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Geomorphological Investigations and GIS Approach of the Tamiš Loess Plateau, Banat Region (Northern Serbia)

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Abstract

The focus of this study was the loess plateau located in the Tamiš River valley in the central part of Banat region (northern Serbia). This morphologic unit has been formed by the loess accumulation process during the last two glacial periods. Digital elevation model (DEM) is based on the 1:25.000 scale topographic maps. Detailed geomorphologic and hypsometric maps are provided with selected cross sections. The borders of the plateau and spatial distribution of the micromorphology are precisely defined on DEM. The plateau rises gradually from the Upper Pleistocene terrace on the north and northwest, while to the east and south slopes and vertical bluffs were controlled by the lateral erosion process of surrounding channels and by the weathering process on the loess. The plateau has an atypical morphology characterized by reduced geomorphologic diversity. Loess topography is significantly flattened by human impact. Its micromorphology is characterised by shallow depressions and gullies.

Key words: loess plateau, Tamiš River, DEM, morphology, morphometry

Introduction

In spite of the worldwide distribution of loess sediments, the international geomorphologic literature related to pseudokarst loess landforms is relatively rare (e.g. Fuller, 1922; Leger, 1990; Kertesz, Schweitzer, 1991; Rozycki, 1991; Rogers, et al., 1994; Zhu, et al., 2002; Móga, Németh, 2005; Gillijns, et al., 2005; Halliday, 2007; Tang, et al., 2008). Serbian loess landforms were also extensively investigated by different aspects (Zeremski, 1955a, 1955b; Zeeden, et al., 2007; Lukić, et al., 2009).

In the Vojvodina region (northern Serbia), typical loess is preserved on six discontinuous plateaus between the alluvial plains of the Danube river network and its tributaries (Marković, et al., 2008). The Tamiš loess plateau is located between the alluvial plains of the Tisa (Hungarian: *Tisza*; German: *Theiss*) and Tamiš (Romanian: *Timiş,* Hungarian: *Temes*) rivers. Previous larger dimensions of the Tamiš plateau have been reduced by intensive fluvial erosion.

The thickest deposits of loess are found in the easter part of the plateau. Pedostratigrapic interpretation of loess and paleosol units preserved in the ~12-m thick Orlovat loess exposure, on the bluff near the highest point of the plateau, provides stratigraphic correlations of lower thinner and upper thicker loess layers intercalated with strongly developed fossil pedocomplex (with V-L2, V-S1 and –VL1 loess paleosol stratigraphic units), respectively, at other loess sections in the Vojvodina region (Marković et al., 2005, 2006b, 2007; Bokhorst et al., 2009; Stevens et al., 2011). Similar description of the Orlovat loess sections has been described by Marković-Marjanović (1955). This complete loess-paleosol succession is probable preserved just in sector between Orlovat and Botoš settlements. Forthcoming magnetic, malacological, sedimentological and luminescence absolute dating investigations will provide more detailed information relevant to understanding of the Tamiš loess plateau morphogenesis.

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In this study we focus on morphological characteristics of the Tamiš loess plateau by using digital elevation model (DEM).

Geomorphological setting and Methods

Field observations were carried out between 2007 and 2011 for detailed geomorphologic mapping. In this study, we applied high-resolution digital elevation model (DEM) as a tool for detailed morphological investigations of the Tamiš loess plateau.

Tamiš loess plateau is situated on the northeast of Serbia in the Pannonian basin and it is the highest morphologic unit of the low-lying central Banat region. Plateau rises from the south-eastern edge of the so-called *Zrenjanin Upper (Late) Pleistocene terrace*, above the alluvial plain of the Tamiš River (Figure 1). The coordinates of the triangular-shaped plateau are 45°19'14"N and 20°29'48"E;

