ACTA CLIMATOLOGICA ET CHOROLOGICA
Universitatis Szegediensis, Tomus 40-41, 2007, 169-178.

RISK ANALYSIS OF THE ARIDIFICATION-ENDANGERED SAND-RIDGE AREA IN THE DANUBE-TISZA INTERFLUVE

G. ZSÁKOVICS, F. KOVÁCS, A. KISS and E. PÓCSIK

Department of Physical Geography and Geoinformatics, University of Szeged, P.O.Box 653, 6701 Szeged, Hungary, E-mail: zsakovics.gergely@gmail.com

Összefoglalás – Jelen tanulmányunkban több szempont figyelembe vételével elemeztünk egy, a Duna-Tisza közi Homokhátságon elterülő mintaterületen feltételezhető vízhiányos állapotokat. Ennek feltárásához vizsgálatainkban az 1970 és 2000 közötti havi csapadékadatok alapján készült SPI aszályindex térképeket, az 1971–2000 közötti talajvízszint-változások eredményeit és a terület talajainak vízgazdálkodási tulajdonságait vetettük össze. A mintaterületen ezek alapján létrehoztuk a vízgazdálkodási szempontból különböző mértékben veszélyeztetett területek eredménytérképét, amit összehasonlítottunk az 1992–2001 közötti időtartam NDVI elemzésével kapott, a klíma változékonysága, változása szempontjából potenciálisan veszélyben lévő erdők területével. Az eredménytérkép tájtervezésnél, tájoptimalizáció során hasznos támpontokat adhat azokon a területeken, ahol elengedhetetlen a vízgazdálkodási és hidrometeorológiai szempontok fokozottabb figyelembe vétele.

Summary – In this study a complex analysis was carried out of a sandy area endangered by water-shortage, located in the Danube-Tisza Interfluve. In our investigations, SPI drought index maps based on monthly precipitation data in the period between 1970 and 2000, result maps of groundwater-level changes from 1971 to 2000 as well as maps describing soil characteristics of the area were applied. Based on the above-mentioned database, we generated a result map of endangered areas threatened to different extents from the viewpoint of water management. The result map was compared with the areas of potentially endangered woodlands, which were taken into consideration with respect to the variability and change of the climate. These latter areas were revealed by the analysis of the NDVI (Normalized Vegetation Index) of the period between 1992 and 2001. The result map can provide a good background to landscape planning where it is indispensable to take the aspects of water management and hydrometeorology into consideration.

Key words: aridification, groundwater-level decrease, endangeredness, drought index-mapping, SPI, NDVI

1. INTRODUCTION

In most parts of Hungary, similarly to the conditions of our study area (*Fig. 1*) located in the Danube-Tisza Interfluve, warm arid and warm-temperate arid climatic regions can be found (*Péczely*, 1979), where from the early 1970s on a continuous, rapid decrease of groundwater level could be detected. The considerable precipitation decrease of the last decades, increasing drought and the intensive use of groundwater resources provide a good reason to study the water economy of the otherwise badly water-balanced area (sandy soils). Additionally, a survey was carried out concerning the distribution of precipitation in the period between 1970 and 2000 applying the evaluation method of the Standardized Precipitation Index (SPI) as well as the average change of groundwater level until 2000 compared to the average of the five years in 1971–1975.

