

# STUDYING THE DEVELOPMENT OF FLUVIAL LANDFORMS IN THE BERETTYÓ-KÖRÖS REGION USING GEOINFORMATIC METHODS

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## Abstract

Development of fluvial landforms from 1980 till nowadays was studied based on digital elevation maps (DEM) composed from contour lines of topographic maps, field data obtained by RTK GPS and aerial photos taken by a drone. Greatest denudation of 6-9 metres was measured in the eastern side of the erosional valley at Pocsaj caused by piping and mass movements. As a result, the valley widened and slightly deepened. Since 1980 around 1-2 metres of accumulation and erosion of similar rate have been measured in the secured floodplain environment dissected by abandoned beds, point-bars and swales at Kismarja. These values, however, rather reflect the geometric uncertainties and deficiencies of the contours of topographic maps than real land changes. Therefore topographic maps can give reliable basis for studying the development of lowland landforms only if they depict adequately large sized (minimum 100 x 100 m) positive or negative forms with great height difference as well (minimum 8-10 m). Accuracy of DEMs composed from aerial photos using photogrammetric methods – taking off height faults caused by vegetation – is around the same as that of the models created on the basis of RTK GPS measurements.

**Keywords:** floodplain accumulation, erosion, land-change study, DEM, photogrammetry, Berettyó

## 1. Introduction

Aims of geomorphological research frequently include the study of the development and transformation of landforms. These can be important in determining the land development of a given area and may yield valuable information for man living and working in the landscape regarding agriculture, nature protection, regional and urban development. In order to study changes of landforms in time map or

aerial photo series covering the same areas but taken at different times shall be applied, however, spatial data obtained by geodetic measurements or remote sensing could be also useful (Kiss 2014). The scale of maps and the spatial resolution of aerial photos enable the study of areas and landforms of a given size. Several authors gave general morphometric analyses of mountains and hills reconstructing certain elements of their land development using digital elevation models (DEM) composed from large scale

topographic maps (Csuták – Bódis 2001; Utasi 2001; Ruzkiczay-Rüdiger et al. 2007; Demeter – Szabó 2008). Studying the morphometry of single landforms is also popular in physical geographical papers thus defining karstic, volcanic and aeolian landforms based on DEM and determining their morphometric parameters helped a lot in finding answers to their development (Kiss 2000; Telbisz et al. 2009; Keresztúri 2009). Studying changes in the forms of monotonous lowland areas poor in large landforms is very difficult due to the scale of available maps and the spatial resolution of remote sensed data. For example, for studying the development of sodic microforms only precision land geodetic measurements or the analysis of LiDAR data can be applied (Kozics 2016; Novák – Tóth 2016; Szabó et al. 2016). Studying landform development via data series is widespread in fluvial geomorphology because based on remote sensed data spectacular results can be achieved regarding the relatively rapid transformation of river-systems like development rate of river bends, rate of bank

retreat, accumulation and denudation of bed forms (Kiss et al. 2009; Bertalan – Szabó 2015; Bertalan et al. 2016).

The aim of this research was to identify the rate of fluvial landform development nowadays in an area that was once shaped by rivers but now located in a secured floodplain environment outside the embankment dam of Berettyó and Ér rivers. The paper also challenged to decide whether topographic maps can be applied to studying changes in landforms or not. Finally, the question whether digital surface models (DSM) created from low elevation aerial photos using stereo photogrammetric methods can be used for the geomorphological mapping of lowland areas characterised by small height differences or not is considered.

## 2. Material and methods

In order to answer the above questions, the digital elevation models of two different landform collectives (one erosional and one accumulative) were compared. One study

