ACTA GEOGRAPHICA SZEGEDIENSIS
Tomus XXXVIII (2004)
http://www.geo.u-szeged.hu/acta

SOME EXAMPLES OF BENCH EROSION FROM THE GREAT HUNGARIAN PLAIN

RAKONCZAI, János – KOVÁCS, Ferenc – ZÁDORI, Adrián

The technical improvements of the past few decades opened up new possibilities for researchers engaged in the investigation of modern geomorphological processes. Methods like the application of various remote sensing and high resolution field mapping techniques, as well as those of absolute dating and modern material science can elucidate information on environmental changes, which previously had been regarded as unattainable. Improvements in computer science and technology opened up new gates for geoinformatics. The increasing accuracy of measurements on the other hand enabled the identification of even short-term changes and events as well. It was mainly this latter factor that gave an impetus for our work in initiating an investigation on the characteristics of the process of a special lowland bench erosion from the second half of the 1990s. With the help of the recorded data embedding 7 years, marked changes can be clearly identified.

Benches introduce some sort of versatility into the relatively uniform landscape of the Great Hungarian Plain. These geomorphological features are generally restricted to areas, which were frequently flooded before the water regulations. But they appear in connection to various landscape management measures as well (road and channel constructions). The characteristic, 10-30 cm high microforms are mostly restricted to alkaline areas. However, as our research results indicate, although alkaline soils may largely contribute to their development, they are not an exclusive prerequisite of bench formation and erosion.

In Hungarian practice the area of the Great Hungarian Plain was generally considered to be not prone to erosion hazards up to quite recently. Areas of this region are not depicted on any maps displaying erosion hazards (e.g. The National Atlas of Hungary, 1989), and not even present in statistical evaluations of the environment (KSH 1986: Environmental conditions and protection measures). Bench surfaces formerly received less scientific attention. However, a detailed investigation of these areas may open up new, more adequate evaluation possibilities in determining the degree of lowland erosion. Frankly, the degree of soil erosion in the Great Hungarian Plain is far more below the value experienced in hilly areas (BARTA, 2001). However, its potentials must not be underestimated. This unique type of erosion, complemented by a gradually increasing aridity, may cause significant transformations in the soil and the environment.

The definition and geomorphological characteristics of lowland benches

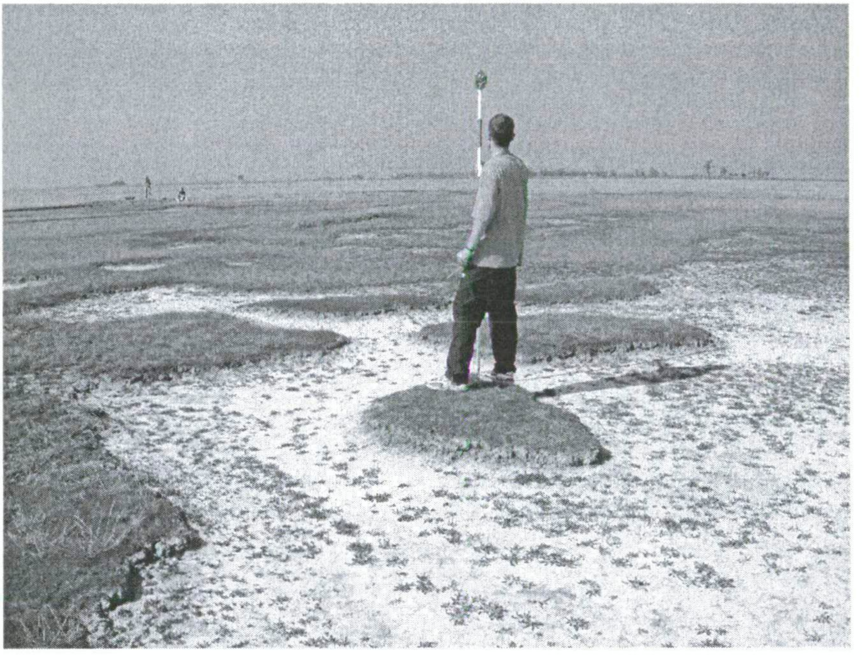
Despite the extensive nature of areas effected by lowland bench erosion in the Great Hungarian Plain being almost a general feature of the *pusztas* of the national parks of this area and mentioned in certain works dealing with the process of alkalinization as well, up to 1970 only a single study dealt with the detailed description of this unique geomorphological feature (STRÖMPL, 1931). Here, the very first attempts to interpret the development of this micromorphological complex have been made, along with the possible roles of water (dissolution, scouring) in their formation.

