THE LAND USE CHANGES IN 20TH CENTURY AND THEIR GEOMORPHOLOGICAL IMPLICATIONS IN LOWLAND AGRICULTURAL AREA (VODERADY, TRNAVSKÁ TABUĽA TABLE PLAIN, SLOVAKIA)

ANNA SMETANOVÁ, MIROSLAV KOŽUCH**, JOZEF ČERŇANSKÝ***

Anna Smetanová , Miroslav Kožuch, Jozef Čerňanský: The land use changes in 20th century and their geomorphological implications in lowland agricultural area (Voderady, Trnavská tabuľa Table Plain, Slovakia). Geomorphologia Slovaca et Bohemica, 9, 2009, 2, 3 figs, 26 refs.

The role of land use changes in acceleration of erosion in agricultural areas is widely recognised. The modifications of landscape structure and land use practices in the 20th century led to significant soil degradation and widening of eroded areas (including so-called bright patches) in Danube Lowland. Lowering of soil profiles and uncovering of maternity rock are important markers of relief re-modelation through erosion. We used aerial photographs and orthophotomaps from two time horizons (1949, 2004) to evaluate the changes of landscape structure and the extent of eroded areas. Relation of bright patches to relief was assessed using DTMs based on detailed tachymetric measurements. The possible influence of water and tillage erosion on their spatial growth was analysed through erosion modelling. The land use history in the 20th century was reconstructed. Slight decrease in total cultivated area was proved. The total number of field decreased 20-times, area of bright patches increased 3.88 - times. Downslope tillage was substituted by contour tillage. Smaller patches situated in areas with higher slope gradient near upper field boundary were predominant in 1949. The change in agricultural practices conditioned widening and prolongation of original patches in new tillage direction. Larger regular long and narrow patches were created on terrain edges. Their relation to areas of higher slope gradient is less visible than in 1949. Content of concave forms of profile curvature within patches increased. Analyses of current water and tillage erosion patterns show influence of both processes on bright patches formation. The relation with areas of most intensive tillage erosion is evident. Results suggest that bright patches were originally created in topographic positions presumable influenced by tillage erosion. Intensification of agriculture induced acceleration of both water and tillage erosion and thereby led to their spatial spreading and re-modelling of areas which had not been influenced before.

Key words: land use changes, erosion, bright patches, relief, GIS

INTRODUCTION

Arable land in Danube Lowland is strongly affected by erosion processes, mainly by water, tillage and wind erosion. Their influence is variable in space and time and depends on diverse factors, including intensity of geomorphological agent, soil erodibility, local topographic conditions and land use. Land use affects erosion through anti-erosion effect of plants and plant societies, landscape structure through the character and density of borders. Overland flow is often retarded on vegetation barriers (hedges, grass strips). Due to difference in infiltration capacity, a fraction of the overland flow infiltrates near the field boundary. Sediment is likely to be deposited there (MEYER et al. 1995, SLATTERY and BURT 1997, TAKKEN et al. 1999 or VAN OOST et al. 2000). Deposition could occur on the leeward side due to wind accumulation. Pavements and roads represent anthropogenic flow lines and contribute to gully formation (STANKOVIANSKY 2003). In the case of tillage erosion each field boundary is a line of zero flux. Tillage erosion occurs at the down slope, accumulation at the upslope side (VAN OOST et al. 2000).

The increase in the intensity of soil erosion and the growth of eroded areas were proved in the second half of 20th century (STREĎANSKÝ 1991, JAMBOR 1992., LINKEŠ et al. 1992, JAMBOR and SOBOCKÁ (1999), ILAVSKÁ et al. 1999, SVIČEK 2001, FULAJTÁR and JANSKÝ 2001, VAN OOST et al. 2005 etc.). SOLÍN and LEHOTSKÝ (1996), HANUŠIN (1998), LEHOTSKÝ and HANUŠIN (1998) or SOLÍN and CEBECAUER

* Department of Physical Geography and Geoecology, Comenius University in Bratislava, Mlynská dolina, Bratislava 842 15, Slovakia, e-mail:smetanovaa@fns.uniba.sk,

