Final report of the „*Assessment of wind erodibility of soils with different methods and the possibilities of wind erosion protection (PD 115803)*" supported by National Research, Development and Innovation Office

The most important preliminary of the present research was three researches supported by Hungarian Scientific Research Fund (OTKA) performed in the previous 12 years, when the geographers of the Szeged and Debrecen Universities carried out common investigations on wind erosion.

The aeolian research was based on measurements in laboratories and at field site. The second largest sand area in Hungary (the Nyírség) was chosen as sample site.

The laboratory measurements on wind erosion and the environmentally friendly methods of protection were carried out in the wind tunnel of the University of Debrecen. Field measurements were made in the Nyírség determining the rate of soil loss on different soil types, at different wind velocity and different vegetation cover. To assess the erodibility of soils, the critical threshold velocity of soils, the rate of soil loss and the value of erodibility factor (EF) were used. On the basis of our measurements the potential erodibility map of the Nyírség was compiled. Also, by using of our database about the wind erosion protection methods the plant cultivation could be became more safer. During our research, the forest map of the Nyírség in different times was also compiled and we qualified the shelterbelts which play an important role in the struggle against wind erosion.

The collected data were analyzed statistically and the spatial analyses were carried out by the application of GIS softwares. Based on the data we created maps of potential wind erosion and built a data-base, which could serve the sustainable agriculture.

The results were presented on conferences, in national and international journals, as well as in book chapters.

Further we will report on the results of the three years research. The citation numbers indicated in the report are the numbers of publications.

Becasue in the last part of the research period a more sum of money was stuck in different part of the budget (1.7., 3.1., 3.2., 3.3.,) we asked for a redeployment to buy new equipment supporting our research. This request was supported by National Research, Development and Innovation Office and the equipment was used in the different area of our project.

Results

The measures of soil loss rate was carried in the wind tunnel of our institute and also on the research field of the Westsik Vilmos Research Institute near Nyíregyháza. Variation of wind velocities above different soils, critical threshold velocity values of the soils and their erodibility, water retaining capacity of the given soil texture classes together with the relationship between wind velocity and drying time were also studied in the wind tunnel. From the results of experiments we built such a database which was analysed and processed by statistical and GIS softwares.

Mathematical and sstatistical relationships (about erodibility and wind profiles etc.) and thematic maps were created by using of analysed data.

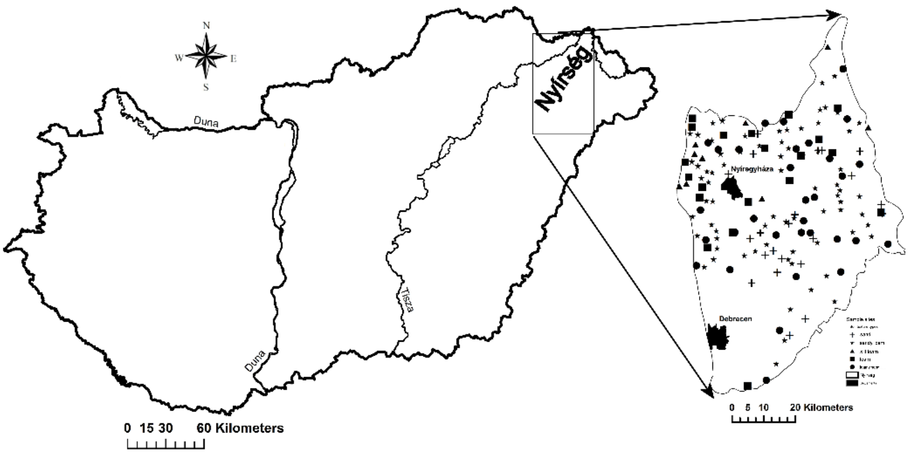

Fig 1. Location of sites of the samples collected for measuring EF-value and wind-tunnel measurements

1. a. The main results of the laboratory experiments

1. a. Results of wind-erodibility measurements

Soil samples were collected from the different part of Nyírség for wind tunnel and Wind erodible-fraction measurements (Fig 1.). We proved by our wind tunnel measurements and statistical analysis that both the threshold wind velocity and erodibility depend primarily on the soil's mechanical structure and composition (1):

- The most important effect has the coarse silt fraction (0.05-0.02 mm); considering it solely in the regression.
- Organic matter had significant correlation with the eroded mass ($r=-0.57$, $p<0.01$); however, it did not had any role in the regression due to its limited influence.
- We experienced the same with other variables (other fractions and $CaCO_3$), i.e. in spite of their correlation with the erosion their contribution was not significant in the multivariate regression model.

