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BRIGHT PATCHES ON CHERNOZEMS AND THEIR RELATIONSHIP TO THE RELIEF

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Bright patches in Chernozems areas and their relationship to the relief. Bright patches are characteristic of loessic hill lands in the Danube Lowland. They represent areas with a shallow and bright humus horizon. Hitherto, mainly spatial distribution and possibilities of their mapping have been studied. The aim of this paper is to contribute to the knowledge of their geomorphic features, relationship to the relief and morphogenesis of arable areas. Using the tools of the GIS, bright patches were identified on the basis of aerial photographs and orthophotomaps. The DEM and the related DTMs were created. Relief characteristics were computed by means of raster statistics and a database was built. On the basis of these sources, features of the bright patches were described and the relationship to relief was analysed.

Key words: bright patches, erosion, DEM, relief analysis, Trnavská Hill Land

INTRODUCTION

Bright patches are characteristic of loessic hill lands in the Danube Lowland. They represent areas with a shallower and brighter humus horizon with considerably lower content of organic matter than those of the surrounding Chernozems and Luvisols. Presuming the original horizon has being reduced, bright patches are areas of relief lowering. Areas where humus material from upper parts of slopes is accumulated represent those of relief elevation. Patches with accumulation of loessic material occur less often (Kohan 1993, Šúri and Hofierka 1994, Fulajtár and Janský 2001). Erosion processes result in significant changes in soil properties, soil degradation (Van Muysen 1999, Fulajtár and Janský 2001, Sobocká 2002, Dolgilevich 2003, Ilavská and Jambor 2005), and yield decrease (Miller et al. 1988 and Moulin et al. 1994 in Van Oost et al. 2006, Fulajtár and Janský 2001, Jankauskas et al. 2007). Therefore, the bright patches are frequently discussed in pedological, erosional or agronomical studies. Their spatial distribution and methods of mapping based on interpretation of aerial photographs, satellite images, modelling and terrain meassurements are investigated (Šúri and Lehotský 1995, Ilavská et al. 1999, Fulajtár and Janský 2001, Milkovič 2001, Sviček 2001 and 2003). Spreading bright patches have been observed since the 1950s (Karniš 1985, Jambor 1999). Water erosion is traditionally considered to be the dominant process in formation of bright patches in Slovakia. Sobocká and Jambor (1998) report that soils on convex-convex and convex-concave elementary georelief forms are the most influenced ones. Linkeš et al. (1992) and Kolény et al. (2004) observed the location of bright patches on the upper parts of slopes. Fulajtár (1994) described their occurrence on slopes steeper than 10.5%, and the presence of slightly eroded soils on longer slopes (> 100m) with inclination lower than 3.5%. Lehotský (2002) identified brighter material deposited on original soil in the accumulation part of

Luvisols catena. With growing recognition of the morphogenetic effects of tillage erosion, subsoil uncovering in convex and accumulation in concave positions (Bac 1928, Lobotka 1958, Lindstorm et al. 1992, Govers et al. 1994, Lazúr 2002) several researchers focused on the role of the tillage erosion in evolution of arable areas in the Carpathians (Stankoviansky 2001 and 2008). Smetanová (2008) used erosion modelling for the preliminary evaluation of water and the tillage erosion contribution to bright patches formation in the Trnavská Hill Land.

The aim of the paper is to deepen the existing knowledge about the relief characteristics of bright patches and to contribute to the discussion on their origin and relief morphogenesis in agriculturally used hilly lands in the Danube Lowland.

STUDY AREA

The study area (31.3 km^2) is situated in the environs of the municipality Voderady in the southwest part of the Trnavská Hill Land in the Danube Lowland (Fig. 1). The softly modelled relief (average slope 1.2%) is dissected due to the neotectonic fault activity into two local depressions with relatively steep slopes (maximum 15.1%). Haplic Chernozems (FAO 2006), strongly affected by erosion, prevail in this region (VUPOP 2005). Average annual temperature is 9-10°C, precipitation 550-600 mm with prevailing NW, N and SE wind direction. Archaeological findings indicated settlement since the Paleolithic (Fűryová 1996). The majority (90%) of the area is changed to arable land, characterized by large fields and massive use of mechanical tillage tools.