** Department of Cartography, Geoinformatics and Remote Sensing, Comenius University in Bratislava, Mlynská dolina, Bratislava, 842 15, Slovakia, e-mail: kozuch@fns.uniba.sk, cernansky@fns.uniba.sk

(1998) studied the impact of land use changes on water erosion intensity. STANKOVIANSKY (2003) researched geomorphological effect of water and tillage erosion in the postcollectivization period in the area of Myjavská pahorkatina. VAN ROMPAEY et al. (2003) modelled the sediment supply to rivers in Czech Republic in that period. However, the effects of the changes in land use and landscape structure were not evaluated in the connection with increasing area and density of so-called bright patches. The change of their relief characteristics was also not studied.

The objective of this study is (i) to describe the post-collectivization changes of land use and landscape structure in a selected part of Trnavská tabuľa Table, (ii) to determine spatial increase of bright patches, (iii) to examine morphometric characteristics of bright patches and their transformation, (iv) to assess possible influence of water and tillage erosion on bright patches spreading, and (v) to contribute to the discussion on exomorphogenesis of lowland agricultural areas in the second half of 20th century.

METHODS

The study area (91.2 ha) is situated near the village Voderady in Trnavská tabuľa Table Plain, which is part of Trnavská pahorkatina Hill Land. It represents first order catchment of shallow dry dellen and adjacent slopes. It cuts a steeper slope between two levels of a tectonic depression of northwest - southeast direction, which occurs in consequence of würm (or earlier) neotectonic fault activity (STANKOVIANSKY 1993, p. 96). Floodplain of brook Ronava creates the western border of the study area. Southwest-oriented slopes predominate, average inclination is 1.3°. Haplic Chernozems on loess are predominant. According to the database of bonited pedo-ecological units (SSCRI 2005), also Mollic Fluvisols Calcaric (14.8 %) and Calcaric Regosols - eroded Haplic Chernozems (12.9 %) occur in this region. 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 2008a) in surrounding area.

Present land use type, land use structure and bright patches were identified by visual interpretation of orthophotomaps. Aerial images from 1949 (TOPU Slovak Military Institute of Cartography) were used to evaluate situation before collectivization. Following categories of land use were defined: road, intravilan, brook (Ronava) and riparian vegetation, abandoned land, fields. Each part of plot with diversified crop rotation was considered as individual field due to different cultivation and the relevance of field boundaries for erosion processes. If definable roads or pavements occur between fields (parts of parcels) they were classified as roads. Tillage direction and fields covered in crop were also identified. Orthorectified aerial images from 1990 (TOPU Slovak Military Institute of Cartography) provided additional information on present pattern of eroded areas. They were used for bright patches identification within fields, which were covered in vegetation or crop residues on orthophotomaps from 2004 (Eurosense). Obtained information were analysed and compared. Land use history since 1949 was also reconstructed using available historical sources and literature.

Total of 756 input points (grid 40 x 40m, with regard to morphology, measured in November 2008) for digital elevation model (DEM) were obtained by electronic tachymeter Leica TC 1100 with precision 0.01m. 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 and 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. Analyses of size, shape, slope, aspect, curvatures, elementary forms, position in relief and relationship of bright patches to slope gradient in two time horizons followed. Changes of these characteristics were evaluated with regard to land use and landscape structure transformation. Water and tillage erosion were modelled in WATEM (VAN OOST et al. 2000) using methodical approach described in SMETANOVÁ (2008b). The results were used to interpret bright patches evolution.

RESULTS

LAND USE HISTORY 1949 - 2004

Arable land in the cadastral territory of Voderady (1245.72 ha) was owned by the count Zichy (41 %) and peasants (59 %) in the beginning of 20th century (ČAMBALOVÁ et al. 1993). During two land reforms (the first in 1923, 1925 and 1927, the second in 1945) small parcels were merged, the property of Zichy family divided and assigned or sold to peasants and state farmstead Československé štátne majetky. The area cultivated by local farmers increased to 77.5 % in 1945. Some fields, mainly those from former Zichy's property, had been tilled with modern implements (steam-engined, later electric tilling tools, sow-

