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THE EVALUATION OF WIND EROSION HAZARD FOR THE AREA OF THE DANUBE-TISZA INTERFLUVE USING THE REVISED WIND EROSION EQUATION (RWEQ)

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Summary

Detailed wind erosion studies were implemented on a pilot area in the Danube-Tisza Interfluve between 1995-2000. With the help of the recorded values, we were to test the applicability of the USDA RWEQ (Revised Wind Erosion Equation [United States Dept. of Agriculture (USDA) Wind Erosion & Water Conservation Service (WEWC): http://www.lbk.ars.usda.gov/wewc/]. to Hungarian sites and examples. The pilot studies yielded a standard deviation of less than 20% from the average for dry barren sandy surfaces affected by heavy gusts (15-22 m/s) with the largest recorded value of erosion at 880 tons/ha; and the largest predicted value of the same variant at 960 tons/ha. In the next step, a wind erosion hazard map was prepared for the area of the Danube-Tisza Interfluve using remote sensing techniques in the evaluation of satellite images, which was then compared to the Potential Wind Erosion Map of Hungary (LÓKI, 2003). According to the calculated values of soil moisture (Landsat5 TM-SWI), and the received erosion rates taken from the RWEQ model, 20-45% of the pilot area could be considered as potentially violated by wind erosion.

Introduction

The gradual increase observable in aridity values, and the increasing susceptibility to heavy droughts in Hungary should be attributed to a possible climate change (MIKA, 1995; WEIDINGER et al., 2000.) affecting primarily the area of the Great Hungarian Plain, and most heavily the region of the Danube-Tisza Interfluve included.

The observed trends of rising temperatures, decreasing precipitation rates, as well as the gradual drop in soil moisture and groundwater levels recorded in regional studies all tend to influence the potential susceptibility of an area to deflation as well (KERTÉSZ et al., 2001.; RAKONCZAI et al., 2001; LÓKI, 2003.; KOVÁCS, 2004.).

One of the major goals of our wind erosion studies was to develop a database, which might be not only useful in directing the attention of decision makers to the potential hazards of wind erosion in the agriculture (MUCSI-SZATMÁRI, 1998.; SZATMÁRI, 2000), but to an important and very serious environmental and public health problem observable in several cities and villages of the Great Hungarian Plain: dust pollution of the air.

Dust pollution observable in the settlements of the Southern Great Hungarian Plain well exceeds the limit of emission, with the largest recorded value present (RAKONCZAI et al., 2000.). The main source of the floating dust particles present in the air can be linked to agricultural dusting of arables, which could be significantly cut back by forestation or grassing of the abandoned arable lands.

Hopefully, the joining of Hungary to the European Union will open up new financial resources to the country, and will also contribute to the initiation of large-scale landscape management in the future. We would like to contribute to the theoretical and practical base of this work with our research results. Detailed wind erosion studies were implemented on a pilot area in the Danube-Tisza Interfluve during the second half of the 1990s (MEZŐSI-SZATMÁRI, 1998.). The present paper discusses the applicability of the USDA wind erosion model to Hungarian examples based on the utilization of our recorded values as input into the model. Furthermore, a detailed wind erosion hazard map has been prepared via the evaluation of satellite images and aerial photographs of the studied area for the period investigated.

Material and methods

In order to record the amount of sand exposed to aeolian transportation, a 50x50 m pilot area was outlined on the sand ridge of Kiskunmajsa-Dorozsma in the vicinity of the hydrometeorological station (**Fig. 1.**). Sand movement was measured with the help of measuring rods at weekly and fortnightly intervals. The pilot area was systematically plowed and exposed to chemical weed control to sustain a surface with scant vegetation cover. This surface is considered to be potentially liable to deflation during the spring and the fall in great extention in the area of the Danube-Tisza Interfluve.

