Transformation of vertical texture-contrasted soils due to accelerated erosion in young glacial landscapes, North-Eastern Poland

Marcin Świtoniak

Department of Soil Science, Institute of Geography, Faculty of Biology and Earth Sciences, Nicolaus Copernicus University, Torun, Email Poland, swit@umk.pl

Abstract
The purpose of the present paper is to elucidate the influence of accelerated soil erosion on vertical texture contrasted soils (VTC-s) in young glacial landscapes of North-Eastern Poland. To solve the problem, a comparison of non eroded forest reference VTC pedons with arable soil has been made. On the basis of the results, five classes of VTC-soil truncation have been distinguished. According to the identified degrees of truncation, maps of soil cover transformation, caused by accelerated erosion, were generated and overlapped on Digital Elevation Models (DEMs). The widespread occurence of strongly and completely eroded investigated soils provides intense anthropical pressure on soil cover in the agriculture areas of North-Eastern Poland.

Key Words
Accelerated erosion, soil truncation, vertical texture contrast, slope processes

Introduction

Soil erosion is a natural phenomenon and has occurred throughout the geological history. Human activities have increased erosion rates. This human influenced process is termed accelerated erosion. Land use conversion modified soil morphological properties along the slope due to soil material redistribution (Papendick and Miller, 1977; De Alba *et al.*, 2004; Marcinek and Komisarek, 2004). Surface soil horizons loss (truncation) occurs on convex parts of slopes and colluvial material deposition takes place on concave areas. Soil erosion is one of the key threats to soil in Poland. Some authors estimated that almost 30% of the total area of the country is considerably degraded by this process (Józefaciuk and Józefaciuk, 1992). Accelerated soil erosion in the hilly young glacial agricultural landscapes of North-Eastern Poland is a particulary important problem (Uggla *et al.*, 1968). Since the end of the 10th century, this area is strongly influenced by anthropic pressure and has suffered a heavy soil erosion, aggravated by agriculture and deforestation (Sinkiewicz, 1998). The strongest transformations occur in regard to arable soils developed on ground moraine deposits in hummocky moraine plateau landscapes. A common feature of untruncated soils in this area is the presence of a coarse-over-fine vertical texture-contrast (VTC) with an abrupt textural change. The VTC is inherited from the parent material: a sandy ablation and fluvioglacial layer (thickness about tenths of centimeters) covering the more heavy lodgment till (Niewiarowski, 1986; Niewiarowski, Wysota, 1986). In most primary pedons, geological VTC was increased by an eluviation-illuviation (*lessivage*) process. In some cases, the features characteristic for clay illuviation were not present. A morphological similarity (despite of differences in pedogenesis) and complicated genetic horizons sequences of forest, non truncated VTC-soils can be useful as reference pedons to a determination degree of arable soils transformation by erosion. Soil profile truncation and accretion have been used by other authors to estimate the intensity of erosion in rural areas (Lowrance *et al.*, 1988; Phillips *et al.*, 1999). In the studied area the problem has not received sufficient attention yet (Sinkiewicz, 1998). The aim of the present paper is to define several classes of VTC-soils truncation and to test their applicability in the estimation of soil cover erosion spatial range.

Methods

The soils of two study sites (1 km square each site) in Brodnica Lake District, North-Eastern Poland (Figure 1) were mapped in detail (soil maps were drawn on a scale 1:10,000). The relief of the studied area is typical for hummocky moraine plateau landscapes. Twenty profiles developed on ground moraine deposits were described and sampled. The first site (A) represents the mixed forest area and a natural stage of a soil cover development. The second site (B) is a rural area with strong modifications of soils due to erosion. Twelve pedons were located under mixed forests (Site A), and eight were situated in arable areas (Site B). Apart from soil pits, 375 augerholes, 200 cm deep, were made. Two Digital Elevation Models (DEM) of the study sites were derived. DEMs were constructed at 10 m resolution by interpolation from the spot heights and digitised contours with 1.25 m interval of the 1:10,000 topographic map. Interpolation was fitted using a

kriging method, incorporated in the Grid tool of SURFER 8 (Golden Software, Inc. 1999).
The samples were taken from selected soil horizons. Standard soil analyses were performed according to the methods as follows (Bednarek *et al*., 2004):
- Organic carbon content – by sample oxidation in the mixture of $K_2Cr_2O_7$ and H_2SO_4;
- Total nitrogen content – Kjeldahl method;
- $CaCO_3$ content – Scheibler volumetric method;
- Grain size distribution – by pipette and sieve method;
- pH of soil-to-solution ratio of 1:2,5 using 1M KCl and H_2O as the suspension medium;
- Hydrolythic acidity by Kappen method;
- Exchangeable Cations content by leaching with 1M ammonium acetate;
- Colour has been described according to Munsell (Munsell Soil Colour Charts, 2000).

