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THE INFLUENCE OF TOPOGRAPHY ON THE SUBSIDENCE PROCESSES OF LOESS-LIKE DEPOSITS FROM SĂLCUȚA PLAIN (SOUTH-WESTERN ROMANIA)

INFLUENȚA TOPOGRAFIEI ASUPRA PROCESELOR DE TASARE A DEPOZITELOR LOESSOIDE DIN CÂMPUL SĂLCUȚEI (SUD-VESTUL ROMÂNIEI)

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Abstract: This paper aims to establish the role of the local topography of Sălcuța Plain (subdivision of the Oltenia Plain) in the subsidence process of loess-like deposits. The relevant features of the topography, especially the slope, were generated using SAGA GIS v.7.8.0 and QGIS v.3.22 software based on an altimetric terrain model. The results obtained highlight the fact that 303 microdepressions were formed following the chemical and mechanical subsidence of the loess deposits. The most important characteristic, which conditions the genesis of the subsidence process and implicitly the formation of microdepressions, is the slope; in this case, the subsidence process occurs in areas where the slope has values lower than 2 degrees. The research advanced by generating the Topographic Wetness Index (TWI) in order to identify areas with moisture excess, the moistening of loess-like deposits being one of the basic conditions in the genesis of the subsidence process. The highest values of the Topographic Wetness Index (TWI), over 10, were recorded in the areas with microdepressions.

Key-words: *tasare, loess, panta, Indicele topografic de umiditate, GIS, Câmpul Sălcuței.*
Cuvinte cheie: *subsidence, loess, slope, Topographic Wetness Index, GIS, Sălcuța Plain.*

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1. INTRODUCTION

Loess is a sediment that appears in the form of deposits composed exclusively of silica, dust, and clay (Bradley, 2015; Smalley & Marković, 2019). In other cases, loess appears together with different sediments or with fossil soils forming loess-like deposits (Wacha et al., 2011; Banak et al., 2013; Meszner et al., 2013; Constantin et al., 2021).

The specific relief of the area covered with such deposits consists mainly of microdepressions, but also suffusion funnels, subsidence steps, valleys, etc. (Achim, 2013). Microdepressions formed in loess and loess-like deposits have been reported and studied in different areas of Europe: Poland (Kołodyńska-Gawrysiak et. al., 2016), Belgium (Gillijns et. al., 2005, Vanwalleghem et al., 2007), France (Etienne et al., 2011), Serbia (Zeeden et. al., 2007), Romania (Gherghina et. al., 2008; Grecu et. al., 2015). In the Romanian specialized literature, these microdepressions have different names depending on the surface: "crovuri" with a diameter of less than 1 km (Posea, 2006; Grecu et al., 2015), "găvane" with a diameter greater than 1 km, and "pădine" with surfaces of several kilometers. The latter can have *crovuri* on their surface (Boengiu, 2008; Achim, 2016; Grecu, 2019). In Romania, microdepressions formed in loess and loess-like deposits are found especially in the southern part of the country, in the Central Bărăgan Plain, Burnaz Plain, the Călmățui basin, their morphometry being researched in detail by Grecu et. al. (2015).

In Serbia, at the level of the Titlel Plateau, the genesis of an impressive network of depressions formed in loess deposits was investigated, the authors suggesting that they formed due to the dissolving action exerted by infiltration water on an initial aeolian relief (Zeeden et. al. 2007).

The formation of microdepressions in loess or loess-like deposits can be different depending on the modeling agent and the lithological characteristics of the deposit (Achim, 2013). The key-factors in the genesis of these microdepressions are the chemical and mechanical subsidence (Florea, 1970), deflation (Kołodyńska-Gawrysiak & Poesen, 2017), the influence of the paleorelief under the deposit (Kołodyńska-Gawrysiak, 2019; Meszner et al., 2013), as well as anthropogenic activities (Kołodyńska-Gawrysiak & Poesen, 2017).