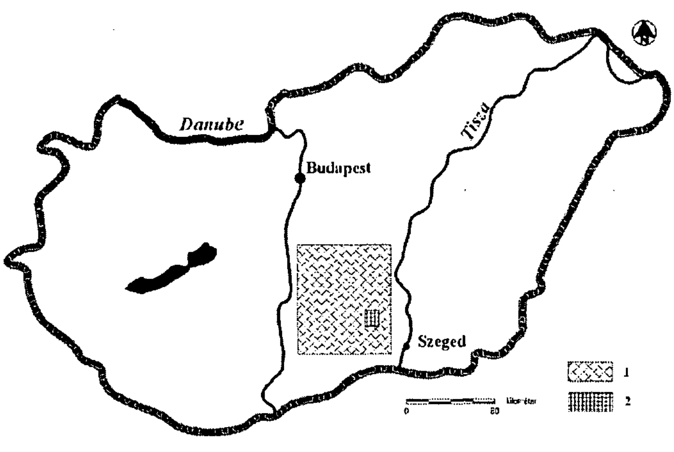

Figure 1. The location of the pilot area.

1: the studied region of the Danube-Tisza Interfluve via remote sensing methods; the area covered by the wind erosion hazard map; **2**: the location of the pilot area and studied lot on the sand ridge of Kiskunmajsa-Dorozsma

The meteorological parameters were recorded both with the help of on-site devices and with those located at the nearby meteorological station. Furthermore, the highly detailed database of the Szeged and Kistelek stations of the Hungarian Meteorological Survey (OMSZ) has also been adopted to our work, and the maximum wind speed values presented in the daily reports of the OMSZ between April 1997 and 2000 for the cities of Szeged, Kecskemét and Kiskunhalas have also been used.

As the second step in our work, an area covering approximately 64 km^2 (**Fig. 1.**) was delineated on the sand ridge with the studied lot in the center. The natural vegetation and landscape utilization of the region located between the cities of Kiskunmajsa and Kistelek are rather versatile.

Geomorphologically speaking, the alternation of sand ridges, interdune depressions and flats characterize this southern part of the Danube-Tisza Interfluve. Soil samples were collected from different sites of the studied area, which were characterized by differing soil conditions and landscape utilization. The sites which are most sensitive to wind erosion have also been identified in the course of multiple field mapping. The most important physical properties of the collected soil samples, especially from the side of deflation processes, were determined in the laboratory. These included the carbonate and organic material content as well as the grain-size composition of the samples.

LANDSAT5 TM multi-spectral satellite images have been utilized for the remote sensing analysis with the values of NDVI (Normalised Vegetation Index) which is the most frequently and widely used index for net produced biomass. The different classes of wind erosion hazard potential were set up for the 6420 km^2 area of the Danube-Tisza Interfluve with the help of the soil wetness index (SWI) derived from LANDSAT images, taken on 14th April 1997 and 22nd April 2000, respectively (**Fig. 1.**). Field reference data for the studied time period used in the classification procedure comes from the recorded soil moisture values at the site near Kömpöc, where according to our personal observations, the emergence of a potential wind erosion hazard is connected to the interval of 0-6% soil wetness.

Ours was one of the very first Hungarian work focusing on wind erosion processes, which applied a test of wind erosion models as well. It must be mentioned however, that these computer based models are user-oriented beta versions prepared by American researchers and come with a built-in meteorological database.

Thus in the vast majority of our work we had to concentrate on developing a suitable meteorological database for use as an input into the model. The most important step involved was setting up a suitable algorithm necessary for wind statistical analyses from the detailed field data available (maximal wind speed and direction values recorded at 10 minute intervals between 1997 and 2000).

Institutes enjoying subsidy from the US Department of Agriculture (USDA), namely the WEWC in Texas and WERU (Wind Erosion Research Unit) in Kansas managed to develop two highly different wind erosion models during the past two decades, working independently from each other.

We had a chance to gain access to and try out these models utilizing our field data with the permission and help of the experts working at these institutes. The present study discusses the testing of the RWEQ model, which predicts soil erosion along a line crosscutting an isolated rectangular lot giving medium to long-range average predictions with low temporal resolution and without any bootstrap of the prevailing processes.

In order to assess accurately the data on the Landsat TM5 images of the region of the Danube-Tisza Interfluve, field data have been collected at 34 points in the pilot area located between Kiskunmajsa and Kistelek including such parameters as vegetation cover percentages, soil samples with determined physical parameters of grain-size composition, carbonate and organic matter content. Areas potentially liable to wind erosion were delineated with the help of the data retained from the satellite images (vegetation and soil wetness index values) and the measured field parameters. The parameters deriving from the field sampling were used as an input in the „soil submodel" of the RWEQ.