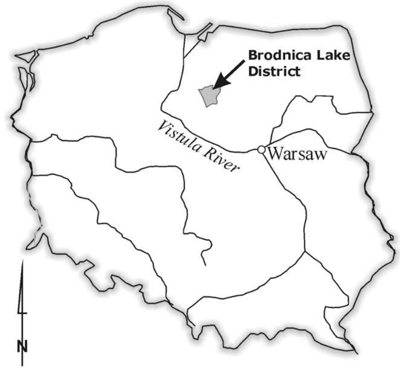

Figure 1. Location of the study area within Poland

For micromorphological investigations 14 samples with undisturbed structure were taken according to Mroczek (2001). Thin sections (55x75 mm) were prepared according to Lee and Kemp (1992). Description of micromorphological features was made according to Mroczek (2008), based on nomenclature created by Bullock et al. (1985) with Stoops (2003) modifications. Thin section and their description were made by Przemysław Mroczek from Maria-Curie Sklodowska University in Lublin, Poland. The soils were classified according to WRB (IUSS-FAO, 2006). The symbols of soil horizons are given after Guidelines for Soil Description (FAO, 2006).

Results

Investigated soils represented whole spectrum of truncation caused by accelerated erosion. Five classes of VTC-soils truncation have been distinguished (Figure 2):

1) Non eroded VTC-soils

Pedons located under mixed forest had fully developed sequences of horizons. Depending on the degree of pedogenesis (Świtoniak 2006, 2008) they were divided into two main groups: Luvisols (VTC-soils with argic horizon) and Umbrisols or Arenosols (VTC-soils without argic horizon). All non-eroded pedons had abrupt textural change at a depth of tenths of centimeters. The upper sandy layer contained, directly below the A horizon, a visible "minimum B-horizon". The transformation of soil material into a Bw horizon is evident as brownish staining caused by the accumulation in situ of iron sesquioxides. A sandy E horizon (Luvisols) or parent material (Umbrisols and Arenosols) exists between Bw horizons and the abrupt textural change boundary.

2) *Slightly eroded VTC-soils*

Soils without Bw horizons. In most non-eroded forest soils Bw horizons thickness was deeper than the average plowing depth in the arable areas. The lack of Bw horizons in arable VTC-soils should be attributed to shallowing due to erosion.

3) *Moderately eroded VTC-soils*

Increased erosion led to truncated E (Luvisols) or C (Arensols, Umbrisols) horizons. Ap horizons overlay directly Bt horizons. The abrupt textural change takes place at 20-30 centimeters and contemporaneously delimits the Ap horizons lower boundary. Surface humus horizons contain sandy material from primarily E or C horizons which were completely mixed by plowing with Ap horizons.

4) *Strongly eroded VTC-soils*

The material from the eluvial horizons of Luvisols was entirely removed. Surface horizons include illuvial material from argic horizons (ApBt). At this stage of truncation, luvisols have a morphology identical to cambisols (A-B-C sequences) and become texturally homogeneous. The illuvial character of the B horizons was established using micromorphology. A basic criterion used to distinguish the argic horizon was the presence of illuvial forms of clay concentration. For VTC-soils without the argic horizons this class of truncation can not be differentiated because these pedons do not have suitable diagnostic properties for an argic horizon.

5) *Completely eroded VTC-soils*

All diagnostic horizons and characteristical properties of VTC-soils were entirely truncated. Pedons represent ACp-C or ACkp-Ck morphology with no other diagnostic horizon than an ochric surface horizon. This minimal development permits to classify these soils only as Regosols.