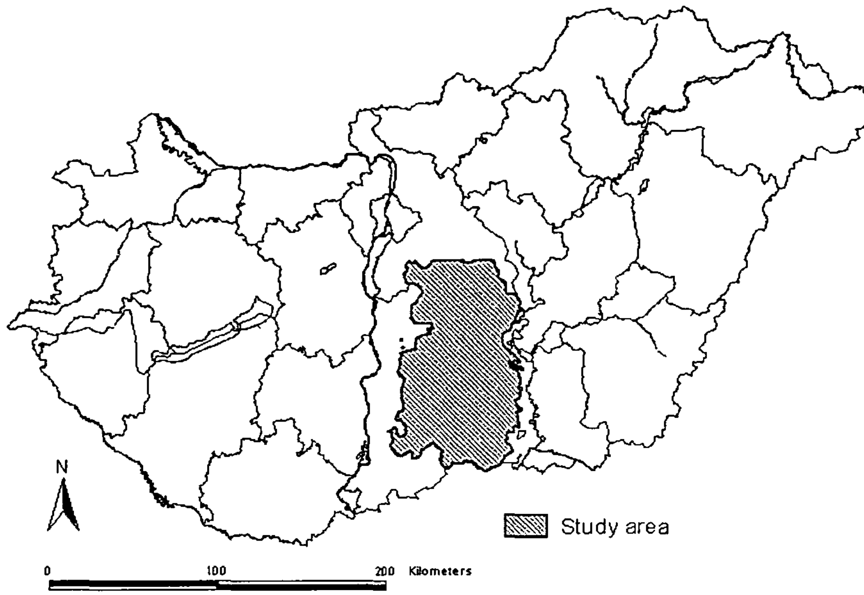

Fig. 1 Location of the study area in the Danube-Tisza Interfluve

The SPI indices express a lack of precipitation and surplus of precipitation respectively on the basis of the precipitation data input. The drop of groundwater level in the study area in the period under survey can be traced back to the combined effects of several factors. The decrease in precipitation, increase in the proportion of woodlands as well as the significant evaporation caused by the increased number of hot days can contribute to this process. A great amount of wells, serving for satisfying the water demand, and the possible groundwater-level decrease due to water-exploitation for agricultural and other utilization cannot be neglected. Therefore, in our study, maps of SPI indices as well as that of the change of groundwater-level were created. Moreover, by using the (Hungarian) Agrotopography Database (AGROTOPO), it is also important to point out those regions of the study area which are endangered to different extents from the viewpoint of water management. Additionally, in order to test our results and for finding the connections with other indicators we compare the result maps with the area of potentially endangered woodlands based on satellite image analysis.

2. MATERIAL AND METHOD

As a backgroud of our investigations, we created the map of the endangered areas by comparing three layers:

As a first layer, SPI indices have been constructed by statistical operations based on the precipitation data of 22 meteorological stations that were represented in our sample area using the chosen interpolation method. Making use of monthly precipitation data we made SPI drought index maps of the study area. The SPI quantitatively determines the lack of precipitation projected to time series. Time series reflect the effects of droughts on the precipitation measurement points and on the surface generated from these points by the above-mentioned interpolation (for more information, see websites No. 1-3 in the REFERENCES). In the course of our study we used three months' SPI time series that, for instance, in case of the value of March, is based on the total quantities of precipitation in March, February and January. Although several other types of drought indices could have been used (relative evaporation, Pálfai's aridity-index – PAI, Palmer's drought index – PDSI, etc.), the SPI was chosen due to its widespread application and the fact that it requires only precipitation data series to calculate drought indices. Categorization of the SPI is represented in *Table 1*.

Table 1 Categorization of SPI values

2.0 –	extremely wet
1.5 – 1.99	very wet
1.0 – 1.49	moderately wet
-0.99 – 0.99	Average
-1.0 – -1.49	moderately dry
-1.5 – -1.99	very dry
– -2.0	extremely dry

As a second layer, raw data of groundwater-level were provided by the database of the VITUKI (Water Resources Research Center) Zrt. referring to the period of 1971 to 2000, based on the series of 210 wells. We utilized five-year absolute mean of groundwater level calculated from the data of each month in the period between 1971 and 1975. The data of the other years were compared to this five-year mean. The map of the average change of groundwater level in March of the 1976-2000 period was generated by adding up the relative changes of each year that demonstrates the groundwater level of the end of winter hydrological terms (*Rakonczai*, 2006).

