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THE INVESTIGATION OF REGIONAL VARIATIONS IN BIOMASS PRODUCTION FOR THE AREA OF THE DANUBE-TISZA INTERFLUVE USING SATELLITE IMAGE ANALYSIS

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Abstract

Quantitative as well as qualitative alterations in the vegetation cover are good indicators of environmental changes. The present paper discusses the problem of the dynamics of vegetation changes in response to short-term climatic changes via the application of remote sensing methods. According to the spatial and temporal analyses of NOAA AVHRR satellite images for the determination of vegetation index (NDVI) for the area of the Danube-Tisza Interfluve, embedding a period of several decades, seasonal and trend-like dynamics seem to govern the alterations of the vegetation. The spatial analysis of the result gained may help us delineate the areas, which are potentially in danger of a presumed minor climate change.
Keywords: multispectral remote sensing, NOAA AVHRR, NDVI, vegetation dynamics, climate change

Introduction

The regional effects of a presumed climate change within the area of Hungary mainly affect the areas of the Great Hungarian Plains, especially the regions of the SE Great Hungarian Plains and the Danube-Tisza Interfluve. The identification of the effects of increasing temperatures, decreasing precipitation (MOLNÁR, 1996; SZÁSZ, 1997), and decreasing groundwater levels (LIEBE, 2000; RAKONCZAI-BÓDIS, 2001) on the environment at a regional scale, as well as the spatial and temporal delineation of endangered areas are highly important both theoretically and practically.

Several works draw our attention, besides the magnitude of potential dangers, to the necessity of increasing the spatial resolution of the environmental studies and the implementation of these at a regional scale, which would enable the accurate evaluation of the direct outcome of changes (KERTÉSZ et al, 2001). The vegetation cover may be a good indicator for such studies as climate can be regarded as one important factor playing a crucial role in the mobilization of biological energies and determining the actual rate of bioproduction. Changes in habitat conditions can be directly measured on the produced biomass. The analysis of the vegetation may solve the problem of evaluating the environmental effects of a possible climate change in Hungary, as the high scatter of meteorological data, thanks to the basin effect and the presence of overlapping climatic influences in the country, does not indicate a univocal change in all cases.

There are several papers available in the literature dealing with the application of remote sensing methods for the determination of biomass production among different climatic conditions both spatially and temporally (CSORNAI,2001; MASELLI et al, 1998) however, no such studies, embedding a longer period have been carried out in Hungary so far.

The available data series in our analysis, embedding a period of 9 years between 1992 and 2000, does not enable the determination of the relationship between identified vegetation alterations and the possible climate changes. *The aim of the author was to shed light on the effects of climatic differences on the environment within a given time period via the analysis of the vegetation.* The question is thus what changes there are in the vegetation and whether or not there is some sort of a trend in these changes. Can we identify important alterations besides the natural fluctuations? With our results at hand we can also justify the applicability of our method – besides the expansion of our work temporally – to study climate-change-induced alterations in surface processes and landforms.

Materials and methods applied

Data analyzed

Our analysis included the area of the Danube-Tisza Interfluve (**Fig. 1.**). According to geographic analyses the landscape ecological value of the region is expected to decrease in the future (MEZŐSI et al, 1996). The signs of soil moisture quality and differences are well-observable – though at different rate – on the composition of woodlands with deep-rooted arboreal and shallow-rooted non-arboreal plants. Furthermore, woodlands tend to preserve precipitation quite well, thus can be regarded as good indicators of long-term droughts or dry periods[1]. Non-arboreal plants in general react more acutely to short term droughts, since for them water supply comes mostly from precipitation. The primary goal was to observe natural water resources, thus large area irrigated agricultural regions do not fall into the area of analysis.