The study aims to present how the local topographical particularities of Sălcuța Plain influence the subsidence process of the loess-like deposits. This process results in a network of 303 microdepressions with various shapes – circular, elongated or irregular.

2. DATA AND METHODS

2.1. Study area

The study area is located in the south-west of Romania (Fig. 1). It has a surface of approximately 220 sq. km and it is known as “Sălcuța Plain” (Geografia României, 2005).

Sălcuța Plain is a subunit of the Oltenia Plain that has a piedmont origin with an interfluve aspect (Posea, 2006). The landscape element that changes the apparent monotony of this area is the impressive network of microdepressions. The largest part of the study area is covered with a 10 to 15 m thick layer of loess-like deposits, intercalated with fossil soils identified in geological profiles (Coteț, 1957; Popovăț, 1945).

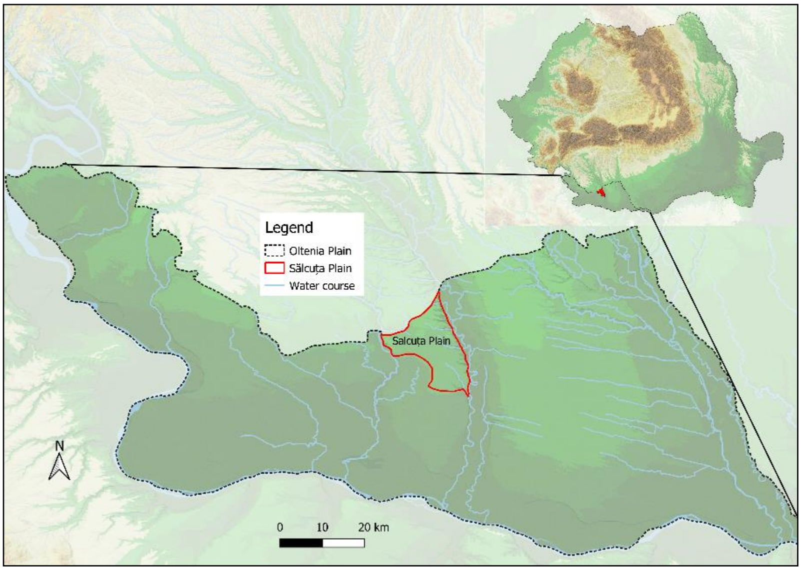

Fig. 1. Study area within the Oltenia Plain
(Source: processed in QGIS 3.12 after Copernicus EU DEM V1.1)

2.2. Methods

The analysis of the topographic features of the studied area was carried out in a GIS environment, using two open source softwares: SAGA GIS v7.8.0 and QGIS v3.12. Two morphometric indicators, with high relevance in influencing the subsidence process, were derived: slope and Topographic Wetness Index (Kopecký et al., 2021). The initial grids were generated in SAGA GIS based on a LiDAR model with a high spatial resolution of 5 m.

To calculate the declivity of the slopes, the calculation algorithm "9 parameter 2nd order polynomial" from SAGA GIS was used, which is based on the calculation method proposed by Zevenbergen & Thorne (1987).

In order to identify the sectors with water saturation, the Topographic Wetness Index was used, because it is a morphometric indicator specific to hydrographic analyses, which highlights the predisposition of a cell in a DEM to accumulate water (Mattivi et al., 2019; Kopecký et al., 2021).

The Topographic Wetness Index (TWI) was also calculated with SAGA GIS software (Conrad et. al, 2015), based on the LiDAR model, using the formula proposed by Boehner & Selige (2006):

$$\mathrm{WI}_s = \ln\left(\frac{\mathrm{SCA}_M}{\tan\beta}\right) \quad (1)$$

where
WI_s – Topographic Wetness Index
SCA_M – Specific Catchment Area
$\tan\beta$ – Slope angle

The microdepressions were identified and mapped based on satellite images retrieved from Microsoft Bing and Google Earth Pro (2011 – 2019 period).