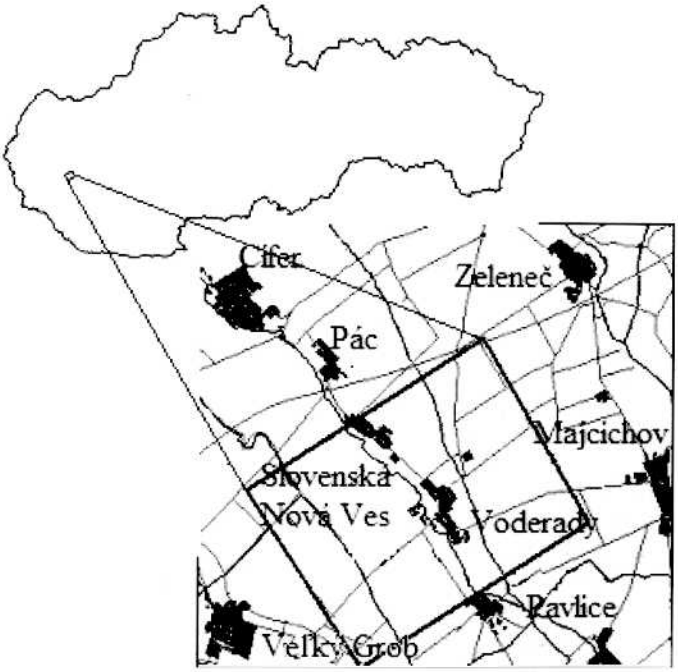

Fig. 1. Study area

METHODS

The relationship between the relief characteristics and the frequency of bright patches was evaluated using the DEM (Digital Elevation Model), aerial photographs and orthophotomaps analyses in the GIS. First of all, the detailed DEM and related DTM's (Digital Terrain Modelling) were created on the basis of topographic map and GPS terrain measurements. Morphometric characteristics of the study site, including slope, aspect, profile curvature, tangential curvature and occurance of elementary forms were calculated using raster statistics methods. Bright patches were identified by visual interpretation of orthorectified aerial photographs and digital orthophotomaps in GIS environment. Sources from two relatively close time horizons (1990 and 2004) were used to evaluate the maximal extent of arable land. In total 847 bright patches covering altogether 4.1 km^2 were identified on 83% of the study area. Patches partly covered by vegetation or crop residues were excluded from the study. Relief parameters for the remaining 776 areas (covering 3.64 km^2) were computed. The area, slope gradient (which indicates the change of slope in this study), average contribution area and slope position were determined for each bright patch. Aspect was evaluated through absolute and relative area of eight directions of orientation. Combinations of orientations appearing in each patch and in the whole dataset were also computed. A similar approach was applied for the areas of nine elementary forms (convex-convex, convex-linear, convex-concave, linear-convex, linear-linear, linear-concave, concave-convex, concave-linear, concave-concave) and their combinations. Change of the curvature within the patches was evaluated on the basis of borders between elementary forms included in them. Shape properties and distribution of bright patches were assessed using the visual analysis. Areal representation of slope, orientation, curvatures and elementary form categories within the bright patches were compared with the corresponding characteristics of the study area. On the basis of these analyses, types of bright patches have been distinguished.

RESULTS AND DISCUSSION

Bright patches are irregularly distributed throughout the study area (Fig. 2). Smaller patches of variable shape (elliptic, bean-like, curved, circular, etc.) often elongated in slope direction are predominant in the western part of the study area, where they occur with high density. Regular, long and narrow shaped patches lie on the higher parts of slopes, on ridges, tops or terrain edges. Larger irregular polycurved shapes occur in tectonic depressions. The area of bright patches varies from 115 m^2 to 5.94 ha. More than half of them are smaller than 0.25 ha, only 16% of bright patches are larger than 0.5 ha.

