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BRIGHT PATCHES IN CHERNOZEMS AREAS ON LOESS – AN EVIDENCE OF SOIL EROSION AND RELIEF CHANGES

Jasne plamy na czarnoziemach – wskaźnik procesów erozyjnych oraz zmian w rzeźbie

Abstract: Soil erosion strongly influences the Chernozems in loessic hilly land in the Slovak part of the Danube Lowland. It leads to transformation of the original humus horizon to a brighter less humic horizon, which is easily distinguishable in terrain or on aerial photographs. Soil profile truncation and accumulation were analysed in the areas of bright patches. Differences in soil profiles, thereby indicating relief lowering or elevation within and between bright patches, were described.

Key words: bright patches, relief changes, erosion, GIS
Słowa kluczowe: jasne plamy, zmiany rzeźby, erozja, GIS

INTRODUCTION

Erosion processes – mainly water, wind and tillage erosion in agricultural areas in the Danube Lowland lead to significant changes in chemical and physical properties of soils (e.g. Bedrna 1970, Fulajtár 1994b, Styk 2002, 2004, Lehotský 2002). Soil material is continuously eroded, transported and accumulated as well as mixed and translocated by ploughing each year during tillage. Such processes could lead to degradation and change of soil types in a longer time period. Jambor (1992) and Jambor, Zrubec (1994) observed a change of Haplic Luvisol to Calcaric Regosols near Kočín in the Trnavská pahorkatkina Hill Land in thirty years (1961 – 1991). Jambor, Sobocká (1999) described transformation of Calcic Chernozems and Haplic Luvisols to Calcaric Regosols. Fulajtár (1999) studied long-term human impact on soils of the Podunajská Hill Land (hilly part of the Danube Lowland). He confirmed transformation of Leached Chernozems to Calcic Chernozems, and Luvic Chernozems to Haplic Chernozems, which had appeared in the past. He also characterized the degradation of Chernozems with mollic A (A_m) horizon to Calcaric Regosols with ochric A (A_o) horizon. This change resulted from intensive agriculture applied since the late 40´s (p. 39). Żyła (2008) brought the overview on research in Chernozems areas in Poland and described transformations of original soils.

The reduction of humus content and its quality, lowering of the thickness of humus horizon, change of carbonate content and other chemical and physical transformations lead to local differentiation of colour and reflectance. Eroded soils are brighter than surrounding Chernozems or Haplic Luvisols with non – eroded or accumulated A horizon. They are termed as bright patches. Their identification from aerial or satellite images is a well-recognized method for erosion mapping and risk assessment (Mulders 1987, Fulajtár 1994a, Šúri, Hofierka 1994, Šúri, Lehotský 1995, Fulajtár 1998, Sviček 2000, 2001, 2003, Fulajtár, Janský 2001, Styk 2003, Kolény et al. 2004). Comparison of aerial images taken in different years is used for evaluation of changes in eroded areas (Kohan 1993, Smetanová et al. *in press*). However, the accumulation of loessic material, liming or anthropogenic inversion of soil horizons could lead to false interpretation of aerial images (Fulajtár 1994a, Kolény et al. 2004). Patches created by accumulation represent areas of relief elevation. In the majority of patches opposite processes is active – the lowering of relief through erosion. Smetanová (2009) proved that geomorphic characteristics of bright patches could be very variable. Five basic types of bright patches were distinguished in 31 km^2 area in the Trnavská Hill Land. They differ in geomorphic characteristics (slope, size, shape, position in relief, content of morphometric elementary forms, concave forms of profile curvature etc.) that could refer to diverse genesis. The study supposes that transition forms between these types occur or parts of patches belong to various categories. Presuming that the bright patches or their parts were created by distinct processes (or their combination) with different intensity, the thickness of soil profiles, thereby relief changes, could also differ within them. The objective of the paper is to examine the differences of soil profiles within bright patches and to contribute to discussion on the use of aerial images in interpretation of relief changes.

STUDY AREA

The study area (91.2 ha) is situated near the village Voderady in the Trnavská pahorkatkina Hill Land, which is a part of the Podunajská pahorkatkina Hill

Land (the Danubian Hills) – more hilly part of the Danube Lowland in Slovakia (Fig. 1). In the Podunajská pahorkatkina Hill Land softly modelled relief on loess and loess-like deposits was developed. Chernozems, Haplic – Luvisols and Luvisols are dominant soil types.