As a third layer, data concerning the soil characteristics of the area from the viewpoint of water management were provided by the AGROTOPO database (for more information, see websites No. 4 and 5 in the REFERENCES).

In order to generate surfaces from the above-mentioned database we applied spline interpolation. This method is suitable for producing such surfaces that have little variation in altitudes. On the other hand, it is not suitable for modelling great alterations in relief that denotes large local differences because it minimizes the differences of altitudes (*Bihari*, 2000; *Németh*, 2004).

3. RESULTS AND DISCUSSION

Comparing the drought index maps of the winter and summer hydrological terms (*Fig. 2*) it becomes obvious that the lack of precipitation mainly occurred in the winter terms. In our reference period, this occured mostly in the SPI means of January and February. In the study area, the lowest SPI means could be found in Kecskemét and its surroundings, so this area can be especially sensitive to damages caused by aridity (*Figs. 3-4*).

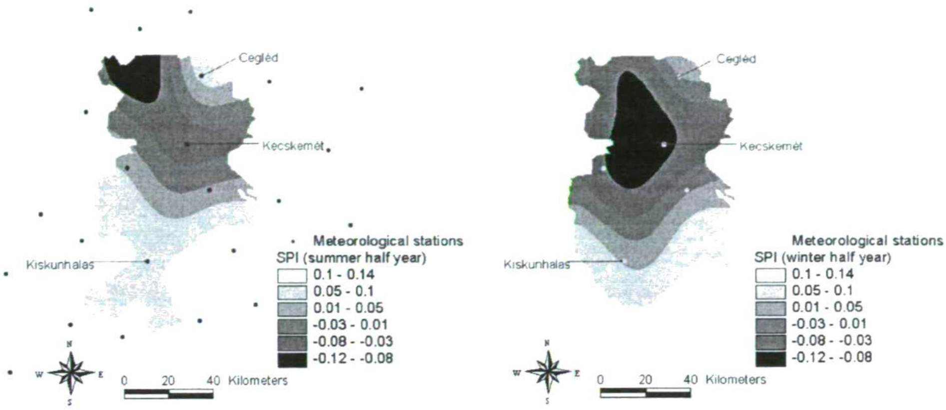

Fig. 2 Means of SPI values in winter and summer terms

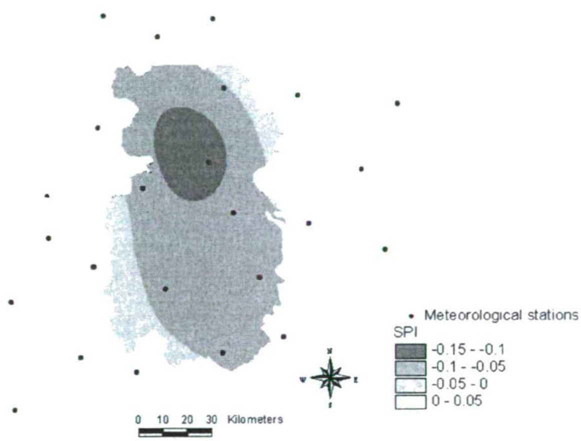

Fig. 3 SPI means of Januaries in the 1970-2000 period

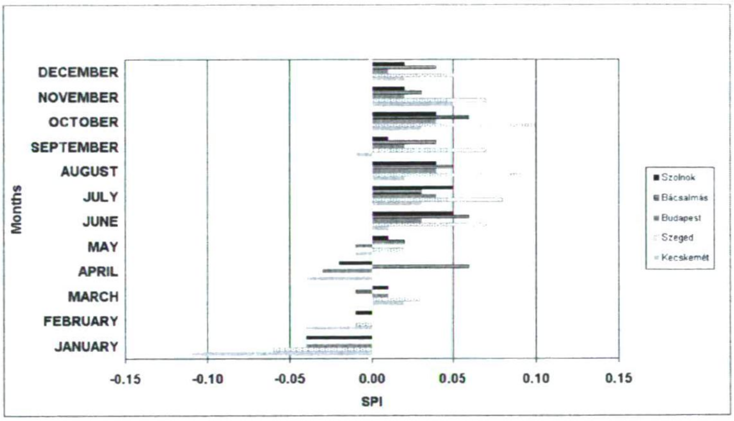

Fig. 4 Monthly mean SPI in some of the measuring stations in the study area