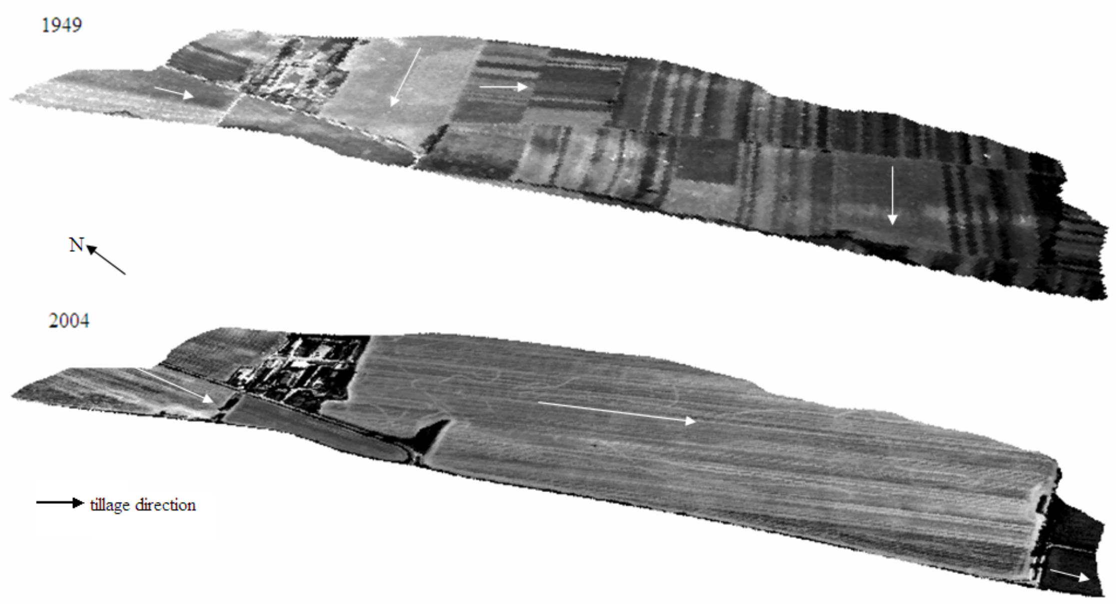

Fig. 1 Land use and tillage direction in a) 1949 and b) 2004

ing, mowing machines etc.) already for more than forty years in 1950s. Animal force and iron plough were less used by small farmers. Two tractors operated in the fields after the establishment of a machinery cooperative farm in 1947 (ČAMBALOVÁ et al. 1993). Mainly wheat, barley, corn and sugar beet were cropped, rye and potatoes were grown only for domestic usage. Tree-field system without fallow was typical for the land use in the first half of 20th century. Fields were tilled tree times per year – shallowly (5 cm) after harvest, intermediate one month after harvest and deep in autumn. The only exception was tillage one time per year when wheat was following after corn (DANTEROVÁ 2006).

Collectivization started in spring 1950. The property of the machinery cooperative farm, the church and additional 30 ha were confiscated. Majority of farmers became members of a new cooperative farm (JRD „of third type", ČAMBALOVÁ et al. 1993, p. 119) founded in 1952, the last farmers joined it in 1958. The collectivization ended in 1959 when machines of peasants were bought out. Post-collectivization period is characteristic with intensive agriculture with large block of fields and usage of massive tillage (sowing, harvesting etc.) implements. Wheat (spring and winter), barley (spring and winter), sunflower, corn, alfalfa and rapeseed were typical crops, 25 – 30 cm (occasionally 40 cm) deep tillage prevailed.

The last land reform was done in 1990s (1992 - 1998) in order to arrange ownership and usage of cultivated land. Type of land use and land use structure has not been changed in the study area. The construction of the factory SAMSUNG Electronics LCD started in the close surrounding of the study area in 2007. Although significant changes of land use and landscape structure have taken place since that time, they have not affected the study area.