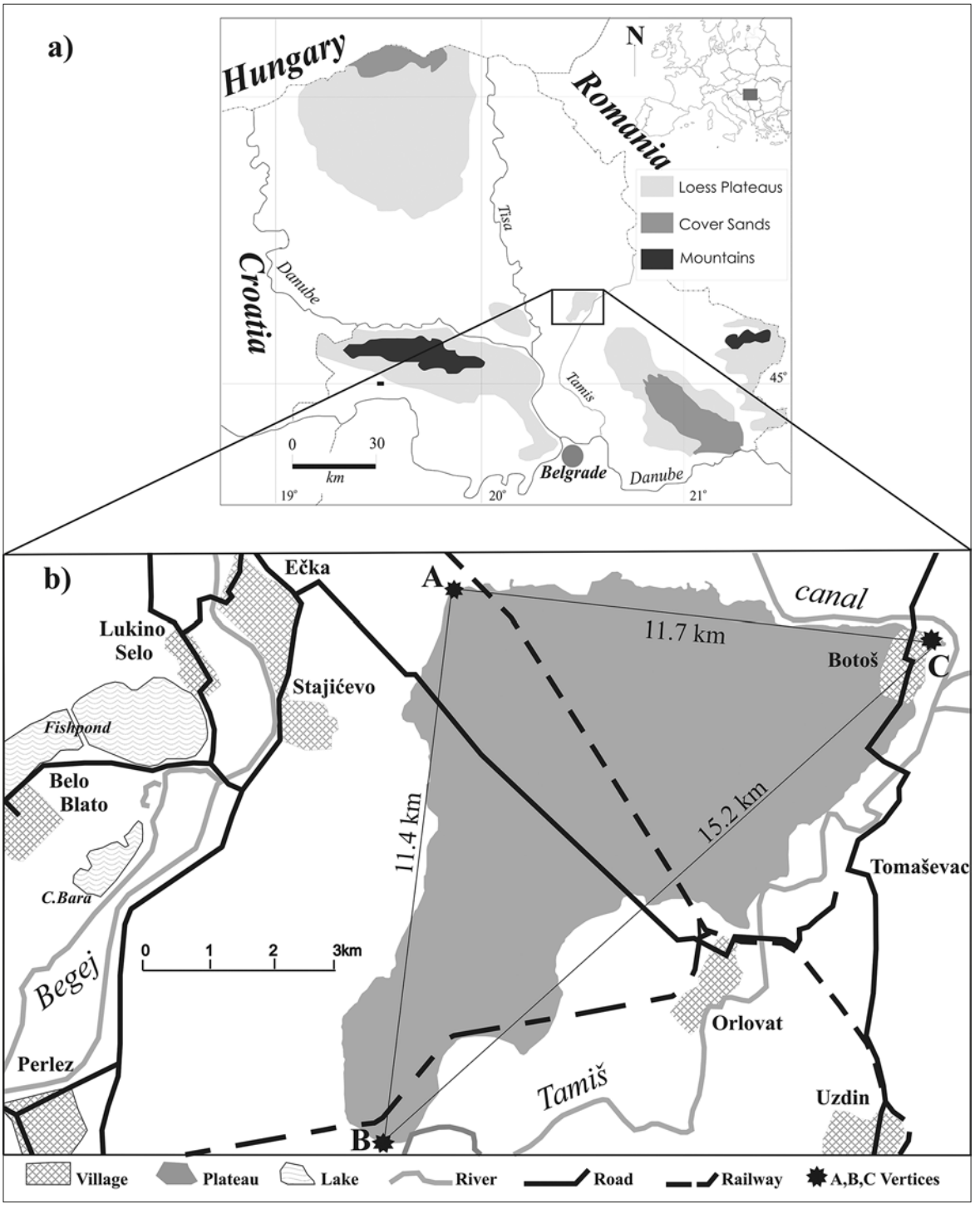

Figure 1. Position of the Tamiš loess plateau in Vojvodina province of Serbia (Marković, et al., 2004, modified) (a); and the basic features of the plateau (b)

45°18'42"N and 20°39'00"E; and 45°12'36"N and 20°28'30"E. The plateau extends between the settlements of Ečka, Botoš, Orlovat and Farkaždin. This plateau is situated between the floodplain of the Tamiš River (on the east-southeast), the paleo-meander *Petra* (west) and the paleo meander *Šozov* (northeast). Paleo-channel Petra is incised between the Upper Pleistocene terrace and the loess plateau. Paleo-Tisa formed this riverbed before the loess accumulation. Hydro-morphometric parameters of the Petra channel support this assumption. It can be plausible that Begej or even Tamiš River used this riverbed after the Tisa has been shifted westwards (Popov, et al., 2008).

