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# POSSIBILITIES PROVIDED BY GIS IN THE EVALUATION OF LANDSCAPE CHANGES ON PLAIN TERRITORIES

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## Introduction

Natural and anthropogenic factors have caused significant landscape changes in the previous centuries. There are several tools to examine these (archaeological information, historic documents, comparison of maps, measurements and statistic evaluations based on these, remote sensing, monitoring, etc.), as we have summarised it detailed in a previous study (*Rakonczai, J. 1988*). These methods are adequate to carry out general analyses, but they are hardly proper or rather improper to evaluate the quantitative changes of the landscape. This problem is especially true in case of plain territories, where there are hardly any points that could be used for reference during evaluation. Hence, those examinations are of great significance that can enable the exact spatial and quantitative evaluation of previously recognised qualitative changes, since, that is how these changes become useable for practical purposes, and authentic for science. The application of GIS provides quality solutions in this field. GIS makes possible to compare formerly separately handled, very different spatial data systems, thus, it may widen the ways of the application of classic methods, too.

Nowadays, there is an increasing practical and scientific demand to determine both the qualitative and quantitative characteristics of landscape changes. Although, landscape development itself can be observed even during a lifetime interval, until the present we could not evaluate relatively small degree annual changes in a quantitative sense. Consequently, there are two opportunities to provide an answer for widened scientific demand during evaluation: on the first hand to improve considerably the precision of analyses, on the other hand to extend the time of investigation. The improvement of geoinformatic methods provides us a chance to widen our scientific interest in both directions: the development of remote sensing, land survey and other techniques increases precision, while the ability of systematising different data bases may ensure the temporal widening of the examination.

The aim of the long-term research that is set forth in the present study is dual. Partly to determine from a methodological point of view how and in what degree can data originating from different periods and from different sources (old maps, topographic maps, airphotos, satellite images) be integrated into a unified information system (at the same time this may give an opportunity to the significant temporal extension of authentic environmental evaluation). Partly, on the basis of relevant data, and information that were transformed into a unified geometrical system, we have been to determine certain landscape changes that later can be applied in the environmental, conservation practice as well.

- The circumspectly chosen studied area, that is a part of the Kiskunság National Park, is located on the territory of the Danube-Tisza Interfluve (*Fig. 1*).

