ACTA Geographica Szegediensis Tomus XXXV. 1994-95. pp 121-135.

ASSESSMENT OF WIND EROSION RISK ON THE AGRICULTURAL AREA OF SOUTHERN PART OF HUNGARY

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Introduction

Wind erosion poses a serious problem in many parts of the world and is a dominant issue in Hungary too, where there are wind-blown areas of a considerable size. These occupy nearly 23 per cent of the total surface of the country. Agricultural land, which is most susceptible to wind erosion is situated in a large blown-sand area in the southern part of Hungary, between the Danube and Tisza rivers (Fig. 1.). Wind-blown sand areas play a considerable part in farming and their importance is ever growing. Thus conservation of light sand soils against wind erosion is apparently vital, so much the more as the privatization started in the first years of this decade brought fundamental changes in facilities of soil protection. In the collectivization period a country–wide soil protection network directed and supervised the research to reduce the damages caused by wind erosion, and the field and laboratory experiments and measurements. However, due to the radical reduction of the network (STEFANOVITS, P. 1996), it is more and more difficult to provide concerned private landowners with suitable information and advice.

Arrangements

The Department of Physical Geography launched a research project on wind erosion in 1994. To study deflation occurring in the Danube-Tisza Interfluve, a research station was located for measurements of deflation and accumulation of sandy soils, of meteorological and climatic conditions of wind erosion (Fig. 2.).

Experimental parcel was located next to the former hydro meteorological station of VITUKI (Research Institute for Water Resources Development) following the concept of KARÁCSONY, J. The main reason of our choice of this territory was that there has been hydrological research since 1962 in the catchment area of Fehértó–Majsa Main Canal, which provides us continuous hydrological, pedological and meteorological series of data on the area. Beside the traditional research methods, most up–to–date methods should also be applied, which enables us to gain information from isolated field data measured on relatively small territories to bigger regions. The specific structure of pedological, land use and water balance features defines the rate of extrapolation. To estimate this rate we suggest using Remote Sensing and GIS methods.

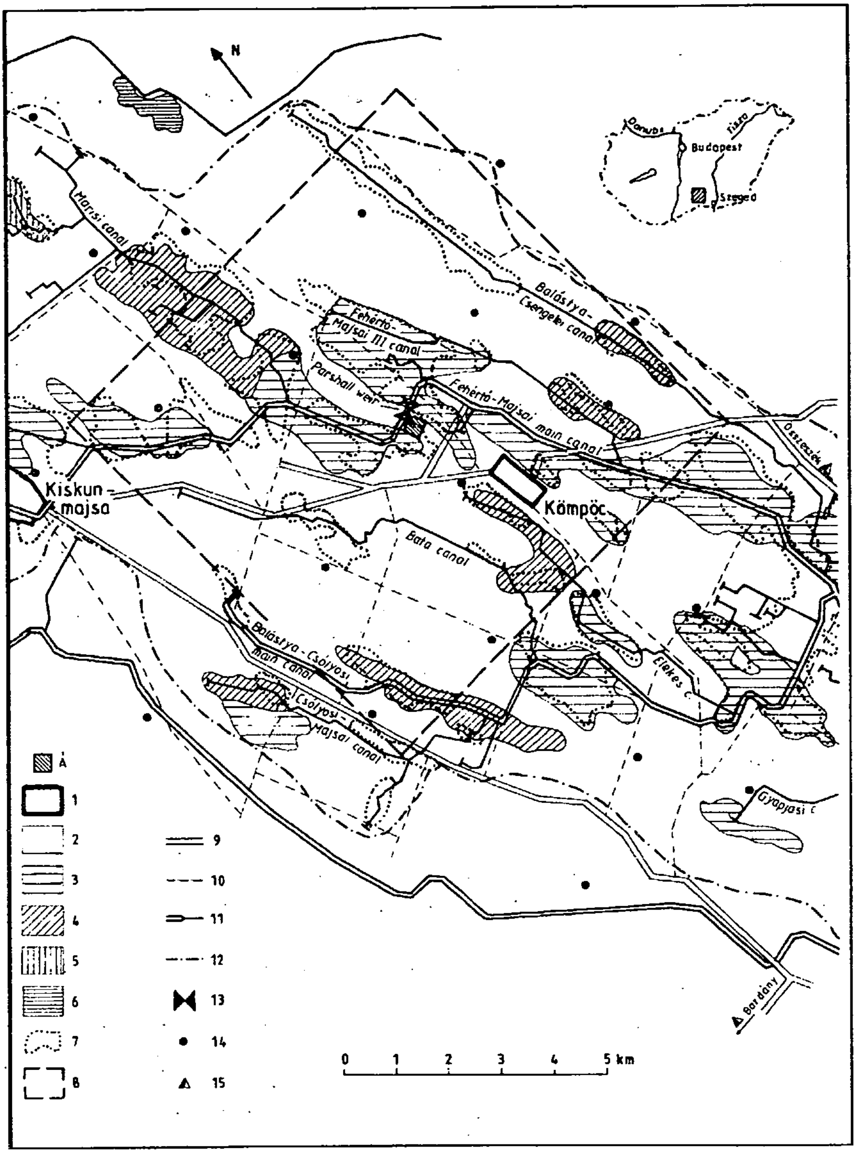

Figure 1. *Fehértó-Majsa Experimental Catchment Á:research station, 1:village; 2:sand; 3,4,5:alcaline soil; 6:lake; 7:temporarily flooded area; 8:test area; 9:road; 10:road; 11:canal; 12:watershed divide; 13:weir; 14:groundwater observation well; 15:archaeological excavations*