Wind-erodible fraction (EF) was calculated as the percentage of dry aggregates<0.84 mm in diameter by using an electromagnetic sieve shaker (Endescitt Minor 200) which was bought by the financial support of the project. EF was also calculated with the equation proposed by Fryrear et al. (1994).

Results show that all soil properties were correlated significantly with EF. The strongest relations were found with textural fractions, positive with sand content and negative with silt and clay contents. Although weaker than the relationship of EF with texture, significant negative correlation was also observed between EF and soil organic matter and $CaCO_3$ content.

The estimation equation of EF proposed by Fryrear et al. (1994) was not fit for predicting EF for soils in Nyírség.

On the basis of measurements with dry sieving shaker we can concluded that the soils with sand and loamy sand texture belong to strongly erodible category, soils with loamy and silt loam texture belong to the slightly erodible category. These results are in good agreement with the results of wind-tunnel measurements, so the EF-value is useful for the characterizing of soil resistance to wind erosion. (the article is under review in Soil Science and Agrochemistry)

1.b. Results of experiments about wind erosion protection methods

Results of irrigation experiments

The importance of irrigation in struggle against wind erosion is that when arable lands are irrigated, the moment of blowing-out could be delayed if the soil is wet, so there is no wind erosion. We found exponential relationship between the wind velocities and the times of evaporation. With regard to the evaporation time durations, we could establish that watering with a quantity equal to 5 mm rainfall – with the exception of sand soils – provided about 5-6 hour protection against wind-erosion, even in case of a wind velocities as high as 15.5 m/s. It can be concluded that the more watering is applied, the longer protection time can be reached.

Comparison of the time durations needed to evaporate the four different water levels showed that the granulometric composition had a significant effect in case of all texture categories except sand. Effect size (r) indicated that the actual soil texture had strong effect on the rate of evaporation; however, the influence was not increasing with the growing ratio of finer particles (i.e. loamy sand and silt loam had similar effect on the evaporation).

By comparing the granulometric composition of the air-dried soils and their surface crusts we could ascertain that mechanical composition of the original soils, the ratio of smaller size particles was found to be increased in the crusts. The increase in the ratio of finer particles and the higher $CaCO_3$ content resulted in strong crust formation.

Unfortunately, our wind tunnel experiments to determine the protecting capacity of crusts against wind erosion were not successful. The largest wind velocity didn’t move crust surfaces; thus, there was no material transport observed. However, under natural conditions this process is performed differently. On the one hand, it is apparent that there is no saltation in wind tunnel because in the field there are non-irrigated areas, and saltating particles are coming from there, and breaking the crust surfaces.

Results of crust strength measurements

Resistivity of crusts developed on the soil due to irrigation was determined by a special product Karuczka-Szőllősi micro-penetrometer.

Crust forming after the 1 mm irrigation does not show any significant resistance. More notable resistance was observed after the 5 mm irrigation. It indicates that different amount of precipitation makes an important role in the formation and structure of the crust.

Our measurements with penetrometer support the results of the sedimentological examinations. The sandy-silty-clay soil containing the largest amount of clay shows the greatest resistance. This is explained by that soil particles can contract and consequently a hard, solid structure forms.

Results of experiments with vegetation

We can concluded that wind always transported less material from the surfaces covered with vegetation thus the protective effect of the 10 cm tall wheat against deflation could be well demonstrated. Also the rows of plants sown in parallel with the wind direction provided a smaller scale of protection for the surface than the perpendicular ones. The corn, in the initial phase of its development, diminishes the energy of the wind only to a small extent due to the large row and stalk distances. The starting sand granules were slowed down at the lower wind speed and no sand movement was observed behind the rows of plants.

2. The results of the field measurements

2.a. The results of field wind erodibility measurements

The results of field measurements conducted in spring and in autumn for three years prove information about the wind erodibility of the site of field researches and its surroundings.