In the 1970s there were four, in the 1980s there were five, while in the 1990s there were already six years that had an average index with negative sign (*Fig. 5*). The latter ones were characterised with lower values, so these years were drier than the earlier period. In this period, in spite of being diversified by wetter years, more and more dry years occurred as time was passing. Among other reasons, this played an important role in the process resulting in the serious drop of groundwater-level, due to the fact that the water consumed in the vegetation season was not retrieved at all in 15 of the 30 years. What is more, on the basis of the drought index maps, between 1970-2000 the most humid year turned out to be 1999, while the driest year occurred in 2000 (*Fig. 6*).

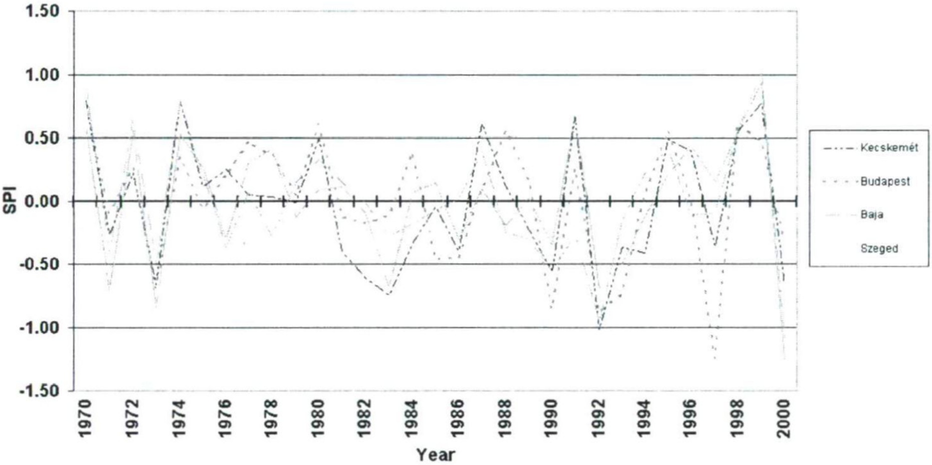

Fig. 5 Annual mean SPI values of the 1970-2000 period

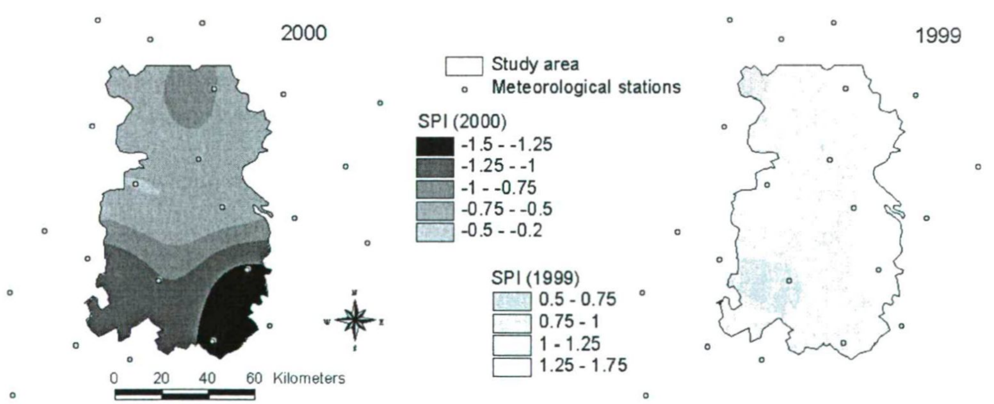

Fig. 6 Annual resolution SPI maps of 1999 and 2000

The winter precipitation – the great lack of which has been previously pointed out – has the role of supplementing the summer loss of groundwater level, so we cross-checked the map of groundwater-level change referring to March with the SPI results of the winter term. Areas of the ridge characterized by great decline were visibly outlined on the groundwater-level change map. Especially the northern and southern parts of the sand ridge had groundwater-levels steadily below the average (*Fig.* 7).

