ACTA CLIMATOLOGICA ET CHOROLOGICA
Universitatis Szegediensis, Tom. 38-39, 2005, 157-162.

DEFINING THE CORROSION SURFACE OF THE DOLINES BY MEANS OF A DIGITAL ELEVATION MODEL

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Összefoglalás – A karsztmorfológia kutatások egyik fontos területe a karsztok jellegzetes formáinak, a dolináknak a sokirányú vizsgálata. A karsztok változatos felszíne, a dolinák alakjának egyedi vonásai megfelelő pontossággal csak szabatos térképészeti eljárások, és teljes körű új felmérés segítségével elemezhetőek. Digitális domborzatmodellek alkalmazása lehetőséget ad a lejtőkategória vizsgálatára, aminek segítségével a felszín valós nagysága (összehasonlítva a felszín síkba eső vetületével) számítható.

Summary – The complex study of most typical karst features, the dolines, forms an important part of karst morphological research. The varied surface of the karst, the individual shapes of the dolines can only be analysed with the help of proper cartographical methods and a holistic approach. The use of dipital elevation models provides pssibility to compőute the precise slope values and trough these to specify the real area values of the surface (as opposed to the area in projection).

Key words: karst doline, surface, GIS, digital elevation model

INTRODUCTION

A complex investigation of the dolines, the most typical features of karsts, is an important domain of karst morphological research. In earlier investigations of the dolines (*La Valle* 1968; *Zámbó* 1970; *Jakucs* 1971; *Ford and Williams* 1989; *Veress and Péntek* 1990; *Castiglioni* 1991; *Bárány-Kevei and Mezősi* 1991; *Farsang and Tóth* 1992; *Hoyk* 2002; *Telbisz* 2003; *Péntek and Veress* 2004) morphometric parameters were defined either on the basis of field observation and measurement, or topographic maps, GPS and total station measurements. The highly varied surface of the karsts, the unique shapes of the dolines in a large area can only be measured and analysed with the appropriate precision by means of proper cartographic methods and a complete new survey.

Digital elevation models are more and more often used for the measuring and representation of elevation data. The available databases (e.g. SRTM) can be well used to describe karstic macrofeatures, on the condition that they are properly extended (*Telbisz* 2004). In an earlier study we showed the extent of differences between the elevation model of the study area (Bükk-plateau) created from available topographic maps and the model of the same area derived from more reliable large-scale aerial imagery by photogrammetric methods (*Zboray and Keveiné Bárány* 2004). In order to carry out analysis on the digital elevation model, it is necessary to precisely define the extent of the dolines, which we described by taking the most external closed contours for boundary.

The advantage of using the most external closed contours as boundary is that it provides a good opportunity for comparison though it is subjective to a certain extent because the dolines do not usually end in the same plane. Another reason for the use of this definition is that in earlier doline morphometric research the height difference between endpoints was not defined when measuring different parameters, like for example diameter. This problem of the dolines' area was also investigated by *Telbisz et al.* (2005), who extended the boundaries to include the dolines' catchment area.

METHODS

Data acquired by remote sensing techniques increasingly gain ground in karst research. The field-photogrammetric measurements of *Tóth and Schläffer* (2004) on karrs proved that this method – combined with field measurements – provides more precise information.

The classic photogrammetric methods we use create stereo-models from aerial images which are suitable for the measurement of height data by stereo-photogrammetric instruments. The advantage of this method is that – when using the appropriate scale – it enables the user to analyse and assess large areas. Aerial images are available of any Hungarian area from different years since 1950 because of the periodic map-revising programs of the last fifty years.

Using the above mentioned GIS database of the Bükk-plateau we interpolated a contour map with 0,5 m intervals (for comparison: the base contour interval of topographic maps is 5 m). Within the limits of the most external closed contour we defined 275 dolines and we created the digital elevation model of the area.

DISCUSSION

In a GIS environment – with the help of the *LEICA ERDAS IMAGINE Slope application* – there is a possibility to quickly define slope categories. Each cell of the slope map contains the slope angle as an attribute (*Fig. 1*) The size of the cells is 2x2 m.