The hydrographic network was obtained automatically from the Openstreetmap website by using the QuickOSM plugin available in QGIS software (data accessed in 2023).

With the help of QGIS software v.3.22, the geospatial data used in this study were redesigned in the Pulkovo 1942(58)/Stereo70 - EPSG 3844 projection, specific to Romania, and subsequently all final cartographic products were stylized and rendered.

3. RESULTS AND DISCUSSIONS

In the studied area, the microdepressions were formed by chemical and mechanical subsidence, in this case water being the modeling agent (Florea, 1970). Rainfall water penetrates the deposit and dissolves the carbonates (Grigore, 1971). Dissolved carbonates are leached at the base of the deposit or sometimes reach directly the phreatic aquifer layer (Florea, 1970). Following the removal of the carbonates, the deposit is compacted and flattened resulting in microdepressions at the level of the topographic surface (Florea, 1970). The accumulation of precipitated carbonates at the base of the loess-like deposits alternating with fossil soils was observed in the field in the opening of the slope near Bâzdâna locality, in the eastern extremity of the study area (Boengiu et al., 2011) (Fig. 2).

Fig. 2. Precipitated carbonates in the loess-like near Bâzdâna
(Photo by Boengiu S., 2009)

The subsidence process of these deposits is conditioned or favored by certain characteristics of the topographic surface, the most important being the slope. On slightly inclined surfaces the water resulting from precipitation tends to accumulate and later infiltrate into the deposit, thus favoring dissolution and carbonate leaching (Florea, 1970).

Water accumulation at the topographic surface level and its subsequent infiltration plays a particularly important role in the genesis of the subsidence process and implicitly the formation of microdepressions

Following the mapping in GIS environment and the validation of the results obtained in the field, 303 microdepressions were identified (Fig. 3), their surface totaling about 11.45 km² or 5.2% of the studied area. The microdepressions were formed in areas where the declivity of the slopes registered values lower than 2 degrees. In the central area, where the declivity is low (below 2 degrees), the density of microdepressions is high (10-12 depressions/km²). In the eastern extremity of the study area, as the slope increases above 20 degrees, there were not identified any microdepressions.

Fig. 3. The location of microdepressions in Sălcuța Plain
(Source: basemap - Google Earth PRO)

The high density of microdepressions in the central area (Fig. 4) is a consequence of the fact that the low declivity (below 2 degrees) favors water accumulation on the topographic surface and its infiltration into the loess-like deposit.

Fig. 4. Loess microdepressions in central part of the study area
(Source: Google Earth PRO)

In the eastern part of the study area, on the alignment of Livezi, Gura Văii, Țuglui, Bâzdâna and Foișor localities, the value of the slope declivity increases above 5 degrees. Thus, the water from the precipitation is drained and captured by the network of parallel valleys (Fig. 5). The direct effect of water drainage from the topographic surface in this area is the decrease in the number of microdepressions.