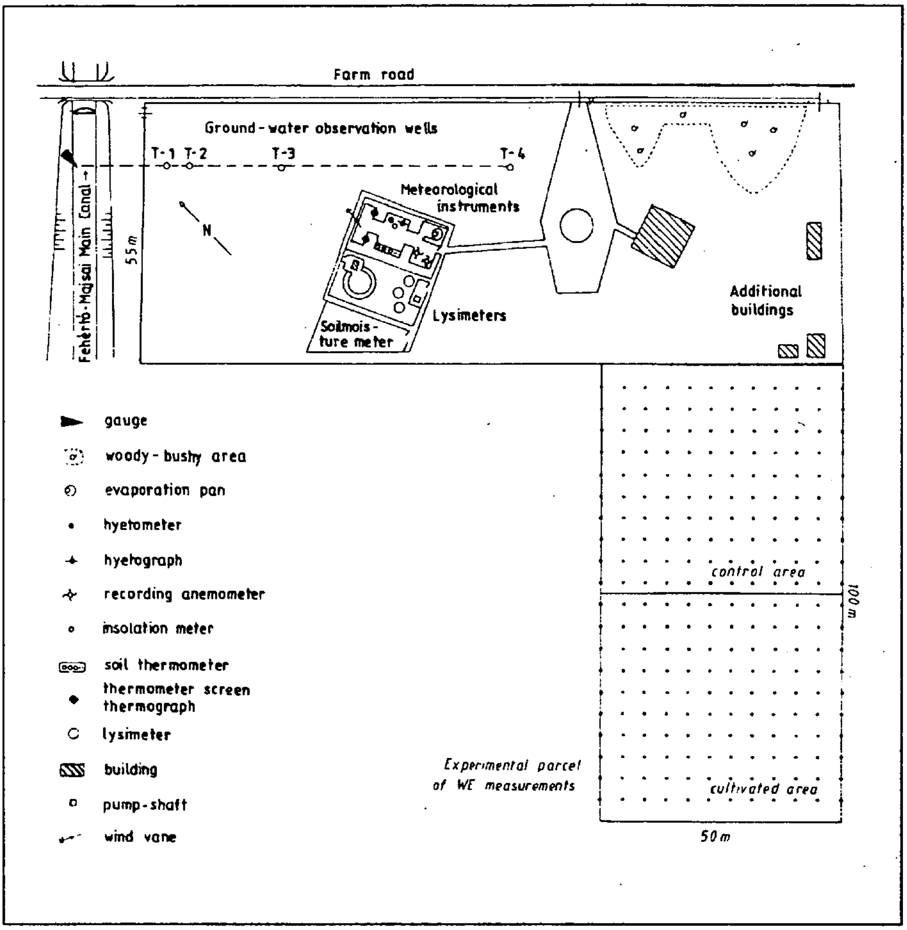

Figure 2. *The hydro meteorological station and the experimental parcel of measurements of wind erosion*

In this detailed study we examine the meteorological aspects of wind erosion and the results of the first year of the research. At the same time the change on land use and theconnection between the land utilization and wind erosion are also investigated on the test area. Remote Sensing is proved to be a possible source of data from which updated land cover information can be obtained effectively (Y. SMARA, et al. 1995). With the help of satellite images we can investigate the most important reasons of wind erosion, e.g., surface temperature, condition of vegetation and soil moisture. By using aerial photos larger accumulated and eroded resultant forms can be characterized. In order to characterise the surface state better, we must integrate data other than remotely sensed ones, such as measured data derived from the field and laboratory work.

The study area

Geomorphology and lithology

The test site is situated near Kiskunmajsa on the SE part of the Danube-Tisza Interfluve. The wind-blown sand areas can be investigated from the western border of the alluvial flood plain of the river Tisza. This area is the residue of the large alluvial fan of the river Danube, which was mainly formed during the Pleistocene. The sand and sandy silt deposits of the alluvial fan ridge have not been shaped by fluvial since the middle of the Würm (up to the Interpleniglacial epoch). In this period, due to structural motions, the Danube gradually abandoned its alluvial fan in the Interfluve and assumed a N-S direction of flow (BORSY, Z. 1982). Particularly in the Late-Pleistocene and during the dry periods of the Holocene the loose fluvial deposits of the alluvial fan were reworked by wind.

The thickness of the transported and accumulated blown sand ranges from 10 to 30 metres. The most characteristic landforms are windrift, residual ridges, sand hills as well as sand dunes. From the aerial photos the long straight valleys can be studied well, opposed to the accumulated positive sand blown landforms. In these valleys, which are parallel to the most characteristic NW wind direction, there are small lakes or sometimes smaller streams. The valleys with infrequent ponds are not only parallel with the dominant wind direction, but indicate the general slope of the area. The lake basins should be regarded as depressions produced by wind erosion. In addition to deepening by wind erosion the evolution of these depressions is partly the result - in the periods of spring snowmelt and rainy weather - of surface waterflow and ground water percolation (JAKUCS, L. 1990).

The soil of the territory consists predominantly of sand (dominant grain–size is 0,1–0,2 mm) with silt in spots. On the bottom of the valleys, silty-sodic sediments are being formed containing dolomite silt (carbonate content of it reaches 80% at certain places) and clay. The thickness of silty and alkaline soil layers generally does not exceed 0,5–1,0 metres (Fig. 3.).