LAND USE AND LANDSCAPE STRUCTURE CHANGES 1949 – 2004

Almost whole area (91.7 %) was cultivated in 1949. Other landscape elements - roads, farmstead Jozefov Majer, brook Ronava with its riparian vegetation covered only 8.1 ha Category „abandoned land" was represented by vegetation surrounding gullied road so-called Hlboká cesta. Pastures and forest didn't occur in the study area. Average field size was 0.48 ha and only 18 fields were larger than 1 ha. The smallest areas were those extended only partially in the study area and were parts of larger fields. The smallest field completely comprised within area was 86 m^2 large, average size of completely included was 6244.51 m^2. Larger blocks of fields, with maximum area of 10.5 ha were less frequent. Majority of the area (76.51 %), represented mainly by smaller fields, was tilled in slope direction, larger fields near Jozefov Majer by contour tillage (**Fig. 1a**).

Contour tillage is predominant also in current land use. Study area is divided into 6 large blocks of fields, with maximum 66.7 ha (**Fig. 1b**). The extent of cultivated land decreased (2.7 %). The area of abandoned land enlarged

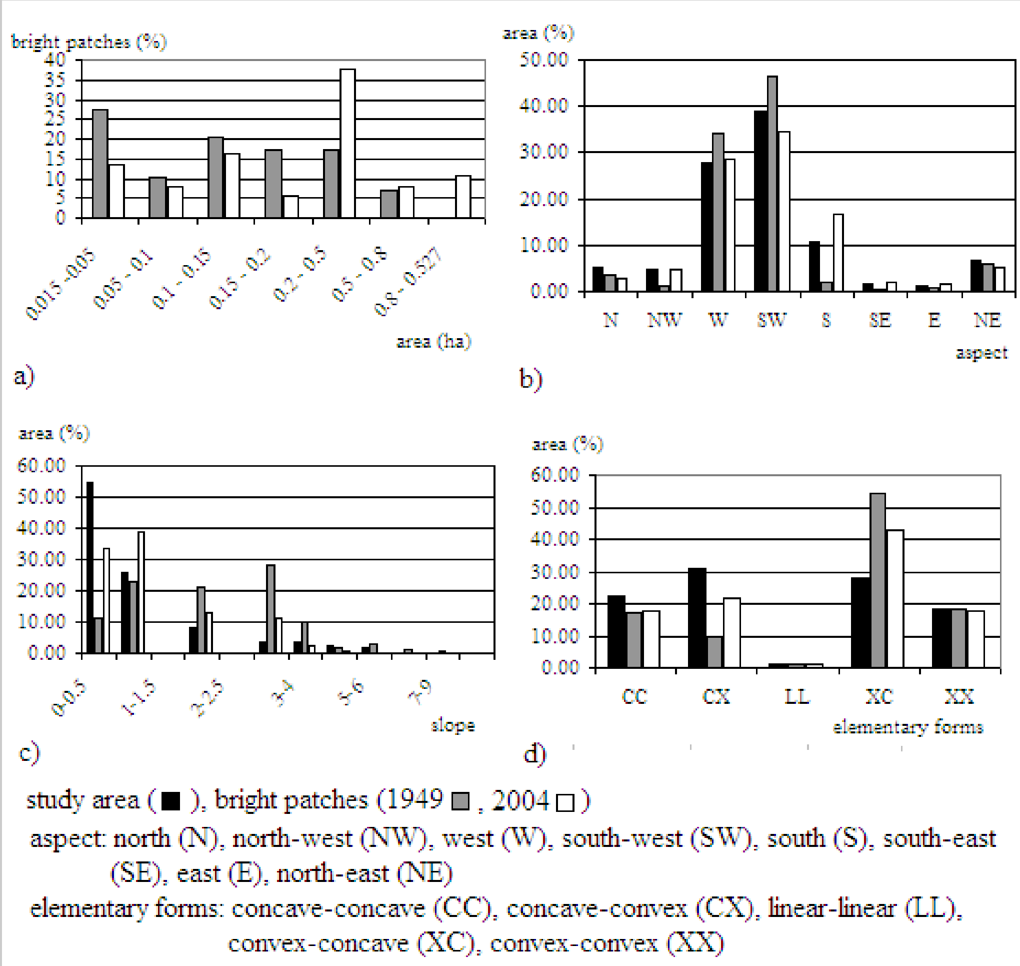

Fig. 2 Comparison between characteristics of study area and bright patches: a) area of bright patches, b) aspect, c) slope, d) morphometric elementary forms

due to occurrence of 2 - 5 m wide unused stripes with grass and shrubs on the field's borders. Furthermore the vegetation near the gully of Hlboká cesta wided, although it no more exists. Many of earlier roads were hardened, a wind-break consisting of acacia trees was planted by one of them. Other significant change was the regulation of brook Ronava and change of its course. Original vegetation was probably cut and substituted by pioneer tree species.