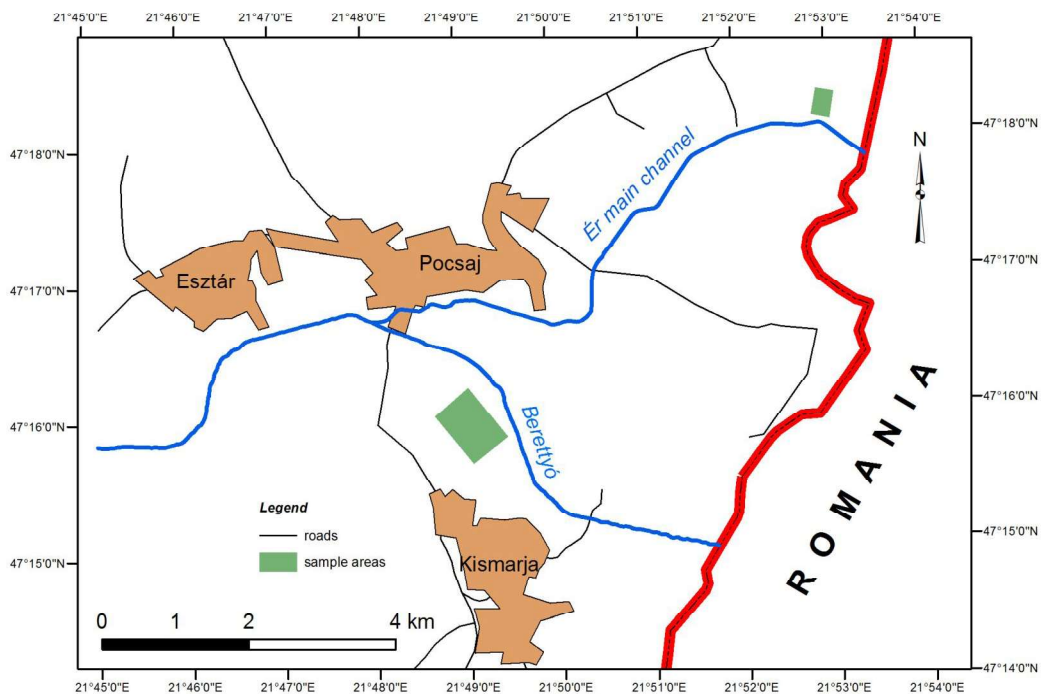


Fig. 1. Geographical location of the study areas

area is located northeast of Pocsaj at the southeast edge of the Nyírség alluvial fan at the so called Pocsaj Port (Fig. 1). The wide valley bottom found here was being cut by the Ancient Tisza and Ancient Szamos rivers for thousands of years, however, rivers left this area at around 13-14 thousand years BP due to the tectonic subsidence of the North Great Plain (Gábris – Nádor 2007; Nádor et al. 2007; Thamó-Bozsó et al. 2007). Today only the small channel of the Ér river runs across the area. The height difference (18-20 m) between the wide valley bottom and the surface of the alluvial fan covered by loess can be regarded as significant in lowland terms. Several valleys cut into this steep slope by retreat erosion. Our study area is one of these valleys with less forest cover (47°18.15'N, 21°52.94'E). The valley forms part of the Pocsaj Port nature conservation site within the Natura 2000 network a great part of which is covered by species rich loess grassland and dry steppe meadow. Its most important botanical values include *Stipa capillata* and *Adonis vernalis* (Magura 2014). Unfortunately the advancement of woodland vegetation can be observed in the double valley head on the steep slope of western exposition with *Prunus spinosa* and *Crataegus monogyna* forming dense stands.

The second study area is located in the former floodplain of Berettyó river north of Kismarja (Fig. 1). The Berettyó supplied a huge swamp system with water in this area prior to river regulations in the 19th century forming large meanders, spectacular point-bars and swales in the inner parts of the meanders that can be seen even today. The river was driven into a 14 km long artificial channel from Sălard, Romania to Kismarja around one and a half centuries ago with an embankment beside it. As a result, the river rarely floods the once rich fluvial landforms in its former floodplain (Ihrig 1973; Mike 1991). The secured floodplain areas formed in this way have been used mostly as pastoral lands forming part of the Natura 2000 network belonging to the special nature protection area of Kismarja-Pocsaj-Esztár

grasslands. Thus the second study area is a secured floodplain with remnants of point-bars and oxbow lakes and sodic grasslands with slightly uneven surface (47°15.9'N, 21°49.1'E).

Detailed geodetic survey was not performed in the two study areas before therefore only the five sections (59-222, 59-224, 59-242, 510-111, 510-113) of the EOTR (United National Area System) topographic map series with the scale of 1:10000 could be used as bases for studying changes in the landforms. Contour lines and height points of the maps created between 1970 and 1980 were vectorized using the software ArcGIS and then digital elevation models of the study areas were composed.