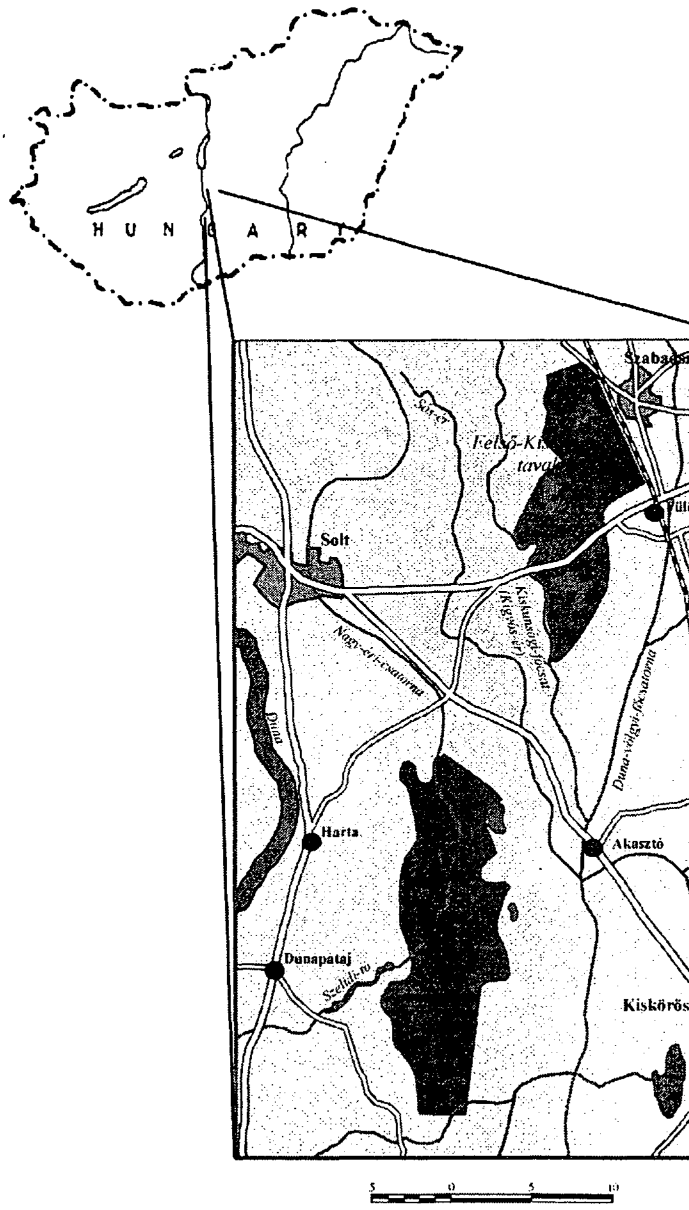



**Figure 1** The study area

Here, at the beginning of the research three geographical, ecological problems occurred that seemed to be answerable with the help of GIS. These are the following:

- Soil erosion processes (sodic bench erosion) that can be inevitably detected on the territory of low relief. The measuring of these only with traditional methods would provide considerable errors due to the relatively short period of measuring.
- The water household of the territory was significantly modified by the hydrological changes that followed the water regulations, then by the increasing utilisation of water resources, and currently by the presumed global warming. Maybe the most notable results of these processes are the decreasing water surfaces, and the disappearing, formerly typical, sodic lakes.
- As an unfavourable ecological result, the invasion of weed associations endangers wet land habitats of the anyway decreasing water surfaces and their vicinity. The exact temporal and spatial evaluation of these processes with traditional methods is not only difficult, but uncertain at the same time.

**Relevant stages of landscape evolution on the studied territory**

The territory, located on the 20-25 km wide Danubian Plain, lies just 4-5 m above the former low water level (characteristic before the flood control operations on the Danube), thus, it is not surprising that due to frequent floods the lower floodplain was regularly inundated by water. The ancient water system was characterised by depression (acting as swampy, marshy territories of poor drainage) that were surrounded by levees, representing the higher flood plain level (point bars, dunes and alluvial fan territories). Due to the limited possibilities of outflow, the water leaving the river remained on these territories for weeks, months, and became pan water, therefore the region had been one of the richest territories of the country in standing waters. We must consider that there had already been sodic areas formerly, but then the evaporation of the waters and the high level and low gradient of the ground water provided adequate conditions for further sodic processes.

The major consequences of human activity on the territory are due to flood control operations. The regulation of the wild world of the Danube floodplains was started with the cut of the river bends, the construction of dams and the Duna-völgy Canal (1914-1930). *After the regulations the territory dried out*, and only on the deeper, shallow areas did swamps of temporary water level remain. Parallel with this, rapid sodification of soils and development of secondary sodic areas became characteristic as well. Documents of preceding times also prove that the extent of ancient sodic plains had not been at all as large as in the era following the 1930s. The set of anthropogenic influences was completed with the spread of extensive animal breeding. The result was a sodic plain with extreme water household and solonchak type soils. It was characterised by sodic reeds, marshes with Bolboschoenus maritimus and extremely sodic patches.

Since, nowadays the dams impede floods, *the eroding and accumulating effect of the Danube is not apparent either*. Thus, the region has become a flood free plain with a poor drainage that have resulted in the development of numerous sodic meadows. Due to the increasing anthropogenic influence the territory have gained a culture-steppe character (*Marosi, S – Somogyi, S 1990*).

## The base of geoinformatic analysis

The major data sources were: *maps covering a two hundred year period, airphotos, satellite images and field work*. After time-consuming preparations all these were composed into one *unified system*, which enables comparisons.

The I. Military Mapping, made in 1783, represents the original natural conditions with 1:28,800 scale. Naturally, the methods of mapping were simple – not even triangulation was applied – hence, the data on these provide just rough information. The subsequent studies on the conditions of the mapping (*Biró, M. 1999*) showed that the maps' quality greatly depends on the person who compiled them, their correctness is questionable, therefore, the borderlines on them have only an informative character, or they can be applied only after further, detailed investigations. The regulation works on this part of the Danube started much later, the region was characterised by regular floods, and among the natural conditions, maintained by the river, the identification of fix points is very difficult.

The II. Military Mapping was carried out in 1852, still with the same scale, but with improved methods. The III. Military Mapping, that was made 30 years later, resembles the changed conditions caused by flood control, with a 1:25,000 scale. The mapping was carried out after the regulation of that part of the Danube that is crucial regarding the studied area, thus, it provides several pieces of information on the transformed ways of land-use.

