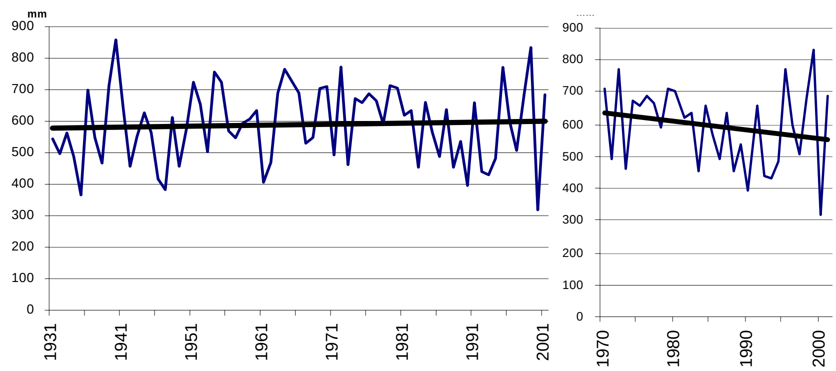
EVALUATING THE PROCESS OF ARIDIFICATION ON THE EXAMPLE OF THE DANUBE-TISZA INTERSTICE

Dr. János Rakonczai – Ferenc Kovács[1]

1. Aridification as a phenomenon

Based on the significant decrease of precipitation in the past 15-20 years in Hungary many times has it been claimed that there is a desertification process in development. However, since yearly precipitation in the country stays below 200 mm-s only exceptionally rarely in very few areas (it did occur in 2000) it is quite inappropriate to talk about desertification. As with any time based dataset, evaluation of precipitation data also contains disputable elements. As an example observe the 70 years data for Kiskunhalas, which shows slight increase instead of decline (Fig. 1). Nation-wide evaluations using various methods however show significant (at least 40-50 mm) decrease in yearly precipitation (Figures 2 & 3). An even greater loss is measurable in some parts of the Alföld (Great Hungarian Plains), especially in the Danube-Tisza Interstice.

Fig. 1: Precipitation values (mm) and trend of its change at Kiskunhalas between 1931-2001 and 1970-2001



Aridification as a process however is not easy to evaluate based on direct consequences (e. g. drought, loss of crop yields), since bad yields can also occur in case of normal precipitation with unfavourable distribution, and scarce rain can be substituted with irrigation. During our research we have sought so called “complex indicators” which can demonstrate the process both spatially and temporally according to changes in the environment.

[1] Dr. János Rakonczai assistant professor, Ferenc Kovács professor assistant, University of Szeged, Dept. of Physical Geography and Geoinformatics, P. O. box 653. Szeged H-6701, HUNGARY

Fig. 2: Chronological series[2] of average precipitation in Hungary (Szász, G., 1997)

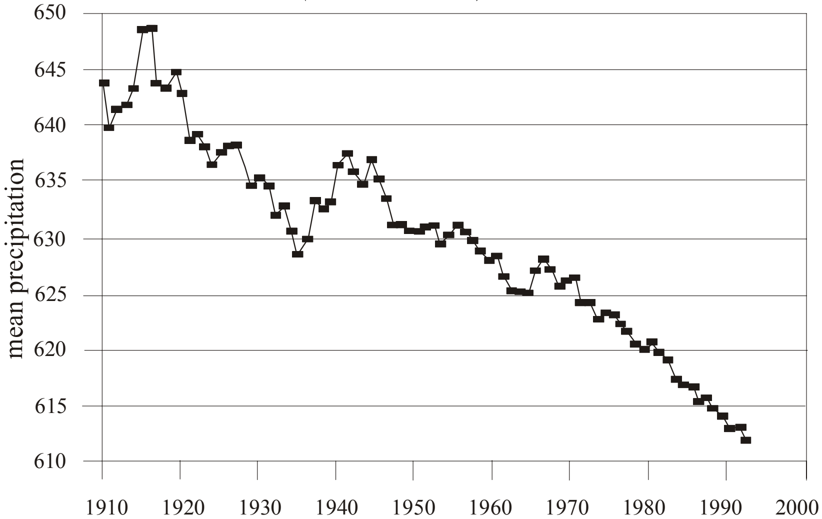
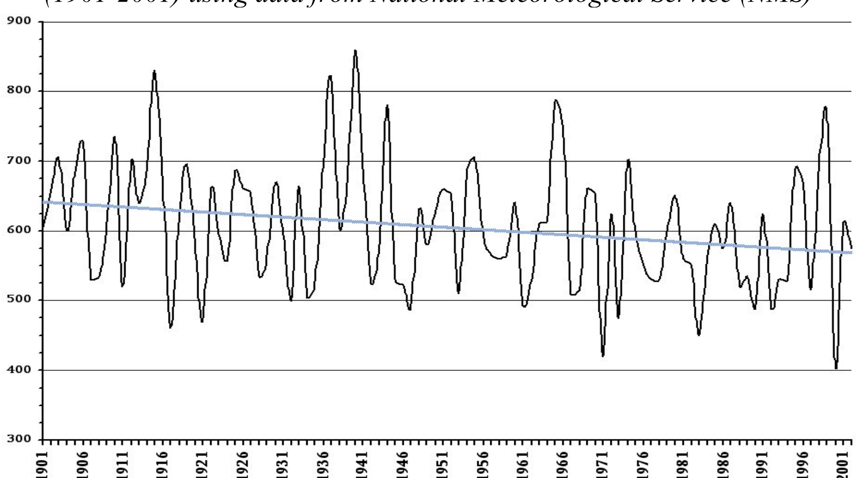