Environmental degradation caused by man

Lack of palaeosol soil prevents us having precise chronological data on sand movements in the Holocene. In the warmer and drier periods of the Boreal and Atlantic phases there may have been significant periods of sand movements (BORSY, Z. 1982). After the Atlantic phase due to the strengthening of the vegetation, sand movement could have only been caused by anthropogenic activities (LÓKI, J. 1994).

Observing soil profiles of archeological excavations near the study area, we came to the conclusion that the possibilities of accumulation of several-metre-thick wind blown sand on these surfaces have been very little in the latest 2000 years.

The deforestation, which extended to larger and larger areas in the 16th century, completely changed the state of land cover. Wind blown sand covered the surface of the Great Hungarian Plain as thick as 20-300 cm. There were devastating dust storms in the Danube-Tisza Interfluve in 1756-58, which were caused by the destruction of grassland downtrodden and poached by inconsiderate grazing (BODOLAY, I. 1965).

Deforestation in the 18th century was extended to dune surfaces with higher relief energy, in order to conquer newer and newer territories for agriculture (BORSY, Z. 1982). Studying Fig. 4. and Tab. 1. we can follow changes in land use on the area if we compare the appropriate classes of first (1782) and third (1881) military mapping and a topographical map from 1983. At the end of the 18th century primaeval forests partially hindered sand movement. In the following century most of these forests were cut and planted vineyards and orchards in several areas, though vast territories were still exposed to damages caused by wind erosion.

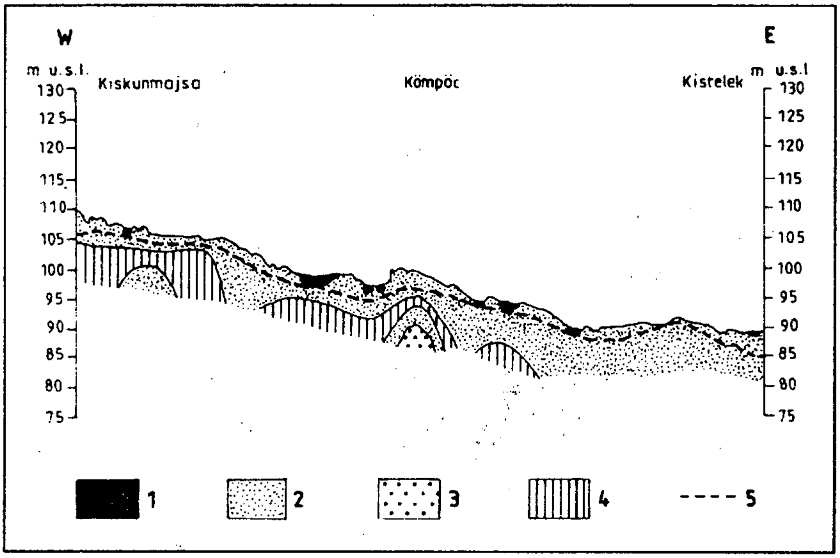

Figure 3. *Geological profile of the test area 1:calcareous mud; 2:wind-blown sand; 3:loessic sand; 4:typical loess; 5:ground-water level (after Kuti, L. 1980)*

Land cover (km^2)	*Year of mapping*		
	1782	*1881*	*1983*
Forest	3.30	1.30	9.67
Vineyard, orchard	0.00	1.70	4.76
Swamp (semlyék)	1.52	7.25	17.04*
Lake	0.04	0.75	0.19