Bright patches 1949 – 2004

Significant enlargement of bright patches was identified. Their total area increased 3.88-times, from 5.2 ha in 1949 to 20.2 ha in 2004 (**Fig. 2a**). Smaller areas with average 0.18 ha (max 0.7 ha) in upper parts of slopes were predominant in 1949. The majority of them occurred in upper slope positions with higher slope gradient and was elongated near upper field boundaries. Some of them were enlarged in the slope (and tillage) direction. Patches crossing field boundaries were also present. Western (W) and the south-western (SW) orientation were the most common within the patches (**Fig. 2b**). Almost 60 % of them were located in areas with slope 1.5° - 4°, one third of them in areas with slope lower than 1° (**Fig. 2c**). They prevailed in upslope position on convex forms of profile curvature (72 % of bright patches area), mainly convex-concave (XC) forms (54.6 % of their area, **Fig. 2d**). These forms were predominant also in 2004, but their area slightly decreased (to 42.8 %) to the exclusion of increase of concave – convex (CX) forms (2.2 - times) and linear-linear (LL) forms (1.19 - times). The area of convex - convex (XX) forms also slightly decreased. The increase of lower slope areas within patches is evident (change from 23.7 % in 1949 to 72.4 % in 2004) and bright patches are rare in areas with slope higher than 4° (from 6.43 % in 1949 to 0.69 % in 2004). The area of bright patches with slope 2.5-3° was 8.14 - fold larger in 1949 and only 3.12-fold larger in 2004 than it would