Based on the experience and results of the three-year measurement period, significant wind movement was detected in spring that can be explained by more windy conditions in March and April, less wet weather and the lack of land cover or underdeveloped vegetation. Deflation was active until vegetation became stronger. Measurements in June and July hardly showed any change in the land surface. On the top of positive forms and in the upper section of slopes mostly erosion processes occurred while more intense accumulation was observed at the bottom of slopes. In deflation flats the movement of sand grains was blocked by the more bond soil, higher groundwater table and more developed vegetation (5).

2.b The results of wind velocity measurements in the surroundings of shelterbelts

Wind velocity measurements were carried out in the surroundings of a multiple-rows shelterbelts with 15 m height in the surroundings of Westsik Vilmos Research Institute. The problem which made the experiments heavier was that we could conclude the measurements in short time, because we could not let our equipment without protection. So, in a consequence of it, a short time measurements are available for us. According to our measurements significant decrease happened on the leeward side of shelterbelts (0-5H) in velocity of wind, it reached its minimum between 2-8H (depending on its porosity), the 80 percentage of original wind velocity happened in 20H, until the total value in 30H. It means that the protected area is about 5-20 of the height of trees.

3. The results of GIS analyses

3.a. The results of surveying of afforested area and shelterbelts

The erodibility of agricultural fields are significantly affected by shelterbelts. To qualify and categorize the different kind of shelterbelts these were surveyed on the field and on maps. The base data for mapping the changes of forests and shelterbelts consisted of the maps of I, II and III Military Surveys of Hungary from the 1940's, civil topographic maps from the 1980's and ortophotographs from 2005. Besides these data sources, CORINE Land Cover database from 2000, 2006, 2012 and a forest database containing the species distribution of forests from 2014 were also used for surveying the changes of forest cover. Constructed maps were complemented by datasets including some of the primary characteristics of shelterbelts (number of rows, porosity, orientation, functional type).

The surveying of shelterbelts was significantly helped by the DJI Mavic Pro quadrocopter bought by financial support of this project, because this equipment prove the precisity of the mapping (Fig. 2.).

Our results pointed out that large differences were found in forest cover and in the length of shelterbelt systems as well as in the tendency of changes in different parts of the Nyírség (Fig3., Fig4.). All the forests and shelterbelts are situated on the two sides of the Nyírség watershed: the dominance of shelterbelts on the northern side and forests on the southern side can be observed in relation with soil properties. Nevertheless, the increase of forest area is continuous but the length of shelterbelts has decreased since the change of regime. Differences in forest cover in the given areas can be explained by soil and thus land-use differences.

Regarding the structure of shelterbelts it can be stated that more than 50% of them meet only partly while 40-70% of them do not meet at all the regulation conditions of planting forest belts. It could be stated than the ratio of one-rows shelterbelts reaches 40-70% (6).