High accuracy RTK GPS measurements were made in the areas in spring 2015 using a Stonex 9 device. In the course of the geodetic survey the signs of generally 16 satellites were detected enabling PDOP value of 1.5 on average, 0.012 m and 0.023 m horizontal and vertical average accuracy respectively. An erosional valley of 4 hectares with 1009 field points has been measured in the study area at Pocsaj where significant height differences (99.27 – 127.94 m a.s.l.) were also measured. In the 25 hectares area at Kismarja dominated by point-bars and swales the coordinates of 3376 field points have been measured with much smaller height differences (100.39 – 103.94 m a.s.l.). From field data obtained in this way DEMs were created using the software GlobalMapper. Cross sections were made along a typical profile in each DEM using GlobalMapper. Difference maps were obtained by subtracting the DEMs prepared based on field data obtained with a difference of almost forty years from each other. As a result changes in the shape of erosion and accumulation landforms became visible in the studied areas.

The two study areas were surveyed again in spring 2016 using a DJI Phantom 3 camera on a drone. Based on the high number of aerial photos taken by a camera with a Sony EXMOR 1/2.3 sensor and with 12.4 megapixels

resolution, point cloud and then digital surface models (DSM) were created using the software Agisoft PhotoScan. These contain the vegetation covering the surface as well thus they gave generally higher elevations (significantly higher in places) compared to the previous two models. In order to obtain accurate field coordinates, 9-15 GCP points were taken in the field the geographical coordinates and absolute height of which were measured using an RTK GPS device.

### 3. Results

Based on three DEMs in each study area, the cross sections and the difference maps produced by the subtraction of DEMs made in 2015 from DEMs made in 1980, we attempted to visualize changes in landforms over almost four decades in areas of erosion and accumulation.

The dry valley formed in the study area at Pocsaj can be regarded a negative form developed by retreat erosion and derasion

that has been changing its size and shape with varying intensity from the end of the Pleistocene. Valley sides were covered primarily by closed grass and in some extent by shrub that can impede linear and areal erosion quite efficiently. Along the deepest part of the 200 m long, 70 m wide and 17 m deep valley erosion of almost 100 cm was detected in the study period. On the east facing slopes of the valley accumulation ranging from a few decimetres to 1.5 metres was found that can be explained by the accumulation of soil washed from the top cultivated with ploughing. In contrast, on the west facing slopes 6-7 metres erosion could be calculated on average along 175 m, however, in places the height of the surface decreased by 9 m (Fig. 2 and 3). Signs of this erosion were detected in the field as well mainly in the form of landslides on the steep valley side and signs indicating piping along the edge of the arable land on the top were found as well. Due to mass movements and piping the valley widened at the bottom

