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BLACK SOILS OUTSIDE OF THE INBS CRITERIA IN SLOVAKIA

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Abstract. The distribution of black soils in Slovakia can be divided into the two basic groups: distribution of black soils according to the International Network of Black Soils (INBS) and distribution of black soils outside of the INBS specified criteria. Black soils outside of the INBS criteria on selected soil profiles are evaluated in this contribution. Indicators of black soils outside of the INBS criteria are very common in comparison with the first group – existence of mollic horizon – but the depth of mollic horizon is often less than 25 cm where the soil properties are practically the same as in black soils using the INBS criteria (represented by Chernozems and Phaeozems). Other special group of black soils without mollic horizon can be also included in the "black soils" category with low soil reaction (pH/H_2O < 5.5 and pH/KCl < 5.0), low base saturation (< 50%) with high content of SOM (10–20%) represented mostly by Andosols and Umbrisols in Slovak conditions. The aim of this paper is to emphasize the significance of black soils outside of the INBS criteria on selected examples of soil profiles in Slovakia. The basic chemical (pH/H_2O, pH/KCl, soil organic carbon (SOC), total nitrogen, humic acids, fulvoacids, colour quotient Q^4_6, available nutrients P and K, melanic index) and physical (fractional mechanical composition) procedures were conducted in NPPC – Soil Science and Conservation Research Institute in Bratislava. Based on the obtained results, the black soils outside of the INBS criteria in Slovakia belong mostly to the most fertile soils with the existence of mollic horizon but often shallower than in black soils according to the INBS criteria (< 25 cm) and cultivated mostly as arable land (represented by Chernozems and Phaeozems). Only a smaller part of these soils – without mollic horizon (Andosols, resp. Umbrisols) – belong to the soils with low fertility and are mostly situated in forest protected areas on some volcanic rocks, especially with the occurrence of volcanic

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glass. Total area of these soils is about 8.7% of soil cover in Slovakia. All the groups of black soils (within and outside of the INBS criteria) have to be strongly protected.

Keywords: black soils, INBS criteria, soil monitoring, Chernozems, Phaeozems, Umbrisols, Andosols, Slovakia

INTRODUCTION

The presentation of the International Network of Black Soils took place during the Global Symposium on Soil Organic Carbon (21–23 March 2017) at GSP FAO headquarters in Rome, Italy. "Black soils" is a term used in some national soil classification systems and may cover very different types of soil. These soils are variously classified, e.g. according to the USDA soil taxonomy, black soils correspond with Mollisols, and in the WRB system (2014), black soils are represented by Chernozems, Kastanozems and Phaeozems. In some countries, e.g. in India, they are classified as Vertisols (Roy and Barde 1962). Black soils in China are represented with high content of SOM (6–8%) (Wen and Liang 2001). According to preliminary analysis, 62 countries in the world have more than 5% of black soils. As regards the EU, they are mostly found in Bulgaria, the Czech Republic, Hungary, Romania and Slovakia (Kobza and Pálka 2017). According to the INBS criteria, black soils in Slovakia are represented mostly by Chernozems and Phaeozems (WRB, 2014). We have already evaluated these soils in 2020. A common feature of mollic floodplain soils in the temperate zone is the accumulation of soil organic matter (SOM), causing enhanced contents and stocks of SOC as compared to terrestrial soils outside of the fluviatile environment (Zehetner *et al*. 2009, Graf-Rosenfellner *et al*. 2016, Rennert *et al*. 2018, 2021). However, information on qualitative SOM composition in mollic horizons of floodplain soils is still very limited (Schmidt *et al*. 1999, Thiele-Bruhn *et al*. 2014). Black soils are characterised by dark grey to black colour with high to very high content of SOM, using the INBS criteria in the range of 2–20%. High content of SOM is not the only criterion for black soils. The other criteria include: min. depth of humus horizon (25 cm); high base saturation (greater than 50%), umbric, also melanic and fulvic epipedons are excluded; poorly-drained soils are excluded as well. In case of the black soils in Slovakia, all these criteria are not met. Limited indicators of black soils outside of the INBS criteria are depth of humus horizon less than 25 cm where the soil properties are practically the same as in black soils using the INBS criteria (represented by Chernozems and Phaeozems, particularly Umbrisols). Another special group of black soils with low soil reaction (pH/H2O < 5.5 and pH/KCl < 5.0), low base saturation (< 50%) with high content of SOM (≥ 5%) is represented mostly by Andosols, particularly Umbrisols. Although these soils constitute only about 8.7% of soil cover in Slovakia, they are very important, especially as regards the landscape protection.