In our work, it was during the middle part of the 1970s through the course of preliminary investigations preceding the protection of the *puszta* of Szabadkígyós (Körös-Maros National Park) that we actually realized the problems deriving from the lack of adequate studies and descriptions of this unique feature. Our morphological and pedological investigations made it rather apparent (DÖVÉNYI et al, 1977) that the formerly established terminology is out of date and requires revision. Furthermore, an acceptable explanation for the development of these microforms could also have been advocated. Frankly, during this early stage the process of bench formation was linked to the alkaline soils, thus the original terminology used formerly was partly preserved in our future works.

The starting main form of bench erosion is the *alkaline bench*, which is a continuously changing feature complex. Thus their components can hardly be interpreted on their own. This bench is composed of various sub-features such as the *bench top*, corresponding to the original surface, the *eroded alkaline flat*, from which the topsoil has been removed, and finally the continuously migrating *bench margin*, as a result of the progressive erosion (**Pic. 1.**). Very often this margin appears as a linear feature. At other times it composes several meter long transition surfaces.

Picture 1. Destruction of bench margin by retrogressive erosion (near Tótkomlós)

During the process of bench erosion the original surface becomes dissected yielding island- and peninsula-like microforms of large variety (**Pic. 2.**). During the whole process the dissoluble salts either infiltrate into the ground or precipitate on the surface. The resulting rock fragments end up either in the fractures, which form during the arid summers and termed as *alkaline veins* (**Pic. 3.**) or are transported away from the surface by the winds.



Picture 2. Isolated bench islands (near Tótkomlós)

The process of bench destruction

The process of bench erosion must be divided into two stages for practical reasons. The first stage involves the actual development of the benches, while the second one is the destruction of these bench surfaces.

The majority of resources in the literature univocally mention the development of differences in the relief as a prerequisite of bench formation and bench erosion in lowland areas. Sometimes this can be even in the cm range. However, there might be several reasons for the emergence of differences in the topography. One of the most commonly appearing cases is when a natural dip in the surface is attributable to the presence of infilled ancient riverbeds and adjacent natural levees in a formerly fluvial landscape. But human activities creating different relief conditions (channels, ditches running along the roads, cart tracks) are almost just as important. However, bench formation may initiate even in totally flat and smooth surfaces as well as a result of soil shrinkage attributable to arid conditions and the formation of extensive cracks in the ground.

Picture 3. Alkaline veins (near Tótkomlós)

The further developmental path of these bench areas is primarily influenced by the relief conditions and the soil structure. But the degree and type of vegetation cover might also be influential.

The solonetz alkaline areas with a well-deformed soil structure tend to give the typical sites for bench erosion yielding benches of the size of 10-30 cm via the erosional removal of the topsoil. Based on his research implemented of what is the most well-known *pusztas* of Hungary, the Hortobágy. TÓTH (2003) managed to classify the erosion types into the following groups: areal, linear, retrogressive and anthropogenic erosion. His findings are more or less congruent with our results. However, according to our findings for extensive areas several other important types are also observable. Conversely, the separate treatment of the anthropogenic type is strictly refused by us for several reasons. On the one hand, the majority of bench erosion is initially connected to some sort of human intervention, the exact type of which can not be fully determined due to the elapsed time. On the other hand, erosion triggered by human influences can be classified into the other groups as well. Like for example along the channels we can observe mainly retrogressive erosion causing bench destruction, while in the case of cart tracks the process is rather linear. If we take these factors into consideration as well then 4 major types of bench erosion could be identified in the area of the Great Hungarian Plain.

