# Soil subtypes classified in Nature Reserve Arboretum Mlyňany, Slovakia

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**Abstract**

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Main aim of this work was soil classification in Nature Reserve Arboretum Mlyňany. In Arboretum locality were dug nine soil pits and in detail characterized soil properties. Near each pit were made 3 soil bores which were analysed only for selected chemical properties. It was found that on the majority of Arboretum area was soil forming substrate loess without carbonates on which was developed Stagni-Haplic Luvisol. Carbonate loess was found at north part of area with East-Asiatic dendroflora, where was developed Haplic Luvisol. Cultivated Stagni-Haplic Luvisol was classified on the area with North-American dendroflora, which was until 1975 used as a vineyard and homogenization characters of ploughing horizon are still clear. Compared to the soil under the rest of natural Oak-hornbeam forest (control), anthropically changed type of vegetation significantly influenced soil chemical properties mainly in humus horizons. The heterogeneity of soil properties was also caused by heterogeneous soil forming substrate, different way of soil use before trees planting, and earth works during Arboretum establishment.

**Key words**

organic carbon, pH, soil classification, soil morphology

## Introduction

Soil properties in the Arboretum have long been neglected, despite beside the climate, also soil significantly decides about growing and adaptation of exotic trees. Soil properties affect not only plants rooting and growth, but also their development, succession and health (Tokár and Kukla, 2008). On the contrary, plants significantly affect soil properties by their root secretions and penetration, plant residues, influence soil erosion and accumulation, soil structure, organic matter dynamics, soil chemical composition and hydrology (Konôpková and Tokár, 2000; Philips and Marion, 2004; Šimanský, 2011, 2012). Hence, the change of vegetation considerably influences soil.

Already Dr. Ambrózy and his gardener Mišák realized that properties of soil where they intended to establish Arboretum were not suitable for demanding Mediterranean trees. On some sites the soil was so poor for mineral nutrients that it had to be excavated and pits were filled by better soil transported from Čifáre. Macroclimatic disadvantages they mitigated by microclimate modification what was reached by various landscaping, soil transfers, creation of artificial slopes, hollows and terraces (Steinhübel, 1957).

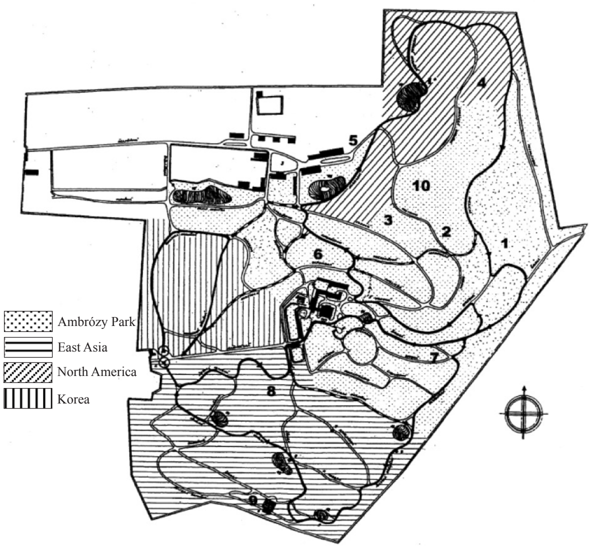
Basic soil survey in Arboretum was done by Cifra (1958), but in the past was valid old soil classification, many analyses were done by other methods and results were evaluated differently. Therefore, main aim of this work was soil survey and soil classification in Arboretum Mlyňany.

## Material and methods

Arboretum Mlyňany (48º19' N, and 18º21' E) is located in southern Slovakia on the north edge of the Danubian Lowland, in the valley of Žitava river, on slightly undulated terrain, at an altitude of 165–217 m above sea level. It is situated on a late Tertiary geological formation, represented by Neogene clays, sands and rubble sands (Steinhübel, 1957). This substratum is almost all covered by wind-deposited loess, mostly without carbonates (Cifra, 1958). Mean temperature in the area is 10.6 °C and mean annual total precipitation is 541 mm (Hrubík et al., 2011).