Fig.2. Application of ortophotoes

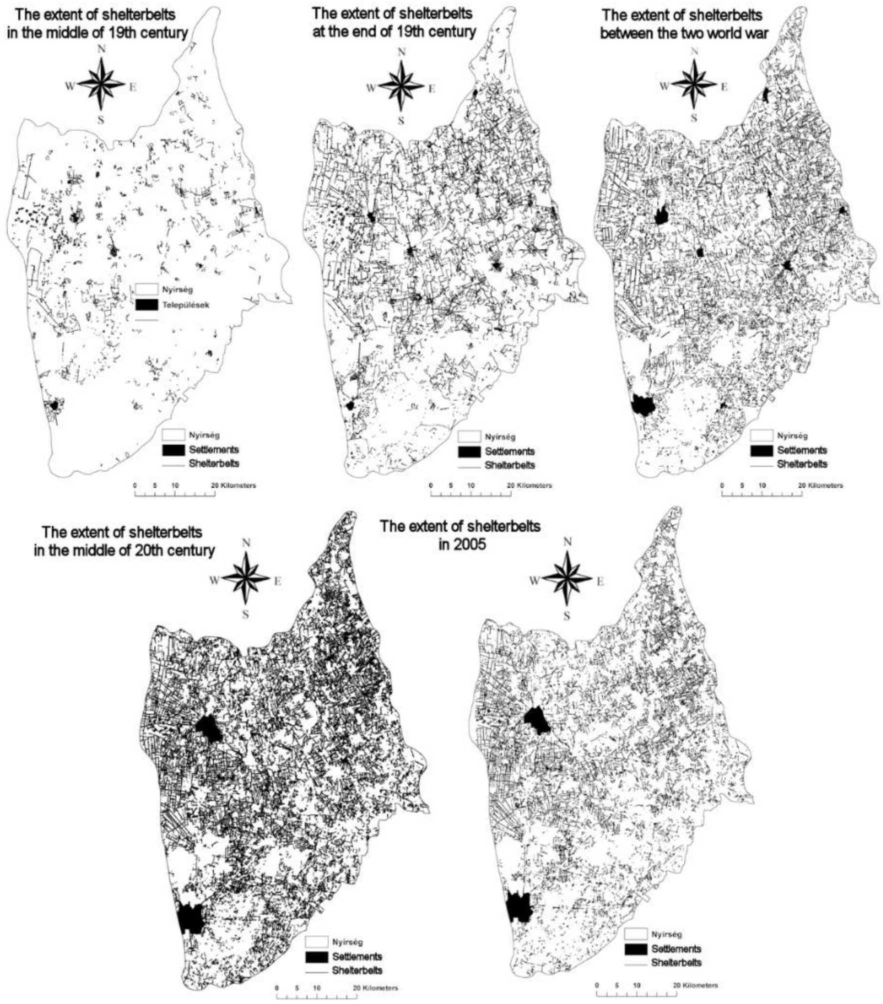

Fig 3. Changes of spatial extent of shelterbelts in the Nyírség

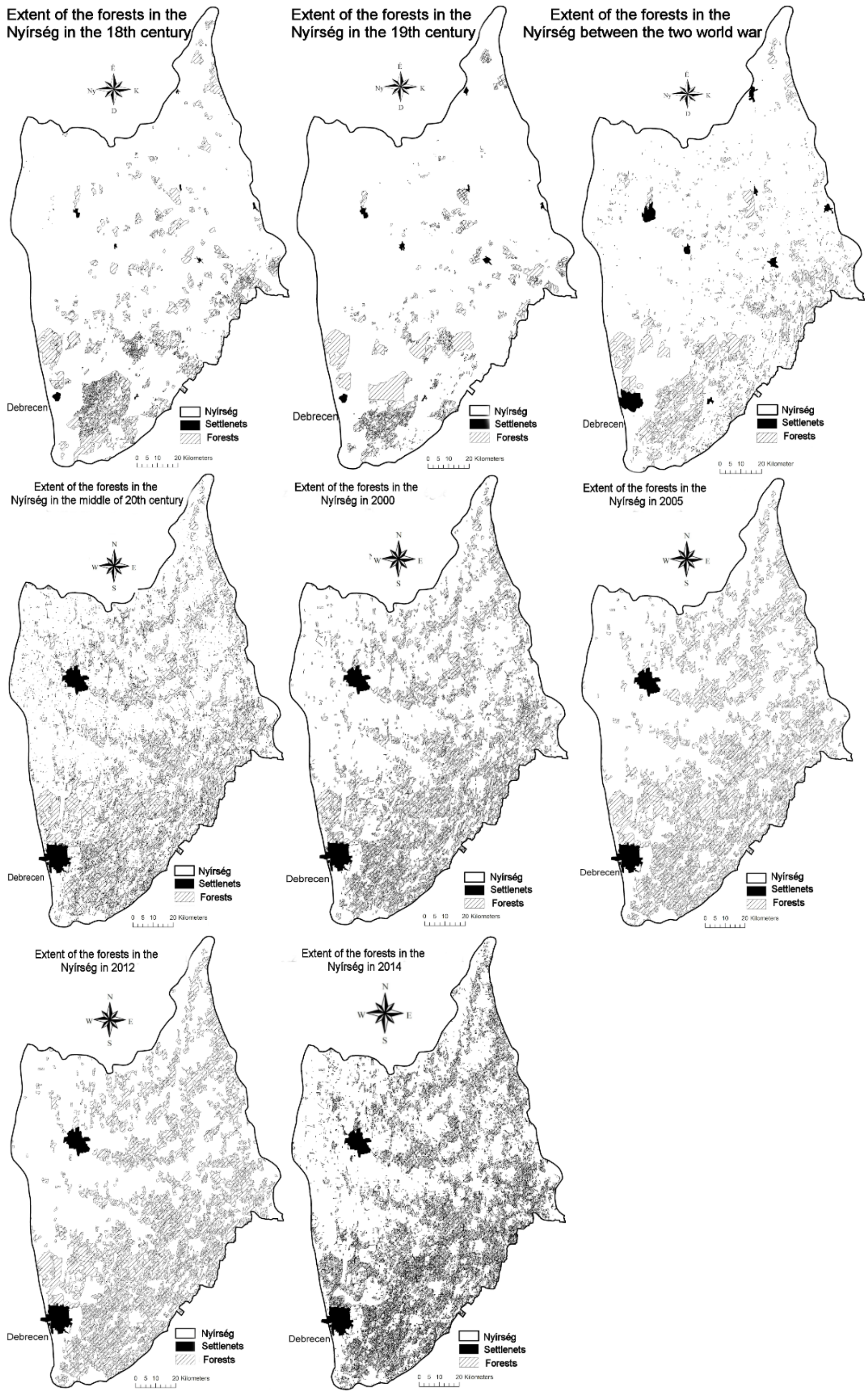

Fig 4. Changes of forest area in the Nyírség

3. b. The results of spatial extension of wind erosion measurements

Based on wind-erodibility measurements conducted in wind tunnel, in terms of susceptibility to wind erosion we classified the soils with sand and loamy sand textures as high risk; the sandy loam texture as moderate risk; and the silt loam and loam texture as low risk. The map constructed from the averaged experimental results and the CORINE (2012) database with the help of the soil texture map of the study area shows the potential erodibility of the Nyírség (Fig.5.) (2, 4).