On the north, the plateau gradually verges into the Upper Pleistocene terrace without a visible staircase. In previous Yugoslavian scientific studies several terms were in use to determinate this terrace unit: the Loess Terrace, the Varoš Terrace (*város* has the meaning *town* in Hungarian, terrace was named that way as a suitable natural location for numerous settlements), the Second Terrace or the Diluvial Terrace. However, these terms do not respond to the real characteristics of the unit. Hence its polygenetic character it would be more accurate to define this morphological unit according to the time of its formation. The structure of sediments is rather heterogenic. The lower part is consisted of fluvial sands of different grain size, while the upper section contains loess-like material (Marković, 2000). The plateau forms the watershed between the Tisa (i.e. its tributary river Begej) and the Tamiš River. Geologically, this landform is built-up by two loess layers with paleosol intercalation (Marković-Marjanović, 1949, 1955). In general, these successions are thought to be result of an alternation of glacial and interglacial periods, with an increased dust deposition resulting in formation of the loess layers during cold periods, and reduced dust deposition followed by increased pedogenesis during the warmer period (e.g. Kukla, 1987; Marković et al., 2006a, 2009, 2011). These successions can reach a thickness of ~ 25m in the eastern part of the Tamiš loess plateau. Thus, loess bluffs toward the meanders of the Tamiš River (Figures 5, 6) should be ideal for future high–resolution proxy record studies such as grain–size variations, MS and for the application of absolute dating methods such as optically stimulated luminescence. However, the morphological evolution of the Tamiš loess plateau is still poorly understood in terms of climatic forcing owing to the lack of a reliable timeframe.

Digital elevation model (DEM) is based of the 1:25.000 scale topographic maps published by former Yugoslav Military Geographical Institute in Belgrade. The following sheets were used: 379-2-4 (Zrenjanin South), 379-4-4 (Opovo), 380-1-3 (Lukićevo), 380-3-1 (Idvor), and 380-1-4 (Botoš). These sheets belong to the third edition of the 1996 Military Geographical Survey of Serbia. Compiling this high–resolution model by using the Microstation (Bentley) software was a time-consuming work. Provided grids were georeferenced into Gauss-Krüger projection by using the IRAS/C software. The vertical contour interval on these maps is 2.5m. Therefore, the vertical resolution of the compiled DEM is one meter and the horizontal resolution was set to 10m. The contours of the following contents were digitized:

- Elevation and morphology (contour lines with vertical interval of 2.5m in the range between 70 and 97.5m).
- Hydrology (contours of Tamiš River, Begej River (Romanian: Bega), branches and drainage canals, fishponds, oxbow lakes and swamps.

Thus, we created an active digital model of the research area, with defined layers that can be combined as needed. The main applications of DEM in this study are:

- defining the exact borders and area of the plateau,
- identification and spatial distribution of the micro-morphology,
- identification of river beds and abandoned meanders,
- precise measurements of horizontal dimensions,
- slope determination.

Results and discussion

Geomorphological mapping and basic morphological data

The Tamiš plateau, the smallest loess plateau unit in the Vojvodina province, has an atypical morphology characterized by reduced geomorphologic diversity. It is probable a consequence of discrete elevation dissection and intensive land use. In the previous geomorphologic literature the basic morphological data about the Tamiš loess plateau does not exist. The essential morphological information of the Tamiš loess plateau is presented in table 1. The plateau has irregular right–angled triangular shape, with 15.2km long curved edge alongside the Tamiš River. Measuring on the DEM has revealed that loess plateau covers an area of 87.63square kilometres, it is 15.2km long, and 11.7km wide at its widest point, along the northern edge between Ečka and Botoš. The southern end of the plateau, between the channels of Petra and Tamiš, is only 2.3kilometres wide.

The borders of the loess plateau are well defined towards the alluvial plain of the Tamiš val-

ley on the east and south. The plateau rises gradually from the Upper Pleistocene terrace towards the east, where it forms 8-20m bluffs above the alluvial plain of the Tamiš River. The plateau is positioned 3-20m above the terrace and flattened gently rolling hills dominate the landscape.

By analyzing elevations, presented as the hypsometric map (Figure 2), it can be seen that the plateau is tilted from west to east, from 83-84m transitional zone to the higher eastern part of the plateau, with mean altitude of approximately 90m. This indicates that loess deposits is accumulated over the paleo floodplain, thus following the local slope of the Pannonian basin and general flow directions. The highest point (Čevina humka, 98.1m) is located only 140m from the Tamiš riverbed. This mound rises 24m above the floodplain, dominating the gently corrugated topography of the plateau. Three representative cross sections of the Tamiš loess plateau are shown in the Figure 3 given below.

