PHYSICO-GEOGRAPHICAL AND CLIMATOLOGICAL LANDSCAPE ANALYSIS IN THE SAND AREAS OF CSONGRÁD COUNTY WITH SPECIAL REGARD TO PREVENTION OF WIND EROSION

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Geomorphological investigation of sand areas in Csongrád county endangered by wind erosion

The analisis of geomorphological conditions at a detailed scale is indispensable in the planning of efficient prevention of damageby wind erosion in the sand areas of Csongrád county. The quality of the surface of the landscape is not only a reflection of recent natural, environmental and human influences, but may also reflect the long-lasting geological and paleogeographical processes which resulted in the present geomorphological structure over long time intervals.

It is also obvious, however, the same natural energies and processes which produced the endowments of the sand areas in the past have to be taken into account in the present and – as tendencies – in the future as well. As *Lajos Kossuth* wrote in 1883: „The natural laws which were active in the infinite past times are equally active today and will remain so in the infinite future."

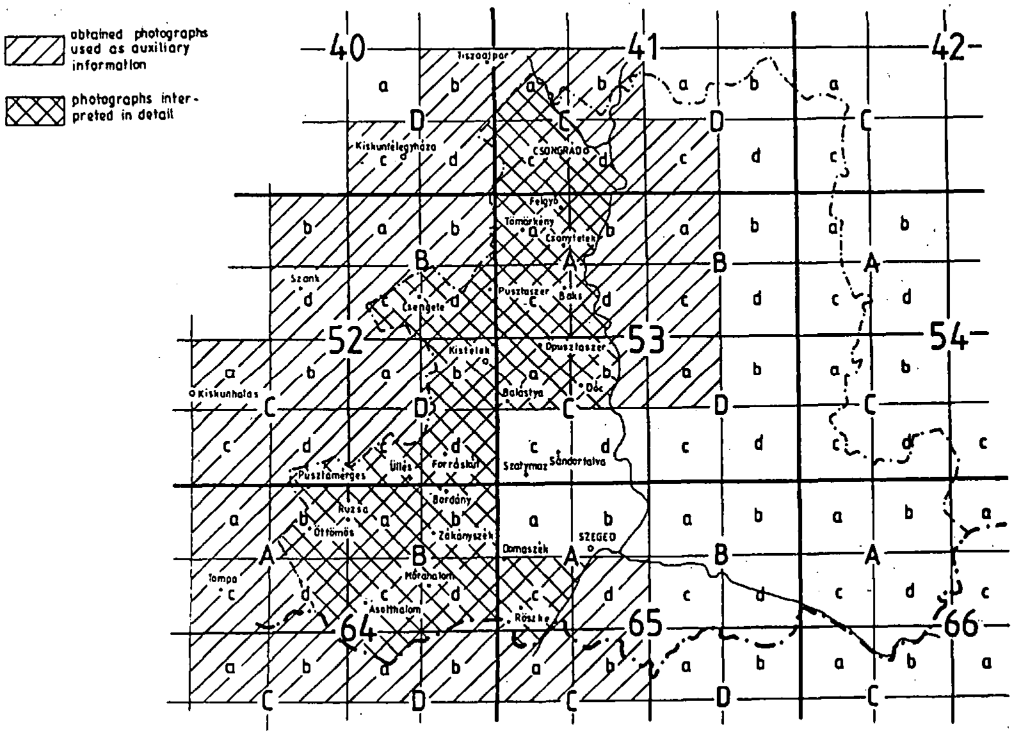
Thus geomorphological map partly shows the actual state of surface landforms in the sand region of Csongrád county and partly indicates what kind of landscape-forming natural energies can be expected to be active in the future over the region under investigation. For this reason, it is regarded necessary that the *methodology of protection* against wind erosion should be adjusted closely to the spontaneous landscape-forming factors active in the area, i. e. the concepts of land utilization applied and to be applied have to rely on scientific knowledge and have tobe in agreement with that.

In order to get an as detailesas possible knowledge on the geomorphology of dans areas inteh county, we were not satisfied with the accumulation and summarization of statements in se literature revealing the results or previous investigations, but elaborated the methods for a new survey and a regional analysis more detailed than before and more adequate to the purpose. To this end – for the first time in the history of geological and geomorphological research around Szeged and in the southern Great Plain – *a detailed geomorphological interpretation of aerial photography* was prepared for almost the total sand region of the county. To achieve this target, the most recend photographs had been purchased from the Institute of Military Mapping (the hatchured area in *Fig. 1*) compiled at 1:25,000 scale (altogether 46 photographs).

Fig. 1.

Sketch showing the aerial photographs at 1 : 25 000 scale obtained and interpreted for wind erosion hazard in Csongrád county

(by L. Jakucs, 1988)



It is to be noted here that four photographs of 1:25,000 scale (coded 53 Cc, 53 Cd, 65 Aa and 65 Ab) could not be obtained, so we had to leave these areas out of aerial photograph interpretation. Another remark to be made is that part of the acquired aerial photographs reach over areas outside the county (particularly in W direction) and another part also shows some areas without blown sand in Csongrád county. It seems logical that is this geomorphological interpretation only the sand areas the county are treated, although for interpretation some neighbouring areas are also included.

For the geomorphological interpretation of aerial photographs an analogue method was applied at the Deparment of Physical Geography, József Attila University, Szeged. The topography and drainage information on aerial photographs and 1:25,000 map sheets were compared and enlarged details for the region in question of *M. Pécsi*'s geomorphological map of 1:500,000 scale and of *T. Zentai*'s sand soils map at 1:100,000 scale were also used.

The comparative analysis allowed major local corrections of boundaries of fomrations or landforms mapped by conventional earth sciences methods and in some areas the recognition and representation on the map of new landscape categories not shown before.

Taking it as a whole, however, the interpretation promised much more new information than received and the explanation for this failure may be primarily that the photographs taken during a single flight in summer could not contain all the characteristics of seasonally changing surface features (or depending on the vegetation cover), which indicate the response of sand surfaces to wind erosion by patches. Wehad to experience even that certain vegetation types (first of all forests) made the observation of sand landform topography so difficult that often even the landforms and elements precisely identified on the spot could not be checked on the photographs.

In several areas the photographs showed spots with unstabilized surface, its sand liable to be transported by wind which proved to be – during the early autumn field checking – semistabilized or grassed surfaces. At the same time, the observation was made that some sand ridges with barren suface in September, when our field-work took place, and suitable to be reshaped by eolian processes, were found still stabilzed in the summer photograph. All this shows that *recently accumulatedsand deposits with no loess fraction and any soil type providing surface stabilization are areas of potentially active wind erosion, where the movement of surface sand is only limited by vegetation cover (or in close assosiation with it the moisture of the ground surface).*

If – to some effect that can be, for instance, deforestacion, stubble turning or grazing – the stabilizing factor of the sand surface in lost (if only temporarily), in a virtually very short time wind erosion becomes active and remains so until a new vegetation cover in not stablished or the surface layer acquires enduring moisture content. It is to be noted that in the cold period of frozen soil (winter half-year) eolian sand transport ceases as either the snow cover or the freezing of vapour condensed from the air on the ground surface ensures sufficient surface stabilization in most cases.