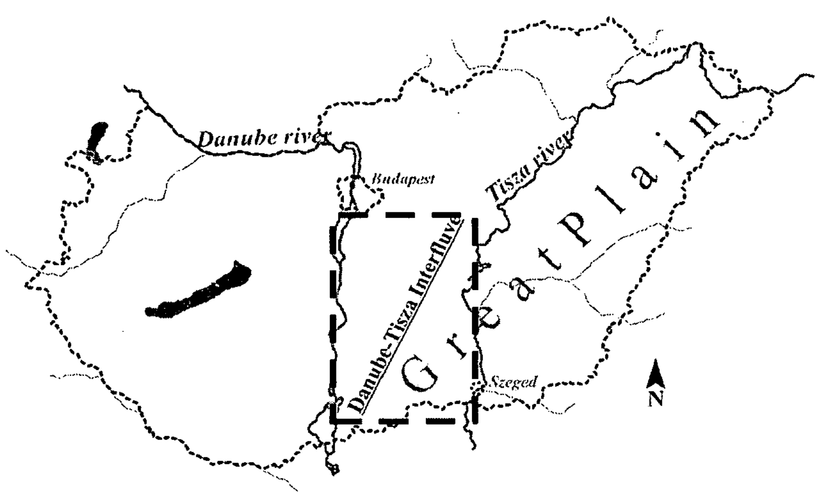


Figure 1. Location of study area (inside the frame)

[1] an important hardship in our work came from the introduction of montane spruces, hardly tolerating droughts, into the area under investigation (Mátyás 1998).

The areas with different surface vegetation were delineated from the digital landscape utilization map of CORINE Land Cover prepared at a scale of 1:100.000. The identification of vegetation cover and surficial forms was carried out on a LANDSAT TM image as well taken in April 1997.

The base of the analyses was given by multispectral satellite images. During the course of our work a monitoring type of analysis was carried out *on the landscape utilization classes of LANDSAT TM image bearing a better resolution with the help of NOAA AVHRR images, bearing a high temporal resolution.* The National Meteorological Survey (OMSZ) did the preparation of AVHRR images providing us with a series of monthly Maximum Value Composites (MVC) with a 1.1 km geometrical resolution for the period between 1994 and 2000, embedding a growth season lasting from April to September. Composites for the years of 1992, 1993 and 1995 are from the free database of the US Geological Survey (USGS) (EIDENSHINK–FAUNDEEN, 1996), which had been utilized following geometric correction. The ranges of wavelengths important for the spectral analysis did not change during the 9 years of the analysis[2].

In order to preserve the best regional resolution and eliminate cloud cover a minimum of 3 and a maximum of 11 MVCs were utilized from the images taken at different times. We have no usable data for several years due to the cloud cover (we have only four complete data series available out of the 9 years analyzed).

For the accurate determination of changes temperature and precipitation data collected by various meteorological stations, located in the area of the Danube-Tisza Interfluve, between 1930 and 2001 have also been utilized (Ásotthalom, Cegléd, Izsák, Kecskemét, Kiskunhalas, Kistelek, Szeged).

The applied methods

The heterogeneous landscape utilization pattern observable in the area of the Danube-Tisza Interfluve prevented a highly detailed determination of plant species or types covering the surface, thus fundamentally two major classes were determined and examined at length regarding the surficial vegetation cover. The class of *woodlands* is made up of the entities of deciduous, coniferous and mixed forests with a spatial value of 25 530 ha, 13 070 ha, and 39 680 ha respectively. These categories were first analyzed individually then the outcomes were synthetized yielding the final results. The gallery forests of Gemenc covering an area of 13 670 ha along the river Danube served as a reference in the comparison with the woodlands of the Danube-Tisza Interfluve.

The class of non-arboreal plants includes the entities of close-to-natural meadows, and pasturelands with a total value of extension of 9560 ha. From the 1,1 km cells of the AVHRR images only the so-called sample or representative pixels were taken into account during the analysis; i.e. those which overlap at least 70-80 % of the given landscape utilization type. Only polygons embedding 3 adjacent sample pixels were evaluated afterwards.

[2] Images between 1992-95. were taken by the satellites NOAA-11, that of 2001 by NOAA-16, and the rest by NOAA-14.