a) *Retrogressive erosion.* According to our field observations, this type tends to be the most commonly occurring with continuous soil erosion along an irregular line at the margin of the bench usually lacking surficial vegetation (see **Pic. 1.** and **2.**). During the process the soil is almost dissected into its basic components and transported away that way from the site. In case of the solonetz areas, the basic type of retrogressive erosion results in the complete loss of the A horizon, exposing the underlying saline layers, which host only salt tolerant vegetation.

If the erosion process decelerates for some reason, the marginal areas of the bench can be widened to such a degree, when changes are observable in the alteration of the vegetation types alone, related to the resulting differential dissolved salt content of the underlying soils (RAKONCZAI, 1986).

b) *Break-away erosion.* This more spectacular and easily divisible type of bench erosion can develop in areas with large relative differences in the relief. This type of erosion could have been observed in Miklapuszta, a former floodplain of the ancient Danube now belonging to the territory of the Kiskunság National Park (RAKONCZAI–KOVÁCS, 2000.). The 60-100 cm thick benches can break off in blocks of several ms (sometimes even 10 m) together with the surficial vegetation as a result of scouring by waters, which accumulated in the low-lying areas (**Pic. 4**).

Picture 4. Broken-off bench margin (Kiskunság National Park, Mikla-puszta)

In this case the soil aggregates of several dm^3 fall apart into their basic grain components only at a later stage. The differential chemical properties of the removed soil blocks also result in initially a transformation then in most cases the complete perishment of the surficial vegetation (**Pic. 5.**).

Picture 5. Lowered surface of broken-off bench remains with vegetation under transformation

c) *Linear erosion.* This erosion type is mostly constrained to the block dissection of the bench surfaces. Very often we can also come across signs of the processes (cart tracks, animal paths) which initiated this type of erosion (**Pic. 6.**). As a result of this process the greater benches are transformed into island- or peninsula-like forms, their gradually increasing marginal areas progressively accelerating the erosion process as well. Sometimes alkaline veins, promoting a fast movement of surficial waters may also develop in these longitudinal forms.

Picture 6. Linear erosion launched by vehicles (Kiskunság National Park, Mikla-puszta)

d) *Areal erosion.* In several cases the erosion of the benches and the removal of the constituting rocks happened not from the direction of the bench margins, but rather from the top downwards as a result of slow material transportation. The presence of grasses in the margin as well as the generally loose structure of the soil covering the benches must have an important role in this process, even though this role is still partly enigmatic to us. As a result of this erosion process the surface of the original bench gradually becomes morphologically uniform with the adjacent lower-lying areas of the salt flats, though to a certain degree these two forms can be easily told apart via careful observation of the surficial vegetation. We have managed to record such transformation of 20-30 cm thick and 10-15 m wide benches in the *puszta* of Szabadkígyós (**Pic. 7.**), which embedded about 25 years.

Picture 7. Former benches lowered by areal erosion (Körös-Maros National Park, Szabadkígyós)

The methods applied for recording erosion

Measuring and quantifying modern geomorphological transformations is a very complex problem. One of the major problems comes from the possibilities for generalizing short-term transformations, observed during the field measurements. Another major problem derives from the accuracy of the measurements, since in these short-term cases we are dealing with small values. Thus for our work a complex array of various methods have been collectively utilized considering the characteristics of the pilot areas, the available past data and the reliability of the measuring instruments. In places, where thanks to the special characteristics of the topography maps from former military surveys were also available, there was a chance of temporally extending the scope of our investigations.