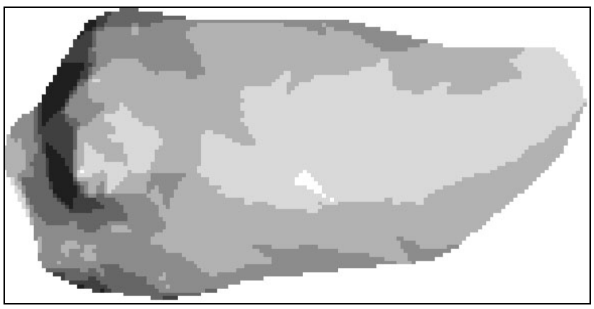

Fig. 1 A doline's slope values in Bükk-Plateau (Bükk-fennsík)

Considering the morphometric parameters of a doline the area of the feature is of utmost importance. It can be approximated with an ellipsoid shape, by measuring the two axes in the field. On a topographic map, contours can be used to define the doline's boundaries but this method, due to the above mentioned reasons, may be highly inaccurate. All of these methods only measure the projected doline area.

Because of the complex spatial form of dolines, their shape and corrosion surface could only be computed using mathematical formulae, considering the doline to be approximately of the shape of a spherical calotte (*Keveiné Bárány,* 1981).

Even in the case of area measurements carried out on digital elevation models (DEM) we must consider that the cells of the DEM represent the projected points of the surface as well. The advantage of this is that DEMs can be compared with different maps of the same projection; however they do not directly provide information on the surface. Yet as the slope angle in each grid point is known, the real surface can be computed in these points (*Fig. 2*).

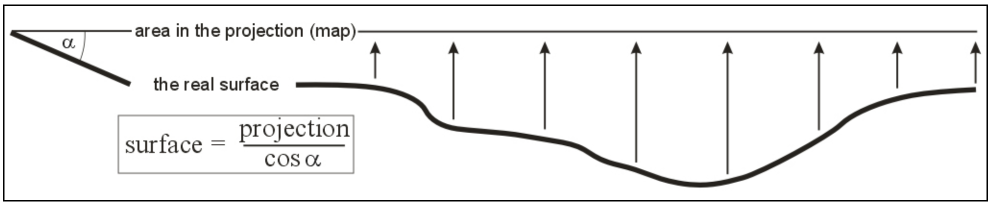

Fig. 2 The computation of the real surface at a point of the doline (cross-section)

The advantage of this method is that by editing the attribute tables, the surface can be computed with any GIS-related software which is able to handle digital elevation models. Besides GIS software there are certain special applications which can directly measure surface (*Telbisz et al.,* 2005)

All GIS data, be it point, line or polygon data, contain an attribute table presentable and editable by even the simplest GIS software. In this attribute table, similarly to Excel tables, we can assign functions to the columns or fields.

In the case of the slope map's attribute table the area belonging to a given slope angle is the frequency times the regular grid size (4 m²). By assigning the formula shown in *Fig. 2* the function of a new column, the real surface area belonging to the given slope angle can be computed (*Fig. 3*). These areas added up equal the real surface of the doline.

Slope	Frequency	Area	Surface
0	36	0.0144	0.0144
1	487	0.1948	0.19483
2	841	0.3364	0.336605
3	587	0.2348	0.235122
4	324	0.1296	0.129916
5	437	0.1748	0.175468

Fig. 3 Inserting the real surface function to the slope attribute table

RESULTS

Using the method described above we computed the real surface area of the 275 dolines of the study area. The result was 1.2397 km^2 as opposed to the 1.2139 km^2 of the projected area so in the case of the Bükk dolines by using this method we get an average 2.13% extra compared to the area measured on maps. Because of the large number of elements we suppose that the proportion of the real surface to the projected area would probably not change significantly if we measured more dolines in the area.

By grouping the differences of real surface and projected area by slope angle values we find the highest values in the case of 15-16 degree slope angles. The gradient, shape and maximum of this surface-addition graph would probably be different in other karst areas. (*Fig. 4*)