Fig. 3: Mean yearly precipitation in Hungary (mm) and its trend (1901-2001) using data from National Meteorological Service (NMS)



[2] The survey contains data between 1881 and 1992 using 16 stations with a full temporal range. The initial value is the average of years 1881-1910, the expanding dataset shows the mean of ever longer periods.

2. Decrease in the level of groundwater

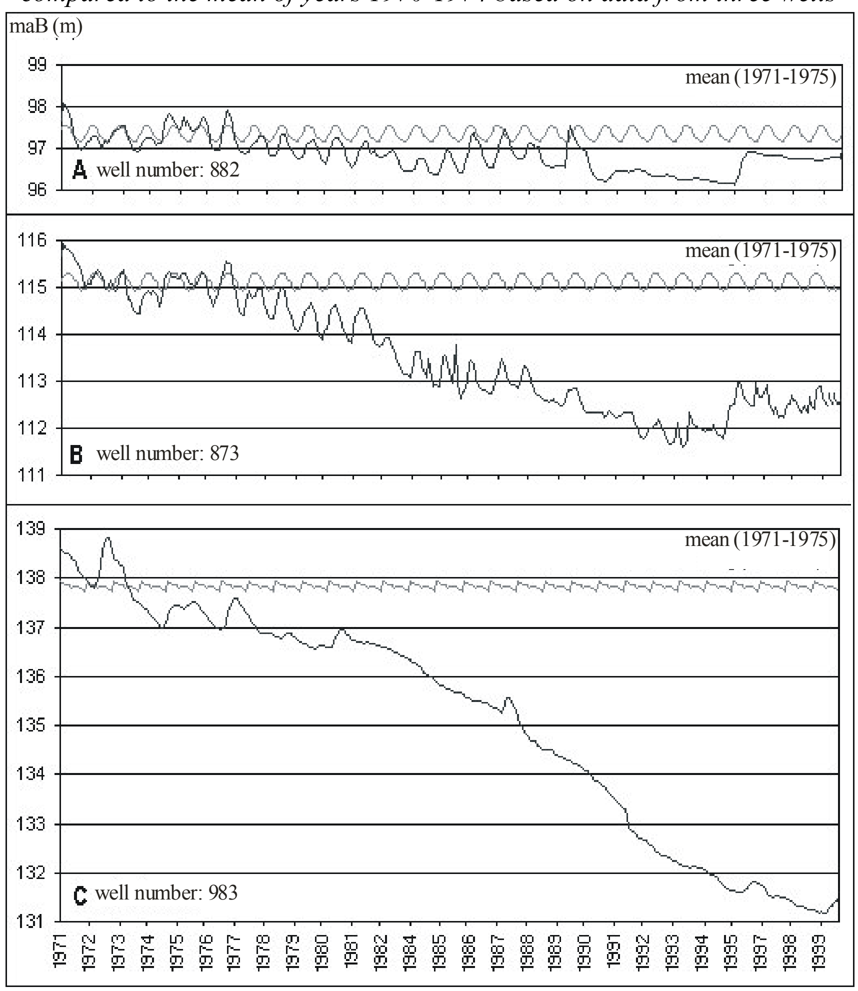
The process of groundwater depression was first observed on regional level in the Danube-Tisza Interstice. Detailed research however demonstrated that decreasing precipitation is only another factor of the phenomenon, in fact it is a very complex process caused not only by natural but social effects as well. The most important characteristics are as follows:

- Scarce precipitation. The region suffered significant loss of precipitation from the early 1980's until around 1995. For more than ten years annual precipitation did not reach 560 mm-s (which is much less than the national average), in fact it fell around or even below 540 mm-s.
- The 1980's was the most intensive period in terms of strato-water extraction. It increased by 2.5 folds to 340,000 m^3/day between 1970 and 1980 in the Danube-Tisza Interstice, causing strato-water levels to drop in addition to their already happening decrease. This was even more significant (e. g. it reached 20-25 metres around Kecskemét by 1990) in areas where water supply originates dominantly from surface infiltration. The intensive drop of strato-water levels in such areas act as a kind of suction for the above lying groundwater as well.
- Due to lack of surface water agricultural irrigation was performed using groundwater of low depth strato-water in many locations. After the collapse of large scale farming cooperatives this effect strengthened significantly.
- In order to drain (at the time) excess precipitation in earlier more humid periods, many canals and other waterways were built. These features still did their job in dry periods as well, helping water to flow away instead of infiltration.
- Land use changed in many areas. Very often tree-planting happened to increase the ratio of forests and this was frequently carried out using poplars growing quickly but demanding much water.

In terms of subsurface water flow it is important to point out that the area lies between the two large rivers as a ridge (its highest points 40-80 metres above them), which means that precipitation is the most important component of groundwater supply (there is no chance for subsurface infiltration from higher areas). Also the effect of the rivers is only perceptible in a narrow zone around them.

Following detailed research (using GIS techniques) of the 8500 km^2 area mostly influenced by the changes it could be determined that the decrease of groundwater levels is closely related to elevation (relief) circumstances (Fig. 4). This leads to the conclusion that the reason of loss should in the end be sought in the climate turning dryer (including the effect of more intensive utilisation of subsurface water for irrigation due to dropping precipitation). Figure 4 shows that the effect of periods with more precipitation is hardly noticeable in case of deeper groundwater levels. So, even if some more humid years in the second half of the 1990's had a relieving effect on water famine (using a mean porosity of 30 % the lack of water was 4.87 billion m^3 in March 1990 and 3.44 billion m^3 in March 1999) there is still a 1500 km^2 area in which the rate of depression is so great that no normalisation seems possible.

Fig. 4: Changes of groundwater level in the Danube-Tisza Interstice compared to the mean of years 1970-1974 based on data from three wells



The aridification process of course does not affect only the Danube-Tisza Interstice area, only in this region it is the most pertinent. One of the reasons for mass tree-deaths in our oak-forests since the late 1970's was thought to be the decade long lack of precipitation. In the South-eastern Alföld (mainly in Békés and Csongrád counties) such soil-depressions occurred due to long droughts that caused massive damages in buildings. The most significant groundwater depressions occurred in the Nyírség and the southern part of Tiszántúl.

3. Short term changes in vegetation

The base idea of our research was that the changes of life-conditions (such as the process of aridification) can be grasped most easily through changes in the amount of biomass. Its temporal and spatial development as a complex indicator will reflect the intensity and chronology of the process. This method enabled us to analyse the 11-year-period in question in terms of the effects on vegetation caused by environmental changes due to climate modification. We could also search for trends in possible changes and see if there is a significant change apart from natural fluctuation and vegetation growth.

Analyses were performed using multi-spectral satellite images. During the research we conducted a monitoring-like analysis on land use classes (CORINE Land Cover 100) derived from LANDSAT-TM images with good spatial resolution using large time-resolution NOAA AVHRR images. From the latter we had monthly and 10-days Maximum Value Composites (MVC) for vegetation periods from April to September[3].