On the whole it must be stated that our investigations on the process of bench erosion were based on different annual data sources, containing data collected with different methods and resolutions. Although the final conclusions were drawn from the analysis of long-term data, the findings on the degree of transformations should by all means be treated with necessary caution and must be improved by further continuous field measurements to consider them fully reliable in the future.

Traditional field measurements started as early as the 1970s in one of the alkaline areas of the Tiszántúl, the *puszta* of Szabadkígyós (SZÖŐR-RAKONCZAI-DÖVÉNYI, 1978).

These were then extended to other areas, bearing different characteristics (the vicinity of Tótkomlós, Miklapuszta) and complemented by the use of more advanced methods and instruments for both data recording (GPS, geodesic stations) and data processing (GIS) from the 1990s onwards (KOVÁCS, 1999; RAKONCZAI-KOVÁCS, 2000).

Another possibility for a comprehensive evaluation of the degree of bench erosion might be the transformation of the data recorded in different times and in different mapping systems into a uniform system. This approach was best suited for the analysis of the erosion of benches with a relatively large size, something what we have encountered in the pilot area of Miklapuszta. As a first step here data maps with a scale of 1:25.000 deriving from the 3rd Military Survey of 1883, as well as that from 1981 with a scale of 1:10.000 was looked at in details. Then in order to capture the modern transformations field measurements were taken using a GPS from 1997, and then a complex geodesic data recording device from 2003. The 1972 panochromatic Corona satellite photos with a geometric resolution of 2.5 m, as well as the 1994 black and white aerial photos on the area with a resolution of 2m, plus the color aerial photos of 2000 with a geometric resolution of 65 cm were also used in our work.

In order to capture the erosion of the low-lying benches field measurements were implemented. In case of the most important sites a direct comparison of the measured values of the recorded sites using the devices of a monitoring station or a GPS enables the attainment of a resolution at a cm scale. Lines prepared via connecting such data points may give the most reliable results on the transformations of the spatial extent of benches. Field measurements happened with the use of a GPS in the first stage of the work (TOPCON Turbo-S II., Trimble Basic+) via the application of a relative spot and go method, requiring a measuring time of 4-5 min before moving onto the next point. Consequently, only the most characteristic sites have been measured at this stage. Field measurements carried out in 2003 were relying on a much more accurate instrument of SOKKIA Set310 geodesic station. The accuracy of angle measurement with this device was 3", while that of the distance measurements was +/- 2 mm + 2ppm /2700 m. The presence of quartic triangular points assigned to the higher areas in the vicinity of our pilot area has offered ideal stand points for our measurements easing our work to a large degree. This latter method offers not only significantly better resolution and reliability, but requires less time for data recording as well, only a couple of seconds. Thanks to this data collection could have taken place in shorter intervals on the field yielding lines representing better the natural conditions in our GIS analysis.

The recorded degree of bench erosion in different type of pilot areas

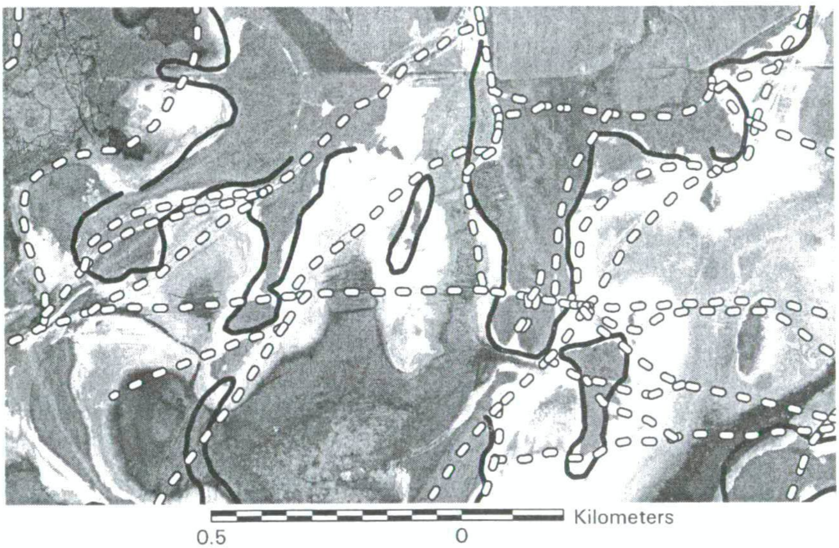
Erosion of large benches with a chernozem soil (Miklapuszta)