About 38.5% of their area occurs in flatter parts with inclination below 0.9%, and some of it in the steepest parts with inclination over 10.5%. The prevalence of higher slope (over 1.7%) within bright patches is evident from the comparison of proportional representation of the area of individual slope categories within patches and relief (Fig. 3a). The total area of bright patches situated on slopes with inclination 1.7-5.2% was 1.67-times higher than expected. Presumably there is a direct correlation between the characteristics of relief and those of the bright patches. A similar situation was observed for slope categories 5.2-10.5%, where bright patches occur 1.41-times more frequently than was supposed using described condition. The significant change in slope gradient (> 1.7%) occurs in more than one fifth of all bright patches, which is typical mainly for those situated on terrain edges, ridges and tops.

Fig. 2. Bright patches of study area

The aspect of bright patches is comparable in the whole study area (Fig. 3b). The SW direction is predominant within both of them, but occurs 1.13-times more frequently within the patches. NW and W areas also occur more often (1.75-, 1.21-times respectively), whereas areas with N, NE, E and SE orientation are less extended within them. About 45% of the patches are oriented only in one direction. SW-oriented patches are the most frequent (1/5 of all patches) and cover the largest area (42 ha). The southern orientation (S, SW, SE or their combination) has 43% of bright patches covering 24% of their total area, but these orientations occur partly in 51% of the remaining patches. Due to higher potential insulation in these areas thawing processes occur sooner. Accelerated drying decreases the soil's resistance to wind erosion. According to the dominant wind circulation this process may be responsible for the creation of NW and W – ward oriented parts of patches.