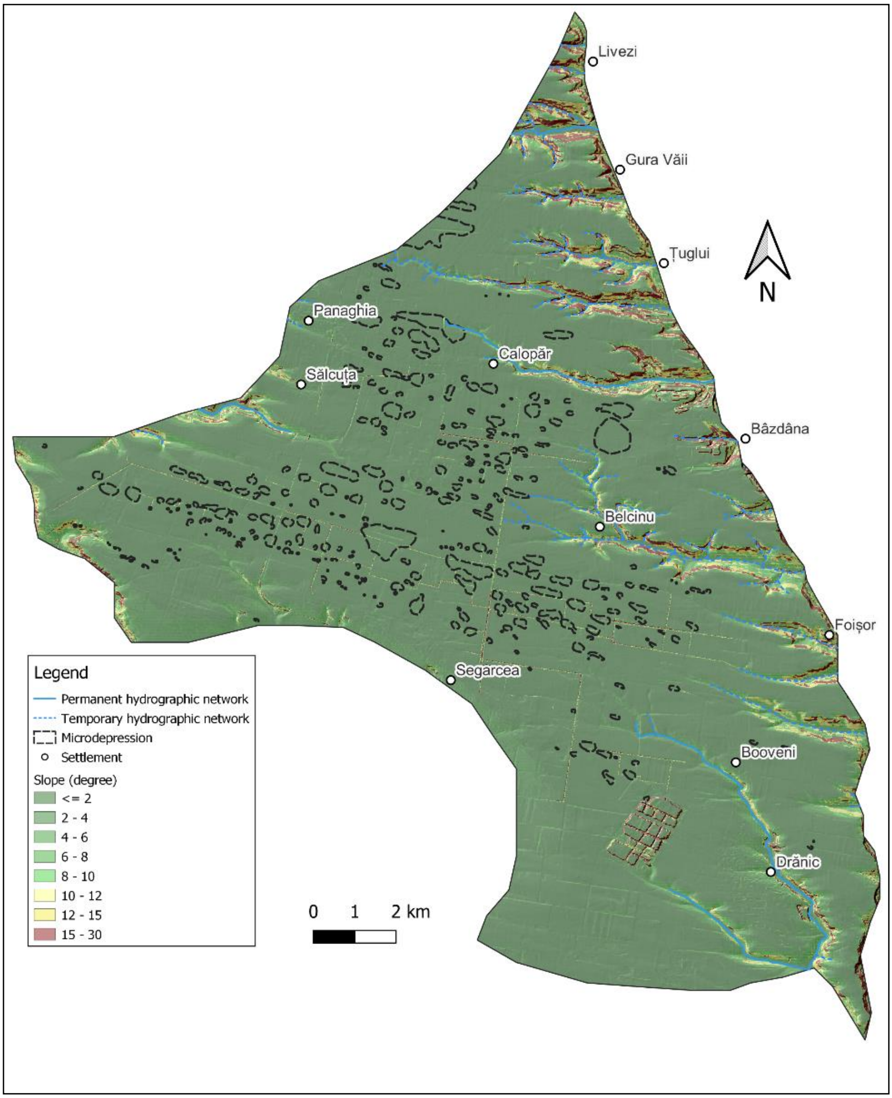

Fig. 5. The declivity map of the slopes in Sălcuța Plain

In the entire study area, there is a slight inclination of the topographic surface on the west-east direction. This explains the elongated shape of the microdepressions on this direction, the infiltrated water in the deposit being drained by the underground hydrographic network in the same direction.

The Topographic Wetness Index (TWI) has values between 5.6 and 14.4 (Fig. 6). The higher the values of this indicator, the greater water accumulation potential is (Mattivi et al., 2019).