### Soil sampling and analyses

In Arboretum were dug nine soil pits in which were characterized soil morphological properties and were taken soil samples for physical and chemical analysing. Near each pit were made 3 soil bores which were analysed only for selected chemical properties. Soil pits were located sophistically, in order to classify soil in Arboretum and hereby to compare soil properties under different introduced and indigenous tree growths and grassland. On the area of original Ambrózy Park, natural vegetation was oak-hornbeam forest, therefore soil under the rest of this forest was chosen as control. Soil pits were dug under following plants: natural oak-hornbeam growth of oaks (*Quercus cerris,* L.) and hornbeams (*Carpinus betulus*, L.), under grassland, dense growth of spruces (*Picea abies,* (L.) Karsten), sugar maples (*Acer saccharinum,* L.), white fires (*Abies concolor,* Lindl. et Gord.), yews (*Taxus baccata,* L.), cherry laurels (*Prunus laurocerasus,* L.), Himalayan pines (*Pinus wallichiana,* Jacks.), Japanese cedars (*Cryptomeria japonica,* D. Don.). Under Jeffrey pines (*Pinus Jeffreyi,* Grev. et Balf.) were made only four soil bores (Fig. 1).




1, Grassland; 2, Spruces; 3, Oaks-hornbeams; 4, Sugar maples; 5, White fires; 6, Yews; 7, Cherry laurels; 8, Himalayan pines; 9, Japanese cedars; 10, Jeffrey pines.

Fig. 1. Location of stands (1–10) in Arboretum.

Total soil organic carbon content ($C_T$) was analysed by Tyurin method (Orlov et al., 1981); soil reaction – potentiometrically in $H_2O$, 1 mol dm$^{-3}$ KCl (1:2.5); exchangeable base ions and hydrolytic acidity by Kappen's method (Fiala et al., 1999).

Each analysis was done in 3 repeats. Results shown in Table 1 represent the average values of the three soil bores and one soil pit made on particular stand. For statistical evaluation was used analysis of variance anova – Scheffe method.

## Results and discussion

Evaluated soil profiles significantly differed in morphological characters, mainly in the horizons thickness, color, depth and rooting intensity. Under spruces, sugar maples, yews and cherry laurels was found also rounded gravel at size about 10–50 mm.

On the majority of Arboretum area was soil forming substrate loess without carbonates and loam on which was developed Stagni-Haplic Luvisol (soil under growth of oaks-hornbeams, grassland, spruces, white fires, yews, cherry laurels, Japanese cedars and Jeffrey pines). Carbonate loess was found at north part of area with East-Asiatic dendroflora (under Himalayan pines), where was developed Calcic Luvisol (WRB, 2006). Homogenization characters of ploughing horizon were still clear in soil, which was until 1975 used as a vineyard, therefore soil on the area with North-American dendroflora (under sugar maples) was classified as Stagni-Haplic Luvisol Anthric (WRB, 2006). Otherwise, soil under area with East Asiatic dendroflora, which was until 1960 used as an arable land had already indistinct homogenization characters of ploughing horizon, therefore soil under growth of Japanese cedars and Himalayan pines was not classified as Anthric subtype.

Soil texture in Arboretum was predominantly silt loam, loam and clay loam. The clay was markedly transferred from surface to subsurface horizons in illimerization process and the coefficient of textural differentiation in all profiles was higher than 1.2. The most significant illimerization was found under cherry laurels, where the coefficient between Bt-luvic and Btg-stagni-luvic horizon reached value 2 (Szombathová, 2010).

The average values of basic chemical properties (calculated from three soil bores and one soil pit made on particular stand) are written in Table 1. Obtained results showed that on some stands the soil properties were considerably heterogeneous. Great heterogeneity could be caused by various soil forming substrate, earthworks done before Arboretum establishment, due to various land use, or growing of different trees.