MATERIALS AND METHODS

Black soils outside of the INBS criteria (depth of humus horizon < 25 cm, content of SOC > 2% and content of SOM in the range of 2–20%, low base saturation < 50%) have been evaluated based on national information system (soil profiles from complex soil survey – 17,620) and national soil monitoring sites of Slovakia (318) in GIS. In addition, the basic soil properties (pH, SOC, Nt, BS, C_{HA}/C_{FA}, Q^4_6, textural fractional composition, bulk density) were compared and evaluated on the example of 4 soil profiles of black soils outside of the INBS criteria according to various land use (arable land, grassland and forest land). A common denominator of these soils is high to very high content of SOM, other indicators in comparison with black soils according to the INBS criteria are different. Finally, it also refers to different soil fertility in comparison with black soils estimated according to the INBS criteria.

Monitored indicators

In the paper, the following indicators were examined: pH/H_2O (1:2.5), pH/KCl (1:2.5), SOC (using the wet oxidation procedure according to the Walkley–Black method), Nt (using the Kjeldahl method, ČSN ISO 1871), humic acids (HA), fulvoacids (FA), Q^4_6 (according to the Kononova-Beľčikova method) available phosphorus and available potassium (using the Mehlich 3 method), base saturation (BS) – using the Kappen method, melanic index (MI) – using a 0.5 M NaOH solution, and the absorbance of the extract is measured at 450 and 520 nm, respectively. There were also analysed the fractional mechanical composition (according to USDA soil taxonomy), and bulk density (using physical cylinders with the volume of 100 cm^3). Chemical and physical procedures have been performed at the National Agricultural and Food Centre – Soil Science and Conservation Research Institute in Bratislava (Kobza *et al*. 2011). The obtained results have been evaluated according to statistical procedures used in GIS.

RESULTS AND DISCUSSION

A common feature of black soils is the accumulation of SOM and its conversion. Composition of SOM depends on soil genesis and conditions in which the soils have been developed. Black soils originally have been developed in steppe conditions mostly on loess, resp. loess-like loam soil forming colder and wetter conditions, especially in volcanic rocks with fragments of volcanic glass (mostly in mountainous regions). Humus horizon of these soils is dark grey to black colour (according to Munsell Soil Colour Chart, value of ≤ 3 moist and chroma of ≤ 3 moist) which is in accordance with high to very high content of

SOM but its quality is rather different (represented from mollic to fulvic humus horizons) in Slovak conditions. A substantial part of these soils does not meet the INBS criteria. Distribution of these soils is shown in Fig. 1.