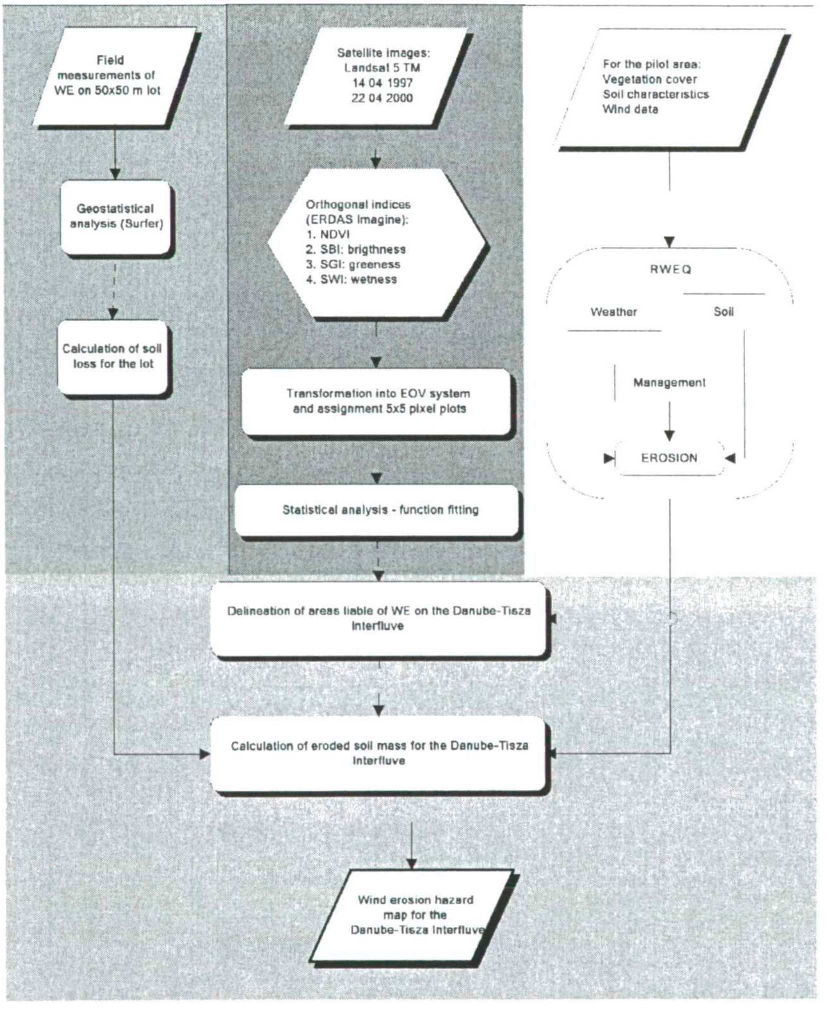

Figure 2. Flowchart of wind erosion measurement steps.
Integration into a complex model.

During the testing process, meteorological data recorded and calculated for the spring of 1997 have been utilized, as this period witnessed the highest values of eroded material due to a relatively intensive deflation lasting for several weeks in the pilot area.

Data coming from different sources, including field measurements and calculated values from remote sensing analyses, as well as general model algorithms, have been integrated into a single system (**Fig. 2.**).