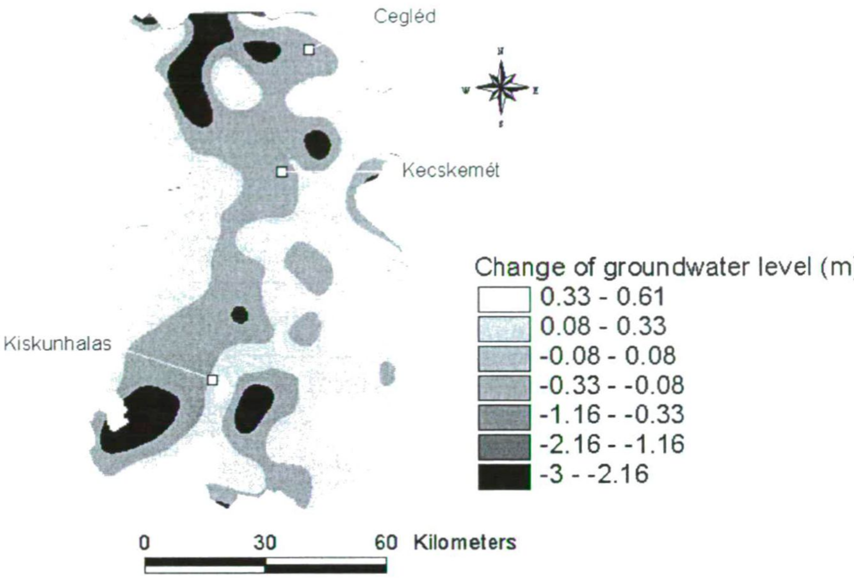

Fig. 7 Map of the mean March groundwater level in the study period

The third layer taken into consideration while marking the endangered areas was constructed on the basis of the data derived from the water economy classification of the AGROTOPO database. Accurate determination of specific aspects was required before starting the selection itself. We reclassified all the three layers in such way that in case of the first and second layers 4-4 categories, while in the case of AGROTOPO database 2 categories were established. The later, different categorisation had to be established due to the disadvantageous (from the viewpoint of water economy) character of the soils in most parts of the study area.

On the basis of this categorization the different soil-types were classified into the following groups. Soils characterized by inadequate water-holding capacity, weak water-storage capacity and very good permeability (sandy soils); soils with strong water-holding capacity and weak water-absorbing capacity (clay) and soils with an extreme water regime are classified into class No. 1. In class No. 2, which is the class of soils with favourable water economy, soils with adequate water-holding and water-absorbing capacity as well as great water-storage capacity (chernozem) can be found (*Fig. 8*).

Four-four restructured classes of the winter-term SPI layer and the surface of the mean groundwater-level change of March were marked with numbers 1, 2, 3 and 4, where class No. 1 was given the interval with the lowest values. New classes accurately demonstrate the spatial distribution of the value domains before classification. In the SPI classification a considerable proportion of the northern part in the study area fell into the first category while in the classification of groundwater level more extended spots showing deep decrease could be found in the southern, southwestern and northwestern parts of the study area (*Fig. 9*).