Geomorphologic map analysis reveals the exact shape of the loess plateau and its position (Fig. 4). The Tamiš loess plateau can be divided into three parts: the lower western, the highest eastern and the elongated southern part that is considerably reduced by the lateral erosion of surrounding abandoned river channels. Polygonal shape of the plateau resulted from various effects of fluvial erosion, in space and time. Local gentle slope of the Pannonian basin controlled the runoff towards the southwest forcing the meandering pattern of Tamiš, Begej and Tisa, which had the key role in modifying and reducing the loess plateau.

The loess has a tendency to erode, forming nearly vertical bluffs. This kind of landforms are particularly well developed towards the Tamiš River and cut-off meanders. Since the late Pleniglacial and the Early Holocene erosion process of the Tamiš River formed vertical ridges of 8-20m, along the eastern part of the plateau, between Botoš and Farkaždin. Upstream from Orlovat (Figure 7) and upstream from Farkaždin (Fig. 8) recent fluvial erosion is still the dominant geomorphic process that shapes the loess plateau. In this sector, floodplain is reduced so that the bluffs rise fully vertically over 20meters directly above the river. On the west, from Stajićevo to Farkaždin, and above the terrace

Table 1. *General morphometric data of the Tamiš loess plateau*

Total area of the Tamiš loess plateau - 87.63 sq km			
Maximum length (N/S)	15.2km	Maximum altitude	98.1m
Minimum length (N/S)	9.0km	Minimum altitude	83m
Average length (N/S)	12.1km	Average altitude	90.5m
Maximum width (E/W)	11.7km	Altitude above 85m	32.07%
Minimum width (E/W)	2.3km	Altitude above 90m	1.21 %
Average width (E/W)	7.05km	Altitude above 95m	0.009 %