*grassland with swamps

Table 1. *Extension of represented types of land cover*

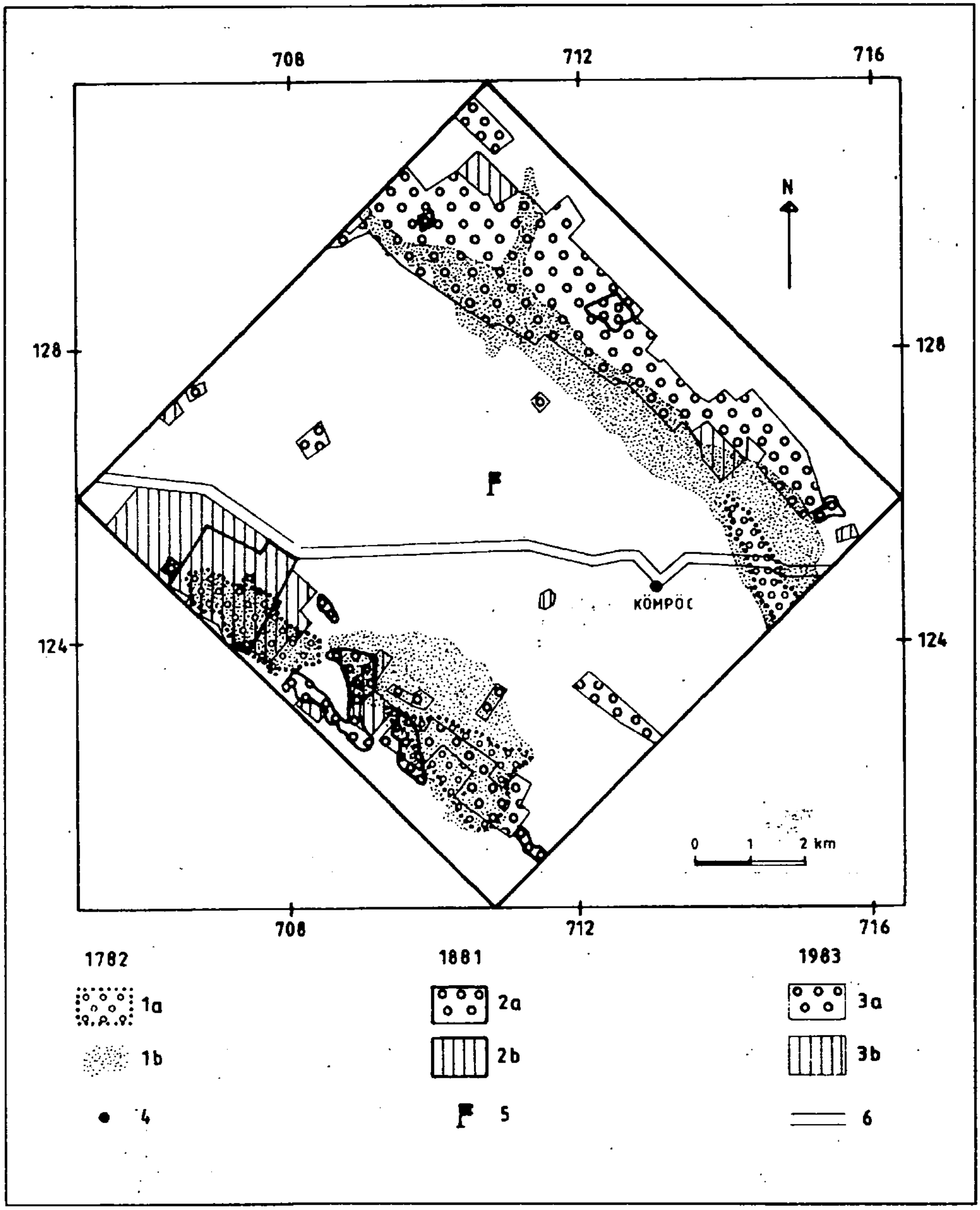

Figure 4.a *Extension of represented types of land cover on different topographic maps between 1782 and 1983 1a-2a-3a:forest; 2b-3b:vineyard, orchard; 4:village; 5:station; 6:road*

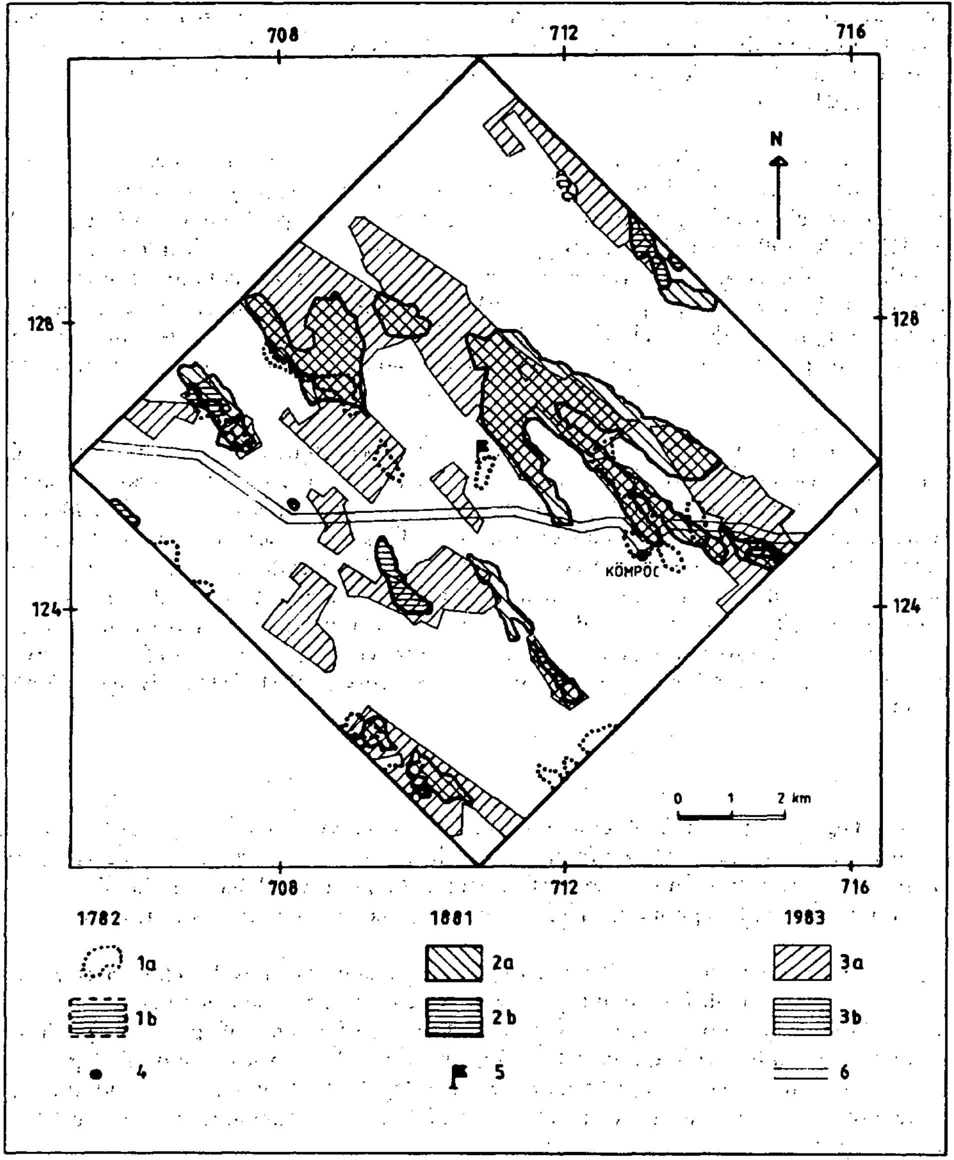

Figure 4.b *Extension of represented types of land cover on different topographic maps between 1782 and 1983 1a-2a:temporarily flooded depression; 3a:grassland; 1b-2b-3b:lake; 4:village; 5:station; 6:road*

Today the NE part of the test area (Kömpöci-erdő) and the SW part of the test area (Aranyhegyi-szőlők, Csólyosi-erdő) are protected against wind erosion. On the Fig. 4.b. we can study the changing extension of grasslands, temporarily and permanently flooded areas. Comparing these map information with the weather conditions of the period and its meteorological data series we can get a more precise picture of the landscape change (SZATMÁRI, J. 1996).