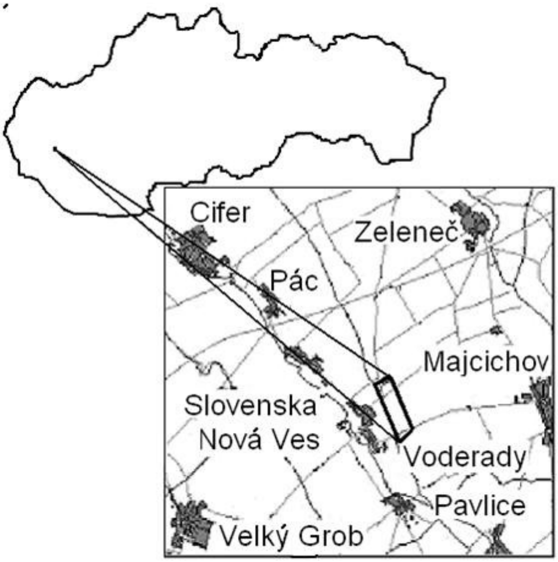

Fig. 1. Study area
Rys. 1. Obszar badań

The study area is situated in a relatively flat part of the Trnavská pahorkatkina Hill Land, in the Trnavská tabuľa Table. It represents the first order catchment of a shallow dry dellen and adjacent slopes. It cuts a relatively steeper slope between two levels of a tectonic depression of northwest - southeast direction. Its occurrence was a consequence of würm (or earlier) neotectonic fault activity. (Stankoviansky 1993, p. 96). A floodplain of a regulated brook of Ronava creates the western border of the study area. The vertical difference is 18m, southwest-oriented slopes predominate, average inclination is 1,3°. Haplic Chernozems on loess constitute the main soil type. According to the database of bonited pedo-ecological units (VUPOP 2005) also Calcaric Regosols - eroded Haplic Chernozems (12.9%) occur on slopes. Mollic Fluvisols Calcaric (14.8%) are situated on the floodplain of Ronava. The cumulative rates of recent erosion were estimated on 15 t $ha^{-1}a^{-1}$ (^{137}Cs measurement, Linkeš et al. 1992) and 6.7 t $ha^{-1}a^{-1}$ (erosion modelling, Smetanová 2008) in surrounding area. Average annual temperature is 9 – 10°C, precipitation 550 - 600 mm with prevailing NW, N and SE wind direction. Archaeological findings indicated the settlement since Paleolithic (Fűryová 1996). The majority (89%) of the area is arable land with large fields and intensive mechanical tillage.

METHODS

Firstly, the digital elevation model (DEM) was created from 756 input points (grid 40 x 40 m, with regard to morphology, measured in November 2008) obtained by electronic tachymeter Leica TC 1100 with precision of 0.01 m. DEM and derived digital terrain models (DTMs) of slope, aspect, profile, tangential curvature, and morphometric elementary relief forms were proceed in Grass Gis 6.3 using regularised spline with tension (Mitášová, Hofierka 1993). Several combinations of spline and tension parameters were tested. TIN model was also created in TerraModeler (MDL Application of MicroStation) to evaluate the interpolation precision. Secondly, bright patches were identified by visual interpretation of orthorectified aerial pictures and orthophotomaps from two relatively close years (1990, 2004). Two sources were used to obtain the largest possible data sets of bright patches. Analyses of their size, shape, slope, aspect, curvatures, elementary forms, position in relief and relationship to slope gradient followed.

Identification of bright patches and their characteristics allowed selection of drill places. Soil profiles were drilled by a percussion driller or dig manually. Their GPS coordinates and the thickness of soil profiles and horizons were registered. Colour, texture and local geomorphological situation were identified. Samples for chemical analyses of humus and carbonate content were taken and characteristics of soil profiles were analyzed. The paper contains preliminary results.