The most generally and frequently used method of predicting net biomass production via spectral analysis is the determination of the Normalized Vegetation Index (NDVI):

$$NDVI = (NIR - R) / (NIR + R)$$

where:

R: the red value of the pixel analyzed,

NIR: close to IR value of the pixel analyzed.

The NDVI values above +0.4 – +0.5 indicate full surficial vegetation cover. Precise surface identification of index values is possible only through on site survey of the sample areas (SZATMÁRI, 2004).

The analysis of NDVI values was carried out monthly and annually for the different individual surfaces. Via considering the distributions of precipitation, *so-called average profiles were constructed for the individual classes analyzed on the basis of the average values of the wetter periods -1996-1999.* The spatial and temporal analysis of alterations from these average profiles may be used for the determination of vegetation growth dynamics and supports delineation of areas threatened by permanent biomass-loss.

The meteorological data series collected in the area under investigation seem to correspond to the trends observable nationally indicating a general decrease in precipitation. They are below the normal value during the analyzed period showing a linearly decreasing trend.

Results

When evaluating the NDVI data the following factor had to be taken into account: *in the period of 1992-1994 the consequences of a period with precipitation decrease beginning in the 1980's, whereas in the second half of the 1990's a phase of higher precipitation (more than 500-600 mm/yr) can be observed.*

The fluctuations of the maximum, average and minimum values of the vegetation index tend to follow a similar path in case of the different vegetation covers, when the whole data series is regarded. A much more rapid spring growth of non-arboreal plants as well as the higher summer biomass production of the woodlands deriving from the foliage can clearly be distinguished in the graphs. Immediate and delayed response of the vegetation to the changes in precipitation can also be observed when viewing the relation between precipitation and NDVI values (**Fig. 2.**).

Concerning yearly NDVI values we can see evenly distributed conditions, so *in general we cannot declare a decreasing or increasing trend of biomass,* however this is not true when dealing with individual months.

When the alterations of the individual monthly values of a growth season are analyzed a *negative trend could have been observed in the average NDVI data series primarily in the months of April, July and September* (**Fig. 3/A-C**). This negative trend tends to be higher for the woodlands compared to the values of the more favorable months (May, June, August). The largest decreasing trend is two times of the value of the largest increasing trend.

Large-scale fluctuations in the NDVI are present in June, with an almost two-fold difference between the average values in the succeeding years. The larger fluctuations of May values tend to level off in the long term.

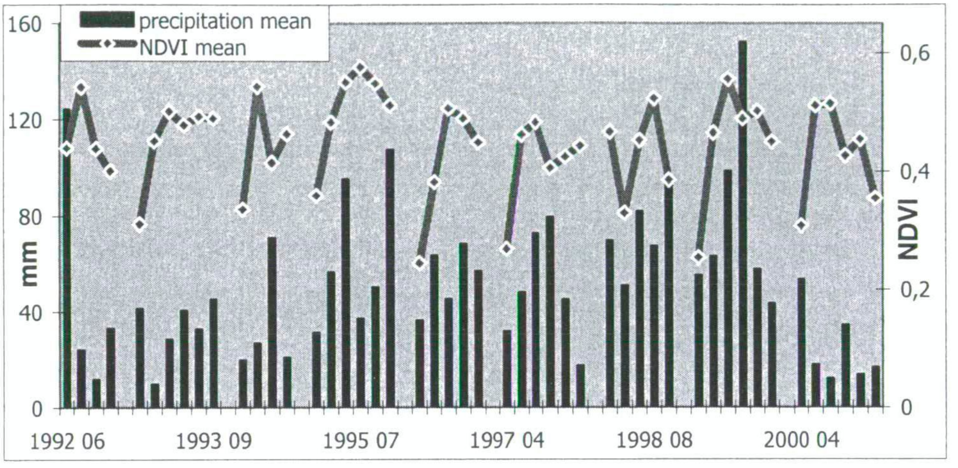


Figure 2. The average NDVI values of deciduous woodlands and average precipitation rates calculated from the measured data of 7 meteorological stations in the area of the Danube-Tisza Interfluve during the summer period