To evaluate the wind erosion map of Nyírség we took into consideration the wind velocity above the soil texture types from the aspect of critical threshold velocity. In the majority of the Nyírség the winds do not exceed the critical velocity during the year, so albeit the soil and land use/land cover conditions would cause, wind erosion harm occur very rarely. In general arable lands situated on lowlands and covered by sandy soils are the most endangered by wind erosion, because they are featured by relatively small critical threshold velocity (6-7 m/s), consequently winds having even gentle energy are capable to transport the upper soil layer.

This map was created by with the co-operation University of Debrecen, Institute for Soil Sciences and Agricultural Chemistry and Hungarian Meteorological Service. (3)

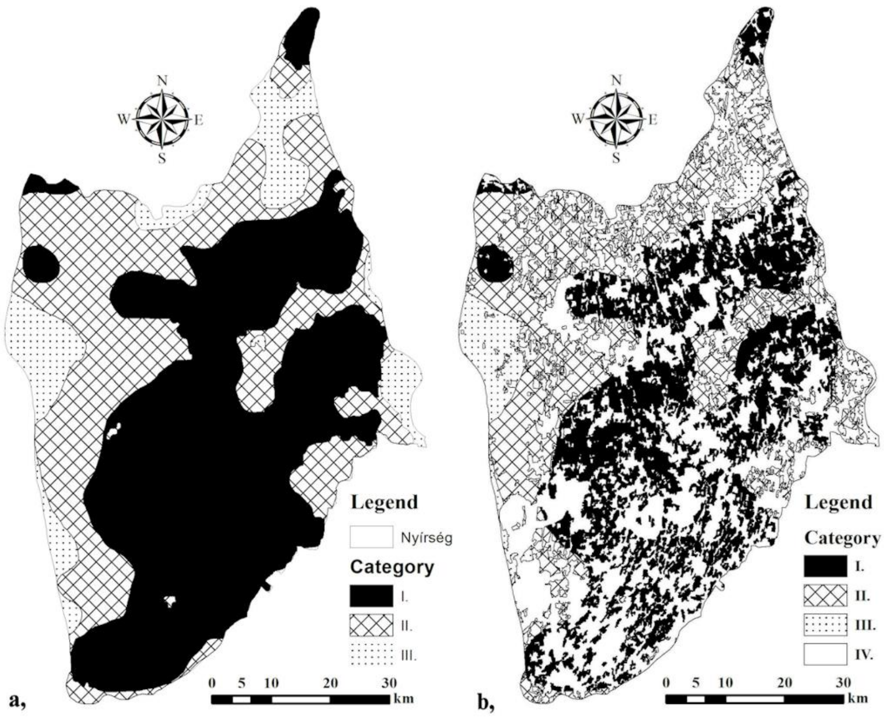

Fig. 5.

Fig 5. Potential wind-erodibility map of Nyírség

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