Source Digital Elevation Model

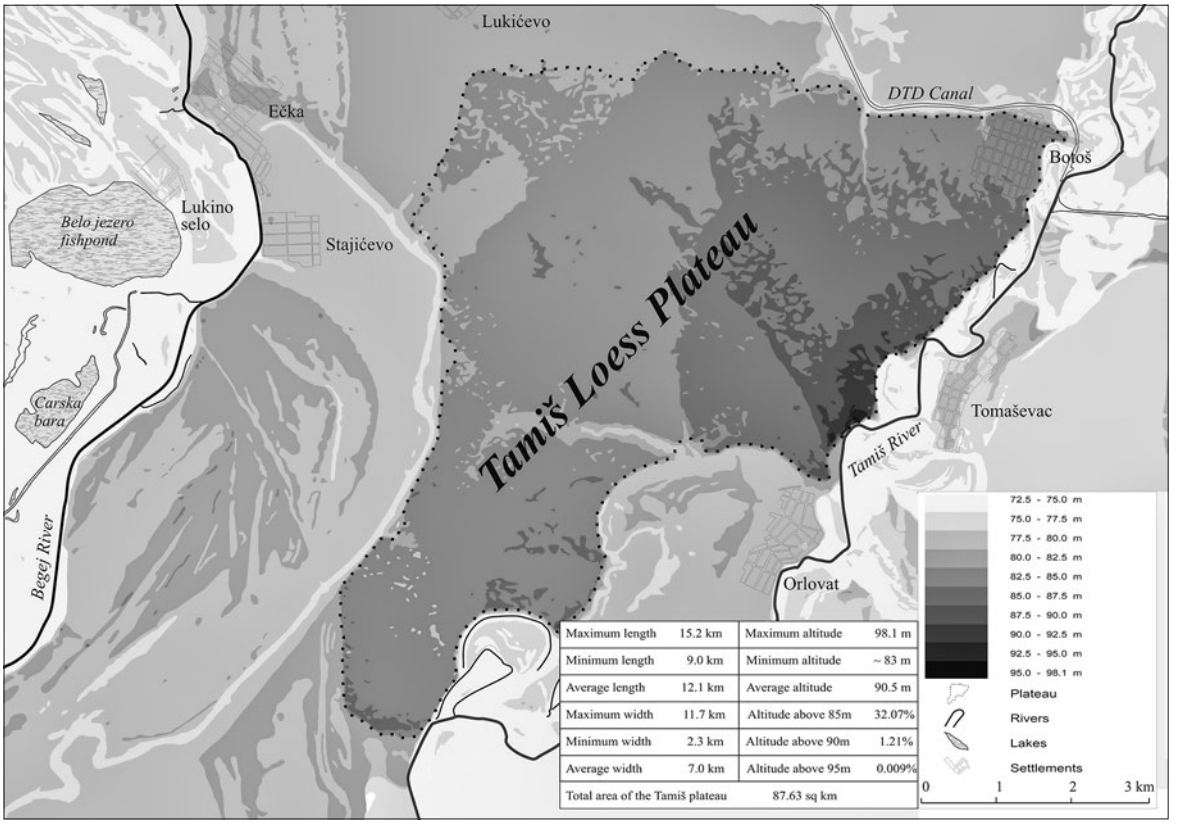

Figure 2. Hypsometric map of the Tamiš loess plateau based on DEM

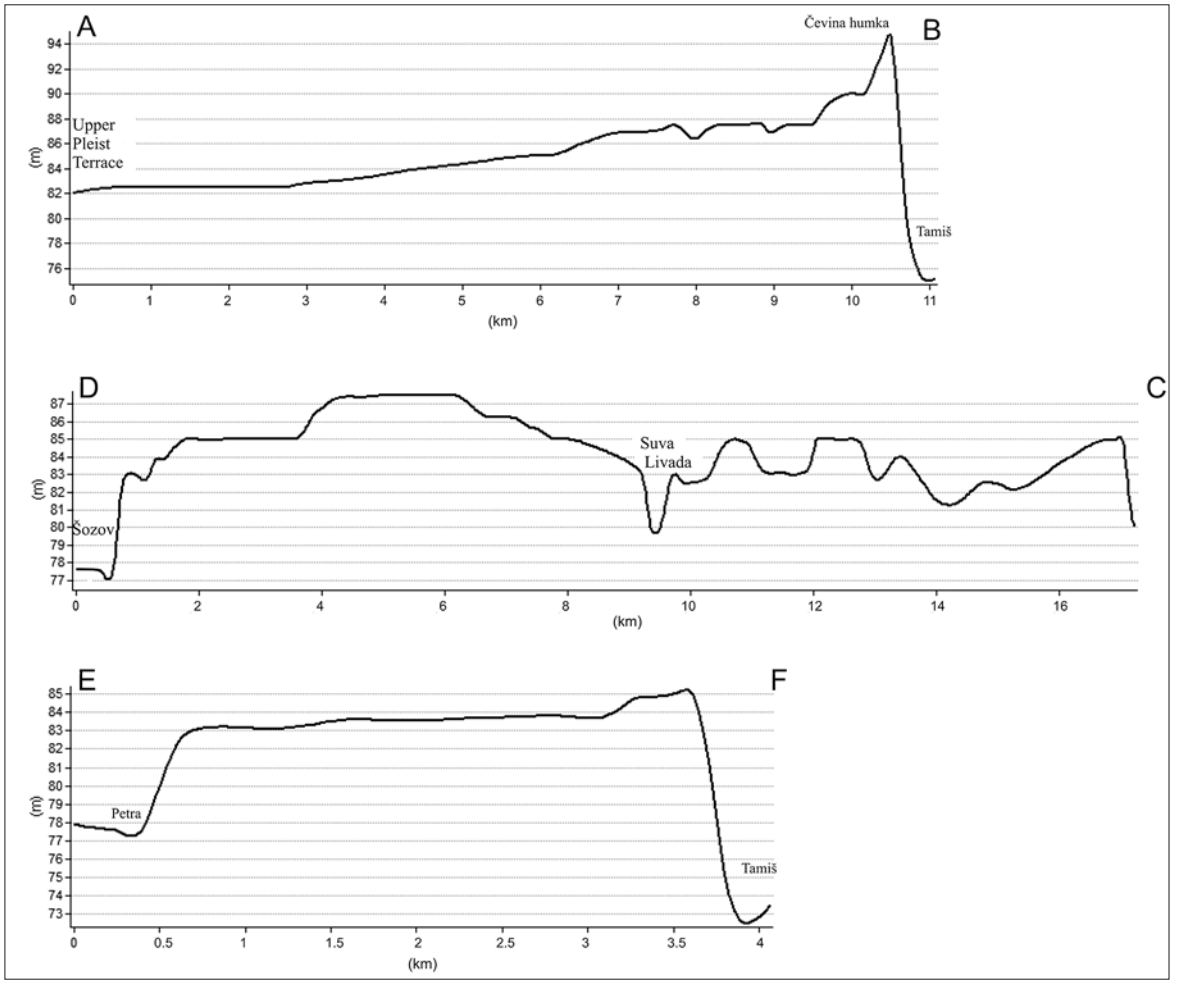

Figure 3. Cross sections of the Tamiš loess plateau. Positions of cross sections are presented on the Figure 4