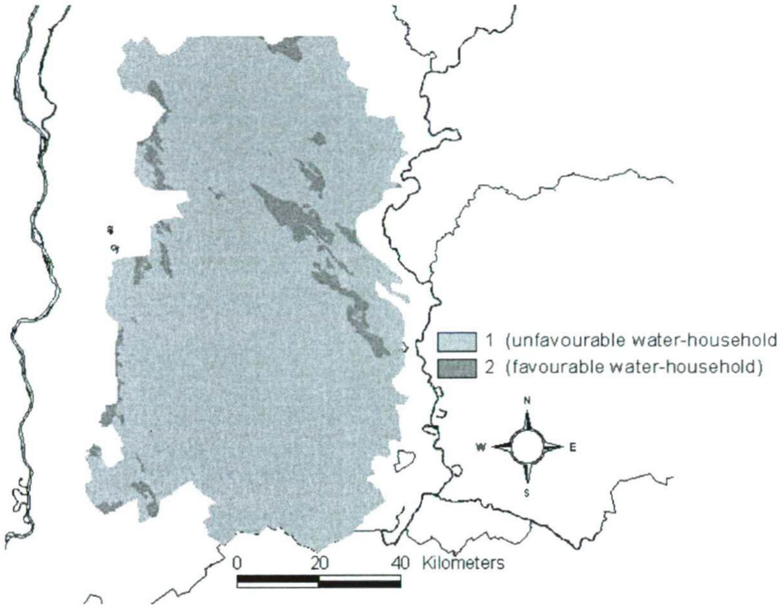

Fig. 8 AGROTOPO layer reclassified from the viewpoint of water economy

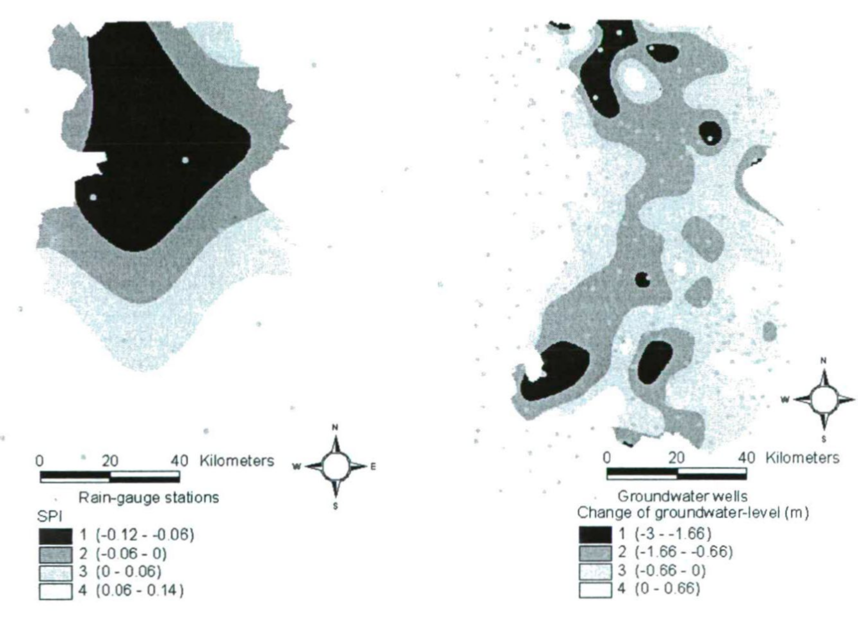

Fig. 9 Reclassified SPI (winter term) and classes of groundwater-level change with measurement points (wells)

As to mark off the endangered areas, we combined the newly determined classes of the three data-layers. Categories of endangeredness were established as the cross-sections of different combinations. The category of „Increasingly Endangered" means cross sections of classes of endangeredness marked by 1; here soil conditions are neglected. The cross section of those areas fell into the „Endangered" category that had soils characterized by inadequate water economy and where one of the classes of the SPI or drop of groundwater level (TVSZ-CS) fell into the first category. The cross-section of the first category of the SPI classes and the drop of groundwater level (TVSZ-CS) made up the area of „Moderately Endangered"; in this case the favourable soil conditions were taken into consideration. We included the combination of the second and third and the second and fourth SPI/TVSZ-CS category-classes in the same type taken as a function of unfavourable soil conditions. All the remaining areas came under the „Less Endangered" category (*Table 2*).