Because of the great variability of land use in the Danube-Tisza Interstice it was expedient to perform analysis of two land cover types close to natural conditions.

- The class *forests* consists of deciduous, coniferous and mixed woods with areas of 25,530 ha, 13,070 ha and 39680 ha respectively. (Gemenc forest of 13,670 ha area in the Danube floodplain served as reference.)
- The class of *soft-stems* contains grasslands, meadows, pastures close to natural state with an area of 9,560 ha.

In order to estimate net biomass production we have used the internationally commonly utilized Normalised Vegetation Index (NDVI):

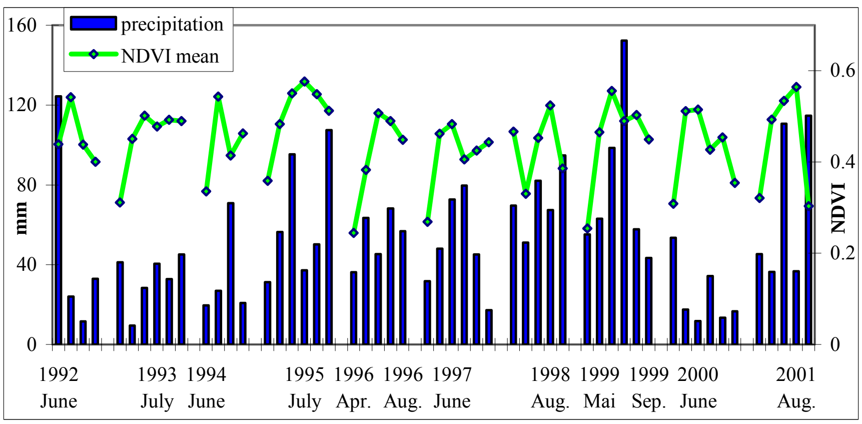
$$NDVI = \frac{NIR_{i,j} - R_{i,j}}{NIR_{i,j} + R_{i,j}}$$

where $R_{i,j}$ is the red value of the given pixel
$NIR_{i,j}$ is the near infrared value of the given pixel

[3] Data from NMS and USGS

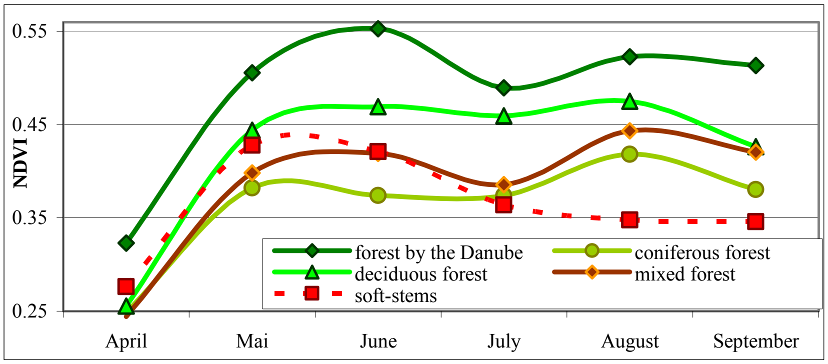
The most important results of detailed analyses:
a) Precipitation and NDVI values showed (as expected) strong correlation, meaning that reaction of vegetation to changes in precipitation can be observed well (Figure 5). Changes in biomass were stronger in forested areas. Inside the vegetation period we experienced long term declining activity in April, July and September. According to various approaches *September can also be listed as endangered period, while June excels with its large scale yearly fluctuations.* The negative trend is more significant than the values of favourable months (May, June, and August).