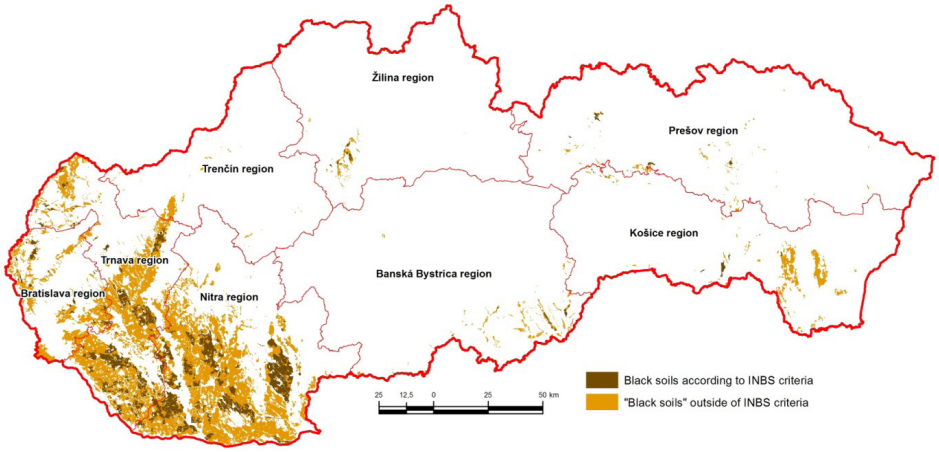

Fig. 1. Distribution of black soils in Slovakia

Black soils with mollic horizon are mostly situated on floodplain. Tockner and Stanford (2002) assumed that floodplains are the most anthropogenically changed ecosystems in Europe. In Slovakia, these soils represent mostly Chernozems and Phaeozems. Łabaz and Kabala (2016) suggested the formation of mollic horizons after drainage and ploughing of histic material, similar to the proposition put forward by Rehfuess (1990), or a constructive process, i.e. formation of stable mollic SOM *in situ*, affected by Ca-containing groundwater (Kohl *et al*. 1954). Black soils outside of the INBS criteria are mostly situated in the south-western part of Slovakia and cover the total area of 381,950 ha, i.e. about 8.7% of soil cover (agricultural and forest land together) in Slovakia. These soils belong to the most fertile soils with mollic horizon represented by Chernozems and Phaeozems. In addition, only a small part of black soils occurs in more cold and moist regions (mostly in volcanic mountains with volcanic rocks – andesites and their pyroclastics) with fulvic humus horizon (melanic index [MI] > 1.7) (WRB 2014). These soils do not form continuous areas but occur only fragmentarily with total area of about 10,000 ha, i.e. about 0.15% of Slovak soil cover (Kobza 1999).

Part of the evaluated black soils with mollic horizon out of the INBS criteria is mostly situated on the edges of Chernozems and Phaeozems areas, especially with Luvisols and Planosols, resp. on the eroded depositions where the humus horizon is shallower than 25 cm which is out of the INBS criteria for black soils (Fig. 2).

Fig. 2. Haplic Chernozem (Siltic, Anthric) with thickness of A horizon less than 25 cm. Locality: Jaslovce (western part of Slovakia)

The occurrence of dark-coloured humus horizons is a reflection of more or less historical hydromorphic phase in soil cover development where the accumulation of humus under recent conditions is rarely a predominant soil-forming process. The change in the groundwater level contributed to historical development of soils under changed hydromorphic, semihydromorphic and automorphic conditions often on small areas. In addition, according to some micromorphological studies, the brown diffusely dispersed forms of humus are often visible (Čurlík 1975). It was confirmed also by detailed quaternary geological research, in which such sediments are described as deluvial or proluvial (Vaškovský and Halouzka 1976, Koštialik 1974). After the Würm period, the origin relief by the planation process has been created with a smooth relief of colourful mosaic of soils (in this case mosaic of black and bright soils – Phaeozems and Planosols) (Fig. 4).

Soil cover in Slovakia is characterised by different soil properties and different fertility. On the example of three localities, basic soil properties of black soils outside of the INBS criteria according to various land use (arable land, grassland and forest land) are evaluated in the next part of this contribution. Tables 1 and 2 show the basic chemical and physical properties in humus horizons of black soils outside of the INBS criteria.