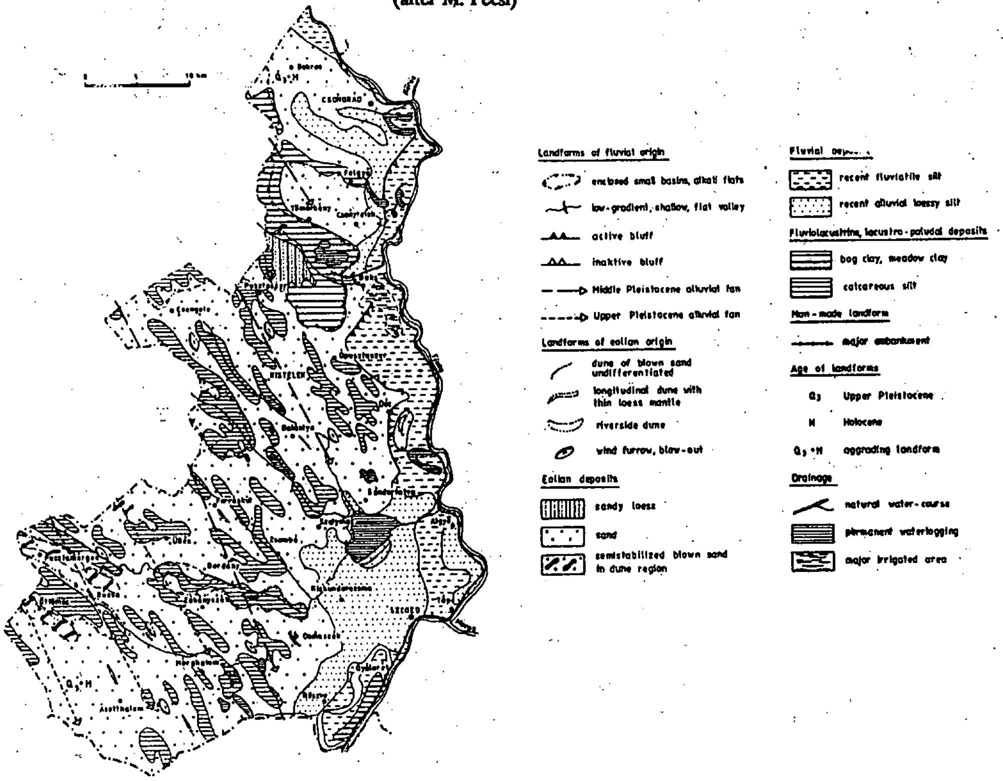
The areas of Csongrád county with wind erosion hazard form a contiguous zone from the part of the county in the Danube – Tisza interfluve, more exactly from the W margin of the right-bank flood-plain of the Tisza river to the county border and even reaching beyond that in W and NW directions. This contiguous sand region, wellcharacterized by geomorphological criteria, is an organic part of the uniform sand region in the Danube – Tisza interfluve. It is obvious that our analysis could not be restricted to the administrative area of the county, since – although the sand ridge of Csongrád county is a contiguous zone shaprly delimited on the E – it cannot be considered a natural physico – geographical unit. The roots of the landscape – forming paleogeographical processes and events, which have shaped the surface of the county's sand region lie somewhere in the Danube valley or in parts of the interfluvial region outside the county. This can be formulated in the following way: the eolian surface of Csongrád county developed to the morphogenetic remote effect of neighbouring areas on the W and NW and this landscape typeis unconfined in genetic directions (see *Fig. 2*).

As it is clear from the geomorphological map, the sand region of Csongrád county, similarly to the whole of the Danube – Tisza sand ridge, is a remnant of the mainly Pleistocene (in a subordinate part Pliocene) vast alluvial fan built by the Danube, in spite of the fact that on or near the surface deposits of direct Danubian origin cannot be found. This contradiction in the origin of sand deposits and lack of fluviatile ones is explained by the fact that the river abandoned its huge alluvial fan in the Middle Pleistocene and its channel shifted to the W into the N – S axis of the present Danube valley. Therefore, the sand and sandy silt masses of the alluvial fan ridge have not been shaped by fluvial but wind erosion since the last interglacial. Particularly in the Riss – Würm interglacial and during the dry periods of the Holocene the loose fluvial deposits of the alluvial fan were reworked by wind in considerable thicknesses, while winnowing by grain size and mineral composition also took place.

Interpreting the aerial photographs showing the region, an additional piece of evidence was found for the theory that the sandof the blown sand areas of Csongrád county were redeposited from the alluvial fan of the Danube primarily in the interstadials of the Würm glacial and in the Holocene.

The clear morphogenetic features on the photographs unambiguously attest that the long, straight, narrow depressions, flats of NW to SE strike cannot be conceived as old Danube channels as it was previously thought. The boreholes show that Danubian deposits lie much deeper under the surn the one hand and the SE-axis valleys are too narrow (locally only 20 – 60 m wide) even to approach the normal chanell width figures of the Danube. Sediment analytical studies in laboratory also prove that most of the sediment on valley floor is also blown sand.

Fig. 2.



Sand areas in Csongrád county as shown on a conventional geomorphological map (after M. Pécsi)

It does not make any difference that on flat valley floors the blown sand is overlain by dolomitic silt or meadow clay and locally meadow limestone. These formations should be interpreted in the light of higher position of groundwater table in the depressions of blown sand, in flats to which – during snowelt and other periods with higher water table – percolating groundwaters are added and surface flow is generatedand naturally its impacts are also reflected in the alteration of sediments and soils.

In some areas blown sand also contains powdery lime cements fine sand grains, particularly so if plant remnants and humic acids promote this process. Stabilized sand primarily forms on deeper-lying surfaces. On the tops of higher dunes, however, it is difficult to stabilize sand. In this position freely moving sand with sparse, xerophile vegetation is dound in many places.

There is a debate in literature what thickness of purely eolian sediments can be estimated for the Danube–Tisza Interfluve and what is the depth where fluviatile sediments begin to dominate. *I. Miháltz* (1953) and *B. Molnár* (1965) published papers on thicknesses of eolian loess and blown sand exeending 120–140 m. These opinions were supported by the spherictysand grains from boreholes and the lack of coarse, splintery, micaceous, typical fluviatile sand or its subordinate occurence.

With knowledge on the morphogenetics of other parts of the Great Plain, however, this statement cannot be generalized. The fluviatile sand – when leaves the channel – becomes the toy of wind, it wears, acquires coating and an opalescent surface and is winnowed out. This alteration can take place on the spot without the sand being transported in greater distance. To draw conclusions from sphericity alone that the area was not affected by fluvial action and the sand arrivedto its present place by eolian transport is unfounded. It is characteristic that sand beds in the South–Jászság depression, studied in the Jászladány deep borehole are worn to the same degree than in the deeper boreholes of the Danube–Tisza Interfluveand the proportion of silt beds similar to loess in considerable. In spite of this, the sequence cannot be called an eolian one.

The thickness of blown sand redeposited by eolian transport and accumulated at a new locality can be estimated at 10–30 m in the territory of Csongrád county. At this depth, however, the certain indications of water transport can be traced, either in the form of more splintery and angular, coarser sand or of silty claz layers. Naturally, well-worn sand is found in the depressions as well, but this only shows that the sands of flood-plains are reworked repeatedly by wind in the Great Plain even in the period of primary sedimentation.

As far as the *types of landforms* produced are concerned, in the area under study wind furrows, sand dunes and residual ridges are most striking. In this respect, the extensive blown sand area can be called a 'wind-furrowed' surface. The lower landforms, wind furrows, residual ridges and blowouts are particularly characteristic of the sand region of the county, since to the W – especially along the margin rising above the Danubian plain – larger accumulation landforms such as parabolic dunes and sand dunes/ became typical.

On the aerial photographs, however, it is not the individual eolian depositions, features of reworked blown sand material aremost triing, but the longitudinal valleys of NW to SE strike, parallel with the direction of the prevailing wind, as well as flats with small ponds or locally (and temporally) living water-courses (see *Fig. 3*).

The valleys with occasional ponds in the sand region of the county are naturally not only parallel with the prevailing wind direction, but indicate the general slope of the area. The NW–SE strikes of lakes also show that the lake basins should be regarded as depressions produced by wind erosion. It is to be noted, however, that in addition to deepening by wind erosion the evolution of these depressions is partly the result – in the periods of spring snowmelt and of rainy weather – of surface waterflow and groundwater percolation. Thus, in some places they are of secondary fluvial nature.

On the floors of blowouts alkali silty deposits also occur locally. During intensive alkalization sodium salts as well as calcareous and magnesian solutions governed the type of alkalization. The carbonaceous solutions of groundwater from the environs concentratedin low-lying flats – often promoted in effect by biogenetic factors – ld to the deposition of dolomitic and calcareous silts and lacustrine chalk.