The solonchak alkaline pilot area located in the northern part of Miklapuszta forms one of the most spectacular alkaline bench areas in Europe with " giant" benches of a height sometimes exceeding even 1 m. Although the location of the alkaline benches was not congruent on the map of the 3rd military survey transformed into the uniform national projection system (EOV) with their modern position, with the help of their unique shape and the surrounding environment they could have been easily fitted into our new system.

During the comparative analysis spanning a period of approximately 100 years, the borderline of the benches was determined in case of the map of 1981 with data complemented from the 2000 aerial photo of the area as well.

The calculated average annual rate of retrogression was extremely high: 10-15 cm! The degree of erosion for the individual benches compared to the data on the map of the 3rd military survey was 40% at an average. So while about 100 years ago approximately 21% of the 340 ha pilot areas was covered by benches, today this ratio is only 12%. This data seems to refer an annual rate of erosion of 1520 m^3 calculated for a realistic bench height of 50 cm.

Another characteristic feature in the pilot area was the dissection of the bench ridges by roads and flock paths leading to the formation of new isolated bench islands. At the given resolution there was a one-third increase in the number of these separate bench islands in the area during the past 100 years, with several extensive benches are lacking in the modern maps (**Fig. 1.**).



thick line: margins of alkaline benches (3rd Military Survey Map)
broken line: roads, paths and channels (map 1981, aerial photo 2000)

Figure 1. The effects of landscape utilization in bench erosion (background: aerial photo 2000.)

The first step of higher resolution evaluations was the investigations of data and changes for the last 30 years with the help of the Corona satellite photos (**Fig. 2.**). The secondary polynomic transformation of the photo with the help of a topographic map had an RMS error of 0.5. The calculated loss of bench islands of 4% /decade using the topographic maps was only 2%/ decade using the satellite photo. Nevertheless the annual rate of retrogression was 8 cm, which is congruent with the values calculated in the long-term analysis.