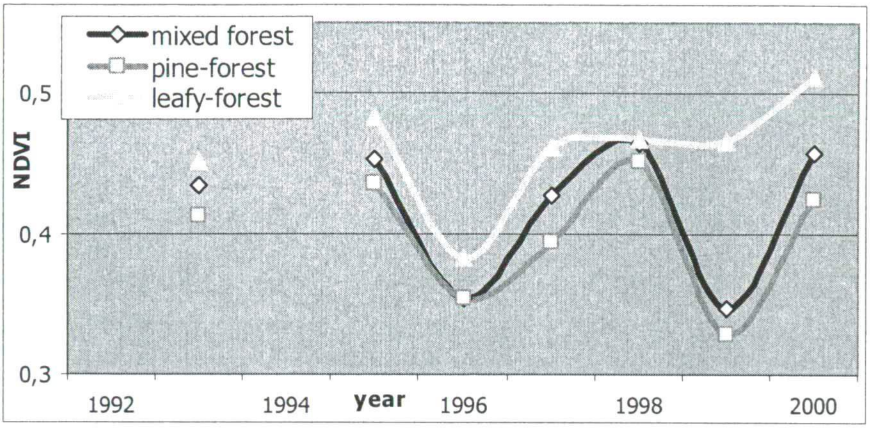
The index profiles clearly indicate the lower biomass values of the much more arid years of 1994 and 2000 as well as the beneficial effects of a more humid 1999 on the vegetation. The year of 1998 is a complex one from the point of NDVI analysis, when these values tend to indicate a more arid period for the months of June and September, and a more humid one for the months of May and August compared to the previous years.

The path as well as the relative position of the reference profile compared to one another meets the expectations concerning vegetation graphs related to different biomass amounts (**Fig. 4.**).

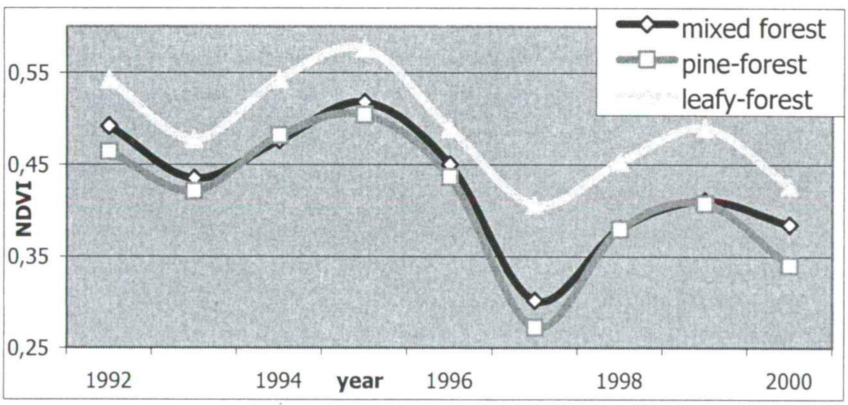
No larger differences than 0.1 can be observed in the deviations from the average. On the whole the positive deviations tend to be prevailing, though there are larger differences in the direction of negative deviations. *Unfavorable alterations are characteristic for the months of June, August and September*, especially in the years of 1994, 1998, and 2000. The smallest negative deviations are observed in the months of April and July.

Via averaging the differences of the years between 1992 and 2000 values between -0.1 and +0.15 were gained. It's important to not that these are average deviations for a period of nine years, thus the seemingly lower values have larger significance. *Fundamentally the amount of biomass produced is decreasing on one fourth of the area of the Danube Tisza Interfluve* (**Fig. 5.**).