between Orlovat and Farkaždin, the relative height of plateau is lowered down to 5-8m above the terrace, and bluffs are transformed into gentle-sloped transitional zones. However, further from the *Petra paleo channel*, on the northwest, the transition into the Upper Pleistocene terrace is completely gradual, without any visible step. On the north, towards the *Šozov paleo channel*, edge of the plateau is eased, as the consequence of long lasting abundance of the active lateral erosion.

Microlandforms analysis

Although this plateau is a loess geomorphologic unit, comparing to the nearby Titel loess plateau, typical micromorphology (depressions, gullies) is not fully developed. The dominant features of the undulating topography are low hills, shallow depressions and gullies. Partially, plateau has developed bluffs, caused by the constant slumping and vertical sheering of the loess soil. Contrary to some other loess plateaus in the region, the Tamiš plateau has only several well-developed gullies on its steep bluffs near the Tamiš River. The initial appearance of loess bluffs were modified by subsequent suffusion and erosion of running water that carved ephemeral landforms – gullies, narrow ridges, usually less than few meters wide, which fall off at near ninety-degree angles on either side. These pseudokarstic microvalleys are the longest on the northern side, towards the Šozov paleo-channel, i.e. the modern canal of the Danube-Tisza-Danube hydro-network. They have length of 2.3km and 1.3km. Along the steep slope, above the Tamiš valley, suffusion features and gullies can be seen. Six northern gullies are carved into the highest section of plateau, above the abandoned and active channels upstream from Orlovat, while the rest four are incised into the southern part of the plateau, above the cut off meander upstream from Farkaždin (Figure 9). On the bluffs, pseudokarstic gullies are shorter but much steeper (do not exceed 500m in their length, depth reaches m).

Developement of loess gullies and depressions is represented by the continuous suffusion, a geomorphologic process characteristic to loess. The summer dryness and winter frost which can determine certain cracks within the soil stimulate the suffusion.

The most dominant feature of pseudokarst on this generally flattened, slightly wavy surface of the loess plateau are depressions. However, intense an-