Table 1. pH values, organic carbon content and soil sorption characteristics

| Horizon, depth | $pH_{H2O}$ | $pH_{KCl}$ | $C_T$ | H | S | CEC | BS |
|---|---|---|---|---|---|---|---|
| [m] | | | [g kg$^{-1}$] | | [mmol kg$^{-1}$] | | [%] |
| | | | Grassland (1) | | | | |
| Au 0.0–0.25 | 6.15±0.3 | 5.79±0.3 | 14.9±1.6 | 20.0±7.6 | 209.0±58.3 | 228.9±63.5 | 91.1±2.6 |
| | c | d | a | a | bcd | ab | d |
| Bt 0.25–0.55 | 6.24±0.4 | 5.70±0.4 | 4.8±0.8 | 17.2±4.6 | 205.9±72.2 | 223.1±76.2 | 92.1±1.6 |
| Btg 0.55–0.80 | 5.68±0.2 | 4.95±0.3 | 3.7±0.9 | 27.6±11.1 | 237.5±78.0 | 265.1±87.1 | 89.4±2.3 |
| | | | Spruces (2) | | | | |
| Ao 0.0–0.15 | 4.43±0.2 | 4.19±0.1 | 20.5±4.2 | 109.2±30.2 | 93.1±39.9 | 202.3±61.7 | 44.9±11.7 |
| | a | ab | ab | cd | ab | ab | ab |
| Bt 0.15–0.48 | 4.6±0.2 | 4.25±0.1 | 9.2±1.5 | 83.4±21.4 | 97.4±40.8 | 180.8±48.0 | 51.7±14.4 |
| Btg 0.48–1.2 | 4.97+0.2 | 4.46±0.1 | 4.3±0.8 | 42.6±9.7 | 232.2±86.5 | 274.9±93.6 | 83.4±4.7 |
| | | | Oaks–hornbeams (3) | | | | |
| Au 0.0–0.15 | 4.66±0.2 | 4.21±0.2 | 22.1±2.5 | 124.7±28.2 | 68.8±27.1 | 193.5±10.0 | 36.1±15.0 |
| | a | ab | ab | d | a | ab | a |
| Bt 0.15–0.50 | 4.73±0.3 | 4.33±0.2 | 12.0±1.4 | 100.1±30.3 | 78.2±27.6 | 178.2±11.8 | 44.3±16.2 |
| Btg 0.50–0.80 | 5.19±0.2 | 4.70±0.2 | 6.8±1.0 | 39.3±6.6 | 189.1±19.8 | 228.4±16.4 | 82.5±3.5 |
| | | | Sugar maples (4) | | | | |
| Akp 0.0–0.20 | 4.73±0.3 | 4.23±0.4 | 23.5±3.3 | 66.4±12.2 | 114.4±27.8 | 180.8±16.1 | 62.4±9.9 |
| | a | ab | ab | abc | abc | ab | abc |
| Bt 0.20–0.40 | 4.63±0.2 | 4.13±0.5 | 12.0±3.7 | 61.2±14.0 | 106.0±31.5 | 167.1±20.8 | 62.4±11.0 |
| Btg 0.40–1.1 | 4.78±0.4 | 4.11±0.5 | 4.5±1.0 | 47.9±8.9 | 143.5±12.9 | 191.2±10.7 | 74.8+4.8 |
| | | | White fires (5) | | | | |
| Ao 0.0–0.10 | 6.12±0.4 | 5.60±0.6 | 36.1±11.2 | 30.1±17.4 | 265.1±59.3 | 295.2±54.2 | 89.3±7.6 |
| | c | cd | b | ab | d | b | d |
| A/Bt 0.10–0.40 | 6.02±0.5 | 5.60±0.7 | 20.9±6.7 | 25.2±15.2 | 228.9±57.2 | 254.2±50.2 | 89.1±7.8 |
| Bt 0.40–0.75 | 6.07±0.2 | 5.44±0.6 | 5.3±1.2 | 16.0±6.1 | 196.6±42.5 | 212.6±40.3 | 92.1±4.0 |
| | | | Yews (6) | | | | |
| Ao 0.0–0.20 | 4.44±0.2 | 3.98±0.3 | 22.5±2.1 | 73.8±4.9 | 119.3±16.6 | 192.9±14.3 | 61.4±4.4 |
| | a | a | ab | bc | abc | ab | abc |
| Bt 0.20–0.60 | 4.47±0.3 | 3.87±0.4 | 11.1±1.5 | 63.0±15.7 | 123.6±32.0 | 195.4±18.0 | 66.3±11.4 |
| Btg 0.60–0.9 | 4.57±0.2 | 3.80±0.3 | 5.1±0.4 | 49.1±5.8 | 204.4±33.5 | 253.5±30.7 | 80.2±4.3 |
| | | | Cherry laurels (7) | | | | |
| Au 0.0–0.23 | 4.92±0.1 | 4.27±0.3 | 22.7±3.0 | 54.3±3.2 | 102.5±18.2 | 156.6±15.9 | 64.8±5.1 |
| | a | ab | ab | ab | abc | a | bcd |
| Bt 0.23–0.60 | 4.8±0.2 | 3.88±0.3 | 9.4±0.7 | 50.1±9.7 | 80.6±18.3 | 130.7±9.1 | 60.8±10.5 |
| | | | Himalayan pines (8) | | | | |
| Au 0.0–0.25 | 6.02±0.2 | 5.18±0.2 | 16.3±3.1 | 27.1±4.0 | 224.5±13.6 | 251.5±12.2 | 89.2±1.8 |
| | bc | bcd | ab | ab | cd | ab | d |
| A/Bt 0.25–0.35 | 6.46±0.3 | 5.34±0.1 | 8.7±1.2 | 24.1±5.9 | 237.6±17.2 | 248.2±8.2 | 90.8±2.0 |
| Bt 0.35–0.60 | 7.30±0.6 | 6.22±0.5 | 5.7±1.1 | 14.1±5.0 | 263.3±16.3 | 277.3±11.7 | 94.8±2.0 |
| | | | Japanese cedars (9) | | | | |
| Au 0.0–0.20 | 5.06±0.2 | 3.37±0.1 | 17.4±3.5 | 49.1±11.2 | 190.6±25.2 | 239.7±18.5 | 79.2±5.3 |
| | ab | a | a | ab | abcd | ab | cd |
| Btg 0.20–0.8 | 5.13±0.2 | 3.27±0.3 | 4.7±1.8 | 37.9±9.5 | 234.1±36.8 | 259.1±22.9 | 85.3±3.0 |

