University of Szeged Faculty of Science

Department of Physical Geography and Geoinformatics

APPLICATIONS OF GEOINFORMATICS AND PROCESS MODELS IN WIND EROSION INVESTIGATIONS

PhD Theses

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1. Introduction

Wind erosion processes endanger nearly 23% of the total surface of the Danube-Tisza Interfluve region. 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. Wind-blown sand areas play a considerable part in farming and their importance is ever growing. Thus it is apparent that conservation of light sand soils against wind erosion is vital. In 1980's a countywide soil protection network directed the research to reduce the damages. After the compensation (1990-1992) the land use type and structure changed. The results of this process were overlapped with the natural aridification tendency of the South Hungarian Region.

The gradual increase observable in aridity values and the increasing susceptibility to heavy droughts in Hungary should be attributed to a possible climate change affecting primarily the area of the Great Hungarian Plain, and most heavily the region of the Danube-Tisza Interfluve is 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 wind erosion as well.

These complexities of processes defined the three types of scientific approach of our wind erosion research:

1. measurements and observations on field plots: most difficult and problematic;
2. wind tunnel study allows the control of process, but at risk of oversimplification and most expensive;
3. statistical comparison of observed soil loss with environmental parameters is the most unreliable, but widely used and improving with new modelling techniques.

By increasing the number of the experimental areas we would like to create a data base which helps draw decision makers' attention to the fact that wind erosion creates damages not only in agriculture but it is the cause of serious health problems in several settlements of the Great Hungarian Plain. Wind erosion is also responsible for dust pollution which exceeds immission level the most in the region's settlements and which can be successfully decreased by carefully and scientifically founded plantation of forest, shelter belts, lines of trees and also by changing non-cultivated areas into grasslands. We hope our data can contribute to this future landscape planning projects.

The relationships of wind erosion, drought and land use, environmental and health problems caused by these processes indicated us to launch a research project to answer the next questions:

- Is it possible to work out applicable wind erosion field measuring methods which are able to serve acceptable information about the dynamics of process and volumetric characteristics of flux?
- Can we apply the process model of USDA in our research under the Hungarian climatic and pedological conditions and which constraints should we take into consideration during the application?
- What kind of geoinformation techniques are applicable to predict wind erosion risk of large areas based on measured and modelled data on study plots?
- Is it possible to find statistically relevant correlation between dust emission caused by wind erosion and the increasing dust immission on settlements of Danube-Tisza Interfluve?

2. Methods

1. 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. 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. Sand movement was measured with the help of measuring rods at weekly and fortnightly intervals. The pilot area was systematically ploughed and exposed to chemical weed control to sustain a surface with scant vegetation cover.
2. In order to gain better and more reliable information on wind erosion regarding such parameters as critical wind speed, and soil conditions we managed to set up with the help of physicists a portable digital measurement station for monitoring wind erosion on the field. The special device we placed in wind tunnel and also on the field can transform the impulses from acoustic microphones that detect sand particle impact into digital ones. The sensors in this device can detect 1-3000 particle impacts per second, thus we can conclude the exact time when the saltated particles begin and finish moving, namely the length and dynamism of erosive period.
3. Ours was one of the very first Hungarian works focusing on wind erosion processes, which applied a test of wind erosion models as well. With the help of the recorded

values, we were to test the applicability of the USDA RWEQ (Revised Wind Erosion Equation) to Hungarian sites and examples.

4. To test WEPS (Wind Erosion Prediction System) Erosion model I used all the wind erosion events between 1995-2000 and with the calibrated and validated programs I ran simulations for the events in the spring of 1997 and March and April of 2004.
5. 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. With the help of satellite images we can investigate the most important reasons of wind erosion, e.g. condition of vegetation and soil moisture. By using the Landsat5 TM SWI- (soil wetness index) image we have classified the driest areas which are exposed to wind erosion to a greater extent. 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 complex geoinformation system (Figure 1). The different classes of wind erosion hazard are drawn on actual wind erosion map which were set up for the 6420 km2 area of the Danube-Tisza Interfluve.
6. 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, 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.