Results and discussion

1. The findings of field measurements in the pilot area

The recorded values for the period of 1995-2000 are depicted on **Fig. 3.**

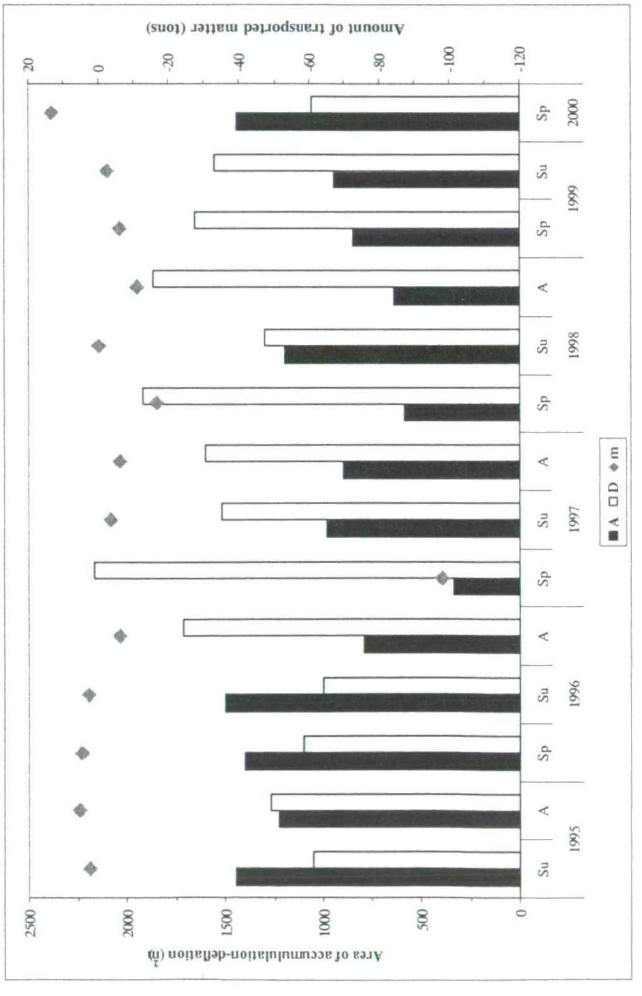

Figure 3. The results of field measurements between 1995-2000 summarized for seasons. A: accumulation (m^2); D: deflation (m^2); m: the amount of transported matter (tons)

The most intensive sand movement could be observed during the springs of 1997 and 1998, when the amount of monthly total transported sand exceeded 200 tons (equaling approximately the removal of 3 cm soil), and 50 tons for the one-quarter hectare of the lot.

No relevant sand movement could be measured or identified in the spring of 2000, when the recording of field data and the second satellite image was taken of the studied area. Our data were then compared to those of DIKKEH (2004.), recorded via utilizing sand traps and measuring stakes on a 1 ha lot near the city of Kecskemét. According to the latter, the rate of soil erosion recorded during a 10 hour and a 20 hour measurement series during the middle of April in 1988 were 59 m^3/ha and 56 m^3/ha (corresponding to a total of 150-160 t/ha eroded soil amount). As the wind speed values were very similar during this time and the first two studied weeks of April 1997, it can be generally stated that strong gusts with a speed exceeding 5-6 m/s are capable to move several hundred tons/hectare of sand from one place to an other within only a couple of hours on a dry, barren sand surface, free of vegetation cover.

2. The outcomes of the RWEQ erosion submodel run

According to our findings (**Table 1.**) the differences between the measured (920 t/ha) values of deflation on a vegetation free lot and those calculated from the model (e.g. Sample M33: 788 t/ha; or Sample M6: 644 t/ha) were less than 25%, which is acceptable. Researchers R. VAN PELT and T.M. ZOBECK investigated the relationship between the deflation values recorded at six stations and the ones predicted by the RWEQ model in details. According to their findings, the correlation of the predicted and actually measured values was between 0.6-0.7, implying the underestimation of the actual deflation values in the model (R. VAN PELT et al., 2002.). The deflation values recorded by us on a lot with vegetation cover (fall wheat) were significantly different from the ones calculated by the model, the underlying reasons of which might be revealed by further program runs only. Naturally no long-term verification statements could be drawn regarding the model as we have only dealt with data for a single event and a single area only so far.

3. The evaluation of wind erosion hazard for the area of the Danube-Tisza Interfluve

The studied area is classified into the category of 99% liable to risk according to the „Potential wind erosion hazard map of Hungary" (LÓKI, 2003.), with a total area under heavily endangered exceeds 50%. From the calculated soil wetness index (SWI) we can draw conclusions reflecting our recorded values for the two spring periods. The April of 1997 was relatively poor in rainfall with frequently recurring strong gusts, also yielding the highest erosion rates on our pilot area during the 6 year of the study (about 900 t/ha/month). Based on the classification prepared via the analysis of the satellite images the regions potentially liable to wind erosion exceeded 40% of the total area of the Danube-Tisza Interfluve, 9% of which was moderately and highly affected by wind erosion (**Fig. 4.**; **Table 2.**).