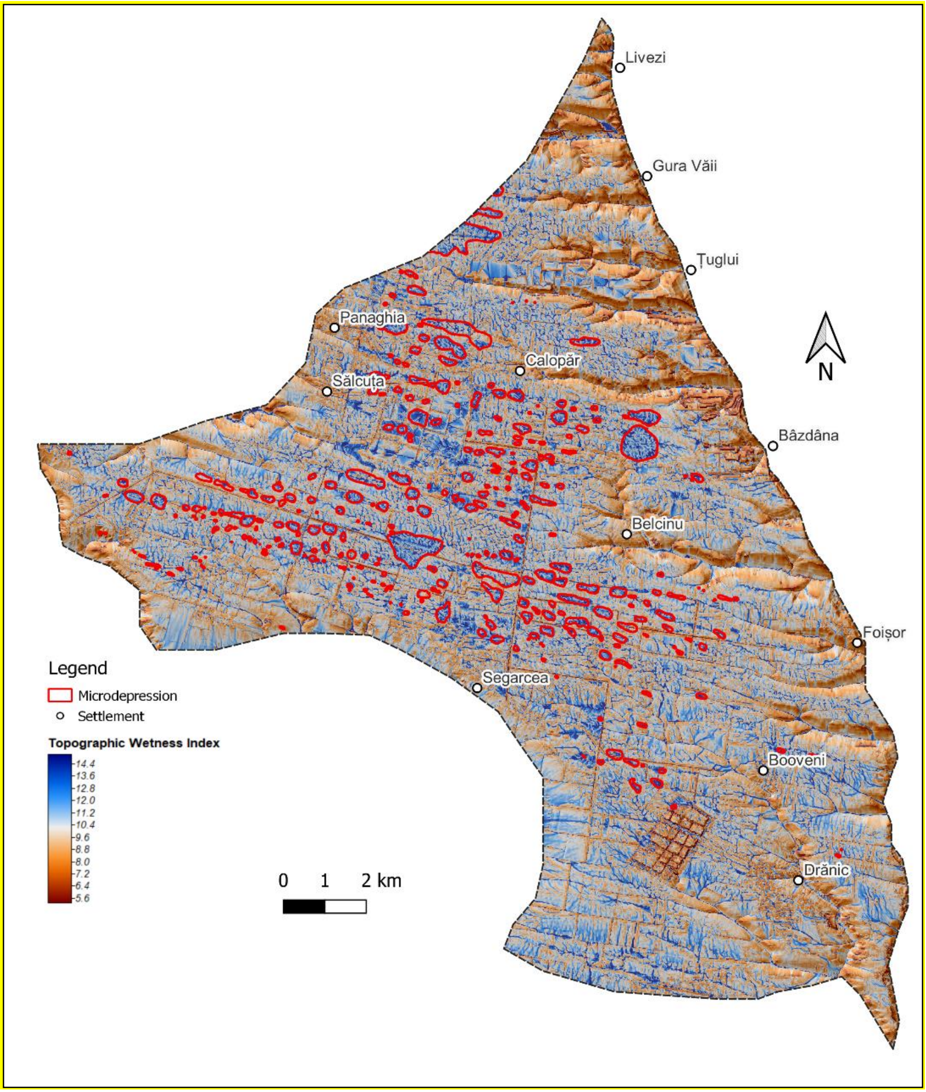

Fig. 6. Topographic Wetness Index map – Sălcuța Plain

Obviously, values over 10 are recorded at the level of microdepressions, because they are small lowland areas that favor water accumulation (Fig. 6). In the immediate vicinity of these microdepressions, the values of TWI are between 8 and 10, indicating an excess of moisture around them. A few areas with a circular shape were also identified, where TWI registers values above 10, but there are no microdepressions. In these sectors, they might have existed in the past, but they disappeared due to deep tillage leveling (Stroe, 2003).

The limitations of the proposed methodology are induced by the limitations of the LiDAR terrain altimetric model used for the present study. The most important limitation is given by the 5-meter spatial resolution of the LiDAR model. A 1-meter resolution model would generate more conclusive results in the calculation of slope gradients. Another limitation results from the one stated previously, the value of the TWI indicator being directly influenced by the slope values.

4. CONCLUSIONS

The characteristics of the topographic surface play an essential role in the genesis of the subsidence process and subsequently in the genesis of microdepressions. In this study area, the most important element is the slope, microdepressions forming mainly in areas with a slope of less than 2 degrees.

The Topographical Wetness Index highlighted the areas with moisture excess, the obvious ones being the microdepressions, but also the areas in their vicinity. The existence of some microdepressions, which currently no longer exist due to the agrotechnical works carried out to expand the agricultural land, were marked by circular areas with TWI values higher than 10.

The results obtained from the applied methodology can be improved by using a LiDAR-type altimetric model, with a spatial resolution of less than 1 meter.

Most of the microdepressions are located on agricultural land cultivated with cereals. Their presence generates a prolonged moisture excess, thus representing a problem for cereal crops. In this sense, the results of this study can be used by farmers to identify areas with high moisture and, thus, apply adequate agrotechnical measures necessary to reduce the negative effects of excessive moisture.

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