The topographic maps of 1:10,000 scale, made in 1961 and 1981, applying stereographic projection and EOV co-ordinates, show the effects of excess water regulations. Considering their scale, correctness, and content, the most information can be obtained from these.

Another group of sources are the photos taken by remote sensing: black and white airphotos (early summer of 1950, April 1973, August 1994 – the seasonal differences made correct comparisons very difficult), their approximate scale is 1:10,000 and 1:25,000. The obtained multispectral Landsat TM photo was made in the middle of April 1997.

In order to determine bench development processes in the future, we made GPS measures, which were complemented with data provided by field geodesy. (We are going to control these results in every five years.)

## Methods of geoinformatic analysis

In case of the Northern Kiskunság and Miklapuszta the first task was to *process the data sources with different scale and projection, from different times in a way that our next aim, the appraisal of data on the landscape development of the territory could be carried out* (i.e. it is important that the data can be *examined independently, but at the same time they can be compared and converted, too*). To carry out this aim, we had to transform different data models of different scale into one system – in our case logically into the EOV Projection System. The processing of raster and vector data was made under *ERDAS Imagine* and *Arc/INFO* softwares, respectively.

Geometrical correction ensured that all of our raster and vector layers contained the co-ordinates of the chosen projection system. The process itself is a projection to plain, through which the data are ordered to a map projection system.

The processing of raster data starts with the searching for well identifiable surface control points both on the maps and the photos. This is called the "image to map" method. The annual and seasonal change, that especially characterises sodic areas, made this difficult. Due to the low number of points, we carried out first order, occasionally second order transformations. After correcting our maps one by one, we chose the "nearest neighbour principle" to resample them. Only in case of the satellite image could we apply the quicker, "image to image" correction method.

During the analyses of maps the shorelines of lakes, roads, and rims of sodic bench were digitised as vector layers. When transforming vector data, we had to *convert three different scales and four different projections into the EOV system*. During digitising the so-called TIC points were obtained from intersections that can be exactly identified both on older and newer maps as well. After determining the corrected values of these points the whole vector layer was placed into a frame marked by these. The overlapping of the transformed layers and their comparison with airphotos, corrected with other methods, proved the correctness of the applied method.

The airphotos having EOV values and the satellite image made it possible to determine the boundaries of water surfaces showing unambiguous changes. After all, we gained 8 vector layers to evaluate the hidrogeographic development of the territory from 1783 till nowadays. The airphotos, thanked to their resolution, provided additive information concerning the rims of sodic benches.

After the multispectral processing of the Landsat TM image, beside the visual display in different band combinations (RGB, 321, 453, 742), with the help of digital image processing we made a Normalised Difference Vegetation Index (NDVI) map, and by automatic classification land-use maps were produced as well. The objective results of these provide further bases for oncoming investigations.

## Results

### Experiences in connection with the establishment of a unified data base

The geocoding, that is necessarry for processing data provided by remote sensing and maps, beside the fact that it is the most adequate for establishing a unified data base, is the first step in the complex geoinformatic analysis. The geocoding proved to be suitable for processing data of different character into a uniform system. The fitting of the layers was excellent, thus, we were able to increase the length of examination period beside preserving the precision of measuring, and it enabled the evaluation of field survey as well. However old a map was, the spatial correspondence appeared correct on all layers.

Regarding especially the sources of the 18$^{th}$ but that of the 19$^{th}$ century as well, the natural conditions of the plain like territory made it difficult to find permanent control points, that would help in the evaluation process. (As we have seen before, even the subjectivity of the surveyor left its mark on the military mappings). In case of the airphotos, the seasonal differences occurring at photographing made the evaluation more complicated. We have found that due to the character of the investigation the major data source of the continuous observation must be air photographing. *According to our experiences gained during the* *analyses, in order to monitor correctly the wetland habitats, detailed air photographing would be necessary at least in every five years.*

Naturally, satellite images may get an important role in the evaluation of landscape, but their resolution is not adequate to analyse local and micro-processes.

Although the geometrical correction does not always provide complete 100% correspondence when mosaicing the different images, it have become an inevitable tool in the objective surveying of landscapes. The establishment of the system is a long process, requiring diverse technical equipment, but the subsequent actualising and enlarging is easier and faster.