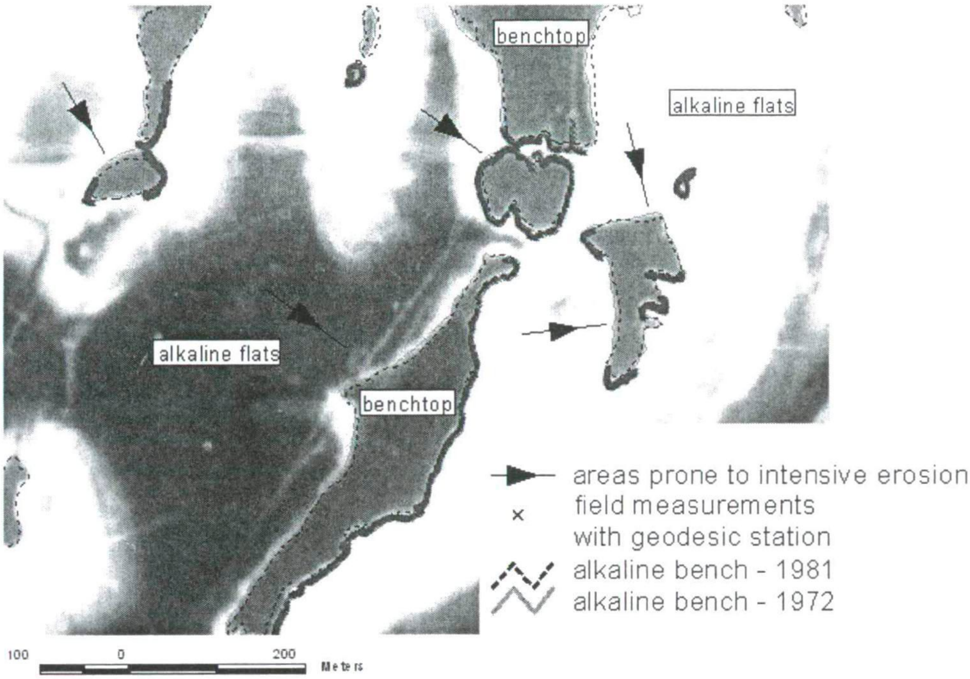


Figure 2. Interpreted bench margins and the comparative analysis of the results of 2003 field topographic survey (background: Corona satellite photo)

The bench erosion of solonetz alkaline areas (Tótkomlós)

10-20 cm high benches emerged as a result of the complete removal of the topsoil (A horizon) in the alkaline steppes SW of Tótkomlós. Here the construction of drainage channels and the ditches running along the roads must be unambiguously blamed for the initiation of the erosion process. Field surveys were carried out in this pilot area from the summer of 1997. In the initial phase the position of the borderline of some characteristic benches were recorded using a GPS like in the former case followed by the implementation of comparative field surveys using a geodesic measurement station from 2003.

According to our findings, here the retrogressive type was the prevalent form of erosion with an approximately 0-15 cm degree per 6 years. Unfortunately, the density of data points recorded during the GPS measurements did not meet the requirements of a high resolution analysis, thus the final results drawn from these data can be regarded as preliminary and informative only. There can be assumed some sort of an aerial erosion as well in several island-like microforms. However, as no elevation values were recorded during the initial survey, as the GPS is unable to trace and record small-scale differences, the relative lowering of these surfaces can be justified only by the photos alone.

The aerial erosion of solonetz alkaline areas (Szabadkígyós)

Detailed topographic mapping using a theodolite and accessory network was carried out in the alkaline *puszta* between Szabadkígyós and Kétegyháza in 1977, preceding the protection of the microforms (**Fig. 3.**). During this time the microforms were bounded by sharp bench margins of 20-30 cm. The vegetation cover of the bench tops and alkaline flats were also clearly different. When we returned to the area during the summer of 2003, we have come across a completely altered landscape. The alkaline flat covered by halophyte plants formerly now had a uniform grass cover, the extensive benches completely disappeared, and the margins of them were hardly discernible.

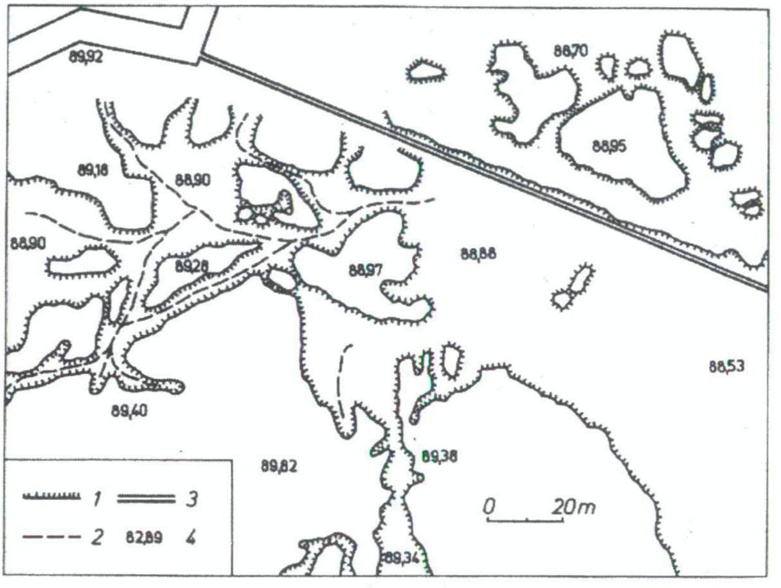


Figure 3. Micro-relief of the "*puszta*" at Szabadkígyós in 1978 (Szőőr-Rakonczai-Dövényi, 1978)