The RWEQ model yielded a monthly average erosion rate of 640t/ha for the moderately and strongly affected dry, barren sand surfaces, and a rate of 150 t/ha for the weakly affected areas. Based on the values for April 2000 2% of the total area belong to the class of highly endangered by erosion and 17% was only weakly affected (**Table 3.**).

Table 1. The actual measured values at the sampling points and the ones calculated from the LANDSAT TM5 images taken on 14th April 1997 (**) and 22nd April 2000 (*)

Type of vegetation cover*	Percentage of covered area* (%)	No. of soil sample*	SWI**	NDVI**	Calculated RWEQ erosion rate (t/2500 m²)
Woodland	100	M11	-14.98	0.36	0
	15	M26	-48.10	0.25	53
Wheatland	75	M27	-41.52	0.37	2
	70	M8	-37.98	0.30	3
	50	M10	-1.65	0.63	8
	50	M30	-30.71	0.37	5
	47	M29	-37.25	0.37	9
	45	M5	-19.28	0.48	15
	37	M32	-19.77	0.51	15
	35	M34	-26.14	0.43	16
	30	M1	-32.4	0.29	21
	25	M24	-27.15	0.47	34
	25	M25	-61.17	0.11	27
	23	M15	-43.63	0.21	35
	17	M36	-55.30	0.21	47
	16	M19	-34.62	0.31	75
	13	M16	-31.38	0.32	67
Orchard	2	M14	-56.47	0.13	173
	0	M17	-58.83	0.08	241
Reed	100	M7	-21.91	0.14	0
Fallow	75	M23	-39.62	0.31	2
	50	M31	-39.07	0.18	8
Meadow	70	M35	-14.22	0.52	3
	50	M28	-29.89	0.41	5
	7	M3	-60.39	0.11	91
Interdune depressions	100	M18	-30.73	0.36	0
	100	M22	-27.81	0.33	0
Arables without plants	4	M12	-46.12	0.16	138
	2	M2	-60.3	0.13	150
	3	M6	-20.72	0.47	161
	1	M20	-59.06	0.21	142
	0	M33	-64.68	0.13	197
Vineyard	90	M4	-58.08	0.08	1
	50	M21	-46.37	0.18	8

Table 2. The evaluation of deflation hazard based on classification for the Landsat5 TM image taken on 14th April 1997

SWI	risk	pixel (30 m / pc.)	area (km²)	percentage (%)
(-120, -80)	high	23062	20,8	0,32
(-80, -60)	moderate	595336	535,8	8,34
(-60, -20)	weak	2528430	2275,6	35,41
(-20, 60)	no	3966697	3570,0	55,54
unclassified		27895	25,1	0,39
Total		7141420	6427,3	100,00

Table 3. The evaluation of deflation hazard based on classification for the Landsat5 TM image taken on 22nd April 2000

SWI	risk	pixel (30 m / pc.)	area (km²)	percentage (%)
(-120, -80)	high	270	0,2	0,00
(-80, -60)	moderate	138920	125,0	1,95
(-60, -20)	weak	1232837	1109,6	17,26
(-20, 60)	no	5690499	5121,4	79,68
unclassified		78894	71,0	1,10
Total		7141420	6427,3	100,00

If these values are taken approximately as the real values at least in their magnitude, then during April 1997 at least a total of 70 million tons of sand must have suffered transportation in the area of the Danube-Tisza Interfluve (**Table 4.**). As it can be clearly seen in **Table 3.**, this mass of transported sand could have been 70-80% less in April 2000 assuming similar wind conditions due to the higher rates of moisture of upper soil layer. However, as we have noted in the section of field measurements no wind action could be detected for this period.

Table 4. The amount of wind-blown sand for the area of the Danube-Tisza Interfluve based on classification for the Landsat5 TM image taken on 14th April 1997 and the calculations of the RWEQ model

risk	area (km²)	percentage (%)	Erosion (thousand of tons)
high	21	0,3	35620
moderate	536	8,3	
weak	2276	35,4	34134
Total	2833	44	69754

According to KARÁCSONY (1992.) and MOHAMMAD D. (1991.), in case of a natural wind erosion process 10-20% of the total transported matter is given by dust particles.