Table 2 Categories of endangeredness

Categories	SPI (1-4)	TVSZ-CS (1-4)	T-VIZGAZD (1-2)
Increasingly endangered	1	1	1.2
Endangered	1	2	1
	2	1	1
	2	2	1
	1	3	1
	3	1	1
	1	4	1
	4	1	1
Moderately endangered	2	3	1
	3	2	1
	2	4	1
	4	2	1
	3	3	1
	1	2	2
	2	1	2
	2	2	2
	1	3	2
	3	1	2
	1	4	2
	4	1	2
Less endangered	2	3	2
	3	2	2
	3	3	2
	2	4	2
	4	2	2
	3	4	1.2
	4	3	1.2
	4	4	1.2

Afterwards, we generated the map of endangered areas by combining the above-mentioned categories. As a result, mainly the northern, central and southwestern parts of the study area turned out to be endangered, whereas less endangered areas could be found in the southeastern sections (*Fig. 10*).

For comparison, the area of potentially endangered woodlands, revealed by the analysis of the AVHRR (Advanced Very High Resolution Radiometer) and the NDVI (Normalized Vegetation Index) of the period between 1992 and 2001, were also included in our investigations (*Kovács*, 2006). We examined the extent of the potentially endangered woodlands (using NDVI indices) compared to the location and extent of the areas marked by the categories of „Increasingly Endangered" and „Endangered" in our result map. Areas characterised in our result maps by these two categories covered 36.89% of the study area, while 56.34% of the endangered woodlands could be found here. We also calculated that only 9.86% of the endangered woodlands are situated in less endangered areas – that cover 23.44% of the study area (*Fig. 11*).

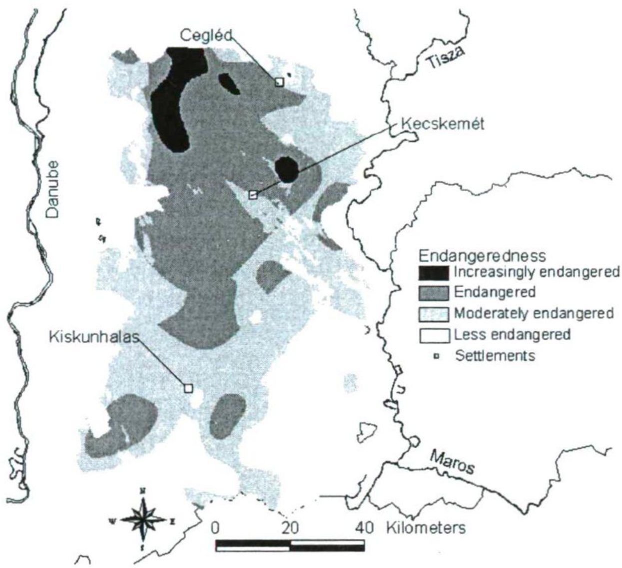

Fig. 10 Categories of endangeredness in the study area

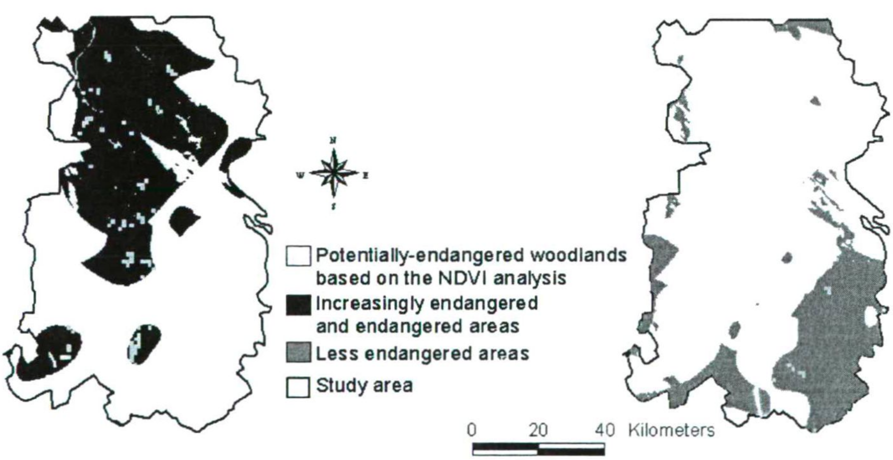

Fig. 11 Area of potentially endangered woodlands (according to the NDVI analysis) located in increasingly endangered, endangered and less endangered areas