Measurable landscape changes in the past two hundred years:

The change of Northern Kiskunság Lakes

The hidrographical changes on the territory have several manifestations: great decrease in the number of lakes (concerning this problem the Headquarter of the Kiskunság National Park has made overall investigations), decrease of water surface of larger extent, and the pervasion of harmful plant associations at the expense of open water surface.

In our case the open water surfaces of a territory of an approximately 11 000 ha size were examined. The size of constant water cover decreased to 16 % from the 18$^{th}$ century till 1994 – naturally, the greatest decrease was due to the excess water regulations after the III. Military Mapping. (At the end of the 1990s, as a result of some wet years, the extension of water surfaces have increased, but very likely this positive change is temporary). The effect of the past 40 years is also significant. During this period, according to the airphotos, the invading weed associations advanced 310 - 350 m – with the strengthening of this process the "puszta" becomes more and more poorer concerning the number of species (*Kalotás 1996*). By knowing the tendencies of the disadvantageous years, it is to be feared that *further 60-70 years will be enough for the complete disappear of open water surfaces.* A good example is the Kisréti Lake, that formerly was the largest standing water here, but now it hardly has open water surface. Its southern neighbour is the Zab-szék Lake, that can be considered the most stabile lake on the basis of its present area, contour, and ecogeography.

Statistically, the airphotos represent an average 1% annual decrease in the water surface. The above mentioned Kis-réti Lake is unique in this sense, since in the past 44 years with its annual 2% surface decrease it has shrunk to a portion of its former size. On the contrary, in case of other larger lakes the degree of change has decreased 50 % since they were declared protected in 1973.

The data obtained from earlier maps differ to some extent from the data of the past few decades. During the examined two hundred years the characteristic pace of decrease was 0.1-0.5 % per year, and it was just occasionally interrupted by advantageous changes. (In case of the Kis-réti Lake the process is more intensive, here the starting surface was 2-3 times larger than the present one.) As we get closer to the present each lakes' surface inevitably started to decrease, e.g. the most changing lake the Kelemen-szék lost most of its open water surface in the past 20 years (*Fig. 2*). *After all, the surface-decrease deduced from the interpreted values is larger than it can be expected from data provided by maps!*

Botanic analyses also support the fact of decreasing water supply in the region. The drying process at Miklapuszta, but on the whole territory as well has had more stages: (1) the swamps sustained by floods and (2) the excess water turned to be sodic marshes, (3) then they gave their place to sodic meadows, (4) on which steppe formation can be observed (*Horváth 1997*).