RESULTS AND DISCUSSION

Total amount of fourteen soil profiles on seven patches were described up to present. Two patches contain drilling at different cross-section and cross-sections with two or more drillings were done in three of them (Fig. 2). Soil profiles consist of different horizons. Mollic horizon with secondary carbonates (A) following by loess parent rock (C) is the typical sequence. Two fifth of drilled

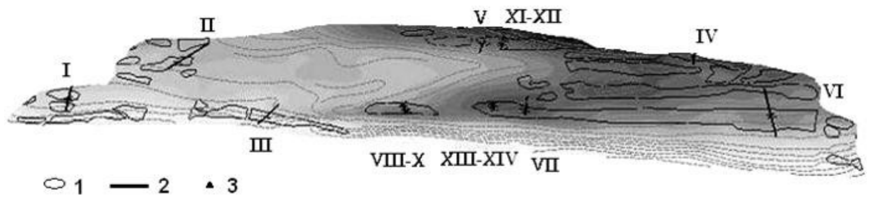

Fig. 2. Cross-sections and drillings: 1 – bright patches, 2 – cross-sections with drillings, 3 – drillings I-XIV

Rys. 2. Przekroje poprzeczne i wiercenia: 1 – jasne plamy, 2 – profile z wierceniami, 3 – wiercenia I-XIV soils contain transitional A/C horizon. First 10-43 cm of soil profile constitute the tillage horizon (Fig. 3). This part of soil is usually brighter, more aerated than underlying A horizon. Often it lies directly on loess. Original A horizon of Chernozems in this area is thick about 50 – 60 cm with 3-4% of humus and secondary carbonates. Erosion processes lead to transformation of this horizon to ochric horizon, where the volume of carbonates is increasing contrary to the decreasing amount of humus. With continuous decline of humus horizon brighter material of A/C or C horizon is slowly mixed into tillage horizon by ploughing.

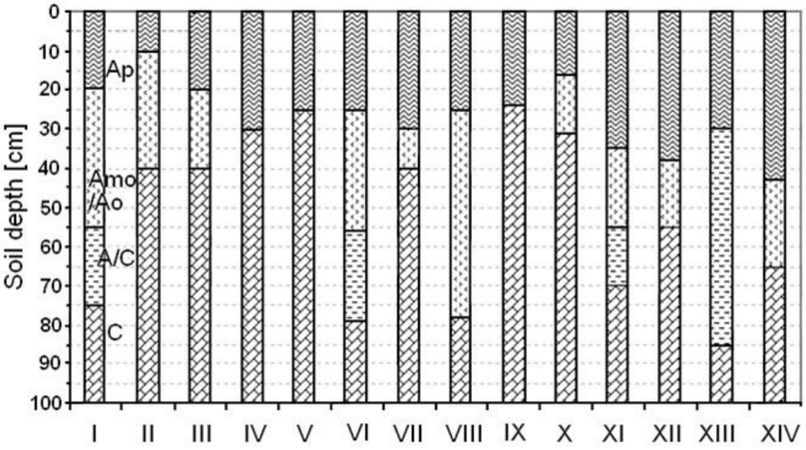

Fig. 3. Drillings: Ap – tilled Ap horizon, Amo/Ao – mollic/ochric horizon, A/C – transitional horizon, C – loess
Rys. 3. Wiercenia: Ap – poziom orny, Amo/Ao – poziom próchnicy mullowej/zubożona próchnica mullowa, A/C – poziom przejściowy, C – less

At the same time loessic material could be transported from upper parts of eroded slopes by water or tillage erosion and again incorporated into upper-most parts of described soil profiles (i.e. number VIII). More than half of the soil profiles (II – V, VII, IX, X, XIII) have mollic horizons smaller than 55 cm, while in the case of profiles numbered I, VI, XI, XII they are 55-56 cm thick. Only profiles VIII and XIV have thicker A horizon (78 cm and 65 cm respectively). Drillings were localized mainly on convex-concave morphometric elementary forms (Table 1), which prevail within the patches in study area. There were four drillings localized on slopes inclined 0-0.5° which dominate within the study area. The same number of drillings were performed on slopes that are most frequent within the bright patches (0.5-1°), other drillings were situated on slopes of 2.5-3°. Oval patches, elongated in tillage direction, predominate in the study area. Smetanova et al. (2009) suggest they have been spreading since 1949 due to prevailing contour tillage applied without consideration of local geomorphological

Table 1. Local geomorphological situation and position of drillings within bright patches
Tabela 1. Sytuacja geomorfologiczna wierceń i ich pozycja w obszarze plamy