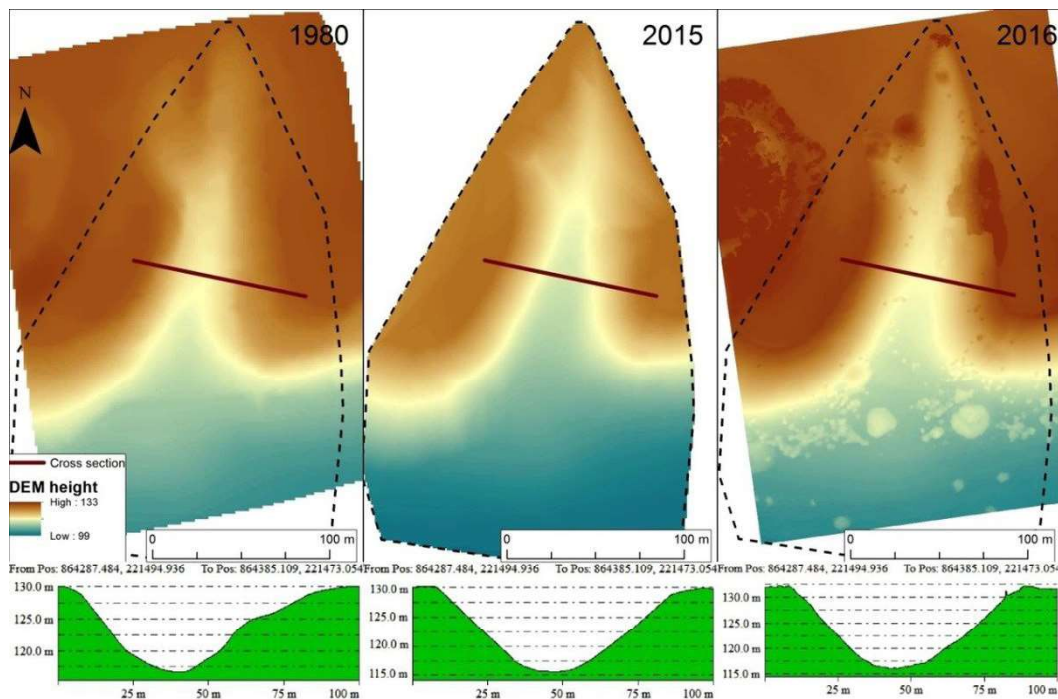


Fig. 2. Digital elevation model of the erosional valley at Pocsaj made from topographic maps (left), RTK GPS measurements (middle) and aerial photos with photogrammetry (right)

and due to occasional torrential downpour it deepened slightly over the last decades. The valley starts with two branches from the north. Due to the uncertain pattern of the contours increase in the length of the source branches was not possible to detect. Currently dense bushes and trees impede the further retreat of the valley. Shape and size of the valley showed great similarities in the DEMs produced on the basis of RTK GPS measurements and photogrammetry from aerial photos. This similarity was also supported by the difference map produced by subtracting the two models from each other. The only difference was represented by darker patches of higher elevations a.s.l. appearing in the DEM produced from aerial photos. These can be identified as tree and bush groups and woodlands (Fig. 2). Results associated with this study area verified that highly accurate geomorphological maps can be made using DEMs composed

by photogrammetric methods from aerial photos.

Much less height differences were measured in the much greater study area at Kismarja (99-104 m a.s.l.). Mapping landforms typical for lowland meandering river floodplains (oxbow lakes, levees, point-bars, swales) and observing changes in the land presented greater challenge due to, on the one hand, the size of the area, and on the other hand, the complexity of landforms. The area covered mostly by sodic grasslands has been covered by bushes recently (*Crataegus monogyna*, *Rosa canina*) making mapping and identification of forms more difficult. Studying the DEMs and the DSM, the three different methods yielded almost the same results. Characteristic forms of the area can be recognised, swales can be recognised and identified in all of the three cases (Fig. 4). Changes in the surface between 1980 and 2015 are much smaller than those in the previous study area. On the basis of the difference maps, changes can be summarised as follows. Changes were hardly detectable over the majority of the area. In most cases 0.5-1.0 metres of accumulation was measured regarding negative forms like oxbow lakes, floodplain flats and oxbow beds. In the deepest forms, however, accumulation almost reached 2 metres. On positive forms like levees and point bars erosion was characteristic with values exceeding 2 metres in certain places (Fig. 5). Data show that the area was levelled in the last decades. The DEM composed from aerial photos is completely the same – except for bushes and forest patches – as the DEM composed on the basis of land geodetic measurements. This is also supported by the cross section (Fig. 4).

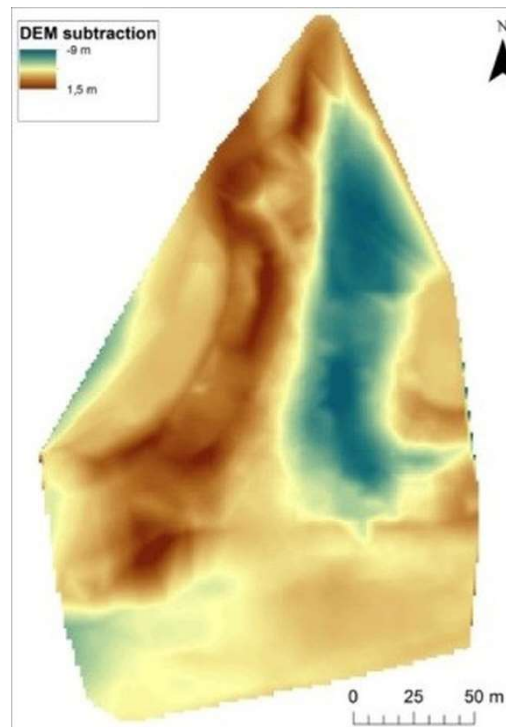


Fig. 3. Difference map of the digital elevation models of the study area at Pocsaj composed of RTK GPS measurements (2015) and the contour lines of topographic maps (1980)

