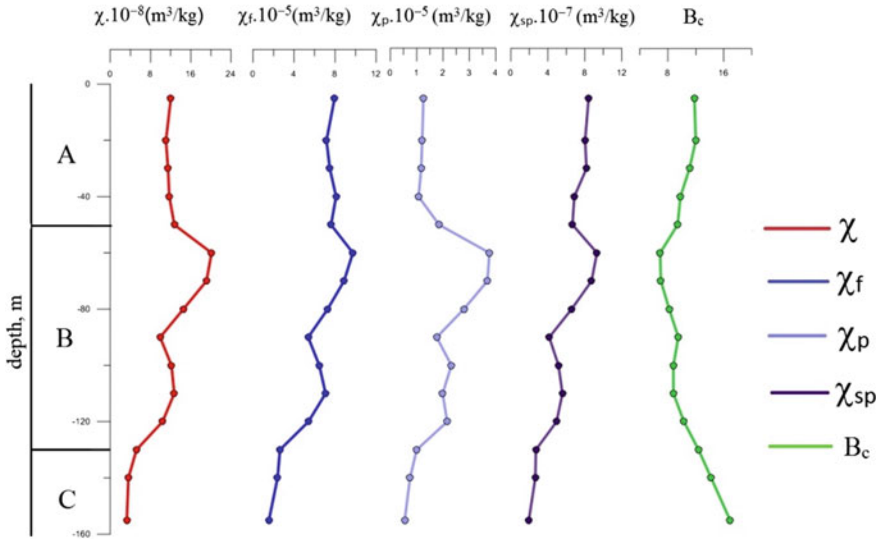

Fig. 2 Magnetic properties as a function of depth (central soil profile)

magnetic susceptibility χ and of bulk coercive force B_c with depth. In our case, the magnetic susceptibility distribution follows the patterns characteristic of the eluvial/illuvial type. This means that the upper part of the soil profile contains relatively small amount of magnetic materials, which increase in the middle part. However, the magnetic mineral content decreases again towards the underlaying soil-forming rock and eventually becomes equal to that of the humus layer.

Coercive spectra can be used to determine the contribution of the dia/paramagnetic (χ_p) and ferromagnetic (χ_f) components to the magnetic susceptibility [16]. The shape of the curves for the paramagnetic, ferromagnetic and superparamagnetic components (Fig. 2) and a direct correlation between the total magnetic susceptibility and its ferromagnetic component (Fig. 3) clearly show that an increase in magnetic susceptibility in the illuvial layer is due to the ferromagnetic component.

Since one profile covers depths to 160 cm, and another six profiles cover depths to 80 cm, it might be interesting to compare the magnetic susceptibility between them. Figure 4 shows that the points 1, 2 and 6 reflect the upper part (0–80 cm) of the central profile, while the points 3, 4 and 5 reflect its lower part (80–160 cm). This indicates the irregular shaped relief. There is a slope gently falling off to the south-east, which means that organic and mineral elements are transported down the slope. This will primarily affect the growing vegetation in the study area. In general, all the magnetic profiles are of the eluvial/illuvial type. B-horizon is rich not only in clay, but also in magnetite, maghemite, hematite and goethite.

Magnetic rigidity and domain state of the magnetic grains were determined using the magnetic hysteresis parameters (*Bc, Bcr, Js, Jrs*), which depend on the composition, magnetic mineral content, shape and size of magnetic grains. *Bcr*/*Bc*

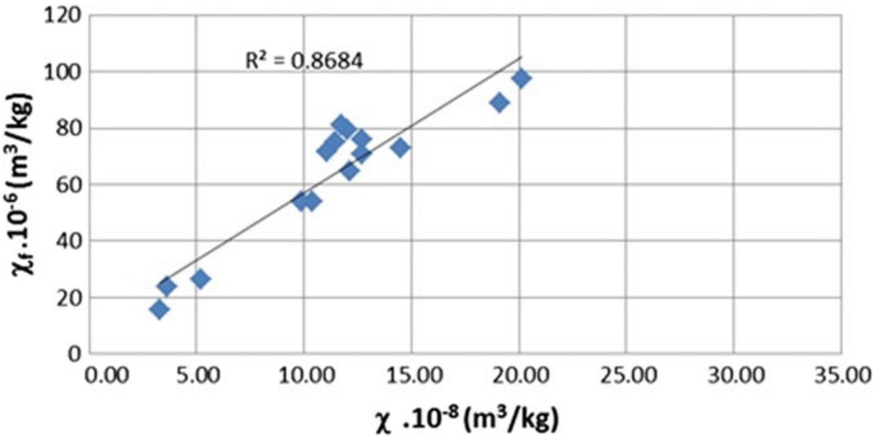

Fig. 3 Relationship between the magnetic susceptibility and its ferromagnetic component (central soil profile)