Based on this value approximately 7-14 million tons of dust could become airborne during our studied period causing significant air quality problems in the nearby settlements.

Summary

This paper presents a method for the accurate and complex treatment and evaluation of field data, those gained from the evaluation of satellite images and the soil erosion values predicted by a wind erosion model as a first step in deflation studies. The final outcome of this work is a wind erosion hazard map of the area on the one hand.

Furthermore, the amount of airborne dust causing air pollution problems could also be predicted for a two-week period of wind erosion.

Our very first findings were rather promising, thus the initial testing and verification of the model utilizing Hungarian site data were worthy, and call for a continuation. This is by no means surprising, considering the long-standing research experiences of the USDA working groups for the development of the tested model.

We shall also carry on our database development for the area of the Great Hungarian Plain via the collection and evaluation of satellite images and aerial photographs utilizing remote sensing approaches, as this database is of primary importance in several ongoing researches, including our wind erosion studies as well.

The most effective and reliable source of landscape utilization, vegetation cover data, and those on soil conditions are materials used in remote sensing.

In order to gain better and more reliable information on wind erosion regarding such parameters as critical wind speed, and soil conditions, we plan to extend our research to other areas of the Great Hungarian Plain potentially liable to wind erosion (Nyírség, the Körös-Maros Interfluve), along with the further refinement of our research methods.