#### 4. Discussion

Based on the results of studying the changes in landforms, erosion and accumulation over forty years reconstructed in both study areas are of metre scale. Linear erosion formed a feature in the study area at Pocsaj large enough for being accurately

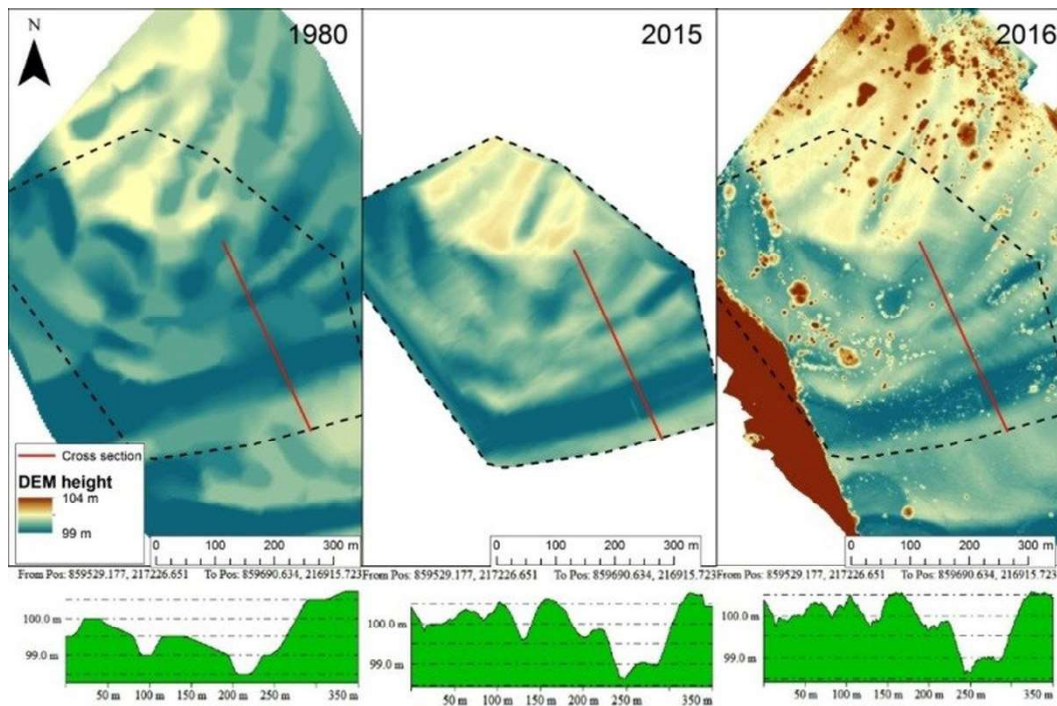


Fig. 4. Digital elevation model of the floodplain at Kismarja composed on the basis of topographic maps (left), RTK GPS measurements (middle) and aerial photos via photogrammetry (right)

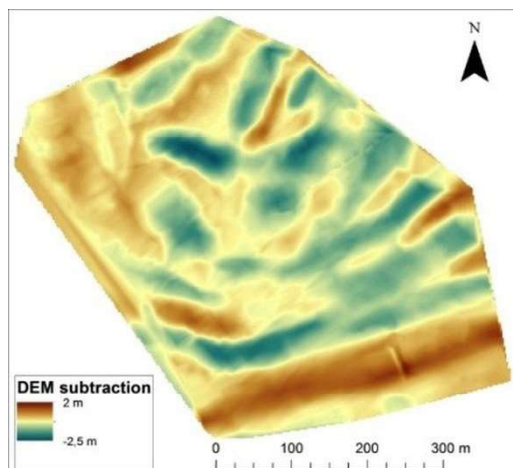


Fig. 5. Difference map of digital elevation models of the study area at Kismarja composed on the basis of RTK GPS measurements (2015) and the contour lines of topographic maps (1980)

and realistically depicted by the contour lines of the topographic map. As a result, exact comparison was made between the spatial data of the topographic map and the land geodetic survey performed in 2015.