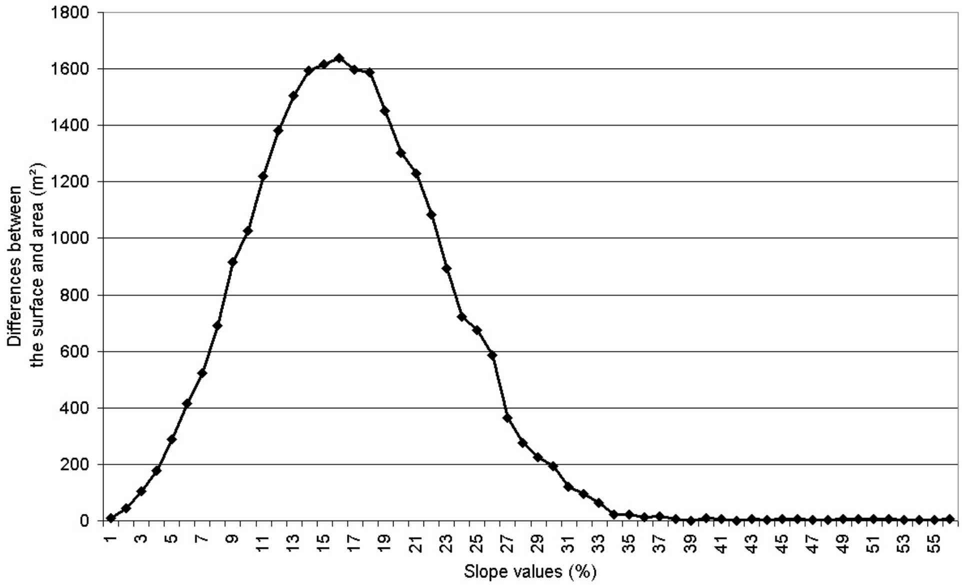

Fig. 4 The surface-addition graph of the slope values within the investigatid area

When comparing the real surface to the projected area we can state that if the quotient of the two is a high value, then the doline is probably deeper than dolines with a lower quotient value. This quotient is the surface rate which describes well the vertical extension of the doline. (*Fig. 5*)

Analysing the graph we can state that in the case of smaller dolines (<0.01 km^2) the surface rate value does not usually exceed 2% apart from the extreme values of a few dolines on the plateau. The bigger dolines (>0.01 km^2) can be characterised by an increasing surface rate though the values are rather varied. Finally the biggest dolines of the study area show a decrease in the surface rate probably due to gravitational mass movements which facilitate the widening of the doline by flattening out the steep slopes (*Telbisz,* 2003). On the basis of these samples we could not establish a significant relationship between the surface rates and the spatial distribution of the dolines, apart from those situated on the plateau. This result does not exclude the possibility that such relationship could be established by further investigations (and different sampling methods). Yet depth characteristics basically describe the unique shape, structure and microclimate of the doline along with the circumstances of formation.

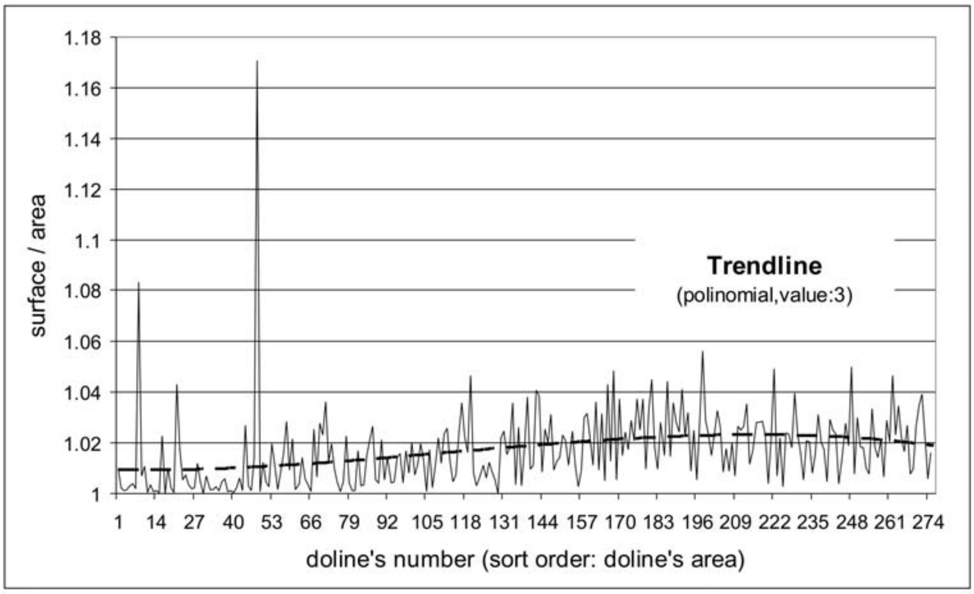

Fig. 5 The dolines' surface rate within the investigation area

CONCLUSION

- The measurement of a large number of dolines in a large area is possible with the use of digital elevation models. The real surface can be computed by defining a function in the attribute tables of the slope map derived from the DEM.
- In the case of the dolines in the Bükk-plateau study area the real surface values exceed the projected area by 2% (in extreme cases even by 17%).
- There is a relationship between the doline's extension, size and the surface rate (the quotient real surface/projected area) which is probably characteristic of each karst type.

Acknowledgement – This research was supported by the grant of the Hungarian Scientific Research Fund (OTKA T/048356).

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