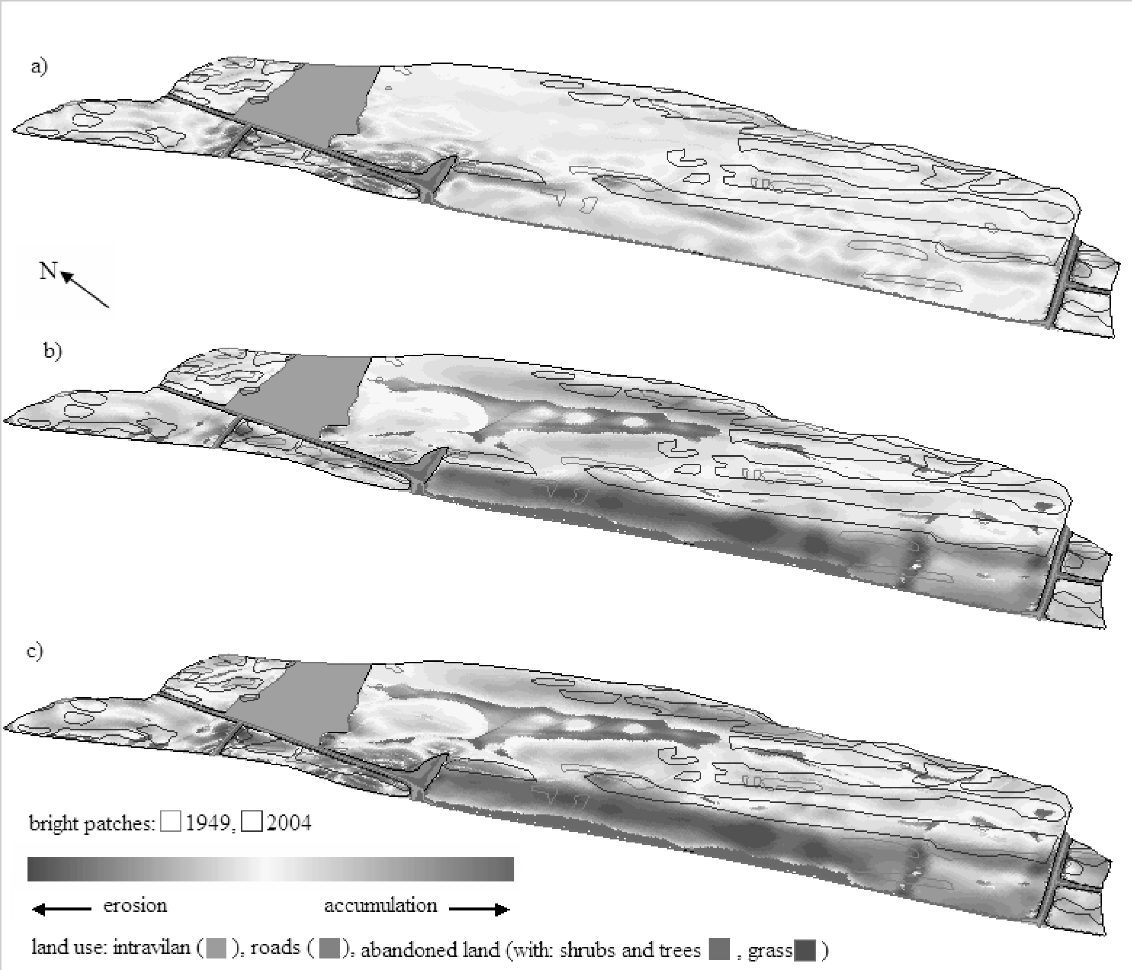

Fig. 3 Recent tillage and water erosion: a) tillage erosion, b) water erosion, c) cumulative effect

be if direct correlation between the characteristics of the parameters of relief and bright patches exists. Bright patches formation on less steep slopes and concave forms of profile curvature is a general trend. Majority of the patches in 1949 was situated in areas, where tillage erosion could occur, while patches lay also in areas with tillage accumulation (**Fig. 3a**) in 2004. Present day patches are connected with areas with lower intensity of water erosion and disappeared from areas, where water erosion is higher (**Fig. 3b**). The pattern of wind erosion was not modelled. However the increase in the area of northwest (NW, 3.9 - times) and southeast (SE, 6.5 - times) oriented patches, thus areas exposed to the first (NW) and third (SE) most frequent winds, could refer to higher influence of wind erosion. The simplification of landscape structure, creation of large fields with contour tillage on the slopes parallel to the main wind streams contributed to its intensification.

DISCUSSION AND CONCLUSION

The results refer to the increase of erosion processes and the change of erosion-accumulation pattern after collectivization. Since they were not modelled for the pre-collectivization period, obtained results refer only to the situation after collectivization and do not explain completely the genesis of pre-collectivization bright patches. It could be partly interpreted on the base of relief analyses, but errors could occur due to lack of precise digital elevation model and unknown changes in landscape structure before collectivization. The misinterpretation of aerial images followed from their lower legibility could bring additional mistakes. Therefore the genesis of pre-collectivization bright patches was not further evaluated.

In spite of discussed inaccuracy significant changes in characteristics of bright patches were proved: (i) their spreading and enlargement in the direction of contour tillage, (ii) decrease of their steepness and convexity, (iii) increase of the area of NW, SE oriented patches, (iv) disappearance of patches in areas of high water erosion, (v) enlargement in areas with more intensive tillage erosion, lower intensity of both processes and tillage accumulation. Post-collectivization changes of land use and landscape structure led to increase of intensity and change of spatial pattern of water, tillage and wind erosion and accumulation. They contributed to modellation of those parts of relief which had not been influenced before, including gentle slopes and concave forms. Based on comparison between soil profile truncation and ^{137}Cs measurement VAN OOST et al. (2005) suggested the shift from water to tillage erosion dominance in relief modeling after intensification of agriculture in 1950s. Bright patches spreading in areas with prevailing tillage erosion and neighbouring areas of tillage accumulation support this statement. Their occurrence in concave forms on slopes could relate to delivery of loess material from upper parts of slopes. However, the evaluation of the role of particular processes on bright patches formation in pre - and post - collectivization period demands further research.

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