Table 1. pH values, organic carbon content and soil sorption characteristics – continued

| Horizon, depth | $pH_{H2O}$ | $pH_{KCl}$ | $C_T$ | H | S | CEC | BS |
|---|---|---|---|---|---|---|---|
| [m] | | | [g kg$^{-1}$] | [mmol kg$^{-1}$] | | | [%] |
| | | | Jeffrey pines (10) | | | | |
| Au 0.0–0.20 | 5.18±0.3 | 4.52±0.3 | 23.4±2.5 | 46.0±6.4 | 145.9±8.4 | 191.8±12.1 | 76.4±2.3 |
| | abc | abc | a | ab | abcd | ab | cd |
| Bt 0.20–0.60 | 5.53±0.4 | 4.48±0.5 | 9.9±1.7 | 32.0±7.8 | 142.7±17.2 | 174.7±16.8 | 81.5±4.8 |
| Btg 0.60–0.90 | 5.17±0.3 | 4.06±0.2 | 4.3±0.5 | 36.4±6.7 | 170.1±11.9 | 206.5±14.3 | 82.4±2.9 |
| Scheffe < 0.05 | 0.9999 | 1.1517 | 16.387 | 46.931 | 125.86 | 126.61 | 26.45 |

Results in this table represent the average values of the three soil bores and one soil pit made on particular stand. Different letters (a–d) indicate, soil properties in A horizons are significantly different at $P < 0.05$ according to Scheffe test.
H, hydrolytic acidity; S, sum of bases; CEC, cation exchange capacity; BS, base saturation; $C_T$, soil organic carbon.

In Arboretum was also examined the influence of different vegetation on soil chemical properties. Differences were studied particularly between humus A-horizons which were the most affected by litter, root exudates and residues. Results showed that humus horizons were statistically significantly affected by vegetation type (Table 1).