3. Results and conclusions

I concluded the answers to the above questions during the research and the preparation of my thesis and I summarized them in the next 6 paragraphs:

1. The most intensive sand movement could be observed during the springs of 1997 and 1998, when amount of monthly total transported sand exceeded 50 tons for the the field plot (Figure 2). Within a two-week long observation interval (from 3 April till 14 April 1997) sand was eroded on the parcel by an extremely strong wind effects (235 tons from the test parcel). The quantity of eroded soil seems to be high, but there were the strongest wind in the last decade, the wind gusts were about 20-25 m/s several times in this period. This method proved that only those deflation and accumulation data could be evaluated which we recorded at least 2-3 mm surface height differences

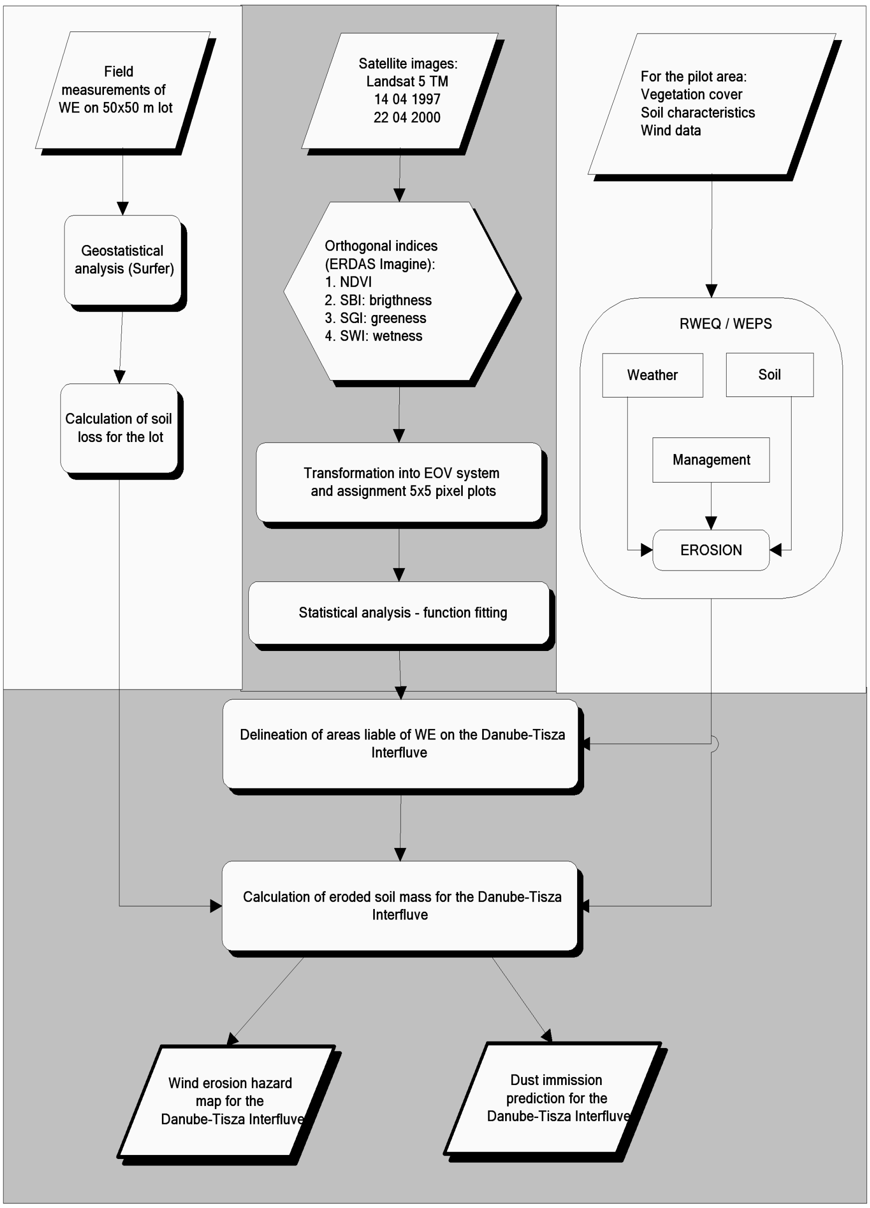

Fig 1. Flowchart of wind erosion measurement steps. Integration into a complex model.

next to the measuring sticks and which showed at least 30-45 t/ha sand movement if we calculate the quantity of the eroded material. Measurement by sticks was not suitable for detecting smaller but more frequent wind erosion phenomena.

2. Measurements and statistics proved that the cubic function well-known in scientific literature can describe the correlation between the wind speed and the quantity of the number of the saltated particles. Our experiments supported scientific literature that the applicability of the device with acoustic microphone is limited to defining the quantity of the eroded material.