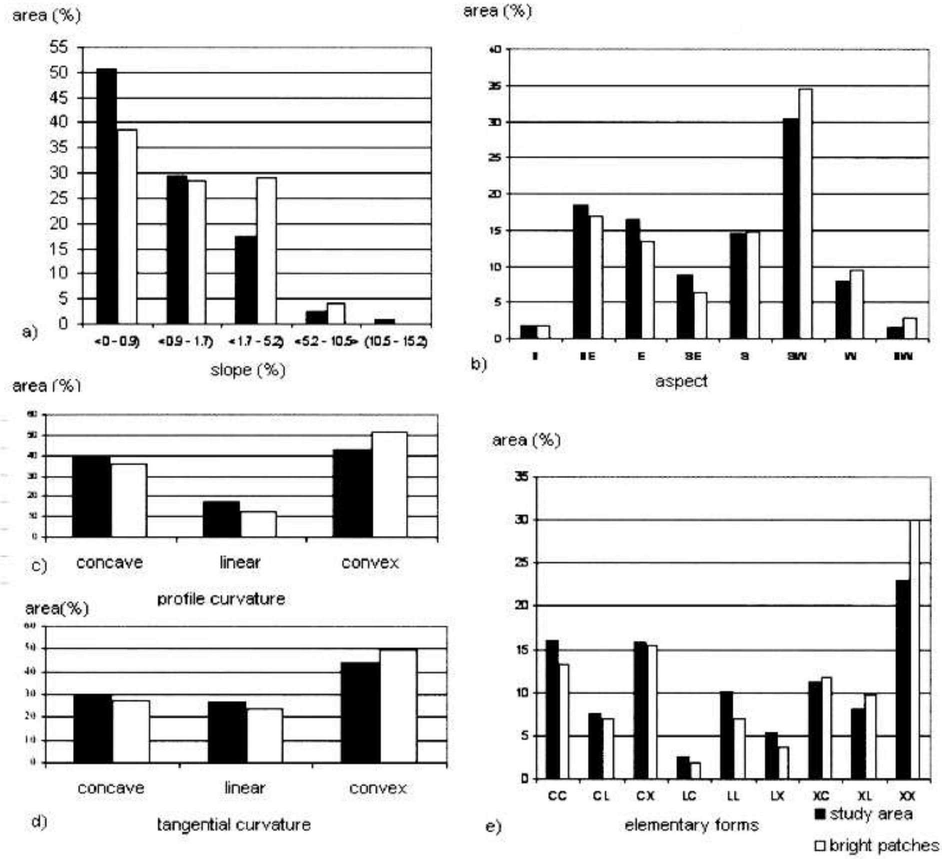

Fig. 3. Comparison between characteristics of study area and bright patches

Convex forms of profile and tangential curvature cover a larger area (1.21 and 1.12-times, respectively) within the patches than was supposed presuming the existence of a direct correlation between the characteristics of relief and bright patches (Fig. 3c and 3d). Concave and linear forms of both curvatures occur less often. Linear forms (linear-concave, linear-convex) have the smallest extent within both compared categories, and even lower within the patches (Fig. 3e). Convex-convex forms are the most frequent and cover 1.3-times larger area within the patches, followed by convex – linear and convex – concave elementary forms. Although concave-concave forms cover a smaller area (0.83-times) than supposed using described condition, they extend within almost 48% of all patches. More than 90% of bright patches consist of more than one elementary form, which occurs in 187 combinations. The most frequent are combinations of concave-concave, concave-convex, convex-concave and convex-convex elementary forms, followed by concave – convex and convex – convex forms. Assessing the type of borders between the elementary forms, a significant dependence on the change of forms of curvature was found (Tab. 1). More than half (59.5%) of all patches are linked to the change of both, profile and tangential curvature. Additionally, more than half of those remaining (23.71% of the total number) are connected with the change of profile curvature, while only 17% of them (6.83% of total amount) depend on the change of tangential curvature. The border between concave and convex forms of both curvatures is the most frequent and is significantly predominant in the case of the profile curvature. Concave to linear to convex change of both curvatures concerns more than 20% of the patches, while other borders are less frequent. The proved large extent of convex-convex and convex-concave forms within bright patches corresponds to the result of Sobocká and Jambor (1998), who consider them to be the most affected ones by sheet water erosion. They diagnosed Haplic Chernozems up to eroded Chernozems with the accompanying units of Calcaric Regosols and accumulated Chernozems. On the contrary, Fulajtár (1994) described the concave-concave forms on the lower parts of slopes as more affected by erosion processes, where the humus horizon has been removed and material from upper parts of slopes has been accumulated subsequently. Research into the tillage erosion (Govers et al. 1996, Quine et al. 1997) proved its predominance on convex slopes. Comparison of bright patch distribution and tillage erosion modelling WATEM (Smetanová 2008) confirmed the effects of tillage erosion. It could be the most intensive within patches on convex slopes and with high change of slope gradient.

According to the computed values, approximately half the bright patches have average contribution areas smaller than 100 m^2. Only in 5% of them its extent exceeds 1000 m^2, mainly in the case of smaller patches lying near local thalwegs. Larger patches within this category extend mostly on slopes adjacent to smaller dells, some of them also reach local ridges. The bright patches lie predominantely on upper parts of slopes. Only 17% of them are closer to local thalweg. Those situated in concave parts below other bright patches could be the result of the displacement of subsoil material from upper parts of slopes if subsoil is present on the surface there (Kohan 1993, Šúri and Hofierka 1994, Fulajtár and Janský 2001). Similar transport of material from lower soil horizons was proved by Lehotský (2002) on Luvisols. Sobocká and Jambor (1998) identified more intensive accumulation of material loosened by sheet erosion and occurrence of Haplic soils and accumulated Chernozems on concave-concave forms. Erosion modelling of tillage and water erosion and accumulation proved that both types of accumulation could be present in these areas WATEM (Smetanová 2008).

CONCLUSION

The described characteristics refer to a relatively high diversity of patches. They are variable mainly in included elementary forms and borders between them as well as in relief orientation. The dataset of the characteristics of slope, position, contribution area and size is more homogenous. Data analysis enables identification of several types of bright patches. Regular long and narrow shaped patches (larger than 0.5 ha) lying on the terrain edges of tectonic depressions, on ridges and tops are connected mainly with convex forms of profile curvature (Fig. 4). The area of concave-concave forms is smaller than 1% in almost half of them. They occur in upper parts of slopes (75% of them have upslope length shorter than 1/3 of the downslope length) and cover areas of higher slope gradient (> 1.7%). Irregular polycurved patches (with at least 2 nearly rectangular edges) are associated with the convex-convex forms, upper parts of slope and mainly with average (or smaller) contribution area and slope gradient (Fig. 5). Patches of variable size and shape with a larger extent of concave-concave forms, downslope position and larger contribution area cover (completely or partly – in the case of larger patches) the bottoms of shallow dells and local depressions (Fig. 6). Partial dependence on higher slope gradient or borders of elementary forms is observed within smaller (area up to 1 ha) in slope elongated patches, which are frequent in the western part of the study area (Fig. 7). Circle-shaped patches are connected with small circular depression not represented in DEM (Fig. 8). Transition forms between these types occur or individual parts of patches belong to different categories.