Almost one a metre erosion at the valley bottom together with the 5-6 metres in the steep slopes to the east and even the 9 metres erosion in places are concordant with literature data. Jakab et al. (2005) published similar or even more intense erosion based on the time line morphometric analysis of 140 ravines in the catchment of the Tetves Stream south of Lake Balaton. Length, width and depth of erosion channels formed in arable lands in hill regions increased fastest meaning 4000 tons of soil loss in the 120 km<sup>2</sup> catchment over the last 30 years (Jakab 2007).

Surface changes obtained via the analyses at Kismarja reflect not the realistic accumulation and erosion values. The maximum 1.5-2 metres accumulation measured in the oxbow lake and in the swales equals 4.2-5.7 cm/year accumulation rate that is more than five times the values mentioned in the literature. According to sedimentological studies accumulation is 0.33-1 cm/year in oxbow lakes along the

Upper Tisza (Szabó et al. 2012, Vass et al. 2010) and similar values (0.2-1 cm/year) were found in oxbow lakes of the Lower Tisza as well (Kiss et al. 2002). Accumulation of active floodplain forms (swales, point-bars) is much smaller, Szabó et al. (2012) measured it to be 0.007-0.034 cm/year in the case of forms in Bodrogzug. The accumulation rate obtained in our analysis seems to be too high since the area has received no water from floods since 1860 due to the establishment of an embankment beside the Berettyó river. Thus the values of change in the surface are wrong that can be explained by the geometric faults of the contour lines of the topographic map used for the analysis and also by the small number of triangulation point with known height depicted in the topographic maps. As a result, DEMs with significant vertical and horizontal faults were performed and these are not suitable for comparison with data of the geodetic measurements. Erosion and accumulation shown in the difference map (Fig. 5) can be originated from the excess or lack of material in the DEM obtained from the map and the inaccuracies of interpolation and vectorization.

## 5. Conclusions

In conclusion it can be stated that studying changes based on topographic maps can be successful only in the case of clear, large forms. In the case of small lowland forms with small height difference that can be depicted difficultly and inaccurately with contour lines this method was not successful. Besides traditional land geodesy mapping DEMs composed from aerial photos made by drones using photogrammetry are similarly accurate. This latter method, however, enable the fast mapping of large areas even though generally the height of objects covering the surface (e.g. vegetation) is determined instead of the height of the surface itself.

## 6. References

- Bertalan, L. – Szabó, G. (2015): Lateral erosion monitoring along a southern section of Sajó (Slaná) River. In: Krizova, A. (Ed.)(2015): Detailed Aerial Mapping and Flood Impact Monitoring in the V4 Region. Brno. p. 4.
- Bertalan, L. – Kovács, Z. – Szabó, G. (2016): A Sajó mederfejlődési dinamikájának vizsgálata térinformatika-alapú morfológiai elemzések alapján. In: Balázs, B. (Ed.)(2016): Theory meets practice in GIS VII. Debrecen University Press. pp. 91-98. (in Hungarian)
- Csuták, M. – Bódis, K. (2001): Digitális domborzatmodell alkalmazása geomorfológiai vizsgálatokban a Velencei-hegység területén. Földrajzi Értesítő. 50(1-4): 73-84. (in Hungarian)
- Demeter, G. – Szabó, Sz. (2008): Identifying lithological features using morphometric parameters derived from DEM. Acta Geographica Ac Geologica et Meteorologica Debrecina. 3:105-112.
- Gábris, Gy. – Nádor, A. (2007): Long-term fluvial archives in Hungary: response of the Danube and Tisza rivers to tectonic movements and climatic changes during the Quaternary: a review and new synthesis. Quaternary Science Reviews. 26(22-24): 2758-2782.
- Ihrig, D. (Ed.)(1973): A magyar vízszabályozás története, Országos Vízügyi Hivatal (OVH), Budapest. 389 p. (in Hungarian)
- Jakab, G. – Kertész, Á. – Papp, S. (2005): Gully erosion in the Tetves catchment. Földrajzi Értesítő. 54(1-2): 149-165.
- Jakab, G. (2007): A vonalas erózió vizsgálata a Tetves-patak vízgyűjtőjén. Tájékológiai Lapok. 5(1): 208. (in Hungarian)
- Keresztúri, G. (2009): A fekete-hegyi salakkúp-roncsok morfológiája (Bakony-Balaton-felvidék vulkáni terület). Földrajzi Közlemények. 133(3): 255-267. (in Hungarian)
- Kiss, T. (2000): Félig kötött futóhomokformák morfológiai vizsgálata a Dél-Nyírségben különös tekintettel az őket ért antropogén hatásokra. In: Keményfi, R. – Ilyés, Z. (Eds.) Tiszteletadás Szabó Józsefnek – Tanulmányok a földrajztudomány témaköreiből. Debrecen. pp. 15-29. (in Hungarian)
- Kiss, T. – Sipos, Gy. – Fiala, K. (2002): Examination of the rate of the recent sedimentation in the Lower Tisza. Vízügyi Közlemények. 84(3): 456-467.