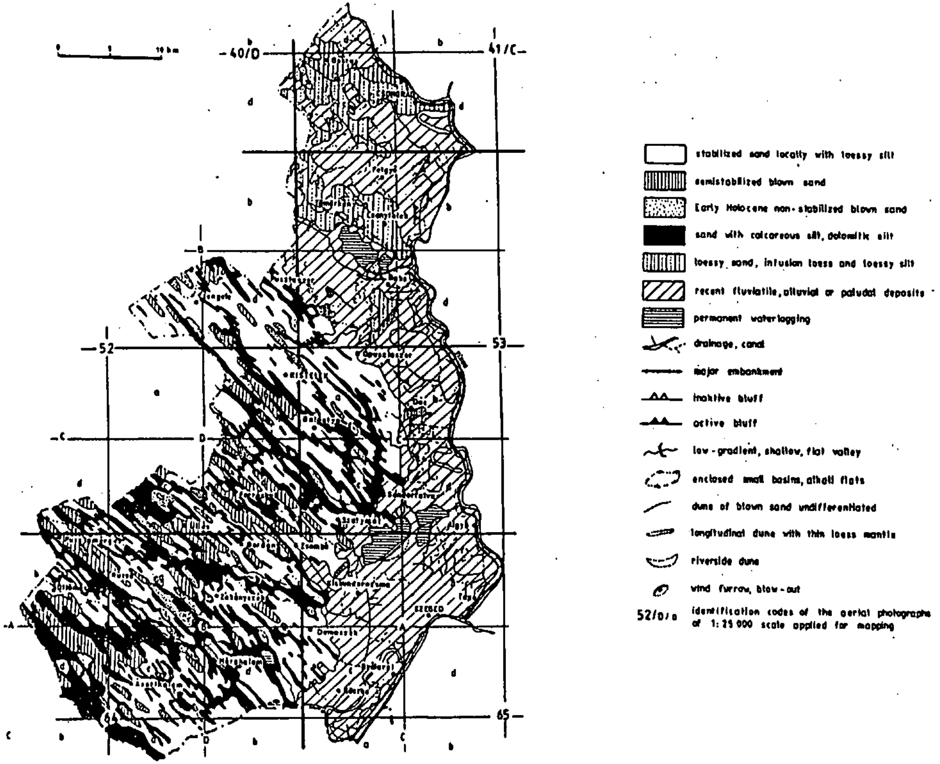
In summary, the statement can be made that in the evolution of the parallel sand ridges eolian accumulation was predominant. It resulted – through repeated reworking of material – in the accumulation of sand deposits of diverse nature, while in the flats limnic sedimentation with a very subordinate fluvial accumulation occured. The remark has to be made here that the few fluvial landforms of the county should be interpreted in a manner that in eolian depressions intermittent groundwater flows and periodic surface runoff developed and in minor sections of the region led *secondarily* to fluvial sedimentation. Obviously, river terraces cannot be found anywhere in the flats of the sand region.

During the interpretation of aerial photography – besides the above aspects – attention was paid to the interesting phenomenon (and also certainly some trends in relief evolution) that the smal ponds of the blown sand region of Csongrád county were – as evident on the aerial photographs – more numerous in the past.

The comparison between various maps of reference in the earth sciences and aerial photographs proved that over the W half of Csongrád county geological structures are closely related ot only to paleogeographic conditions and sedimentation factors determining the arrangement of facies, but also with processes shaping the surface after the sedimentation phases and influencing geomofphic evolution in the present particularly with the *land use patterns applied in agriculture*. The spatial pattern of *soil quality* essentially shows the same, but here the pedogenetic factors (primarily anthropogenic ones) of the present play an even more important part.

Fig. 3.

Sand areas of Csongrád county as shown on the geomorphological map corrected from aerial photograph interpretation (by L. Jakucs, 1988)



Climatological investigation of sand areas of Csongrád county endangered by wind erosion with special regard to the conditions of wind erosion

The principles and tasks of an efficient protection against wind erosion in the sand areas of Csongrád county cannot be outlined without detailed knowledge on the climatic parameters, first of all precipitation, evaporation and wind conditions,the quantitative and qualitative grades of the individual climatic elements are as important factors of wind erosion hazard as pedological, lithological, hydrological or geomorphological characteristics. Naturally, this is a rather general statement if the various areas are concerned. However, it is even more valid for our area of investigation than for more remote parts of the Danube–Tisza sand region where sand movement ceased centuries ago as a result of more cohesive soils or permanent stabilization by vegetation and the stabilization of the surface from the viewpoint of wind erosion can be regarded satisfactory.

In order to achieve our target, first the *precipitation* conditions of the area have to be considered, since precipitation is a fundamental factor of soil moisture content and *sand movement can only occur on dry, uncohesive sand surface* and *decisively bound to dry periods*. In the blown sand region of Csongrád county – besides Szeged – rainfall gauges with long and regular measurement series exist at Kiskundorozsma, Ásotthalom, Kistelek and Csongrád. In order to obtain a better picture of the spatial pattern of precipitation distribution the observation series of the Kiskunmajsa and Kiskunfélegyháza meterological stations were also taken into consideration, since – although these sites lie outside the county boundary – they represent the immediate neighbourhood of the area studied and are located upwind in the direction of winds bringing most of the precipitation. The average monthly and annual precipitation figures of the observation sites listed for fifty years (1901–1950) well represent the basic characteristic of drought (550 mm average precipitation) for the area as the differences between the observation sites are negligible. A more detailed analysis of data reveals that there is a rising trend in the amount of precipitation beginning with the turn of the century in the area. Compared to the first decades of our century, the spring and late aurumn-early winter months became drier, while other months relatively wetter. Naturally, this statement is only valid in general, irrecpective of this the climatre of the region remained arid and also shows extremities: in the individual years the differences in the amount and seasonal distribution of rainfall are great.

For judging the conditions of wind erosion the knowledge of short-term rainfall amounts and their predicted frequency is vital. To this end, the table of average precipitations for pentades (five-day intervals) is also presented on the basis of the data from the Szeged meteorological station (see *Table 1*). It clearly shows that the relatively rainiest period is between the end of May and about June 20th, when the multiyear average is ca 71.9 mm precipitation during 31 days. In addition to the precipitation maximum in late spring-early summer, the pentade values well demonstrate the presence of a dry period in early spring, middle summer, late summer and early autumn.

Average precipitation (mm) in pentades for Szeged, 1890–1960 *Table 1*

	PENTADES					
	1	2	3	4	5	6
January	4,7	6,1	5,9	7,6	4,1	5,1
February	7,2	7,0	7,2	5,1	4,4	3,5
March	6,9	7,5	5,1	3,2	5,0	9,6
April	6,3	7,9	8,6	9,9	8,3	8,0
May	*11,9*	*11,8*	9,1	8,8	*10,5*	*13,8*
June	*12,7*	*10,4*	*13,2*	*11,3*	9,5	9,0
July	10,0	9,3	9,5	8,0	9,1	8,0
August	8,5	8,6	8,9	6,0	6,9	7,5
September	8,4	5,2	9,7	6,3	6,1	7,7
October	7,2	8,6	6,8	6,3	7,5	*13,4*
November	8,5	8,3	7,1	9,5	6,8	5,5
December	6,8	6,6	7,2	5,9	5,0	8,1

A particular attention is to be paid to the higher precipitation values in autumn and early winter, which is due to mediterranean influence in the area.

The Probability of dry period is highest in March, July, August, September and October and the lack of preciptation in these months inhibitscultivation to a considerable degree.

In the second half of the summer the probability of prolonged rainless period is much higher here than in other regions of Hungary. The probability of no precipitation for at least 10 days is 10 per cent fruy, 13 per cent for August, as opposed to the respective values of 4 and 6 per cent for Debrecen and Keszthely, 6 and 8 per cent for Budapest and 5 and 6 per cent for Mosonmagyaróvár. Consequently, the conclusion can be drawn that *liability to drought inmiddle and late summer is strong in the landscape*, on the average twice as high as for other meteorological stations as seen from the 90-year data series.

The figures both for the year and for the growing season reveal that viewing consecutive years, three out of four is characterzied by drought. Particularly in the summer large water deficits are redcorded. No precipitation higher than 40–54 mm can be expected in winter with 15 per cent probability. Naturally, precipitations above 100 mm may occur, but not more frequently than 2–3 per cent of all cases. In the spring months precipitations between 60 and 90 mm have 15 per cent probability and naturally amounts above 160 mm are also possible.

In the summer amounts of rainfall show a wide range. 80–90 mm precipitations have 15 per cent probability, but in extrem cases there is more precipitation, compared to previous decades. With 15 per cent probability, ca 60 mm rain falls in autumn.