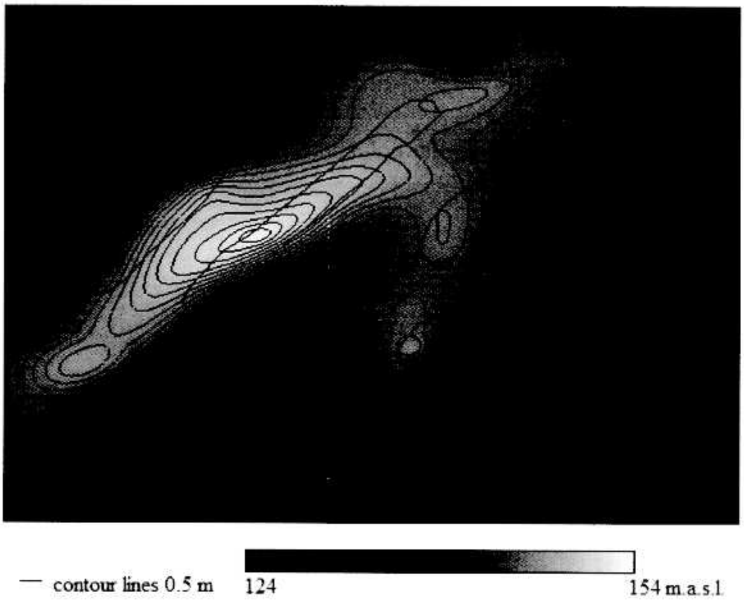

Fig. 4. Regular long and narrow shaped bright patches on terrain edges, ridges and tops

The differences between the bright patches refer to dissimilarities in their genesis. Patches with a large extent of convex forms, higher slope gradient and upslope position are more probably of tillage erosion origin. Those elongated in slope direction including higher slope gradient or borders of elementary forms tilled down the slope could also be influenced. Erosion modelling WATEM (Smetanová 2008) confirmed water erosion in these areas, hence their poly-