Since spatial results concluded are very similar to each other, clear parallels can be detected between our result maps and that of the NDVI analysis. Although the reasons and level of connections should be the topic of further investigations, the map of endangeredness demonstrates well the differences in the degree of endangeredness of the vegetation in the area which has a given sensitivity from the viewpoint water economy.

4. CONCLUSIONS

Using SPI values we pointed out that the winter term in the reference area is much more arid than the summer term. Moreover, it appeared that Kecskemét and its close surroundings are the areas most exposed to aridification processes. The decrease of groundwater level in the greatest extent could be observed in the northern and southern parts of the study area. As a third layer soil classification, based on water storage capacity and permeability was also carried out in our survey. Using the results of three data layers, a map of endangered areas was generated. It can be stated that the northern, central and southeastern parts of the study area are the most endangered, while in the southeastern parts less endangered areas can be found.

The result map was compared with the area of potentially endangered woodlands. These areas were indicated by the analysis of the NDVI (Normalized Vegetation Index) referring to the period of 1992–2001. In our case, 56.34% of the woodlands fell into the „Increasingly Endangered" or „Endangered" categories which is a considerable proportion compared to the whole size of the study area (3.89%). On the other hand, only 9.86% of the endangered woodlands are situated in the less endangered areas (23.44% of the sample area). Thus, although the detection of possible reasons is a subject of further research, strong parallels could be detected between the condition of the vegetation and our categorization of endangeredness.

Acknowledgement – The research was funded by the EU project FP-6 Millenium.

REFERENCES

Bihari, Z. 2000: Magyarország új éghajlati térképei. [Recent climatic maps of Hungary. (in Hungarian)] *Élet és Tudomány 55/6*, 175-178.

Kovács, F. 2006: A biomassza-mennyiség regionális változásainak vizsgálata a Duna-Tisza közén műholdfelvételek alapján. (Regional differences of biomass production in the Danube-Tisza Interfluve using satelite image analysis). In *Kiss, A., Mezősi, G.* and *Sümeghy, Z.* (eds.): *Táj, környezet és társadalom.* (*Landscape, environment and society*). SZTE, Szeged. 413-425.

Németh, Á. 2004: Az aszályérzékenység meghatározása térinformatika alkalmazásával. [Defining drought sensitivity using GIS. (in Hungarian)] *Acta Agraria Kaposváriensis 8/3*, 25-34.

Péczely, Gy. 1979: *Éghajlattan.* [*Climatology.* (in Hungarian]) Tankönyvkiadó, Budapest. 282-283.

Rakonczai, J. 2006: Klímaváltozás-aridifikáció-változó tájak. (Climate change-aridification-changing landscapes). In *Kiss, A., Mezősi, G.* and *Sümeghy, Z.* (eds.): *Táj, környezet és társadalom.* (*Landscape, environment and society*). SZTE, Szeged. 593-601.

(1) *http://www.drought.unl.edu/monitor/spi/program/spi_program.htm.*

(2) *http://www.drought.unl.edu/whatis/indices.html.*

(3) *http://www.wrcc.dri.edu/spi/explanation.html.*

(4) *http://gisserver1.date.hu/Uniphorm/workshop/talajadatb.htm.*

(5) *http://www.otk.hu/cd00/3szek/bakacsizsofia.htm* - Agrotopográfiai database (AGROTOPO database).