As far as the intensity of precipitation is conserned, in the warmer half of the year (especially in summer) higher intensity ranifalls occur than in the colder halfyear. Thus single events above 20 mm rainfall are primarily expected in the months from May to October. Within that period heavy rains in short intervals are characteristic in June and July.

In order to appreciate and manage the impacts of wind erosion information on *temperature conditions*, their temporal and regional distribution, ie. spacial and temporal variations, is indispensable. The monthly and annual averages compiled from 50-year temperature data series convince us that the region – on the basis of its principal temperature indicators – can be classed with the so-called *continental, warm sand steppe with hot summers.*

The most important temperature feature of the area is hot summers, reflected not only in mean temperatures, but also in the high frequency of hot days. July mean temperature is above 22 °C. The *largest number of summer days* (on the average 85–90) are found here and hot days are also the most abundant, more than 30 annually. A long, warm autumn is typical; the daily temperature sinks below 10 °C after October 25th and the first autumn frost is generally recorded between November 1st and 5th. Winter is moderately cold, the mean temperature for January is around –1.5 °C and the number of winter days ranges from 25 to 30. In spring daily mean temperatures rise above 10 °C as early as April 5th and 10th.

The extremity of air temperatures and the occurence of the so-called cold and warm years and seasons are not indifferent for the actual processes of wind erosion in the sand region. Cold years are defined as those when annual mean temperature is below 10 °C. In warm years mean annual temperature is above 11.5 °C, usually associated with a mid winter.

Cold and warm years are usually clustered together. About 4 or 5 successive warm years are followed by relatively colder weather in one or two years. The amount of precipitatin is generally higher in cool years. In relatively cold years spring is usually cool, while the temperature figures for summer or autumn are not lower than in average years. The explanation of cooler spring lies in the lower temperature of the winter and more considerable accumulation of precipitation in the winter.

In autumn temperature values - with high probability - reflect submediterranean climatic influences.

It is explained mostly by the above overviewed regional temperature conditions and precipitation distribution that in the blown sand region of Csongrád county *potential and actual evapotranspiration* shows a wide gap from May to September and this means a considerable water deficit in the area. This *water deficit* has an everage value of 10 mm in May and 22.6 mm in June, bat rises to an average 47.8 mm in July and 48.8 mm in August. This means that in these month the deficit is so large that the ground surface dries out totally, the sands and upper soil horizons lose the moisture indispensable for cohesion beetween aggregates and grains and - if there is no deeper rhizospheric vegetation to stabilize - wind erosion sets the sand moving, transports and reworks it. The difference between actual and potencial evapotranspiration is reduced (only 24.8 mm water deficit) in september, but it is not due to a better water balance of the area (resulting in more efficient sand stabilization), but to the absence of evapotranspiration of cultivated crops in that period as they are either harvested or dried out. Thus the soil remains dry and one of the most important factor inhibiting wind erosio is not even present in September in the region (see *Table* 2).

Figs 4 and 5 demonstrate the figures of average monthly and annual water deficit in the blown sand region of Csongrád county and the above formulated statements are also confirmed by data on the areal distribution of air moisture at 14.00. While in April and October relative moisture at 14.00 exceeds 50 per cent (in the winter months to a large extent), in July it is between 44 and 46 per cent. Consequently, the region shows the characteristic features of drought.

Summarizing the above analysed *temperature and precipitation conditons* in the sand region of Csongrád county, it is claimed that neither the temperature nor the precipitation pattern is favourable for the restriction of the impacts of efficient wind erosion. During the summer half-year the unstabilized sand is exposed to wind action and the resulting damage. The extent of the latter entirely depends on the actual wind. Therefore, in the following a detailed description of the wind conditions of the area is presented.

From the measured data of the Ásotthalom, Szeged and Kecskemét stations the percentage frequency of winds of different directions were collected for the individual months. The wind frequency plots for the month critical from the aspect of wind erosion, i. e. April, July and October, are shown for the stations in the vicinity of the area investigatedin *Fig. 6.* It is to be noted that in the half of Csongrád county which lies on the sand ridge observations onwind are only avaitable for the Szeged and Ásotthalom stations and this motivates the inclusion of the Kecskemét meterological station, since in this way a more proporcionate interpretation can be made for the are studied.

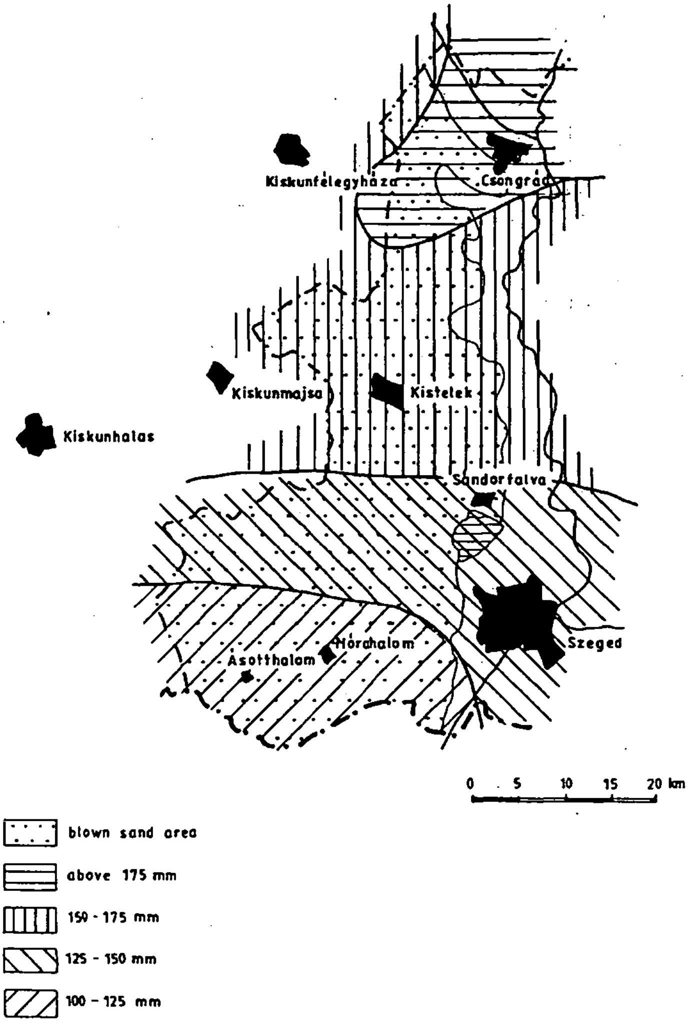
Table 2

Avarage monthly potential (A) and actual (B) evapotranspiratipon expressed in height of water column (mm) in the blown sand region of Csongrád county and its immediate environs, 1901–1950 (by L. Jakucs)

Observation sites		I.	II.	III.	IV.	V.	VI	VII.	VIII.	IX.	X.	XI.	XII.	year
Ásotthalom	A	0	1	20	52	95	121	137	124	79	43	14	1	687
	B	0	1	20	52	92	108	100	82	60	43	14	1	573
Csongrád	A	0	0	20	51	99	123	142	124	81	43	14	1	698
	B	0	0	20	48	85	95	88	74	52	43	14	1	520
Kiskun-félegyháza	A	0	1	21	52	99	124	146	127	81	43	13	1	708
	B	0	1	21	49	88	97	95	76	56	43	13	1	540
Kiskunhalas	A	0	2	20	52	99	130	141	122	81	43	13	1	704
	B	0	2	20	52	85	103	89	70	54	43	13	1	530
Szeged	A	0	1	22	53	98	124	145	127	83	46	16	2	717
	B	0	1	22	52	90	106	100	79	59	46	16	2	573
Averages for the stations of the area studied	A	0,0	1,0	20,6	52,0	98,0	124,4	142,2	124,8	81,0	43,6	14,0	1,4	702,8
	B	0,0	1,0	20,6	51,5	88,0	101,8	94,4	76,0	56,2	43,6	14,0	1,4	547,2

Regional distribution of annual water deficit in the blown sand areas of Csongrád county
(by L. Jakucs, 1988)