Fig. 5: NDVI mean value of deciduous forests and monthly precipitation values in the summer half-year in the Danube-Tisza Interstice.



b) Based on mean NDVI values taken from more humid years (1996-1999) we defined so called *average profiles* for each vegetation class, because this would probably demonstrate the growth of specific groups in case of sufficient precipitation (Figure 6). Deviation from this profile on the other hand could express irregular vegetation dynamics, helping to pinpoint endangered areas (Figure 7).
c) According to detailed spatial analyses we could observe *basically declining tendency of biomass amount in about ¼ of the Danube-Tisza Interstice area*. The most sensitive contiguous areas can be found in the central and south-eastern parts of the region (Figure 7). Mixed forests react especially strong to changes.
d) Looking at yearly means we can observe similar conditions, thus *there is no way to speak generically about trend-like increase or decrease*, but in spite of the short period of time *there are deviations which can be taken as the result of aridification in the area!*

Fig. 6: "Average profiles" derived from humid years



4. Changes of natron lakes in the Danube-Tisza Interstice

A transgression of vegetation zones was observed in the wet habitats of the Danube-Tisza Interstice ridge beginning in the 1980's. Weeds gained territory in natron lakes in drier periods bringing practically all the lakes to almost total obliteration in ten years. In the area of former lakes saline grasslands became predominant (Iványosi, 1994).

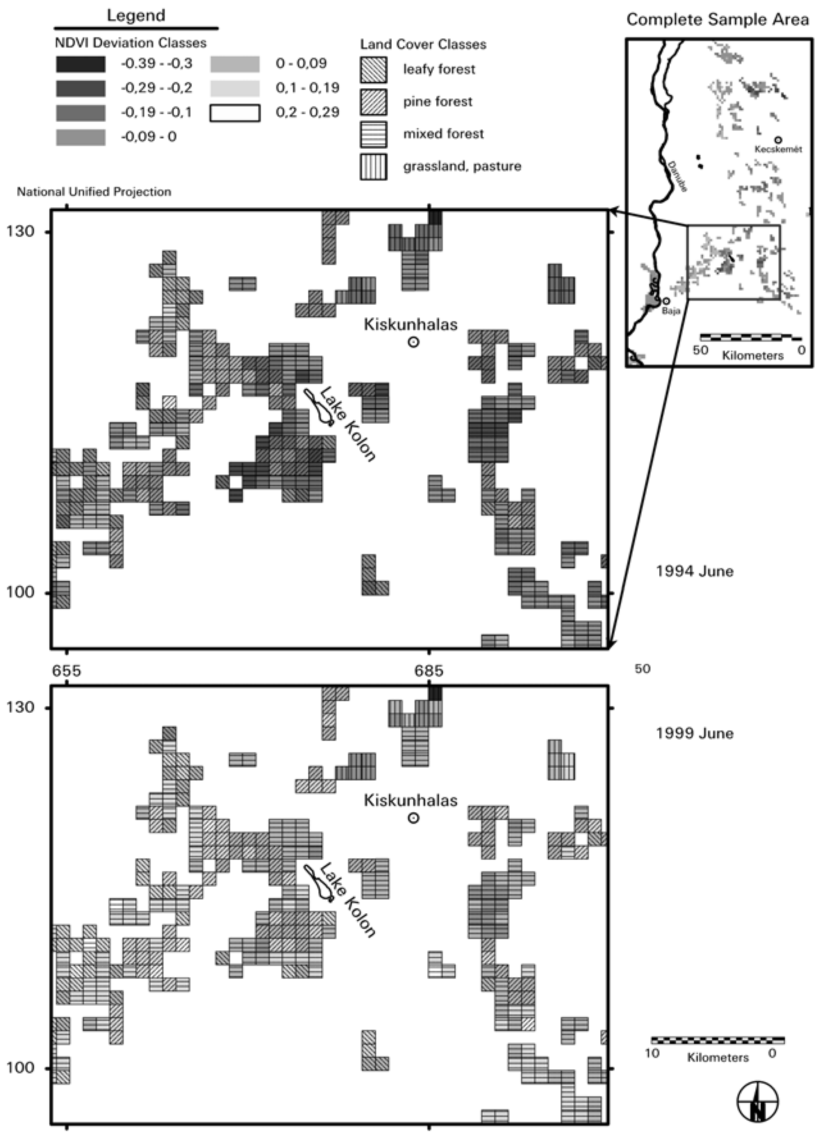
Lakes seem to gain strength in more humid years (at least their area increases) which can temporarily weaken the real process of lake destruction – contributable mostly to aridification processes. The use of proper analysis tools however can still discover the actual procedures.