- Kiss, T. – Blanka, V. – Sipos, Gy. (2009): Morphometric change due to altered hydrological conditions in relation with human impact, River Hernád, Hungary. *Zeitschrift für Geomorphologie*. 53: 197-213.
- Kiss, T. (2014): Geomorfológiai vizsgálati módszerek. JATEPress, Szeged. pp. 25-44. (in Hungarian)
- Kozics, A. (2016): Detecting salt berms on the Hortobágy from ALS data. In: Balázs, B. (Ed.) (2016): Theory meets practice in GIS VII. Debrecen University Press. pp. 265-269.
- Magura, T. (ed.) (2014): A Pocsaji-kapu (HUHN20010) kiemelt jelentőségű természetmegőrzési terület fenntartási terve. HNPI, Debrecen. pp. 2-70. (in Hungarian)
- Mike, K. (1991): Magyarország ősvízrajza és felszíni vizeinek története, AQUA Kiadó, Budapest. 698 p. (in Hungarian)
- Nádor, A. – Thamó-Bozsó, E. – Magyar, A. – Babinszki, E. (2007): Fluvial responses to tectonics and climate change during the Late Weichselian in the eastern part of the Pannonian Basin (Hungary). *Sedimentary Geology*. 202(1-2): 174-192.
- Novák, T. J. – Tóth, Cs. A. (2016): Development of erosional microforms and soils on semi-natural and anthropogenic influenced solonchic grasslands. *Geomorphology*. 254: 121-129.
- Ruszkiczay-Rüdiger, Zs. – Fodor, L. – Horváth, E. – Telbisz, T. (2007): Folyóvízi, eolikus és neotektonikai hatások szerepe a Gödöllői-dombság felszínfejlődésében – DEM alapú morfometriai vizsgálat. *Földrajzi Közlemények*. 131(4): 319-342. (in Hungarian)
- Szabó, J. – Vass, R. – Tóth, Cs. (2012): Examination of fluvial development on study areas of Upper-Tisza region. *Carpathian Journal of Earth and Environmental Science*. 7(4): 241-253.
- Szabó, Zs. – Szabó, Sz. – Tomor, T. (2016): Előzetes eredmények a hullámtéri formaelemek LiDAR alapú meghatározásáról. In: Balázs, B. (Ed.) (2016): Theory meets practice in GIS VII. Debrecen University Press. p. 455. (in Hungarian)
- Telbisz, T. – Móga, J. – Kósik, Sz. (2009): A Pelsőci-fennsík digitális domborzatelemzése és töbör-morfometriai jellemzése. *Karsztfejlődés*. 14: 121-137. (in Hungarian)
- Thamó-Bozsó, E. – Magyar, A. – Nagy, A. – Unger, Z. – Kerckmar, Z. (2007): Osl dates and heavy mineral analysis of upper quaternary sediments from the valleys of the Ér and Berettyó rivers. *Geochronometria* 28: 17-23.
- Utasi, Z. (2001): A Heves-Borsodi-dombság morfometriai elemzése térinformatikai módszerekkel. Magyar Földrajzi Konferencia tudományos közleményei. Szeged. (in Hungarian)
- Vass, R. – Szabó, G. – Szabó, J. (2010): Examination of sedimentary deposition in the active floodplains of Bereg-plain. *Acta Vasile Goldis, Rumania Studia Universitatis "Vasile Goldis", Seria Ştiinţele Vieţii*. 20(4): 105-110.