

## EFFECT OF CHANGES IN SOME CLIMATIC FACTORS ON WIND EROSION RISKS – THE CASE STUDY OF SOUTH MORAVIA

Jana Podhrázská, Josef Kučera, Filip Chuchma, Tomáš Středa, Hana Středová

**Received: May 16, 2013**

### Abstract

PODHRÁZSKÁ JANA, KUČERA JOSEF, CHUCHMA FILIP, STŘEDA TOMÁŠ, STŘEDOVÁ HANA: *Effect of changes in some climatic factors on wind erosion risks – the case study of South Moravia*. Acta Universitatis Agriculturae et Silviculturae Mendelianae Brunensis, 2013, LXI, No. 6, pp. 1829–1837

The intensity of wind erosion is determined by climatic factors (wind direction and wind speed, precipitation, temperature, humidity, presence of negative temperatures), soil and geological factors (geological composition of the area, the size and shape of soil particles, soil moisture, soil structure, mechanical stability of soil), vegetation factors (vegetation cover, crop residues), geomorphological factors (shape and distribution of the slopes, the incidence planes and leeward sites) and anthropogenic factors (length and orientation of land, farming, irrigation). Potential exposure of the wind erosion can be expressed through indexes of soil susceptibility to wind erosion in conjunction with the effects of climatic factors. In connection with the fluctuating values of climatic factors induced by climate changes, differences can be expected to occur also in the size of areas threatened by wind erosion. One of the areas, most endangered by wind erosion in the Czech Republic, is South Moravia. In this region there was performed the regionalization of localities, endangered by wind erosion. This paper presents results of analysis the erosion risks according to climatic and soil characteristics statistically processed for the period from 1901–1950. These are then compared with areas endangered by wind erosion that were established based on the updated set of climatic data and its statistical processing from the period of years 1961–2000. The results are processed into map outputs by using GIS.

wind erosion, climatic change, soil characteristics

The Czech Republic is situated in Europe within the temperate zone, in the central-European transitional climate sub-zone. It means that our climate is affected by the Atlantic Ocean and to a lesser extent by the Euro-Asian continent with the continental character of the climate growing from the west of the Czech Republic to its east border by about 10%.

Erosion and its consequences on agricultural land represent a process whose graduation is generally perceived on a pan-European scale. It is expected that the climate change will have further impacts on the European ecosystems, which will result in frequently repeated water deficits, more frequently occurring and severe drought spells and more frequent danger of floods on a larger part of the European territory.

Forecasting the influence of the fluctuating values or even permanent changes of meteorological constituents on the evolution of erosion processes requires to investigate relations between climatic conditions (precipitation, temperature, weather situation etc.) and other factors involved in erosion. Here we have to take into consideration namely morphological conditions, soils, geological basement and vegetation, which consequently influence other economic, technical and social conditions of land use (Toman, 1994). Regarding the character of agricultural land resources and their management, the Czech Republic has been struggling for already some time with the issue of erosion in general. In the field of wind erosion, the situation is even more complicated since wind erosion has been always perceived in the Czech Republic as a marginal problem and has not been

given virtually any attention since the 1970s. It is estimated that wind erosion potentially threatens ca. 10% of all arable land; some authors mention even up to 26% (Švehlík, 1996). In addition to these areas, wind erosion effects are also observed in open localities with drought prone fine-grained soils and regular and strong wind currents (Kubeš, 1996). Freezing and melting, these soils disintegrate during the winter time on the surface into very fine dust particles that are easily taken by wind (Švehlík, 1985). The spatial delimitation of areas susceptible to wind erosion is made by using soil and meteorological factors. Such maps were created for the territory of the former Czechoslovak Socialist Republic by Cablík and Jůva (1963), or Stehlík (1983); more recently also by Janeček *et al.* (2000) or within the framework of SOWAC GIS (2011).

In connection with temporal changes in the values of climatic factors we can assume that some differences will also reflect in the size of areas threatened by wind erosion. This paper presents results from the regionalization of areas endangered by wind erosion according to climatic and soil characteristics statistically processed for the period from 1901–1950 and compares them with the occurrence of areas endangered by wind erosion determined on the basis of an updated set of climatic data collected and statistically processed for the period from 1961–2000. The research results are GIS-processed into map outputs. The administrative unit of South Moravia was chosen as a model area. In respect of climatic conditions (low precipitation amounts, high sum of annual temperatures and low water security) and soils, the territory is considered highly risky as to the occurrence of wind erosion. The percentage of arable land is high in the region, especially in the districts of Znojmo and Vyškov where the soils are light, sandy and drought-prone.

## MATERIAL AND METHODS

Areas of increased wind erosion hazard were plotted by using the system of classified soil ecological units (BPEJ). The BPEJ classification system came to existence in 1973–1980 as a logical climax of the accomplished comprehensive research of soils in the Czech Republic (Mašát *et al.*, 2002). The system includes basic data on soils occurring in the country and consists of five-digit numerical codes. Each of the digits (or pairs of digits) in the code expresses a certain soil characteristic. The system makes it possible to define 2199 BPEJ for which economic characteristics are available as well. Thus, the BPEJ system reflects all specific traits and differences of a certain agronomic area (climate, soils and their morphology). The spatial division of individual BPEJ codes is expressed in the form of a digital set of BPEJ soil maps, i.e. by means of boundary lines around the respective BPEJ area units with their numerical designation. The system is used in the Czech Republic to establish administrative price of land. Apart from that, it is

used for example for various GIS analyses of soil and site characteristics according to the respective codes or their combinations.