Table 1. Basic chemical properties in A horizon of black soils outside of the INBS criteria

Localities	pH/ H_2O	pH/ KCl	BS (%)	SOC (%)	Nt (%)	C/N	C_{HA}/C_{FA}	Q_6^4	P ($mg.kg^{-1}$)	K ($mg.kg^{-1}$)	MI (%)
Jaslovce (arable land)	7.5	7.1	96.6	1.32	0.15	9.0	1.23	4.22	43.9	247.0	-
Dúbrava (arable land)	6.3	5.6	78.3	2.57	0.30	8.56	0.75	4.40	103.6	230.0	-
Poľana – Kalamárka (grassland)	5.5	4.8	15.0	5.5	0.47	11.7	0.90	4.06	45.61	142.74	1.75
Suchá Hora (forest)	4.3	4.0	2.0	12.7	0.92	13.8	0.38	6.36	21.18	125.68	2.63

BS – base saturation, SOC – soil organic carbon, Nt – total nitrogen, HA – humic acids, FA – fulvoacids, Q_6^4 – colour quotient, P – available phosphorus, K – available potassium, MI – melanic index

Table 2. Basic physical properties in A horizon of black soils outside of the INBS criteria

Localities	Fractional mechanical composition (%)			Bulk density ($g.cm^{-3}$)
	< 0.002 mm	0.002–0.05 mm	0.05–2 mm	
Jaslovce (arable land)	28.64	50.76	20.60	1.23
Dúbrava (arable land)	11.71	66.45	21.84	1.00
Poľana – Kalamárka (grassland)	10.45	65.73	23.82	0.82
Suchá Hora (forest)	10.72	29.72	59.56	0.42

Soil profiles presented in Table 1 represent two basic groups of black soils outside of the INBS criteria. The first one includes similar soil indicators like black soils with the INBS criteria except depth of humus horizon which is shallower than 25 cm (Fig. 3). The next soil profiles are significantly different with their soil indicators except colour (10YR 2/1, 2/2) (Fig. 5 and 6).

Fig. 3. Luvic Phaeozem (Anthric, Loamic).
Locality: Dúbrava (*Liptovská kotlina basin*) in central Slovakia

Fig. 4. Heterogeneity of black and bright soils in small area (*Turčianska kotlina basin*) in central Slovakia

Fig. 5. Skeletic Umbrisol (Andic, Loamic). Locality: Poľana – Kalamárka (central Slovakia)

Fig. 6. Dystric Umbric Andosol (Fulvic, Loamic, Thixotropic).
Locality: Suchá Hora in the Kremnica Mountains (central Slovakia)

Jaslovce – the first of the study areas – is situated in the western part of Slovakia where black soils predominate (Fig. 2). These soils are characterised by neutral soil reaction and high base saturation and soil humus is of high quality ($C_{HA}/C_{FA} > 1$). In addition, C/N ratio belongs also to the main indicators of the quality of SOM (Sotáková 1982) and, at the same time, it is a good indicator of dynamics of soil quality (Franzluebbers 2002). According to our previous work (Kobza and Pálka 2020) concerning black soils in Slovakia, the values of C/N ratio are even tempered and they range between 8.08 to 11.57, which confirms a medium supply of nitrogen. Jaslovce meets this range of C/N ratio at the level of 9.0 (Table 1). Similar value of C/N (8.56) has a soil profile Dúbrava (Liptovská Kotlina Depression) (Fig. 3), but the humus is worse in terms of quality (C_{HA}/C_{FA} is less than 1, only 0.75) (Table 1). Since it is arable area, the content of available potassium is good, but the content of available phosphorus is mostly low (Kobza and Gáborík 2008). Finally, the content of available phosphorus is low to very low also in the next soil profiles – Poľana Kalamárka (grassland) and Suchá Hora in the Kremnica Mountains (forest land), which is a result of natural supply without fertilization (Table 1, Fig. 5 and 6). These two soil profiles are situated in the central part of Slovakia – in volcanic mountains (Poľana and the Kremnica Mountains). These soils are acid to very acid, unsaturated with high content of soil organic carbon (SOC) (5.5–12.7%) calculated on SOM (9.5–21.9%) (Table 1). The highest value of SOC was determined logically in the area covered by forest (Suchá Hora in the Kremnica Mountains). The high content of humus in this soil can be caused by the creation of allophane-organic matter complexes (Kobza 1999).