	Local geomorphological			Bright patches		
Soil profile	Slope (°)	Aspect	Morphology of slope	Size (m^2)	Description	Position of drilling
I	0-0.5	SW	concave-concave	2925	circle-oval	on lower border
II	0.5-1	W	convex-concave	4768	irregural elongated in tillage direction	middle
III	2.5-3	W	concave-concave	7006	elongated in tillage direction, near upper field border	middle
IV	0-0.5	E	convex-concave	8215*	elongated patch on ridgeand saddle	on the ridge
V	2.5-3	W	convex-concave	26898*	irregural elongated in tillage direction, follows ridge, go over and on the ridge	under the ridge
VI	0-0.5	NE	convex-concave	52602	elongated in tillage direction (longer side 836 m long)	near SE border
VII	0.5-1	SW	convex-concave	see VI	see VI	middle
VIII	2.5-3	NE	concave-convex	7003	elongated in tillage direction	lower part
IX	2.5-3	NE	convex-concave	see VIII	see VIII	middle
X	0.5-1	E	convex-concave	see VIII	see VIII	upper part
XI	2.5-3	SW	border concave-convex and convex-convex	see V	see V	see V
XII	2.5-3	W	convex-concave	see V	see V	see V
XIII	0.5-1	SW	convex-concave	see VI	see VI	near NW border
XIV	0-0.5	E	convex-concave	see VI	see VI	near NW border

* area of bright patches extends over the border of study area

conditions. Local geomorphological situation of each drilling in a down-slope direction is presented in figure 4. If we compare four cross-sections (VI, VII and XIII, XIV) situated on the same patch, the change of topography within the patches is apparent. Drillings V and XI, XII represent two cross-sections on the same patch. They are 47 m distant from each other. Despite of the fact that drilling V is situated it the lower border of the bright patch, it shows a soil profile more eroded that in the drilling XII situated higher on slope on the same elementary form type. Sobocká, Jambor (1998) described similar occurrence of accumulated Chernozems within the same elementary forms. In the case of other patches (VIII, IX, X), the lowest drilling (VIII) shows a soil profile with the deepest, accumulated, A horizon. The soil profiles drilled on slope cross-section differ. Truncation is lower near the culmination of the cross-section profile (X, XIV) and accumulation is higher in lower slope position (VIII), which corresponds with the results obtained by Šúri, Lehotský (1995). The most eroded are