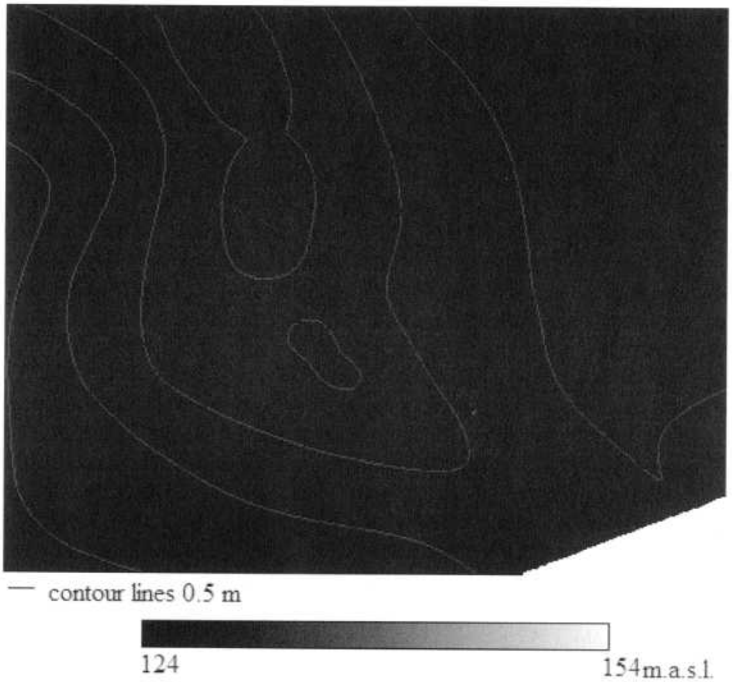

Fig. 5. Irregular polycurved bright patches

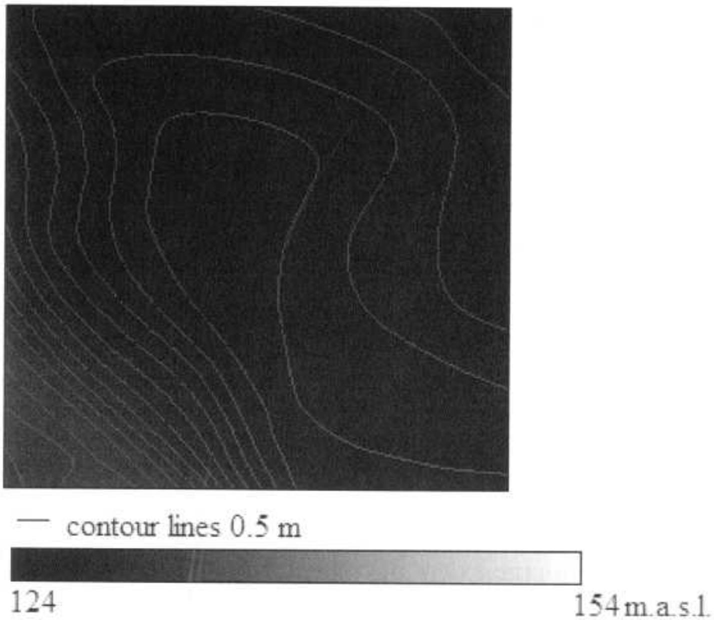

Fig. 6. Bright patches in downslope position with larger contribution area and extent of concave – concave forms