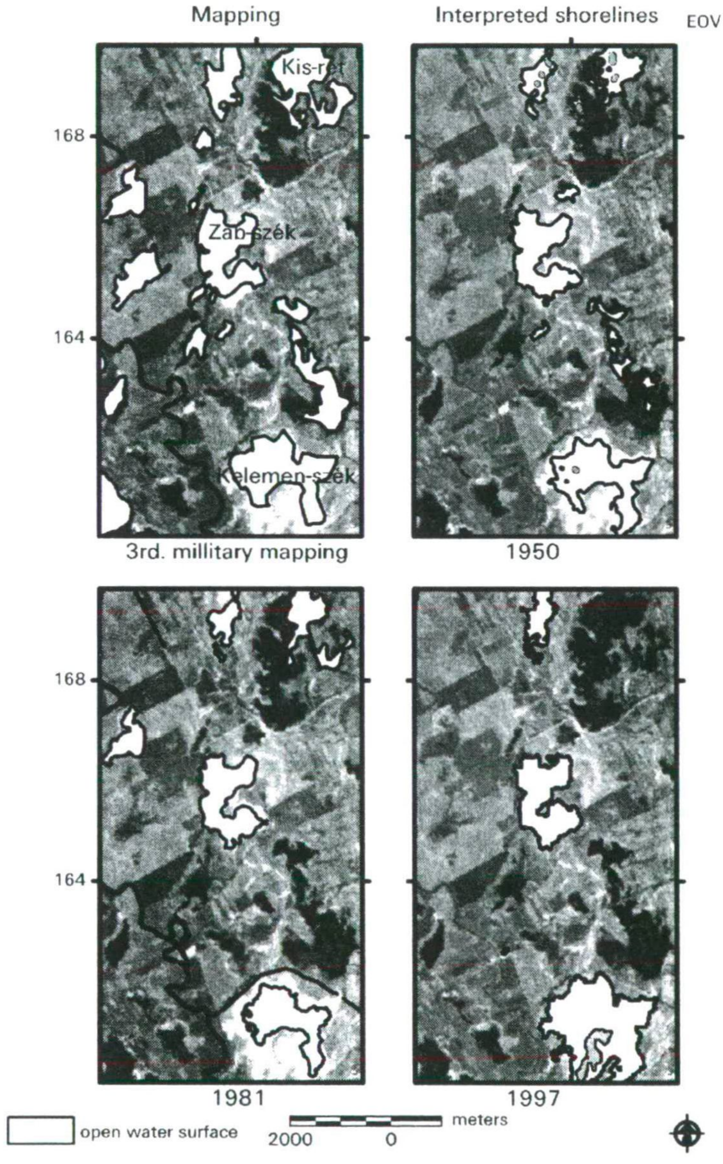



**Figure 2** Hidrographical changes of the lakes in the northern Kiskunság (the background is a Landsat TM satellite image)

## Geomorphologic analyses

The height of sodic benches (80-130 cm) on the territory of Miklapuszta, made up of solonchak type soils, is outstanding in Hungary. The established data base made possible to determine the rate of retreat in terms of sodic bench rims (a typical form of soil erosion on plains). Based on the comparison of the III. Military Mapping with the combined maps and airphotos from the 1961-1994 period, we got the approximate erosion of a hundred years. *The gained 20 m/100 year mean value supports our former assumption that annually even a 15-30 cm retreat can be observed.*

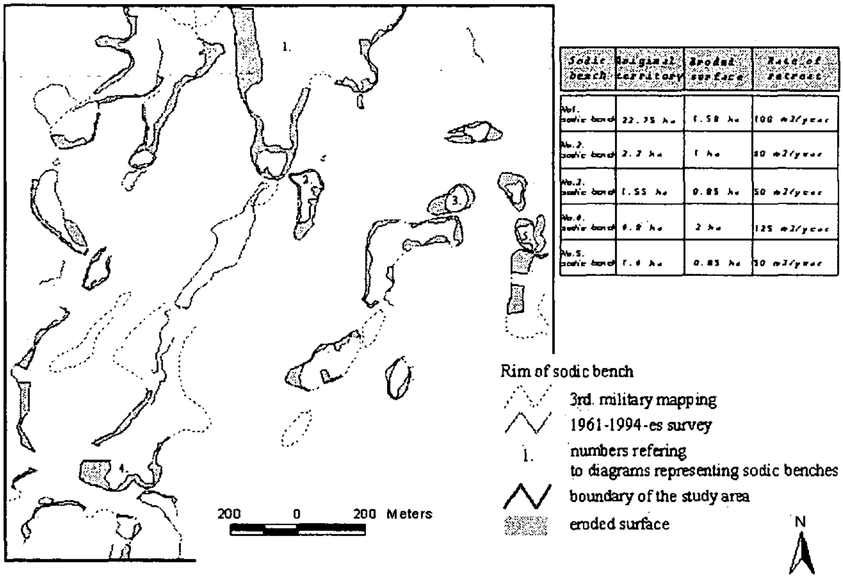
From the 516.88 ha territory involved in the detailed analysis, 25.38 ha, i.e. almost 5 % of the surface, had eroded during 80 years (1882-1961). Even by assuming just a 50 cm average height for benches, this means the erosion of 127 000 $m^3$ (!) material, that is equal to 1600 $m^3$/year, and 3$m^3$/year/ha values.

Concerning the actual rate of surface erosion this value can serve as a minimum, since the average benches are higher, and the uncertain territories were not involved in the evaluation. (Since 1997 we have carried out GPS measurements on the territory in order to determine the present rate of erosion. For more exact evaluation we suggest a 4-5 year periodicity in remeasuring.)

Detailed examinations also point at the causes of erosion, e.g. herds have a great role in the dissection of uniform benches, and along their major routes – around watering places, wells – rills can be noticed on the surface of the benches. The mapping of roads used by vehicles is difficult because car-tracks can be found all over the plain. Due to the temporary marshy character of the territory the real roads run mainly at the base of the benches, thus, they greatly increase the rate of erosion. The process is especially characteristic in the vicinity of agricultural lands, where the tractor-tracks and vehicle turns noticeably have a great effect on the surface. Due to the quality of soil, the accumulating and water collecting effect of the tracks running through sodic meadows gives a linear structure to the vegetation (*Fig. 3*). The effect of tracks made by one but heavy vehicle can also be observed, even after they were covered, too! Narrow ditches running along the plain, serving the faster drying of the territory, close to the benches also take part in the degradation of the soil cover. As an anthropogenic effect, also along roads, cattle tracks and ditches there is an increased erosion where deepening occurs. That is why Horváth, A (*1997*) suggested that it would be desirable to forbid car traffic and restrict the grazing of cattle on the territory.