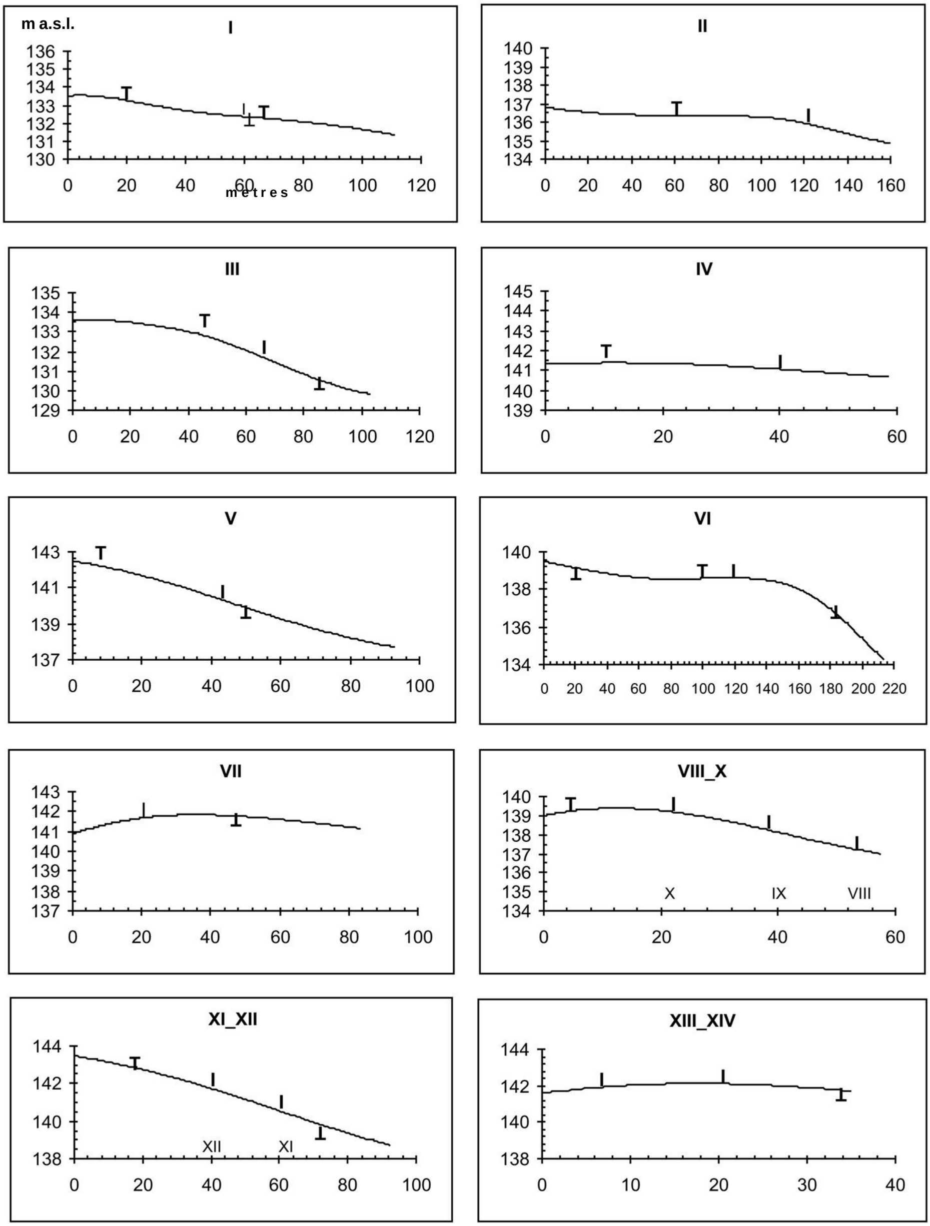

Fig. 4. Cross-section in slope direction: I – drilling, $\mathrm{T_T}$ – upper and lower border of bright patch (in slope direction)

Rys. 4. Przekroje poprzeczne w kierunku spadku: I – wiercenie, $\mathrm{T_T}$ – górna i dolna granica obszaru jasnej plamy (w kierunku spadku) middle parts, positioned further from culmination, as it is in the case of profiles IX and XIII. There is no thickness difference between A horizon of the higher situated drilling XII and the lower XI. Most eroded soil profiles (drillings IV, V, IX) have A-C profiles where tilled horizon is slightly distinguishable from brighter C horizon. Chemical analyses should be used to identify possible tillage of C horizon.

CONCLUSIONS

Preliminary results show differences in the degree of soil truncation between and within bright patches. Bright patches consist of eroded, non-eroded and accumulated soils. In non-eroded and accumulated parts, the mollic horizon is thicker due to in-situ development or accumulation of humus-rich material transported from upper parts of slopes. The tilled parts of soils are being changed by incorporation of bright material transported from eroded parts of slopes. Therefore visual interpretation of aerial images could bring incorrect results. More sophisticated methods based on combination of numerical interpretation of aerial images and relief analyses, together with larger amount of drillings need to be tested in further research.

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STRESZCZENIE

Na użytkowanych rolniczo obszarach czarnoziemnych jasne plamy na powierzchni gruntu są dowodem procesów erozyjnych, jakie zachodzą na stokach. Plamy te powstają w wyniku działania erozji wodnej, eolicznej i uprawowej. Są to miejsca, gdzie poziom orny gleby jest przekształcony do tego stopnia, że różni się jasnym kolorem od ciemnego poziomu próchnicznego czarnoziemów. Do oceny intensywności i kartowania zasięgu tego zjawiska wykorzystano zdjęcia lotnicze i satelitarne. W oparciu o wiercenia stwierdzono, że miejsca te charakteryzują się zróżnicowaną głębokością poziomu próchnicznego gleby oraz jego kolorem. Parametry te mogą być także zmienne w obrębie jednej plamy. Najbardziej zerodowane miejsca (plamy) znajdują się w górnej części stoku. Na obszarach położonych niżej najczęściej występują gleby niezerodowane lub deluvialne, w których dochodzi do akumulacji jaśniejszego materiału pochodzącego z górnych parti stoku. Może to prowadzić do błędów przy interpretacji zdjęć, kiedy miejsca, w których nastąpiła akumulacja - podniesienie powierzchni, są interpretowane jako miejsca dotknięte erozją, powodującą obniżenie terenu. Dlatego też celem dalszych badań będzie sprawdzenie możliwości wykorzystania bardziej zaawansowanych metod do analizy obszarów występowania jasnych plam.