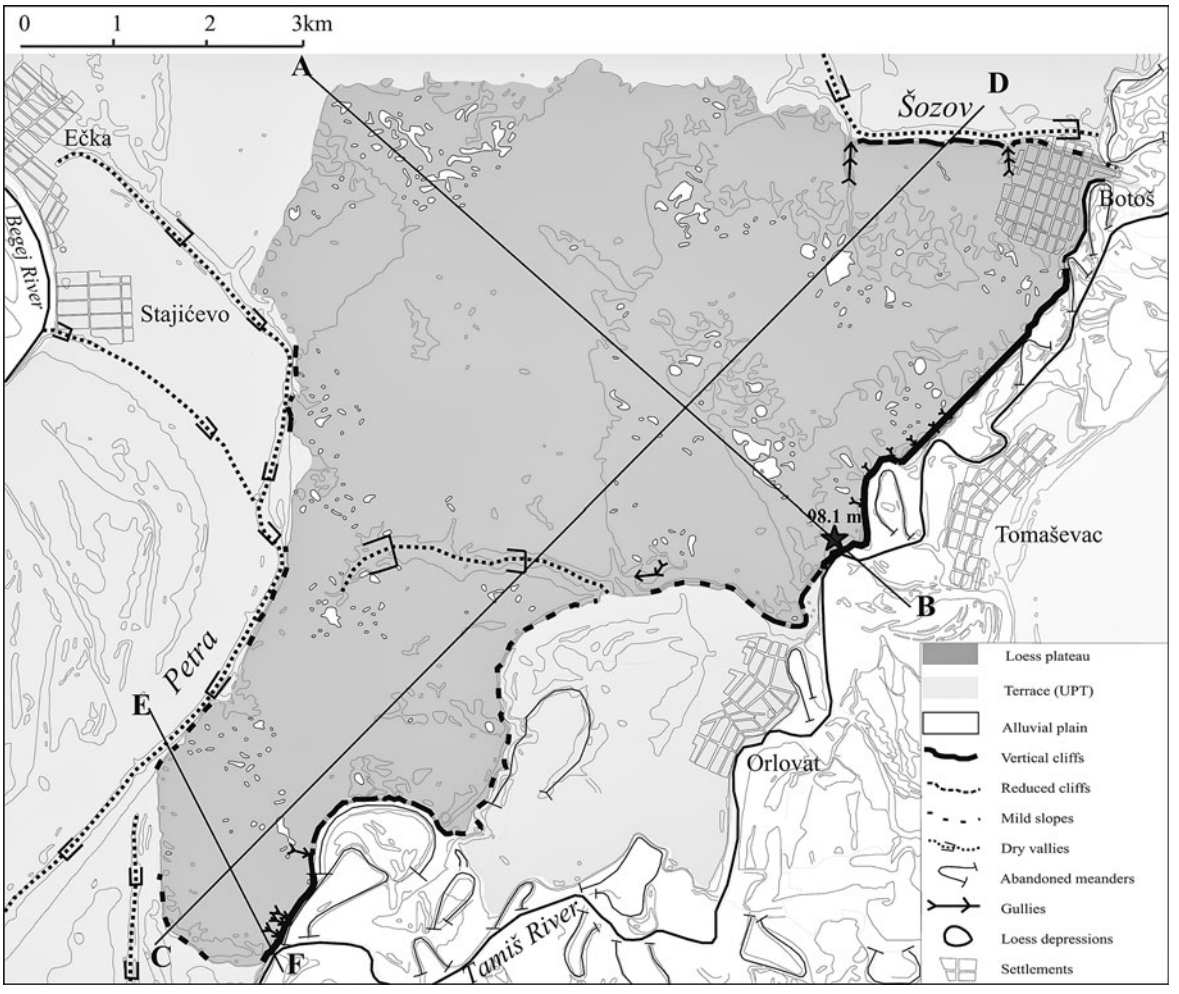

Figure 4. Geomorphologic map of the Tamiš loess plateau based on DEM. Cross sections: A-B, C-D, E-F are presented on the Figure 3

thropogenic pressure caused the erosion, thus reducing the topographic dissection and depressions. Comparing to the nearby Titel plateau (13.4 depression per sq km, Zeeden, et al., 2007), depressions on the surface of the Tamiš loess plateau are not common, only 2.8 depression per square km. These pseudokastic microelements are not evenly distributed throughout the surface of the plateau; they are concentrated mainly in eight spatial groups of which the largest one is located in the northern part of the plateau. General dataset of depressions are given in the table 2. Spatial trends for the preferential direction of depressions (total number of depressions per given spatial group) are plotted on figure 5. The orientation of depressions is relatively northwest-southeast bound, reaching an average angle of -33° (clockwise from north). In the northern and northwestern part of the plateau depressions have substantial northeast-southwest orientation. The direction of the longest axes for all depressions are given as inset in figure 5. A northwest-southeast orientation slightly prevails over a northeast-southwest classes of orientation axes. The elongate northwest-southeast alignment, similar to conditions of the Titel plateau (Zeeden et al., 2007), indicating the dominating wind direction within the Pannonian Basin (Roszycki, 1967; Pecsi and Richter, 1996) and deflation process.

Table 2. *General dataset of depressions*

Total number of depressions	246
Mean density of depressions (per sq.km)	2.8
Mean length of depressions (in meters)	141
Mean width of depressions (in meters)	73
Mean orientation angles of depressions	33°

Depressions show an elongate form. Only 8 out of 246 depressions do not have clear preferential orientation. A dependency of length and width of depression axis may be observed independently of the size of depressions. Figure 6 shows the relationship of length and width of depressions, the length to width ratio is lower than two for most depressions.

The largest depressions are accreted into irregular shaped forms, with area of 0.02-0.15sq. km. The origin of the pattern of the depressions is not considered here.

Figure 5. Mean orientation of the depressions axis on the Tamiš loess plateau based on DEM for selected groups of depressions. Arrows represents mean depression orientation of the group, the length is proportional to the total number of depressions within the group. Inset shows classes of orientation axes of all depressions. The absolute number of depressions per directional class is given by the radial axis.