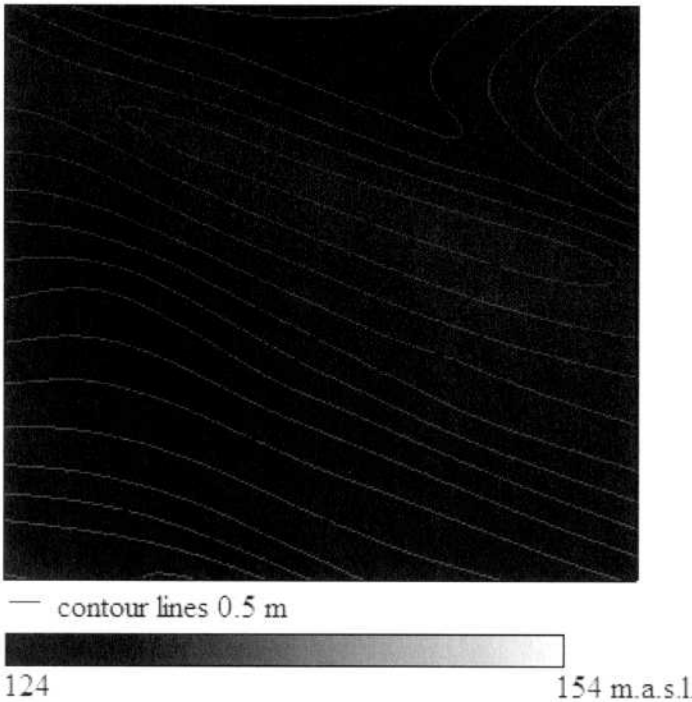

Fig. 7. Bright patches elongated in slope direction

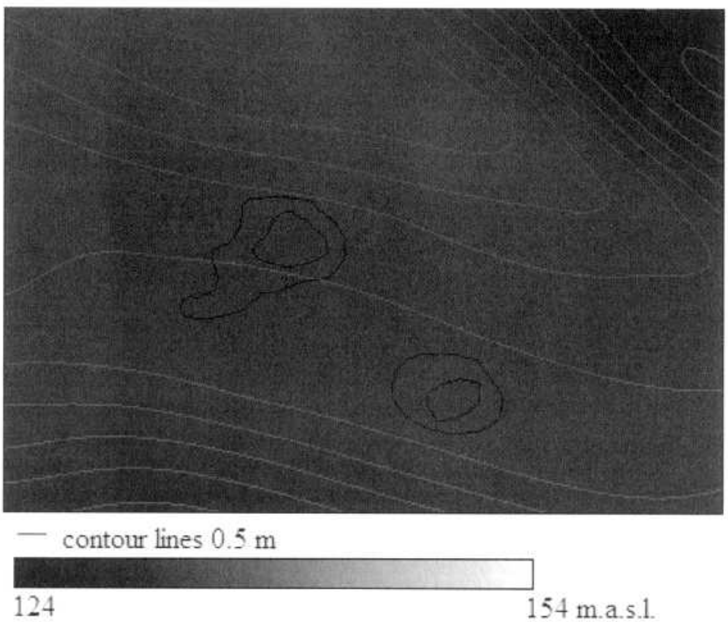

Fig. 8. Circle – shaped bright patches

genetic origin is more probable. Accumulation should be considered with the growing extent of concave-concave forms, mainly within patches in an upslope position. Polycurved patches may be related to the former land-use pattern or it may be the result of gradual merging of smaller patches. Individual genesis of different parts of bright patches seems to be possible also in the case of large patches extending from slopes to adjacent dells or depressions. Wind erosion, the role of which is to be evaluated, may be responsible for the formation of the NW oriented patches. The discovered discrepancies between bright patches and postulated inferences on their genesis refer to the necessity of revaluation of the existing perspectives concerning the formation of bright patches as well as the development of the relief of arable areas in the Danube Lowland. Spatial and temporal variability of tillage, water and wind erosion and accumulation should also be considered.

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SVETLÉ PLOCHY V ČERNOZEMNÝCH OBLASTIACH A ICH VZŤAH K RELIÉFU

Svetlé plochy sú charakteristickým krajinným prvkom sprašových pahorkatín Podunajskej nížiny. Sú areálmi so svetlým a plytkým humusových horizontom, vyznačujúcim sa nižším obsahom organického materiálu, ktorý vizuálne ostro kontrastuje s tmavým A horizontom okolitých černozemí, hnedozemí a luvizemí. Ak predpokladáme, že pôvodný humusový horizont je odnášaný, predstavujú svetlé plochy miesta znižovania reliéfu. Naopak areály, kde dochádza k akumulácii materiálu odneseného z vyšších častí svahov, sú miestom jeho zvyšovania. Za dominantné procesy spôsobujúce odnos pôdy sú považované ronová, menej veterná erózia a čoraz častejšie i orbová erózia. Cieľom práce je detailným štúdiom vlastností ich reliéfu prispieť k diskusii o vzniku svetlých plôch a formovaní reliéfu nížinnej poľnohospodárskej krajiny.

Na základe ortorektifikovaných leteckých meračských snímok a ortofotomáp bolo v území okolo Voderad na Trnavskej pahorkatine s rozlohou 31,3 km^2 identifikovaných 776 svetlých plôch. Za použitia podrobného digitálneho modelu reliéfu boli vyhodnotené ich morfometrické i tvarové parametre, poloha a prispievajúca plocha, ktoré boli porovnávané s reliéfom študovaného územia. Boli pozorované výrazné väzby na zmenu sklonu, krivostí a výskyt konvex-konvexných foriem v rámci svetlých plôch. Väčšina sledovaných areálov sa nachádza v hornej časti svahov a má malú príspevkovú plochu.

Tie, ktoré sa nachádzajú na terénnych hranách, chrbtoch alebo v blízkosti vrcholov a sú viazané na výraznú zmenu sklonu a konvexné formy vertikálnej krivosti, vznikajú pravdepodobne pôsobením orbovej erózie. Menšie, tvarovo viac variabilné plochy, viažuce sa na výraznejšiu zmenu sklonu, ako aj plochy pretiahnuté v smere orby, majú pravdepodobne zložitejšiu genézu s príspevkom orbovej i ronovej erózie. Areály so severozápadnou či severnou orientáciou, ktorých rozsah v rámci svetlých plôch je významnejší ako v študovanom území, môžu vznikať pôsobením vetra. Výskyt viacnásobne zakrivených svetlých plôch, či plôch prechádzajúcich zo svahov do priľahlých depresií, indikuje možnosť individuálneho vývoja ich jednotlivých častí, ktorý môže prebiehať aj vo väzbe na prvky krajinnej štruktúry. Pozorované rozdiely a závery dotýkajúce sa vývoja svetlých plôch poukazujú na potrebu prehodnotenia názorov na ich vznik i formovanie reliéfu nížinnej poľnohospodárskej krajiny.