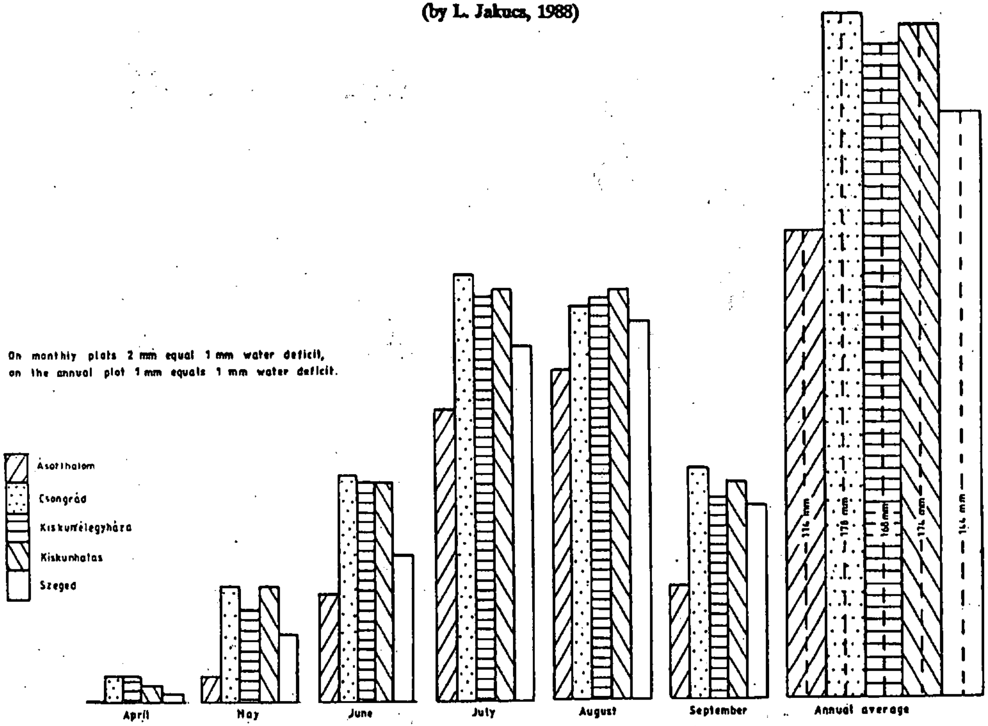
Fig. 4.



Average monthly and annual water deficit in the blow sand region of Csongrád county and its environs, 1901–1950

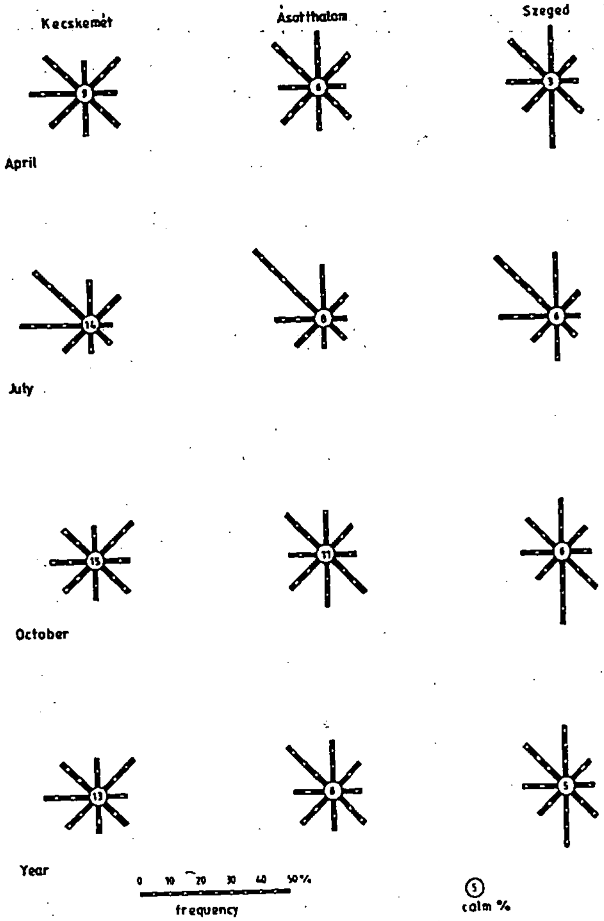
(by L. Jakucs, 1988)

Fig. 5.



On monthly plots 2 mm equal 1 mm water deficit,
on the annual plot 1 mm equals 1 mm water deficit.

Characteristic wind direction frequencies in the blown sand areas of Csongrád county *Fig. 6.*
(by L. Jakucs, 1988)



The data in the table clearly indicate that the prevailing wind in the NW, while the second most frequent direction is the SE, with higher frequencies mostly in the spring and autumn months. The relatively higher speed of this circulation is associated with the frequent NE wind of storm intensity occuring in spring in the Lower Danube gorge (called kossava). When the latter reaches the SE margin of Hungary, it loses of its strength, but still remains one of the liveliest winds. The moisture conditions of the area are consequtly governed by two air movements of entirely different direction.

The *highest amount of precipitation* – an annual average of 160 mm – is brought by *SW winds*. Similarly impprtant are the rains brought by E winds, on the average ca 150 yrwle the share of N winds is only 80 mm. *The least amounts of rainfall* come from S and SE winds and air masses (36.5 mm). In their case the foehn effect is strong. The dry descending wind is particularly damaging in the growing season, when atmospheric drought comes about and evaporation increases to high values exerting a deleterious influence on the physiological processes of vegetation and desiccating soils rapidly.

Naturally, in sand movement – in addition to wind direction – the *intersity of winds* in also an important factor. Low-intersity air motion is unable to move sand and thus they can be neglected from our present point of wiew. In oruer to attain a better understanding of relationships, the separate study of winds *efficient* in causing wind erosion seemed to be useful. For this we regarded the *3 °B (Beaufort scale) as the threshold of efficient wind velocity* and assumed that air motion stronger than that may be important – with other conditions favouring wind erosion – in the reworking of surface sand.

In *Tables 3 and 6* the monthly frequency of winds in the ca 3 °B velosity province are shown on the basis of measurements at Szeged and Kecskemét. The frequency of directions for winds around 4 °B (5.5–7.9 m per sec) velocity is demonstrated in *Tables 4 and 7*, in a breakdown according to the 16-arrow wind rose, since the tables also underline that considerable differences in wind in wind energy may emerge even with a divergence of 22 ° 30'. Finally, *Tables 5 and 8* include the monthly rquencies of winds with higher than 5 °B (8 m per sec) velocity by cardinal points.

The comperative analisys of data makes the nature of the relationship between wind direction and energy unambiguos in the various months. The essence of this system of relationships can be summarized as *the strongest winds blow from NW throughout the year in the S half of the area* under study. The strong NW and NNW (above 5 °B) winds are most frequent between June and September. At the same time, the nost intense SE and SSE winds in the area occur in the auutumn and early spring months, while their frequency in the period between May and September in not at all significant.

Table 3

Monthly frequency of directions of winds of ca 3 °B (3.4–5.4 m per sec) velocity in Kecskemét, 1958–1962

(by L. Jakucs)

Period	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	6,9	2,9	5,0	2,4	3,1	4,6	8,2	4,4	11,7	2,9	9,8	7,5	11,5	8,9	8,6	1,6
II.	2,1	2,6	5,1	3,0	4,9	6,7	5,0	4,6	7,7	5,5	8,3	7,0	12,0	13,3	9,7	2,5
III.	3,3	4,6	8,0	6,2	5,4	5,3	10,4	6,7	5,9	3,7	4,2	13,7	5,3	6,3	9,1	1,9
IV.	10,0	5,1	7,6	4,1	5,7	5,6	8,3	5,0	7,0	3,0	7,0	6,7	9,7	5,8	8,2	1,2
V.	4,4	3,9	6,9	5,5	4,6	3,4	2,5	2,2	3,1	3,8	7,5	16,2	16,6	7,0	10,7	1,7
VI.	6,3	4,3	9,2	3,6	4,9	2,3	1,1	1,4	4,6	3,8	5,9	9,6	19,2	9,5	12,3	2,0
VII.	2,3	1,4	3,1	1,5	1,2	2,1	3,0	0,6	4,4	2,5	10,1	20,1	19,3	9,9	17,3	1,2
VIII.	2,1	2,5	4,8	2,6	2,4	2,5	3,5	1,8	3,6	2,4	8,8	18,0	19,5	7,9	15,1	2,5
IX.	4,5	5,0	10,1	9,7	8,0	4,7	0,8	2,3	2,0	4,1	7,0	10,2	14,6	9,4	6,3	1,3
X.	2,1	7,6	10,4	3,6	7,8	7,4	8,6	7,1	5,8	3,4	8,9	7,5	5,7	7,3	6,8	0,0
XI.	3,3	3,5	8,8	10,8	16,4	10,2	8,4	3,3	9,7	2,3	4,7	9,0	6,1	1,0	1,6	0,9
XII.	7,0	6,5	6,4	3,5	5,7	6,9	8,5	8,3	13,3	3,6	4,5	8,0	6,4	4,5	4,2	2,7
YEAR	4,7	4,2	7,0	4,7	5,8	5,2	6,0	4,2	6,8	3,4	7,1	11,1	11,8	7,3	9,0	1,7