Using remote sensing data (aerial and satellite images) in the strictly protected area of the lakes in Felső-Kiskunság not only the actual extent of lakes can be discerned, but also the areas of lakebeds taken over by vegetation. Thus if instead of seasonally changing water level we locate vegetation-less depressions that could potentially be flooded we can measure the expansion of vegetation and with this the amount of degradation consequent to aridification.

Apart from larger lakes there were also smaller water surfaces (in total about 20-45 % of all lakes) in the 1950's, but today these are gone, only the large lakes were able to survive.

The expansion of vegetation in the examined 52 years (1950-2002) occasionally reached 250-300 metres, which results in more than 5 metres of annual change! In case the current tendencies continue the natron lakes so characteristic about this region can disappear altogether in another fifty years.

Fig. 7: Spatial distribution of NDVI deviation values in the areas of the Danube-Tisza Interstice that are most affected by aridification[4]

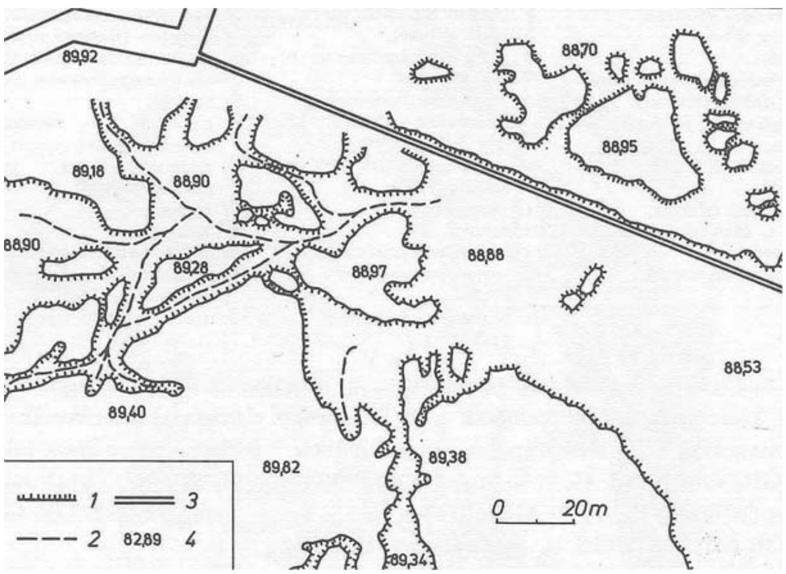


[4] Analysis was performed in case of app. 1.1 km × 1.1 km cells in which the land cover class occupied at least three cells.

5. Changes in vegetation and soil conditions

The depth of groundwater has a definitive influence on the formation and changes of soil types and indirectly on the development of natural vegetation. Thus the aridification process, apart from permanent groundwater depression and the previously mentioned short term consequences, can also be proved soil modifications requiring a longer amount of time. Since this can only be achieved by detailed on location survey – before the processes – we can only show an example to prove the above claim, the extent of the area involved in the changes could not be estimated at the time.

Fig. 8: Micro-relief of the "puszta" at Szabadkígyós in 1978 (Szöőr, Rakonczai, Dövényi, 1978)



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

We have conducted detailed geomorphologic and pedologic analyses in the "puszta" at Szabadkígyós, as part of the efforts to place the area under protection. During this research we could map natron micro-features which are so characteristic of the region in one of the small natron landscapes (Figure 8). Defining the boundaries of natron benches was simplified by the fact that they were marked not only by a 20-30 cm elevation change, but also the vegetation and soil type was different from the surrounding plains. Higher areas harboured grassy vegetation on steppe-like pasture solonetz while low plains were so-called "vakszik", with some salt enduring plants.

The results of analyses 25 years later (in 2003) we could not only discover the diminishment of benches but we could observe vegetation and soil changes as well. In the previously almost barren plains there was grassy vegetation, the higher benches disappeared completely in some places due to bench erosion, the rest had grass and patches of saline plants – while barren natron surface have vanished completely. *Permanent groundwater depression caused apparent landscape changes.*

6. Conclusion

The fact of aridification in the Alföld is not only visible through the constant decrease of precipitation, but also in consequent changes. In short term the lack of precipitation can be measured from vegetation changes, long term scarcity can lead to regional groundwater depression. This latter can cause genetic change in soils, which causes the vegetation to transform even during a human lifetime.

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