Legend: 1: boundary between natron bench and natron plain, 2: natron stream, 3: canal, 4: elevation above sea level (m)

There were two important environmental changes, which affected the area during the past 25 years. As a side effect of the gradual increase in aridity and drop in the groundwater level the alkaline soils and the vegetation was largely transformed, just like the original bench microforms. The most spectacular changes from a morphological point of view was observable on several benches, which could have been clearly mapped and identified in 1977.

The former morphologies were reflected only in their different vegetation cover without any discernible deviations in the topography. In the place of these former benches we have come across saline spots (Limonium Gmelini) or even fresh meadows (see **Pic. 7.**).

All this seems to pint to the transformation of the formerly retrogressive type of erosion into an aerial type. Since in case of a retrogressive erosion the size of the resulting soil patches would be smaller than the original size of the bench. However, due to the lack comprehensive, continuous field surveys in the pilot area the possible links between the increasing aridity and the transformation in the type of the erosion could only be assumed and not clearly justified.

The consequences of the erosion process

In the light of our findings it can be clearly seen that the process of bench erosion is a relatively rapid landscape transformation factor, restricted mostly to lowland areas utilized as pasturelands or meadows. Since the rate of erosion is in the cm scale, the effects of the process are rather considerable even within the span of a couple of decades. There are two important consequences of the process cited. On the one hand it causes significant soil erosion. On the other hand it also brings about a destruction of the protected microforms even in a natural, preserved setting without leaving any possibilities for actual preservation even among the highest measures. Transformations in the groundwater levels related to climate change, and the concomitant soil and vegetation changes may also play a role in the transformation of the erosional forms.

References

BARTA, K. (2001) A EUROSEM talajeróziós modell tesztelése hazai mintaterületen. – In: A földrajz eredményei az új évezred küszöbén. A Magyar Földrajzi Konferencia CD anyaga.

DÖVÉNYI, Z.-MOSOLYGÓ, L.-RAKONCZAI, J.-TÓTH, J. (1977) Természeti és antropogén folyamatok földrajzi vizsgálata a kígyósi puszta területén - Békés Megyei Természetvédelmi Évkönyv II. 43-72.

KOVÁCS, F. (1999) Térinformatikai módszerek használatának lehetőségei egy táj állapotváltoásának vizsgálatában. OTDK dolgozat. SZTE Természeti Földrajzi Tszk. p.30.

RAKONCZAI, J. (1986) A Szabadkígyósi Tájvédelmi Körzet talajviszonyai - Környezet- és Természetvédelmi Évkönyv 6. 19-42.

RAKONCZAI, J. - KOVÁCS, F. (2000) Possibilities provided by GIS in the evaluation of landscape changes on plain territories. - Acta Geographica Szegediensis 83-92.

STRÖMPL, G. (1931) A szik geomorfológiája. - Földrajzi Közlemények. 4-5. 62-74.

SZÖŐR, GY.-RAKONCZAI, J.-DÖVÉNYI, Z. (1978) A szabadkígyósi puszta talajainak vizsgálata derivatográfiás és infravörös spektroszkópiás módszerrel. - Alföldi Tanulmányok 75-99.

TÓTH, CS. (2003) A Hortobágy negyedidőszak végi felszínfejlődésének főbb természeti és antropogén vonásai – PhD értekezés. Debrecen. 244 old.

This work was supported by National Research Fund (OTKA) Grant 17T/048400.

RAKONCZAI, János CSc
KOVÁCS, Ferenc
ZÁDORI, Adrián
University of Szeged, Faculty of Sciences
Department of Physical Geography and Geoinformatics
H-6701 Szeged, Egyetem u. 2-6., P.O.B. 653., Hungary
rjanos@earth.geo.u-szeged.hu