Table 4

Monthly frequency of directions of winds of 4 °B (5.5 – 7.9 m per sec) velocity in Kecskemét, 1958 – 1962

(by L. Jakucs)

Period	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	10,1	12,1	5,9	2,2	1,0	1,0	1,0	1,4	14,0	2,1	5,9	3,1	9,7	16,0	11,4	3,1
II.	0,0	1,4	2,3	1,7	1,4	2,0	2,8	1,4	4,3	8,5	6,8	4,0	13,3	24,3	25,2	0,6
III.	1,2	2,5	13,6	7,6	1,0	3,0	7,7	6,6	12,6	4,3	3,7	14,4	6,5	6,5	8,5	0,3
IV.	4,0	9,4	9,0	4,5	6,5	2,0	6,4	4,3	10,3	2,5	5,0	6,3	11,9	8,1	8,7	1,1
V.	2,8	2,1	8,7	5,2	3,1	0,8	3,8	2,2	0,8	4,5	10,5	18,2	20,6	6,6	10,1	0,0
VI.	1,2	2,5	5,4	2,9	3,7	0,0	0,0	0,0	0,0	3,8	1,2	6,2	27,0	14,8	28,1	1,2
VII.	0,0	0,5	1,0	1,2	1,2	1,8	0,5	0,5	1,0	4,6	4,6	22,6	16,6	18,9	25,0	0,0
VIII.	0,0	3,7	2,1	2,1	3,7	0,5	2,1	0,0	4,7	3,2	2,6	26,3	20,0	7,4	21,1	0,5
IX.	0,0	3,8	8,9	8,9	7,0	15,2	0,0	0,0	1,2	5,1	3,8	5,7	12,6	6,3	21,5	0,0
X.	1,5	5,4	5,4	3,3	6,9	6,2	10,7	4,7	10,0	4,0	6,5	4,3	2,2	11,6	14,8	2,5
XI.	7,0	6,4	8,3	4,4	21,0	10,8	4,4	0,6	14,0	0,0	4,5	6,4	9,6	1,3	0,0	1,3
XII.	7,3	8,1	7,1	2,2	0,7	3,9	2,4	1,9	21,0	4,7	5,2	11,0	8,6	9,8	3,9	2,2
YEAR	3,1	5,2	7,3	4,1	3,9	3,2	4,3	2,7	9,2	4,2	5,1	10,3	12,0	10,9	13,4	1,1

Table 5

Monthly frequency of directions of winds of velocity higher then 5 °B (8.0 m per sec) in Kecskemét, 1958–1962

(by L. Jakucs)

Pe-riod	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	0,0	33,1	6,1	1,0	0,0	0,0	0,0	1,0	10,0	1,0	0,0	1,0	1,0	22,4	22,4	1,0
II.	0,0	7,0	1,4	0,6	0,0	0,0	0,6	0,6	0,0	2,5	5,7	3,8	13,4	24,8	38,2	1,4
III.	3,5	2,8	7,7	9,1	1,4	0,0	4,2	2,1	14,1	0,7	5,7	9,2	7,8	14,8	16,9	0,0
IV.	1,7	0,8	17,1	3,4	2,6	2,6	2,6	0,0	8,5	4,3	11,1	0,0	5,1	20,5	19,7	0,0
V.	0,0	0,0	9,4	0,0	4,7	1,6	1,6	0,0	1,6	7,8	21,8	10,9	15,6	4,7	18,8	1,5
VI.	0,0	3,1	0,0	3,1	3,1	0,0	0,0	0,0	3,1	0,0	3,1	3,1	21,9	31,3	21,9	6,3
VII.	2,9	0,0	0,0	2,9	2,9	0,0	0,0	0,0	2,9	8,8	5,9	11,8	5,9	35,4	20,6	0,0
VIII.	0,0	13,4	0,0	0,0	6,6	0,0	0,0	0,0	13,4	0,0	6,6	13,4	0,0	33,3	6,6	6,7
IX.	0,0	0,0	6,6	0,0	6,6	0,0	6,6	6,6	13,4	0,0	2,6	0,0	0,0	13,4	13,6	6,6
X.	1,8	0,0	5,6	0,0	0,0	12,9	9,3	5,6	26,0	1,8	5,6	0,0	0,0	7,4	11,1	12,9
XI.	0,0	0,0	4,2	0,0	14,3	14,3	0,0	14,3	0,0	0,0	0,0	0,0	14,3	0,0	0,0	0,0
XII.	13,6	12,3	3,7	0,0	0,0	1,3	1,3	0,0	9,8	4,9	8,6	3,7	8,4	16,0	1,3	14,9
YEAR	2,5	7,5	6,7	2,6	1,6	1,6	2,2	1,2	8,5	2,9	7,6	4,5	8,1	19,0	20,2	3,3

Table 6

Monthly frequency of directions of winds of ca 3 °B (3.4–5.4 m per sec) velocity in Szeged, 1958–1962

(by L. Jakucs)

Period	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	9,9	10,0	3,8	0,5	0,2	0,7	21,5	20,6	7,2	2,4	3,7	1,4	4,2	4,3	5,2	4,4
II.	6,4	8,8	2,4	0,5	0,1	1,8	18,2	16,0	9,9	3,4	2,3	3,5	6,4	6,1	9,1	5,1
III.	4,7	10,3	7,8	0,8	0,6	1,3	22,9	13,0	5,2	2,2	2,3	2,0	6,5	8,6	6,4	5,4
IV.	4,5	13,1	5,1	0,7	0,9	3,9	21,6	12,1	7,2	2,6	2,5	3,0	4,0	7,0	8,7	3,1
V.	8,8	12,6	4,5	1,0	0,8	1,8	7,8	6,2	4,7	3,6	3,0	5,1	6,2	6,2	13,2	14,5
VI.	11,4	15,3	4,6	0,2	0,6	1,0	6,8	6,6	4,3	2,3	2,4	5,0	6,2	6,9	12,7	13,7
VII.	10,6	5,9	1,4	0,5	0,3	1,0	7,9	7,2	4,4	1,7	1,9	1,4	4,6	11,0	21,2	19,0
VIII.	9,5	9,1	1,8	0,1	0,2	0,1	7,6	8,8	3,3	1,4	2,6	3,6	5,5	12,2	17,4	16,8
IX.	7,4	14,6	3,1	0,7	0,2	1,6	18,9	5,8	3,3	1,1	2,5	2,9	5,1	5,5	15,4	11,9
X.	4,3	8,5	1,4	0,0	0,0	1,0	29,9	19,1	4,8	2,0	2,8	4,6	6,7	5,2	6,7	3,0
XI.	3,8	2,8	2,0	0,7	0,2	5,2	41,0	14,7	5,1	1,5	1,7	1,3	4,6	4,6	6,2	4,6
XII.	5,9	12,2	4,5	0,3	0,1	1,5	28,3	16,5	6,0	2,4	2,3	2,8	5,0	4,2	4,6	3,4
YEAR	7,2	10,1	3,7	0,6	0,4	1,8	19,7	12,4	5,7	2,4	2,5	3,0	5,4	6,7	10,1	8,3

Table 7

Monthly frequency of directions of winds of 4 °B (5.5 – 7.9 m per sec) velocity in Szeged, 1958 – 1962

(by L. Jakucs)