According to our experiences, the degree of degradation significantly depends on the length of the rim that can be attacked by erosion (*Fig. 3*).

These draws the attention to the danger meant by newly (last few decades) established roads and ditches, that increase erosion by providing further attackable surfaces. Based on the analysis of airphotos, the severe problem of desection of the territory is inevitable (*Fig. 4*). Since, long ago we have done the first steps toward launching sodic bench erosion, that is very hard to stop, it is not difficult to predict that this valuable landscape of ours is going to disappear.




| Sodic bench | Original territory | Eroded surface | Rate of retreat |
|---|---|---|---|
| No.1. sodic bench | 22.75 ha | 1.58 ha | 100 m3/year |
| No.2. sodic bench | 2.7 ha | 1 ha | 80 m3/year |
| No.3. sodic bench | 1.55 ha | 0.85 ha | 50 m3/year |
| No.4. sodic bench | 4.8 ha | 2 ha | 125 m3/year |
| No.5. sodic bench | 1.4 ha | 0.83 ha | 30 m3/year |

**Figure 3** Rate of sodic bench retreat at the northern part of Miklapuszta

Based on our pragmatic investigations, a question arises: how could more than a hundred thousand m$^3$ material left the territory? Although, there are documents proving that a considerable amount of native soda was collected and taken away from panned waters of the territory at the end of the 19$^{th}$ century, we assume that aeolian activity played the major role in transportation.

## Conclusions

During our research we managed to establish a data system that made the evaluation of landscape changes – two hundred years retrospectively – possible even on a plain territory with relatively few TIC points. With the application of this system the evaluation of geographical processes can support the realisation of practical tasks as well. In addition, it provides a chance to predict the future occurrence of negative processes that require intervention.

On our studied territory the greatest environmental problem is the withdrawal of water surfaces and sodic bench erosion. The previous one can be solved by keeping back water or by supplying the territory with extra amount of water (this must be complemented with the repression of harmful vegetation). To treat the other, drastical land-use restrictions would be necessary (on vehicles, grazing, construction of linear establishments), but still, these would only have limited results. After all this implies that environmental protection should not remain on the level of using passive methods on the territory.

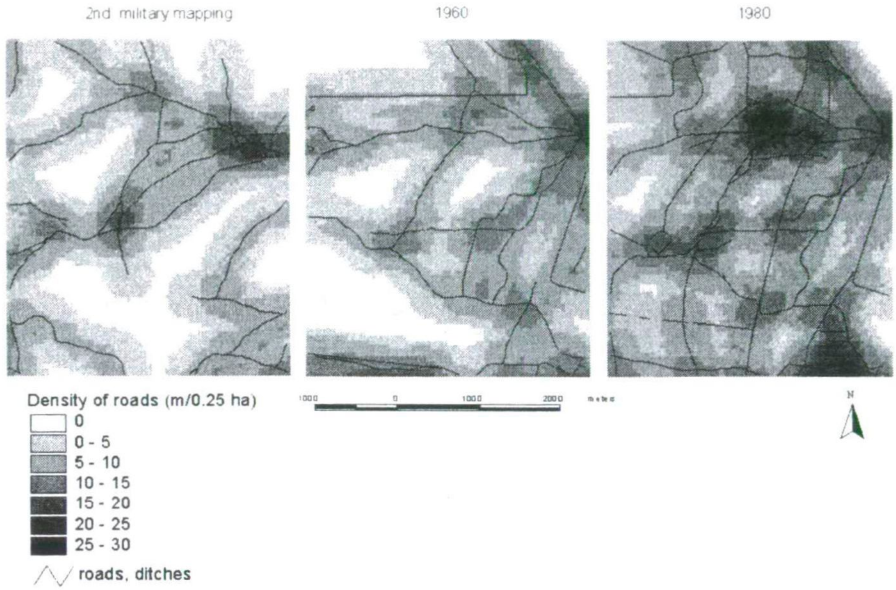



**Figure 4** Change in the density of roads on the northern part of Miklapuszta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