The most attractive interferences within the agricultural landscape, however, were those of the modern times in which the territories most threatened by wind erosion were the most intensively used agricultural lands with the highest production (HRADEK, M.; SVEHLIK, R. 1995). The largest intervention within the structure of farm plots, however, was that of the collectivization period which features the agriculture of this country between 1960-1989. The spreading of plant cultivation technologies necessitated the creation of larger fields, which increased the length of affected areas. Large areas of fields on which there was no vegetation in repeated seasons have been now exposed to wind erosion.

The structure of land use in the early 1960s with much smaller fields and with a dense *tanya* (grange) network and rows of trees (shelter belts) approached the optimal organization of plough-fields. We compared the topographic maps (scale of 1:100000) of the test area mapped before the collectivization and mapped much later, in the 1980s. The number of granges on this area was 160 at the end of the 19th century, 340 in the early 1960s whereas this number is nowadays 190. The disappearance of the granges was accompanied with a significantly decreasing length of rows of trees and shelter-belts. A way to improve the spatial organization, which is unfavourable today, is to form a complex shelter-belt system in all the areas sensitive to wind erosion (BAUKÓ, T.; BEREGSZÁSZI P. 1990).

Climate

The average annual precipitation for this area is lower than 550 mm. The average monthly and annual precipitation figures show the presence of a dry period in early spring, middle summer, late summer and early autumn. In the second half of the summer the probability of a rainless period is much higher here than in other regions of Hungary.

The investigated area has a continental climate and may be characterized as a warm sand steppe with hot summers. In warm years mean annual temperature is above 11.5°C. July mean temperature is above 22°C. The largest number of summer days (85-90) is found here and hot days are more than 30 annually. A long, warm autumn is typical; the daily temperature sinks below 10°C after October 25. Winter is moderately cold, the mean temperature for January is -1.5°C. In spring the daily mean temperature rises above 10°C as early as April 5.

The potential and actual evapotranspiration show a considerable water deficit in the area from May (10 mm) to September (in August 48.8 mm). Consequently, the soil surface totally dries up during this period, the grains of the upper sandy soil lose their water content which is necessary for bonding. In this way, wind erosion can remove, blow out, transfer and accumulate sand (MUCSI, L. 1993).

The prevailing wind is the NW, while the second most frequent direction is the SE, with higher frequencies in the spring and autumn months (TAR, K. 1991). The strong NW and NNW (above 5°B) winds are most frequent between June and September (JAKUCS, L. 1990).

Based on the data series of measurement between 1963 and 1973 (source: KIENITZ, G. 1974) the weekly frequencies of winds higher than 3 m/s (daily averages) and the averages of dry soil state (BODOLAY, I. 1965) were compared. The values clearly indicate that the months of April, October and November are critical from the aspect of wind erosion (Fig. 5.).

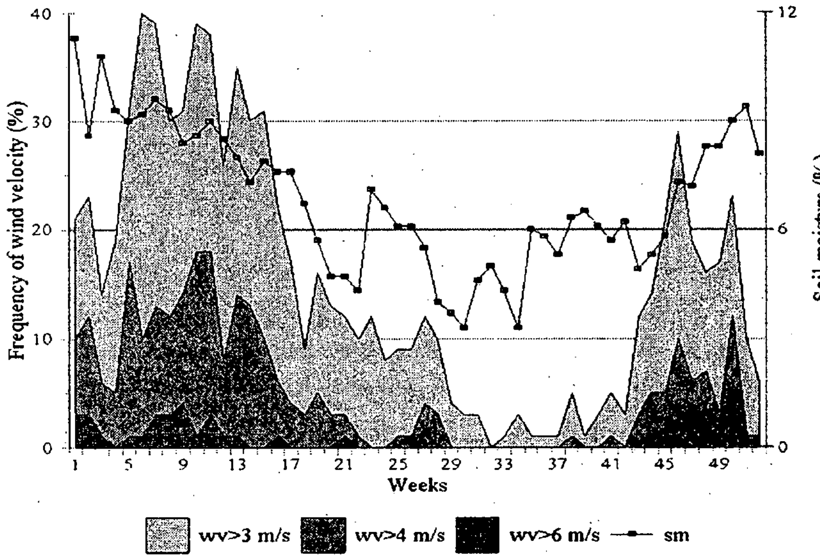

Figure 5. *Weekly frequencies of wind velocity (wv) and the averages of dry soil state (soil-moisture=sm<6%) between 1963-1973*

Comparing relationships between the frequency of different wind velocity with the frequency of values of soil moisture the correlation coefficients show significant relationship between the winds which are stronger than 3-4 m/s with the dry soil state (0.6-0.7). There was a weaker correlation (0.4) in the case of weekly frequencies of winds with higher than 6m/s velocity, suggesting that the strongest occurrences of wind (February-April, November) do not coincide with the driest periods of soil state in the area (July-August).