Period	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	6,9	10,5	6,9	0,0	0,0	0,5	15,0	22,6	1,5	0,5	0,7	0,9	1,9	7,3	15,2	9,6
II.	7,3	8,2	1,2	0,3	0,0	0,9	7,7	14,5	9,7	2,4	2,1	4,1	4,7	8,0	11,8	17,1
III.	4,8	8,6	1,8	0,0	0,0	0,0	22,8	18,5	2,4	0,6	1,8	1,6	4,0	6,9	13,0	13,2
IV.	4,3	15,3	1,3	0,0	0,0	0,9	19,1	12,9	5,7	1,7	1,7	3,2	4,0	5,7	15,3	8,9
V.	11,4	13,6	0,3	0,0	0,0	0,3	3,8	4,1	2,7	1,9	5,4	5,4	5,7	7,4	16,6	21,4
VI.	10,8	6,2	0,7	0,0	0,0	1,0	1,6	1,3	2,0	2,3	4,6	3,3	6,6	6,6	20,6	32,4
VII.	7,4	1,7	0,3	0,0	0,3	0,3	1,9	3,4	0,3	1,1	2,2	3,1	8,2	15,2	27,2	27,4
VIII.	7,9	1,8	0,3	0,0	0,0	0,0	0,3	4,3	1,8	2,2	3,9	2,9	3,2	11,1	35,9	24,4
IX.	8,3	1,1	0,0	0,0	0,0	0,6	26,7	2,8	0,0	2,2	5,6	3,9	2,8	7,2	22,1	16,7
X.	1,6	1,3	0,0	0,0	0,0	0,3	38,6	16,7	2,0	0,9	4,3	2,9	4,6	9,5	10,8	6,5
XI.	3,4	1,3	0,0	0,0	0,0	2,8	43,7	27,0	1,2	0,0	2,8	0,9	1,3	1,9	6,8	6,8
XII.	3,6	12,3	2,8	0,2	0,0	0,0	27,8	17,7	4,0	0,9	1,9	1,9	4,9	11,0	8,5	2,5
YEAR	6,1	7,8	1,5	0,0	0,0	0,6	17,9	13,3	3,0	1,3	2,8	2,7	4,4	8,1	16,0	14,5

Table 8

Monthly frequency of directions of velocity higher than 5 °B (8.0 m per sec) in Szeged, 1958–1962

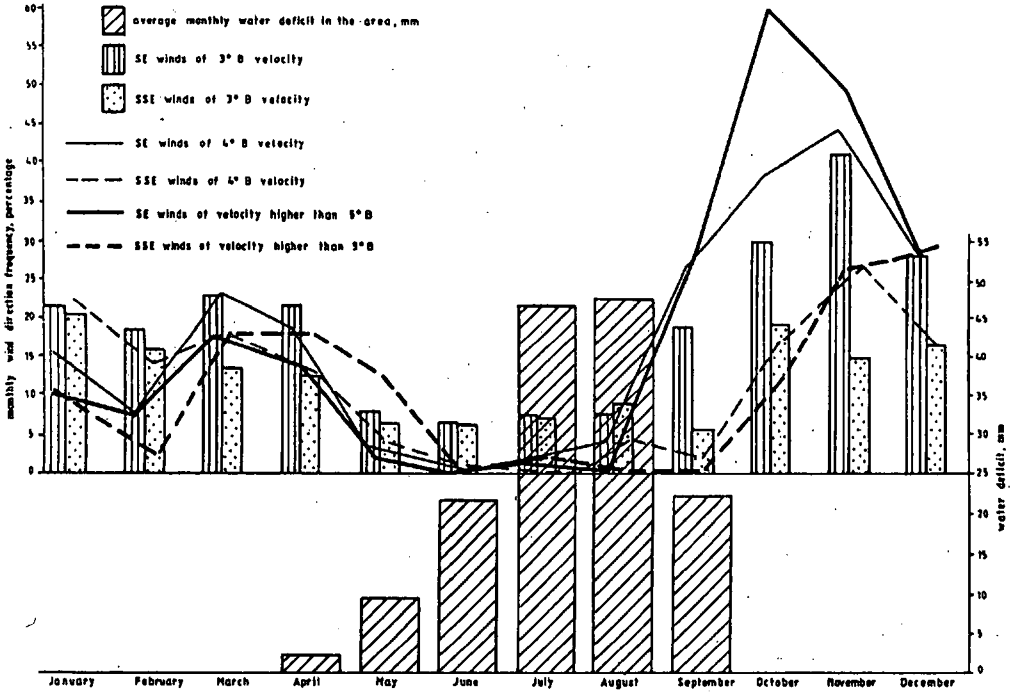
(by L. Jakucs)

Period	N	NNE	NE	ENE	E	ESE	SE	SSE	S	SSW	SW	WSW	W	WNW	NW	NNW
I.	9,6	15,6	0,1	0,0	0,0	0,0	10,5	9,9	0,0	0,0	0,0	4,2	9,2	4,9	25,5	10,5
II.	1,5	0,2	0,0	0,0	0,0	0,0	7,0	4,0	0,0	2,5	0,0	1,0	4,0	17,6	43,1	19,1
III.	5,6	11,8	0,0	0,0	0,0	0,3	17,3	17,1	0,3	0,0	0,0	3,4	1,5	8,2	22,6	12,0
IV.	3,7	8,3	0,0	0,0	0,0	0,0	14,8	17,6	1,9	0,9	1,4	1,4	1,4	3,7	23,6	21,3
V.	10,3	0,0	0,0	0,0	0,0	0,0	3,4	12,5	0,0	0,0	0,0	11,4	5,6	14,7	27,3	14,8
VI.	3,9	6,5	0,0	0,0	0,0	0,0	0,0	0,0	0,0	0,0	2,6	0,0	0,0	2,6	28,6	55,8
VII.	4,2	5,6	0,0	0,0	0,0	0,0	1,4	2,8	0,0	0,0	1,4	1,4	1,4	9,9	36,6	35,3
VIII.	0,0	0,0	0,0	0,0	0,0	3,3	0,0	0,0	3,3	0,0	0,0	0,0	10,0	13,3	40,1	30,0
IX.	3,3	0,0	0,0	0,0	0,0	0,0	24,6	0,0	0,0	0,0	3,3	4,9	1,6	4,9	34,4	23,0
X.	0,0	0,0	0,0	0,0	0,0	1,4	60,0	11,5	0,0	0,6	0,6	2,1	1,4	5,5	12,2	4,7
XI.	0,9	0,0	0,0	0,0	0,0	0,0	49,5	25,2	0,0	0,0	0,9	0,9	0,0	0,9	11,3	10,4
XII.	0,5	17,8	0,0	0,0	0,0	0,0	27,6	29,1	1,5	0,0	0,0	1,0	1,0	4,4	13,2	3,9
YEAR	3,7	7,5	0,0	0,0	0,0	0,2	20,0	13,9	0,5	0,5	0,6	2,5	2,5	7,4	24,6	16,1

The relationship between SE and SSE winds of 3° beaufort scale and stronger and monthly water deficits in the sand region of Csongrád county by months

(by L. Jakucs, 1988)

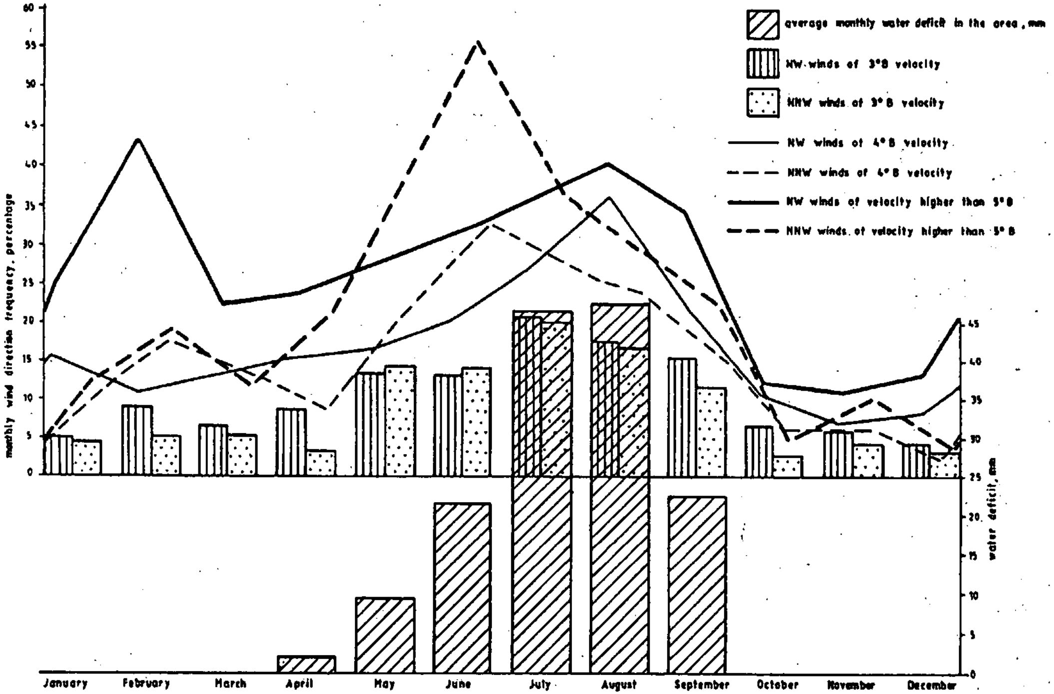
Fig. 7.