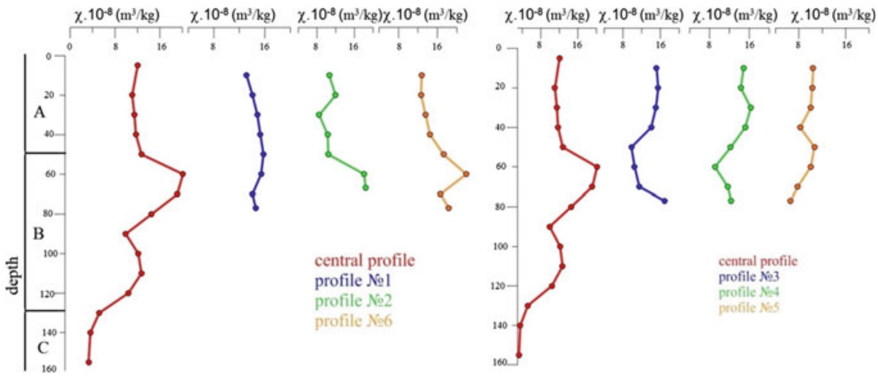

Fig. 4 Magnetic susceptibility as a function of depth (various profiles)

and *Jrs/Js* ratios reflect prevailing grain size and ratios between magnetic fractions with different domain structures. The Day plot [17] is usually used to visualize these characteristics. It shows (Fig. 5) that the magnetic grains in the soil under study are pseudo-single domain particles or a mixture of single domain and multi domain grains.

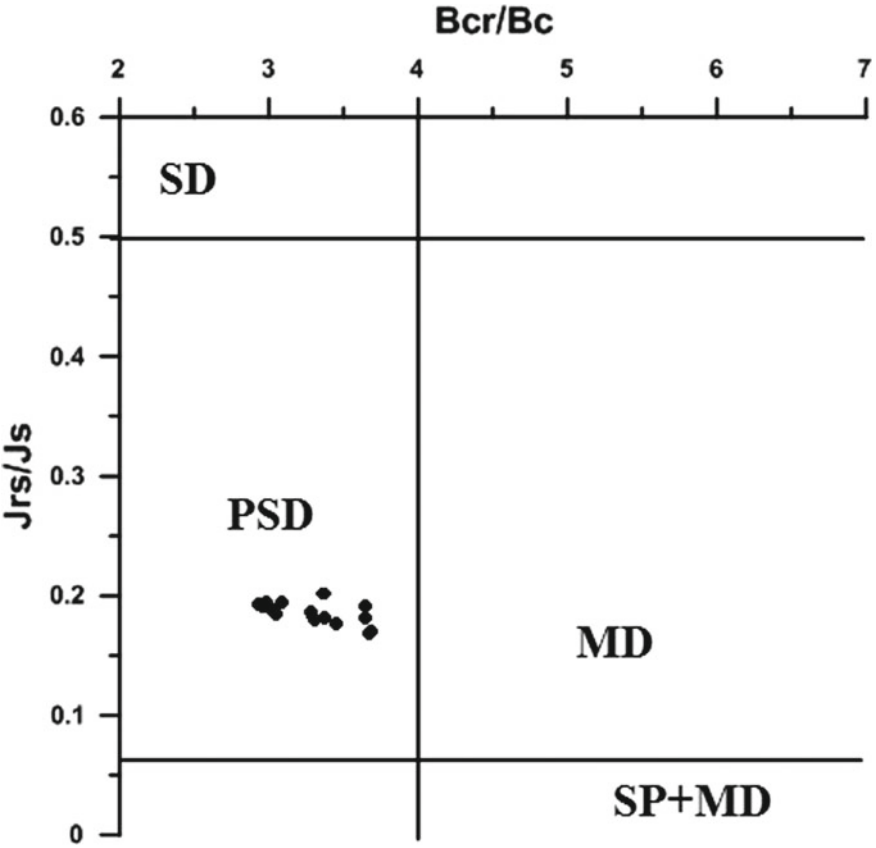

Fig. 5 Day plot

4 Conclusions

Fallow sod-podzolic soils of the Volga-Vyatsky region were studied using a complex of modern magnetic analysis methods, including magnetometry and coercive spectrometry. Magnetic susceptibility, being the ultimate characteristic of magnetic properties, depends primarily on the ferromagnetic component. The shape of the magnetic susceptibility distribution suggests that fine-grained superparamagnetic mineral particles were formed due to the structural and material transformations of iron-containing minerals introduced into the soil from the parent rock. The increase of χ_f in the profiles coincides with the increase of χ_{sp}. So, the χ_f values are enhanced by the presence of superparamagnetic particles that follows the "pedogenic" mechanism of rock-magnetic changes in soils [18] which suggest χ_{sp} as an indicator of pedogenic degree. A gentle slope in the study area indicates different conditions for the formation of sustainable plant successions. It is intended in the future to study soil samples and separate <2.5 μm specimens using the differential thermomagnetic analysis (DTMA) to gain more information on the magnetic and mineralogical features of the studied soils.

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