The climatological prognostics suggest 1 mm annual precipitation loss for the next decades and the predicted rise in temperature is 0.5°C in twenty years and 1.0°C rise in fifty years in the Danube-Tisza Interfluve. All these mean that the annual rainfall will drop below 500 mm and that will not cover the water demand of the region. They result in a growing aridification and in dropping of the ground water table, which is to mobilize the sand movement in the region. Due to the changing climatic conditions 30-50 percent increase of the wind erosion rate may be predicted (MEZŐSI, G. 1996).

Methods

The purpose of our research is to work out the wind erosion model of the Danube-Tisza Interfluve: to mark the territories endangered by wind erosion and to define the size of these areas and the mass of sandy soils removed by the wind. Between 1995-1998 we have been drawing up and testing the methods of wind erosion monitoring on the test area at Kömpöc.

We started this job by having a parcel formed out next to the Hydrometeorological station at Kömpöc, where we measure the intensity of wind erosion and the quantity of the soil transported by wind. On the 50 metres by 100 metres parcel we set 1-metre-high stakes beside which we weekly measure the eroded and the accumulated quantity of sand. One part of the parcel is agriculturally cultivated where we plant different types of crops each year. The other part is an uncultivated control area where we can measure erosion arisen on strongly erodible soil surface.

Continuous observation was carried out on the parcel between May 31 and November 29, 1995. These data were computerized by Surfer software (Fig. 6.). Fig. 7. shows that within each two-week-long observation interval, sand was accumulated on the parcel except for some shorter deflational periods. Data series of six months makes us assume that this surface is a depositional area of the sediment removed by wind, which supposition must be supported by further sedimentological analysis. At the border of the control and the cultivated areas, a deep, deflational zone was formed which proves that the densely planted wheat has wind driving effect. We have calculated the mass of accumulated and eroded sand on the 2750 m^2 large uncultivated plot. In 1995, the cultivated part of the parcel was sown by wheat and sand movement practically was not learnt here. In the fall of 1995 we planted clover to this area. A storm-wind at the beginning of November, 1995 totally eroded the first sowing so it had to be repeated in spring. Though there was no wind erosion on the parcel partially due to tillage problems.

Next we marked out a 64 km^2 large test area which has the parcel within its centre. The monitoring methods of the test area were elaborated. We prepare the geomorphological, soil and land use maps of this area. These data form the basis of the remote sensing analysis. We collected airborne photos (1964, 08/05/1988, 04/05/1992), LANDSAT TM satellite images (03/08/1985, 29/08/1992) and SPOT image (21/09/1993) of the test area and we are paying attention to obtaining the latest images as well.

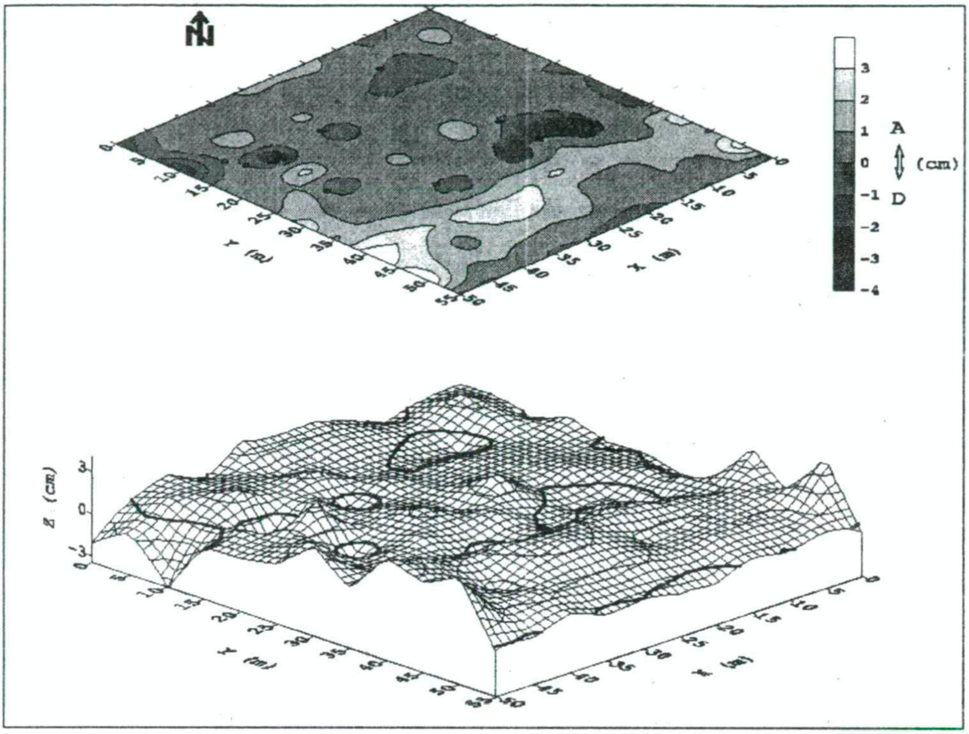

Figure 6. *Contour map and surface of the parcel showing the differences between the initial values and the last measured values in 1995. A=accumulation, D=deflation*