The relationship between NW and NNW winds of 3° beaufort scale and stronger and monthly water deficits in the sand region of Csongrád county by months

(by L. Jakucs, 1988)

Fig. 8.



All thes mean that *the main driving forces of sand movement are not the dry southerly winds* – as some authors thught previously – but winds close to the NWdirection (WNW, NW and NNW). Although it is true that southerly winds are mostly dry and exert a foehn effect, but their strongest occurences do not coicide with the driest periods in the area and therefore their contribution to sand movement is small. It is also true that the NW winds are often associated with precipitation, in the summer half-year they are still important as desiccanting influences on the sand, since the rain brought by them is not sufficient to compensate the summer demand of evaporation. Therefore, in the intervals between rainfall events the soil dries out intensively (the wind only increases this desiccation) and the sand becomes the victim of wind erosion.

To illustrate how important the NW winds in generating sand movement as *primary cause, Figures 7 and 8* provide convincing evidence. These figures show the coincidence of the high frequency of main wind directions with months of water deficit in the area. It is obvious that the frequency maxima of stronger SE and SSE winds fall to months without water deficit (see *Fig. 7*) and in months with water deficit such winds are not characteristic. *Figure 8* serves to illustrate *that the maximum curve of intense NW winds follows the maximum curve of great water deficit in the area.* Consequently, *the joint occurence of all of the conditions of wind erosion is really associated with NW winds.*

In an earlier part of our study where the landforms of the sand region were evaluated from a genetic aspect, we also had to point out that NW winds played a decisive role in the early Holocene reworking and resettling of the sand material of blown sand ridges. The comprehensive analysis of the present climatic conditions ofthe region provided unambiguous evidence that in the region *no major change has taken place in respect to the direction and factors of sand movement since the early Holocene.*

References

BACSÓ, N. 1973. *Bevezetés az agrometeorológiába* (Introduction to agrometeorology). – Mezőgazdasági Kiadó, Budapest.

BERÉNYI, D. 1948. *Az éghajlat természetes és mesterséges befolyásolása* (Influencing climate in natural and artificial ways). – Agrometerology, Budapest.

BODOLAY, I. 1966. *Die Rolle der bodenkundlichen Faktor im Windschutz der Sandböden.* – Agrokémiai Kiadó, Popert.

BODOLAY, I. 1975. *A szélerózió fellépése és megelőzése ásványi eredetű talajainkon* (Occurrence and prevention of wind erosion on Hungarian soils of mineral origin). – Candidate's dissertation Budapest.

BORSY, Z. 1972. *A szélerózió vizsgálata a magyarországi futóhomokterületeken.* (Investigation of wind erosion on blown sand areas). – Földr. Közl. pp. 156–160.

BORSY Z. 1974. *A futóhomok mozgásának törvényszerűségei, és a szélerózió elleni védekezés* (Laws of blown sand movements and prevention against wind erosion). – D, Sc. Dissertation, Debrecen.

CHEPIL, W. S. 1957. *Erosion of soil by wind.* – Yearbook of Agriculture, pp. 308–314.

EGERSZEGI, S. 1961. *A homokvédelem fontosságáról* (On the impotance of protection of sand areas). – Magyar mezőgazdaság, 16. 16. p. 16.

FEKETE, Z.–KIRÁLY, M. 1971. *A deflaciós talajpusztulás nyári és őszi elosztásának hatása a Duna–Tisza közi ültetvényekben* (Impact of soil erosion by wind in the plantations of the Danube–Tisza Interfluve im summer and autumn). – Kertészeti Egyetem Közleményei, XXXV. pp. 215–221.

FEKETE, Z.–KIRÁLY, M. 1973. *Duna–Tisza közi homoki ültetvények talajvédelme* (Soil conservation in the plantations on the sands of the Danube–Tisza Interfluve). – Kertészeti Egyetem Közleményei, XXXVII. pp. 173–179.

GÁL, J. 1966. *Szélerózió elleni védekezés mezővédő erdősávokkal* (Prevention of wind erosion with shelter belts). – Agrokémia és Talajtan, 15. pp. 199–211.

KÉGL, L. 1954. *A nedvességtartalom hatása a talaj néhány szerkezeti tulajdonságára* (Impact of moisture on some structural properties of soils). – MTA Agrártud. Oszt. Közl. 3. pp. 61–86.

MIHÁLTZ, I. 1938. *A Duna–Tisza közi futóhomok* (Blown sand on the Danube–Tisza Interfluve). – Földrajzi Értesítő, 3. pp. 114–121.

MOLNÁR, B. 1961. *A Duna–Tisza közi eolikus rétegek felszíni és felszín alatti kiterjedése* (Surface and subsurface extension of eolian beds in the Danube–Tisza Interfluve). – Földtani Közlöny, pp. 300–315.

MOLNÁR, B. 1966. *Adatok a Duna–Tisza köze harmadidőszaki és negyedkori rétegeinek tagolásához és származásához, nehéz ásvány-összetétel alapján* (Data on the divisions and origin of Tertiary and Quaternary layers in the Danube–Tisza Interfluve based on heavy mineral composition). – Földtani Közlöny 95. pp. 217–225.

PÉCSI, M. 1960. *A Duna–Tisza köze geomorfológiai problémái* (Geomorphological problems in the Danube–Tisza Interfluve). – Földrajzi Közlemények, 8. pp. 23–29.

RÓNAI, A. et al. 1979. *Az Alföld földtani atlasza* (Geological atlas of the Great Hungarian Plain). – MÁFI, Budapest.

STEFANOVITS, P. 1968. *A homoktájak talajai és a bennük rejlő lehetőségek* (Soils and their potentials in the sand regions). – Földrajzi Közlemények. XVII. pp. 272–278.

SÜMEGHY, J. 1953. *A Duna–Tisza közének földtani vizsgálata* (Geological investigations in the Danube–Tisza Interfluve). – Annual report, Geological Survey, for 1950, pp. 233–264.

ZENTAY, T. – PRETTENHOFFER, I. – KISS, L. 1974. *Laza homokterületek javítási lehetőségeinek felkutatása a közöttük előforduló mélyfekvésű, humuszos, ill. kötött talajok felső rétegeivel* (Perspectives for amelioration of soils in loose sand areas with the topsoil of adjacent humic or cohesive soils in depressions). – Research Report, Szeged

ZENTAY, T. – GEREI, L. – BALOGH, J. 1985. *A Duna–Tisza közi homoktalajok néhány vízgazdálkodási tulajdonságának vizsgálata* (Investigation of some water budget properties of sand soils on the Danube–Tisza Interfluve). – Földrajzi Értesítő, 34. 1–2. pp. 123–132.

ZÓLYOMI, B. 1952. *Magyarország növénytakarójának fejlődéstörténete az utolsó jégkorszaktól* (History of vegetation in Hungary since the last glacial). – MTA Biol. Oszt. Közl. I. p. 491.

ZENTAY – HARMATI – JAKUCS – RÉDEI – VÁGÁS 1989. *A szélerózió elleni védekezés lehetőségeinek, módszereinek feltárása Csongrád megye homokterületein* (Perspectives and methods of wind erosion prevention in the sand areas of Csongrád county). – MTA Szeged Committee, Szeged. p. 1–128.