Total nitrogen (Nt) content is in correlation with high content of SOM. The content of Nt in compared soil profiles (Poľana and the Kremnica Mountains – Suchá Hora) was determined in the range of 0.47–0.92% (Table 1). These values are the highest from among the soils of Slovakia (Bielek 1984). The C/N ratio is in the range of 11.7–13.8. The C_{HA}/C_{FA} ratio is lower than 1 which indicates the poorest quality of SOM. Melanic index is higher than 1.7 which refers to fulvic humus horizon (WRB 2014). It is in accordance with colour quotient Q^4_6 which is higher than 4. The content of available nutrients phosphorus and potassium is low, only the content of available potassium in Poľana – Kalamárka locality is sufficient. It is a natural supply of available nutrients (extensive grassland and forest). Basic physical properties (texture – fractional mechanical composition and bulk density) are listed in Table 2.

From among the compared soil profiles, the highest content of silt fraction prevails, except for the soil profile in forests where the sand fraction is highest due to weathering of the gravel material. Clay fraction (< 0.002 mm) predominates in Jaslovce (Chernozem, arable land) which is in correlation with bulk density where its value is the highest but suitable for agricultural cultivation (MPRV SR, Decree 59/2013 of the Slovak Republic). Average value of bulk density for black soils in Slovakia is 1.30 $g.cm^{-3}$ (Kobza *et al*. 2019).

The next soil profiles (Poľana and the Kremnica Mountains – Suchá Hora) are rather different, especially as regards the bulk density which is in relation to soil organic carbon (SOC). Bulk density of these soil profiles is represented by low values (< 0.9 $g.cm^{-3}$) what is one of the criteria for Andosols. The content of SOC is highest in evaluated soil profiles, but it is of the poorest quality ($C_{HA}/C_{FA} < 1$, $Q^4_6 > 4.0$).

In comparison, the average qualitative parameters of SOM in black soils according to the INBS criteria in Slovakia are as follows: C_{HA}/C_{FA} – 1.28, C/N – 9.79 with an average depth of A humus horizon (mollic) 57 cm (Kobza and Pálka 2017, 2020).

Limited factors of black soils outside of the INBS criteria is the depth of A humus horizon (mollic) – often shallower than 25 cm, also the black soils often with worse quality of SOM ($C_{HA}/C_{FA} < 1$) – fulvic horizons. Finally, black soils are very heterogenous with different soil properties (pH, base saturation, quality of SOM, textural fractional composition, content of available nutrients) which is in relation to genesis and soil forming materials as well as the way of cultivation and land use.

CONCLUSIONS

Black soils in Slovakia could be divided into the two main groups, the first one is represented by black soils determined according to the INBS criteria with the total area of 93,655 ha (2.1% of soil cover) (Kobza and Pálka 2020). The second group is represented by black soils outside of the INBS criteria with the total area of 381,950 ha (8.7% of soil cover). It may be said that soil properties of both groups are very similar (represented mostly by Chernozems and Phaeozems), only in the second group of black soils, minimum one parameter is outside of the INBS criteria (humus horizon A is shallower than 25 cm and/or content of SOC is slightly lower than 2%). A small part (less than 1%) of this group is represented by Andosols which are situated mostly in forests in volcanic deposits often with the occurrence of volcanic glass. These soils (compared to black soils according to the INBS criteria) (Kobza and Pálka 2017) are characterized by low base saturation (50%). In general, black soils in Slovakia belong mostly to the most fertile soils, cultivated as arable land (represented mostly by Chernozems and Phaeozems), only a small part of these soils – Umbrisols, Andosols – is situated mostly in forest protected areas on some volcanic rocks, especially with the occurrence of volcanic glass.

Finally, in order to better characterize black soils, it would be more useful (apart from the recommended diagnostic criteria according to WRB 2014, resp. 2015) to get to know other analytical characteristics, especially those concerning the fractional composition of humus and humic acids. It is necessary that all black soils (evaluated both according to the INBS criteria and outside of them) are strongly protected.

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