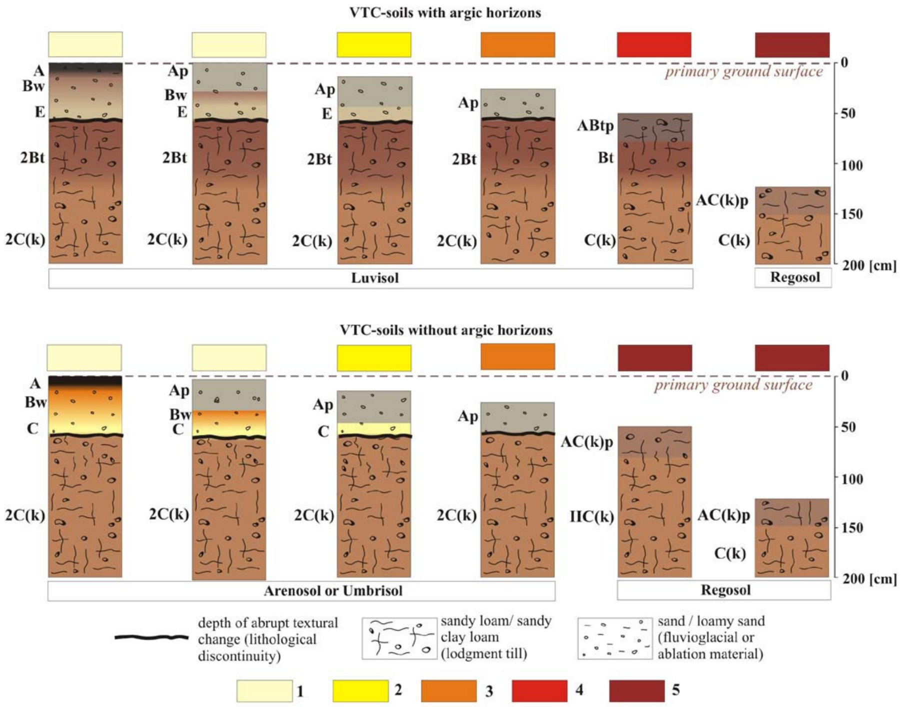

Figure 2. Classes of VTC-soils truncation: 1 – non eroded, 2 – slight, 3 – moderate, 4 – strong, 5 – complete

According to the identified degrees of truncation, maps of soil cover transformation caused by accelerated erosion were generated and overlapped on DEMs (Figure 3).

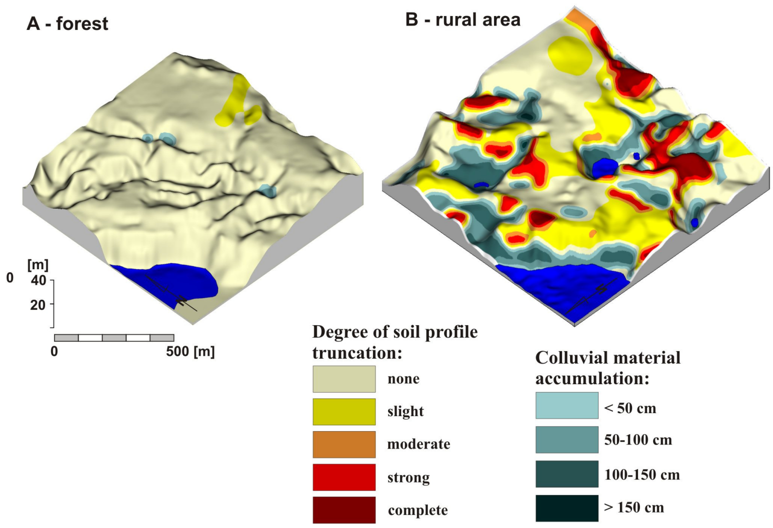

Figure 3. Soil cover transformation due to accelerated erosion on the two study sites.

Conclusion

The distinguished successional stages of VTC-soils truncation can be used as a suitable indicator of accelerated erosion range and intensity in young glacial landscapes. The widespread occurence of strongly and completely eroded investigated soils provides intense anthropic pressure on soil cover in the agriculture areas of North-Eastern Poland. Truncation of pedons with abrupt textural change due to the slope processes lead to disappearance of vertical textural contrasts and the formation of new soil units. The insignificant degree of erosive alteration and the range of soil cover transformation in forests areas prove that it is ananthropogenic character.

Acknowledgments
This work was supported by Ministry of Science and Higher Education, Poland. Research grant No. N N305 283337.

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