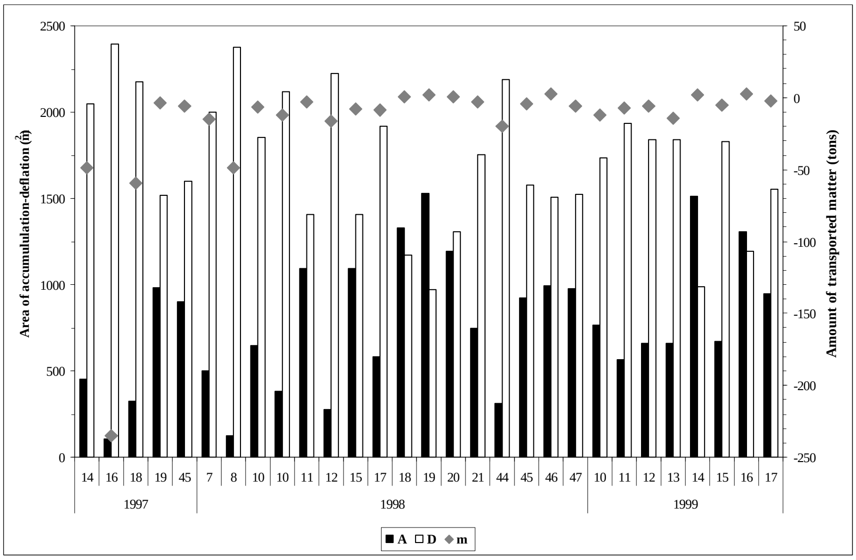

Fig. 2. The results of field measurements between 1995-2000 summarized for seasons. *A*: accumulation (m^2); *D*: deflation (m^2); *m*: the amount of transported matter (tons)

3. The pilot studies yielded a standard deviation of less than 20% from the average for dry barren sandy surfaces affected by heavy gusts with the largest recorded value of erosion and the largest predicted value of the same variant, which is acceptable. 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. The main problem with the application of the model in Hungary is that it needs a meteorological data base which is difficult to obtain: wind statistics broken down by the month, and two weeks is the shortest period for which simulation is done.
4. As the WEPS program could deal with the detailed estimations in two dimensions for a certain parcel it proved to be more reliable, controllable and suitable device than RWEQ, and this is why I recommend its application in Hungarian wind erosion experiments. It is worth to continue to test the above introduced wind erosion models with data taken and measured on newer test areas as the test results mentioned in my dissertation, especially in case of WEPS model, are very promising. If we consider climate change, more exactly aridification tendencies, with a wind erosion model calibrated and validated on different and numerous test areas we can make simulation predictions which can be the basis of estimations on the development of the dynamism of wind erosion on arable lands and also an expectedly increasing dust immission on settlements as an indirect effect.
5. According to the calculated values of soil moisture, 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. 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 years of the study. Based on the classification prepared via the analysis of the satellite images the regions potentially liable to wind erosion exceeded 40% of the pilot area of the Danube-Tisza Interfluve, 9% of which was moderately and highly affected by wind erosion. 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. 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. 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.

6. Dust pollution observable in the settlements of the Southern part of the Great Hungarian Plain well exceeds the limit of emission, with the largest recorded value present. In the investigated settlements of the Danube-Tisza Interfluve I detected that dust immission significantly exceeded the end values for many times in the analyzed periods (1995-2001 and 2004-2005). I found that this is closely related to spring wind erosion and dust emission from agricultural fields (Figure 3). The main source of the floating dust particles present in the air can be linked to agricultural dusting of arables.

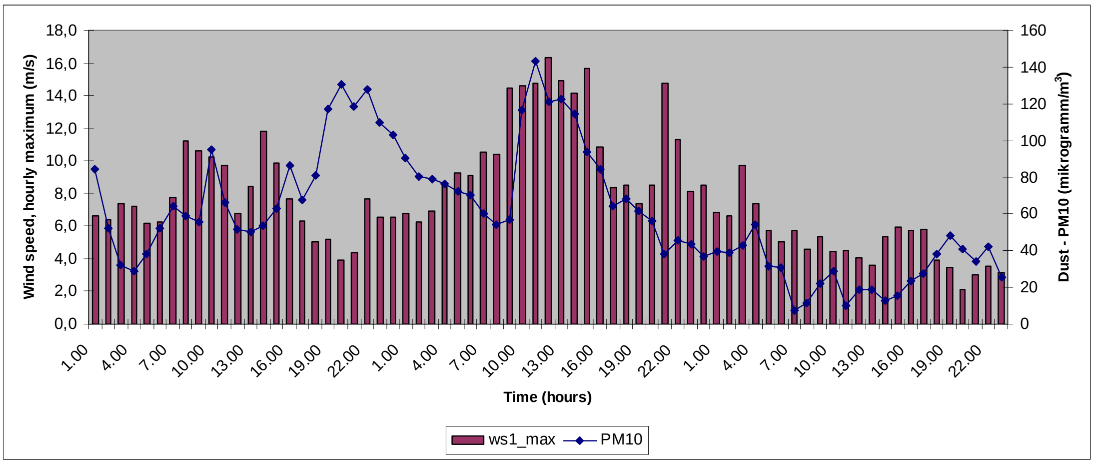

Fig 3. Hourly maximum wind speed and dust immission values (PM10) for 20-22. March 2004 in Szeged

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