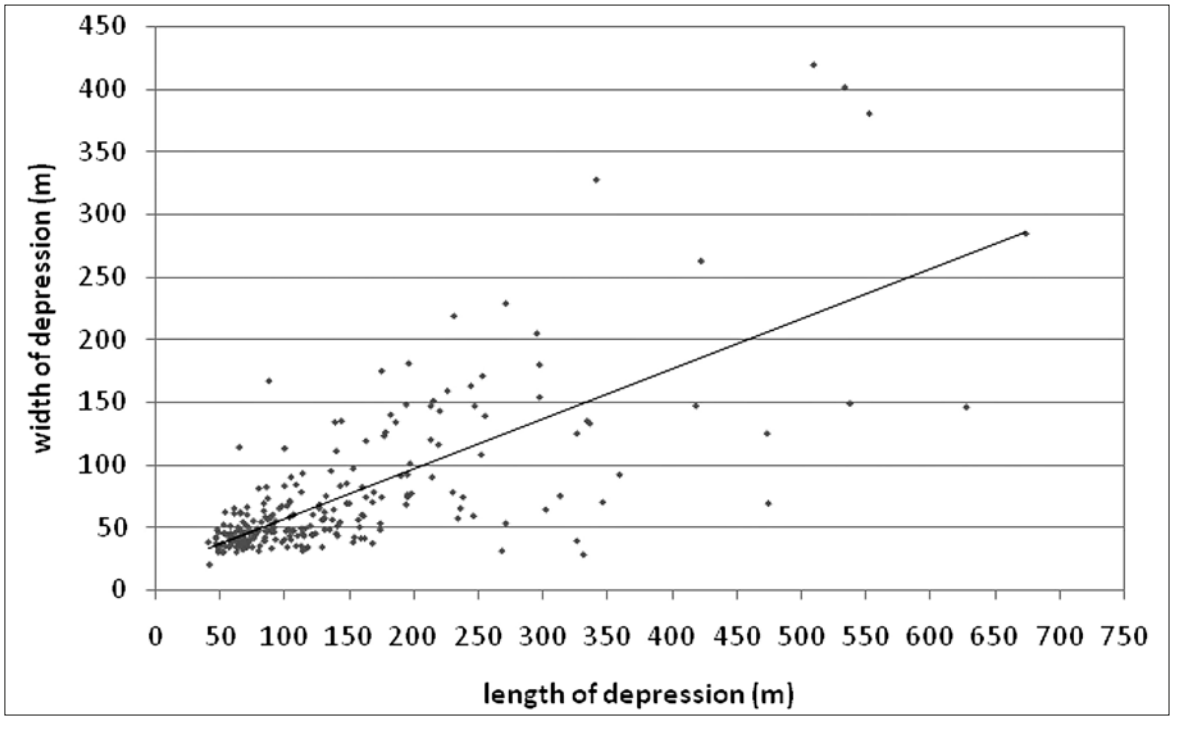

Figure 6. Relation of length and width of all depressions

Figure 7. Bluff of the loess plateau above the Tamiš River cut-off meander, between Orlovat and Botoš

Figure 8. Bluff of the loess plateau above the Tamiš River cut-off meander, upstream from Farkaždin

Figure 9. Typical gully cut into the loess bluff above the Tamiš alluvial plain, near Farkaždin

Conclusions

The Tamiš loess plateau is one of the six loess plateaus in Vojvodina province (northern Serbia) formed during the Pleistocene glaciation. However, it is one of the least studied units of the regional morphology, although it is situated in the central part of the province. Specific position between the river channels (both paleo and active streams) controlled the morphology and the shape of the plateau. This study presents the application of digital elevation model for defining the exact spatial data of the Tamiš loess plateau (borders of the plateau, slope determination, identification and spatial distribution of the micromorphology, precise measurements of all horizontal dimensions). The high-resolution model is based on the 1:25.000 scale topographic maps. Active fluvial erosion is still a dominant geomorphic process on the short section where the loess bluffs rise vertically and directly above the river for more than 20meters. Further research on the exposed ridges may contribute to understanding the evolution of the plateau. Application of absolute dating methods (e.g. optically stimulated luminescence dating) should be considered. Beside the fundamental importance, presented research can be applied in investigations related to erosion problems and flood risk management; bluffs of the plateau with its surroundings represent diverse natural habitats for many endangered species hence these results can have application in environmental studies.

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