(A) MAY



(B) JULY



(C) SEPTEMBER

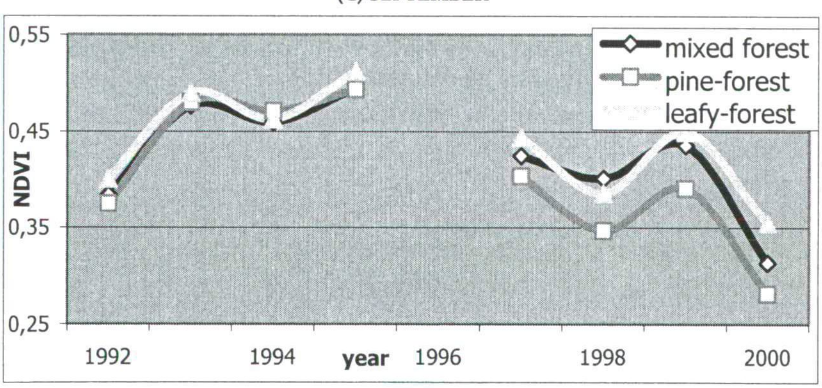


Figure 3. The monthly average NDVI values for the area of the Danube-Tisza Interfluve for deciduous and coniferous woodlands

The most sensitive regions, regarding alterations in the environment are located in the central and southern regions of the area of the Danube-Tisza Interfluve with patches of sensitive areas present in the northern edges as well. Especially it is the mixed forest areas that react the most badly to environmental changes in a given period.

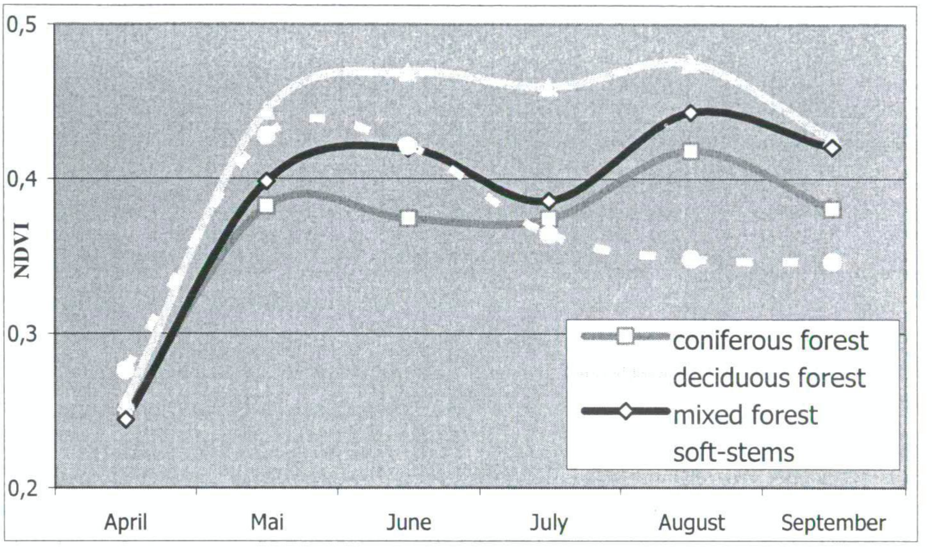


Figure 4. Average profiles for the humid periods

The most important remarks of the analysis

The dominant character of precipitation change is generally well-observable in the vegetation. When looking at the annual values we can observe balanced conditions in the area under investigation, thus no *general decreasing or increasing trends could have been found in this case*. Changes in the biomass are most prominent in the woodlands. One can expect a decreasing activity in the months of April, July and September during the growth season on the long run. According to the results of several approaches, *September can be regarded as a potentially imperiled month and one must account for a great fluctuation of the June values changing annually in the short run.*

No general trend could have been seen either after the analysis of deviations. The negative values of June and August, being favorable formerly, and the favorable values of July are quite remarkable. The prevailing positive deviations are counterbalanced by the large but less frequent negative deviations. *We must account for a decrease in the biomass in case of the woodlands of the central and south-eastern parts of the Danube-Tisza Interfluve.* There are significant differences in the NDVI values of the gallery forests along the river Danube, originally marked out for a reference area, which would require further investigations on the conditions of the vegetation.