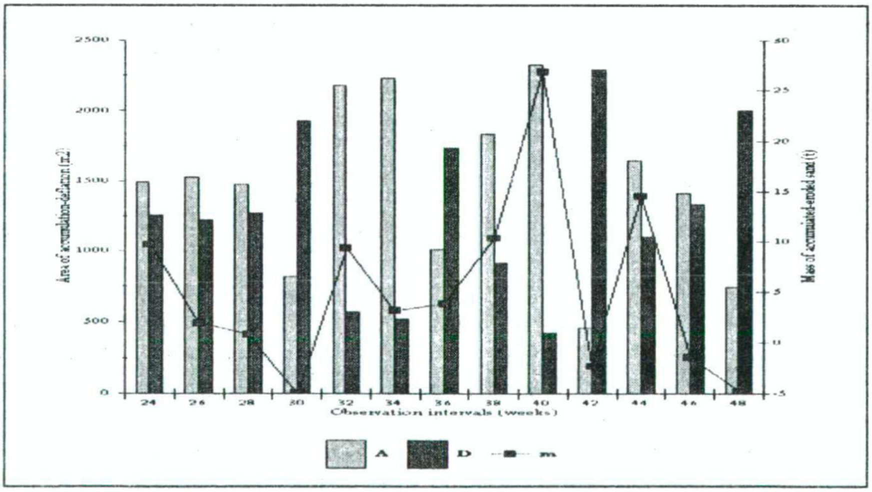

Figure 7. *Area of accumulation (A) and deflation (D) on the experimental parcel (m^2) and mass (m) of the accumulated and eroded soil (ton) between May and November 1995*

We have produced several thematic maps and layers of the test area using ERDAS IMAGINE 8.2 software:

- two photo maps (scale of 1:25000) showing the differences of land use, the spatial structure of farming, wind breaking systems ...etc. of the state of 1964 and 1992 years;
- different real colour and infra red images are used to compare the yearly and seasonal changes;
- airborne photos, satellite images and topographical maps are used to define the different classes of land use maps (Tab. 2.);
- thematic layers based on different indices (VGI, SWI, etc.) and
- soil temperature maps (LANDSAT Band 6).

Year	***Land use (%)***						
	arable	*garden*	*built-up*	*vineyard*	*orchard*	*grassland*	*forest*
1965	64		1	8		24	3
1992	33	14		5	7	24	17

Table 2. *Land use classes in 1965 (on the catchment area of the main canal) and in 1992 (on the test area)*

The introduction of digital images has expanded the techniques of the change detection. According to the NDVI and Vegetation Greenness Index (VGI) which is strongly related to the amount of green vegetation (ERDAS Field Guide 1994)

$$VGI = -0.2848(TM1) - 0.2435(TM2) - 0.5436(TM3) + 0.7243(TM4) + 0.0840(TM5) - 0.1800(TM7),$$

it can be deduced that there are significant and sharp differences in plant cover. The ploughed land and the vineyard are very dry and hot. This can be seen on the pseudo colour image based on the values of Soil Wetness Index (SWI) which relates to canopy and soil moisture:

$$SWI = 0.1509(TM1) + 0.1973(TM2) + 0.3279(TM3) + 0.3406(TM4) - 0.7112(TM5) - 0.4572(TM7).$$

By using the SWI-index image we have classified the driest areas which are exposed to wind erosion to a greater extent. The total size of these areas covers 17.5 km^2 of the 64 km^2 large test site (27%).

On Fig. 8. we signed with the help of remotely sensed data those territories which are endangered by wind erosion. We have also indicated the extension of alkaline soils and the temporarily flooded areas. Comparing Fig. 4. and Fig. 8. we can conclude that remote sensing procedure showed that those agricultural lands are exposed to erosion which were classified neither as afforested nor as temporarily or permanently flooded areas nor as grassland by topographic and field data. In the orchard-vineyard category there was some overlap as these sand surfaces are dry but are less endangered by wind erosion, and they cannot be separated clearly from ploughed lands because of their scattered vegetation.