Soil reaction is the most important indicator of the state, functioning and fertility of soil. In Arboretum profiles dominated slightly acidic to acidic active soil reaction, exchangeable soil reaction was acidic to strongly acidic. The type of vegetation had significant effect on changes of active soil reaction in A horizons, and the highest statistical difference was found between spruces and grassland. For exchangeable soil reaction the highest statistical difference was in A horizons between the cedars and grassland ($P < 0.05$). On the area of old Ambrózy Park, soil reaction of humus horizon significantly increased under grassland compared to the rest of original oak-hornbeam forest (Table 1).

Beside pH, usual indicators of soil acidity are cationic composition of sorption complex and soil saturation by aluminum. Porębska et al. (2008) stated that pH values can be considered as an indicator of overall soil acidification for a period of time, while changes in cationic composition of sorption complex reflect particular stages of this process. In Arboretum, high production of fulvic acids and low molecular organic acids during decomposition of poor quality residues provided by trees, resulted to very strong hydrolytic acidity (H), especially in the A and Bt horizons. Acids in the soil reacted with base cations and percolating water moved them from upper parts of profile to lower. Simultaneously, the sorption complex in A and Bt horizons was saturated by acidic cations, while in lower parts of profiles were accumulated base cations. This resulted to increased sum of exchange base cations (S) as well as the degree of sorption complex saturation by base cations (BS) in lower parts of profiles (Table 1).

In humus horizon, under the rest of original oak-hornbeam forest were recorded significantly ($P < 0.05$) the highest values of H and the lowest S, as well as BS (Table 1). Stronger soil acidity under oak-hornbeam growth was probably due to longer period of its influence on soil (Arboretum was established in year 1892 in the original oak-hornbeam forest). Since other tree species were younger, the duration of their action on soil was shorter therefore their influence on soil chemical properties was not so distinct. According to Hagen-Thorn et al. (2004), 40–50 years old trees in temperate regions distinctly influenced soil chemical properties in upper 0.0–0.1 m, less in layer 0.2–0.3 m. In Arboretum, the time of influence of particular trees on soil was different, because the area with East-Asiatic dendroflora was established in 1964, North American in 1975, and with Korean dendroflora in 1985.

The content of total organic carbon ($C_T$) in soil is regulated by the balance between biotic inputs and losses and abiotic conditions involving climate, topography and soil type. Plants belong to major source of carbon inputs to soil. The quality of plant residues significantly affects their decomposition and loss of carbon from soil (Vesterdal et al., 2008). In all studied profiles of Arboretum, the $C_T$ content decreased with increasing depth (Table 1) and the type of vegetation had statistically significant effect on changes of $C_T$ content in humus horizons. The highest statistical difference was found in A horizons between grassland and white fires ($P < 0.05$).

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# Pôdne subtypy klasifikované v Prírodnej rezervácii Arborétum Mlyňany, Slovensko

## Súhrn


Bol urobený pôdoznalecký prieskum a klasifikácia pôd v Prírodnej rezervácii Arborétum Mlyňany. V lokalite Arboréta bolo vykopaných deväť sond, v ktorých boli podrobne charakterizované morfologické, fyzikálne a chemické vlastnosti pôdy. V blízkosti každej sondy boli urobené tri pôdne vrty, v ktorých boli analyzované vybrané chemické vlastnosti. Bolo zistené, že na väčšine plochy Arboréta boli pôdotvorným substrátom odvápnené spraše a hliny, na ktorých sa vyvinula hnedozem pseudoglejová. Karbonátový sprašový substrát bol zistený v severnej časti plochy s východoázijskou dendroflórou, kde sa vyvinula hnedozem modálna. Subtyp hnedozem kultizemná pseudoglejová bol klasifikovaný na ploche so severoamerickou dendroflórou, ktorá sa do roku 1975 využívala ako vinice a homogenizácia ornicového horizontu je dosiaľ zreteľná. V porovnaní s pôdou pod zvyškom pôvodného

dubovo-hrabového lesa (kontrola), antropicky zmenený druh vegetácie preukazne ovplyvnil chemické vlastnosti pôdy najmä v humusových horizontoch. Heterogenita pôdnych vlastností bola zapríčinená aj rôznorodým pôdotvorným substrátom, rôznym spôsobom využívania pôdy pred výsadbou drevín, ako i zemnými prácami pri zakladaní Arboréta.

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