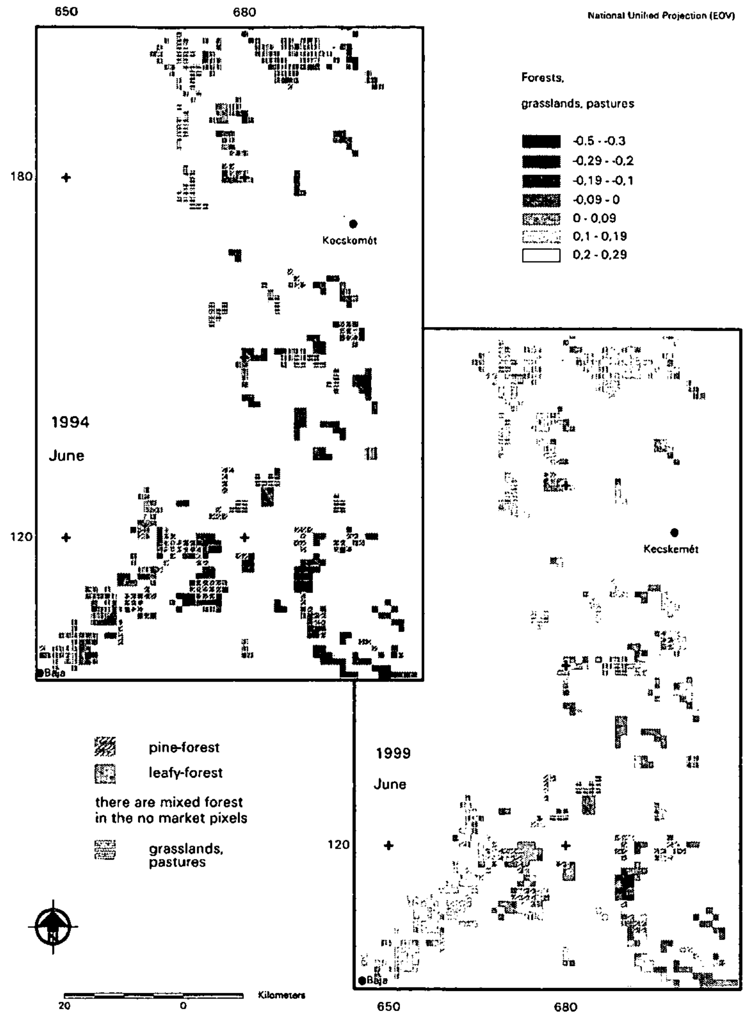


Figure 5. The regional distribution of NDVI differences for the area of the Danube-Tisza Interfluve

Summary

Multispectral vegetation analysis is considered to be the most frequently used and general tools of remote sensing. With the results reflecting geographical and environmental changes on a regional scale at hand we can say that this method, formerly applied to several other areas in different studies, is suitable for the investigation of highly heterogeneous areas regarding landuse at the given scale of the analysis. However, in order to gain objective results the steps of geoinformatical processing should be adhered to within the possibilities of the given heterogeneity and resolution.

The multiaspect analysis of NDVI data during the investigation of spatial and temporal vegetation changes enabled the determination of periodic, trend-like and other irregular fluctuations of the vegetation within the time span of nine years. Despite the short time involved, several alterations could have been identified reflecting natural and antrophogenic aridification. However, a further extension of our analysis in time as well as the comparison of our findings with other measured data on the surface is necessary for the refinement of our findings. The discovery of a strong link between the satellite images with different spatial resolution necessary for long-term multispectral analysis would open up newer possibilities for objective data evaluation. If we manage to find sufficient correlation between the vegetation index values calculated from the LANDSAT TM images and the NDVI values of the AVHRR images then the formerly mentioned method utilized in our analysis is applicable to data available down to the 1980's.

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