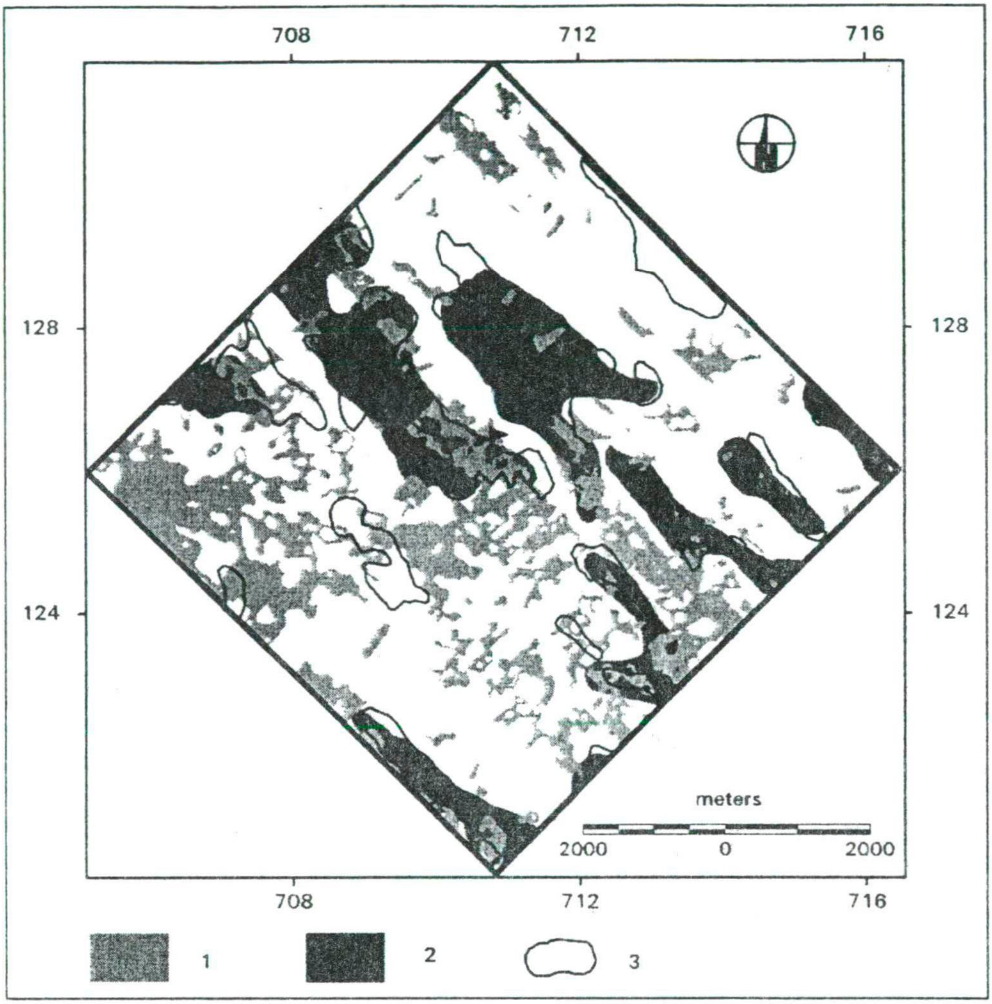

Figure 8. *Map of areas endangered by wind erosion (1; A=17.5 km^2) 2:alkaline soil (14.98 km^2); 3:temporarily flooded area (12.32 km^2)*

Discussion

Research on aridification processes in the Carpathian Basin (KERTÉSZ, Á. 1996; MEZŐSI, G. et al. 1996; MIKA, J. 1993) predicts generally drier conditions in the following decades. Consequently, soil protectionists face increasing work, of which we would like to take our shares. Our long-run aim is to build an observational network on wind erosion in the Danube-Tisza Interfluve. The first steps have already been taken and are summarized below.

- to collect field data of fundamental importance by making measurements on the parcel;
- to mark out large territories which are endangered by wind erosion, using remote sensing which proved to be a reliable means;
- we assume that satisfactory results can be gained from a continuous monitoring of the Danube-Tisza Interfluve based on field experiments, up-to-date remote sensing data and GIS methods. It could be reached only if sciences and their experts concerned cooperated more efficiently than today.

References

BAUKÓ, T.; BEREGSZÁSZI, P. 1990. Simplifying agricultural patterns – Increasing damage by wind in Békés county. Környezetgazdálkodási évkönyv, pp. 87-95

BODOLAY, I.né 1965. Szélerózió elleni védekezés öntözött homokterületeken (Protection from wind erosion in irrigated sand areas). Agrokémia és talajtan. 14. 1-2. pp. 1-15

BORSY, Z. et al. 1982. Phases of blown-sand movement in the North-East part of the Great Hungarian Plain. Acta Geographica Debrecina. XX. pp. 35-50

HRADEK, M.; SVEHLÍK, R. 1995. Dust storms in Moravia and Silesia. In: Natural hazards in the Czech Republic, Brno, pp. 81-109

JAKUCS, L. 1990. Physico-geographical and climatological landscape analysis in the sand areas of Csongrád county with special regard to prevention of wind erosion. Acta Geographica Szegediensis. XXVIII-XXX. pp. 3-30

KERTÉSZ, Á. 1996. Az aridifikáció fogalmának értelmezése. Földrajzi Értesítő XLV. 1-2. pp. 5-9

LÓKI, J. 1994. Mezőgazdaság-központú természetföldrajzi vizsgálatok a Duna-Tisza köze É-i felének példáján. Kandidátusi értekezés. Debrecen. p. 199

MEZŐSI, G. 1996. The predicted wind erosion rate in the Carpathian Basin. Abs. of the IAG ERC'96, Budapest, p. 86

MEZŐSI, G. - KEVEI, F.né - GÉCZI, R. 1996. A Duna-Tisza köz néhány táji értékének prognosztizálható változása. in: Szabó L. (ed.): A termőföld védelme. Gödöllő. pp. 34-48.

MIKA, J. 1993. Az Alföld éghajlatának megváltozása a globális klímaváltozás összefüggésében (Climatic changes in the Alföld in relation to global climatic change). Alföldi Tanulmányok, Békéscsaba XV. pp. 11-31

KIENITZ, G. (ed.) 1974. Data of representative and experimental basins. I. Fehértó-Majsa experimental catchment. Budapest. pp. 105-472

MUCSI, L. 1993. Soil erosion and sand movement in the Southern part of Hungary. In: Proc. of EARSeL'93 Conf. Dundee. pp. 189-200

SMARA, Y. et al., 1995. Methodology for degradation monitoring in an arid and semi arid region. In: Proc. of EARSeL'95 Conf., Czech Rep., pp. 30-39

STEFANOVITS, P. 1996. A talajvédelmi szemlélet globális és regionális módosulása. in: Szabó L. (szerk.): A termőföld védelme. Gödöllő. pp. 3-12.

SZATMÁRI, J. 1996. A természeti táj ember általi átalakításának hatása a szélerózió dinamikájára Duna-Tisza közi mintaterületen. In: Geográfus doktoranduszok első országos konferenciájának előadásai. Pécs.

TAR, K. 1991. Magyarország szélklímájának komplex statisztikai elemzése (A complex statistical analysis of wind climatology in Hungary). OMSZ kisebb kiadványai. 67. pp. 28-88

Geologic map of the Great Hugarian Plain scale of 1:100.000, ed.: KUTI, L. 1980.

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