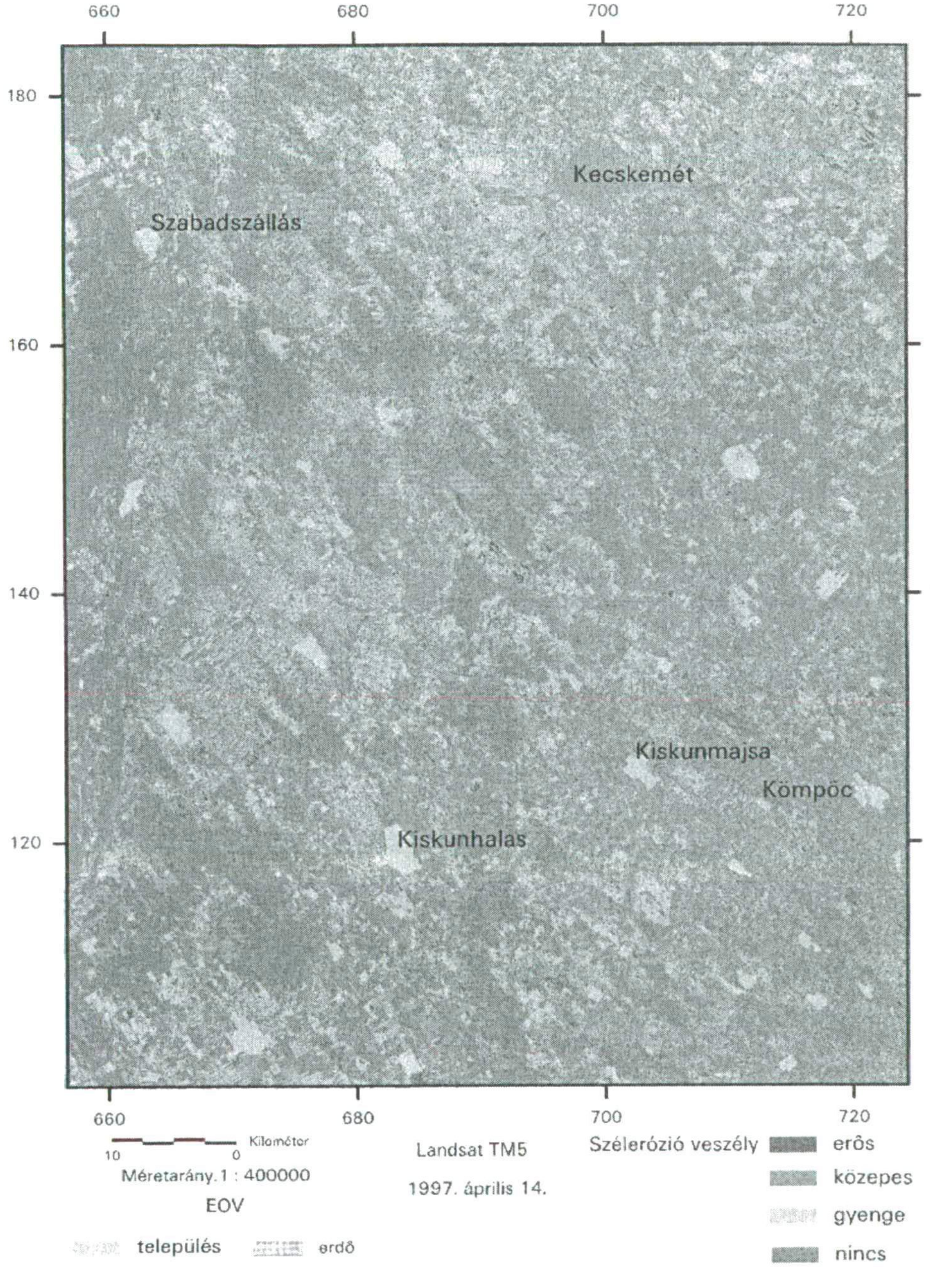

Figure 4. Wind erosion hazard classes
(erős: high, közepes: moderate, gyenge: weak, nincs: no hazard)

References

DIKKEH, M. (2004) Comparing wind erosion field measurements with simulated by WEPS. Proceedings of ESSC Conference. Budapest. p. 350.

KARÁCSONY, J. (1992) A szélerózió elleni védekezés fizikai alapjai. Kandidátusi értekezés. Gödöllő, p. 117.

KERTÉSZ, Á. et al. (2001) Az aridifikáció folyamatai a D-T közén, Földrajzi Közlemények, pp.75-92.

KOVÁCS, F. (2004) Környezeti változások értékelése a Duna-Tisza közén, különös tekintettel a szárazodás problémájára. MFK előadásai. CD-ROM.

LÓKI, J. (2003) A szélerózió mechanizmusa és magyarországi hatásai. MTA doktori értekezés. Debrecen p. 264.

MEZŐSI, G.-SZATMÁRI, J. (1998) Assessment of wind erosion risk on the agricultural area of the southern part of Hungary. Journal of Hazardous Materials 61. Amsterdam. pp. 139-153

MIKA, J. et al. (1995) Az Alföld éghajlatának időbeli változékonysága és változási tendenciái a hazai szakirodalom tükrében. Vízügyi közlemények LXXVII.évf. pp. 262-283

MOHAMMAD, D. (1991) A szélerózió néhány törvényszerűségének és védekezési lehetőségének vizsgálata. Kandidátusi értekezés. Gödöllő.

MUCSI, L.-SZATMÁRI, J. (1998) Landscape changes of a blown sand surface on the Great Hungarian Plain. The problems of landscape ecology Vol. III. Warsaw. pp. 215-222

R.S. VAN PELT et al. (2002) Validation of the Wind Erosion Stochastic Simulator (WESS) and the Revised Wind Erosion Equation (RWEQ) for Single Events. In: Proceedings of ICAR5, Texas, USA pp. 292-295

RAKONCZAI, J. – BÓDIS, K. (2001) A geoinformatika alkalmazása a környezeti változások kvantitatív értékelésében. In.: A földrajz eredményei az új évezred küszöbén. CDROM ISBN 963482544-3. p. 15.

RAKONCZAI, J. et al. (2000) Csongrád megye kistérségi komplex környezet-védelmi programja, Szeged: http://www.geo.u-szeged.hu/kornyprog/csongrad

SZATMÁRI, J. (2000) Elfújta a böjti szél. In. Baukó T.(ed.): Az Alföld a XXI. század küszöbén. Békéscsaba. pp. 391-394

WEIDINGER, T.-BARTHOLY, J.-MATYASOVSZKY, I. (2000) A globális éghajlatváltozás lokálishatásainak vizsgálata hazánkban. Földrajzi Értesítő, pp. 115-126

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