In order to specify areas threatened by wind erosion, we used the data from the BPEJ code, which characterize climatic conditions of the areas, i.e. codes of climatic regions and soil characteristics – main soil units.

### Soil characteristics

By means of the second and third digit in the code, the BPEJ system includes characteristics of 78 main soil units. The main soil unit is formed by an aggregate of genetic soil types, sub-types, soil-forming substrates, soil texture and soil depth, degree of hydromorphism and relief of the area. In evaluating the area susceptibility to wind erosion, light and drought-prone soils with a low proportion of clay particles are considered as the most endangered.

### Climatic regions

Climatic regions include territories with approximately identical climatic conditions for the growth and evolution of agricultural crops. The categorization of climatic regions takes into account namely the factors of temperature and humidity recorded during the growing season of agricultural crops and affecting yields over a long term.

Basic criteria for the classification of climatic regions that should manifest identical conditions for the growth and development of agricultural crops considered in working out limit values for the respective climatic areas were as follows:

- sum of average daily temperatures equal or higher than 10 °C
- mean annual temperatures and mean temperatures in the growing season (IV–X)
- mean annual precipitation amount and precipitation in the growing season (IX–IX)
- probability of the occurrence of dry growing seasons in % (IX–IX)
- calculation of water security
- calculation of drought limit in the growing season and other factors, altitude, data about the known climate singularities and lastly but importantly also the factor of relief.

As groundwork for the regionalization of climatic regions for the purposes of soil classification in the BPEJ system, the Czech Hydrometeorological Institute (ČHMÚ) evaluated data from the period 1901–1950. This database served to establish 10 climatic regions with the defined intervals of climatic criteria (Tab. I).

Various authors (Středová *et al.*, 2012; Fukalová *et al.*, 2009; Rožnovský, 2008; Dufková, 2005) point out the fluctuation of climatic indicators and their dynamics in the latest tens of years in the Czech Republic.

In order to evaluate the development of individual climatic characteristics determining the climatic

I: Characteristics of climatic regions (Decree No. 327/1998 Coll. issued by the Ministry of Agriculture) from the 1901–1950 data

Code of the region	Symbol of the region	Region characteristic	Sum of temperatures above 10 °C	Mean annual temperature in °C	Mean annual precipitation amount in mm	Probability of dry growing seasons	Water security
0	VT	very warm, dry	2 800–3 100	9–10	500–600	30–50	0–3
1	T1	warm, dry	2 600–2 800	8–9	< 500	40–60	0–2
2	T2	warm, mildly dry	2 600–2 800	8–9	500–600	20–30	2–4
3	T3	warm, mildly humid	2 500–2 800	(7) 8–9	550–650 (700)	10–20	4–7
4	MT1	mildly warm, dry	2 400–2 600	7–8.5	450–550	30–40	0–4
5	MT2	mildly warm, mildly humid	2 200–2 500	7–8	550–650 (700)	15–30	4–10
6	MT3	mildly warm (to warm), humid	2 500–2 700	7.5–8.5	700–900	0–10	> 10
7	MT4	mildly warm, humid	2 200–2 400	6–7	650–750	5–15	> 10
8	MCH	mildly cold, humid	2 000–2 200	5–6	700–800	0–5	> 10
9	CH	cold, humid	< 2 000	< 5	> 800	0	> 10

regions, climatic data were collected and processed for the period 1961–2000, too.

New climatic regions were established by using a technical series of climatic data processed in the grid of 10 times 10 km. The technical data series are based on the ČHMÚ network of stations and are created for grid points of outputs from the regional climatic model ALADIN – Climate/CZ.

To be able to make a complex evaluation of the entire territory in question, certain representative sites had to be chosen for which the values of climatic regions would be ascertained and the sites would then form together comprehensive areas. For this purpose, the territory was covered by a regular network of square polygons 1 × 1 km. Average value was calculated for the area of each polygon from the original grids of climatic characteristics by using geo-statistical methods in the GIS environment. Thus, a GIS layer of polygons was created with the table of attributes containing values of all five climate characteristics for each polygon. Furthermore, a corresponding number of the climatic region was ascertained for each polygon according to the interval of the values of climatic characteristics.

A simple synthesis of grids that would distinguish the climatic regions appeared to be problematic. The reason were differences between the values of temperatures and precipitation amounts in the period 1901–1950 (based on which the boundaries of climatic regions had been established) and the values recorded in the period 1961–2000.

In a majority of cases, the difference occurred in the probability of dry growing seasons. The reason is that the calculation entered the indicator of mean temperature the value of which increased in the period 1961–2000 as well as the indicator of mean precipitation amounts, which did not show any significant change; a change was however recorded rather in the volume of precipitation amounts in individual seasons of the year, e.g. vegetation period.

In this decision-making process, the importance of individual climatic characteristics was considered, too. The least emphasis was put on the probability of dry growing seasons, which was the most

problematic, and the fluctuation of values within one climatic region was conspicuous. On the other hand, the greatest emphasis was put on the values of temperature sums, precipitation amounts and water security. The statistical processing of the 1961–2000 data and its expert evaluation resulted in the creation of polygons expressing the new whole-area delineation of climatic region in the administrative unit of South Moravia.

### Establishing the potential wind erosion threat to soils in the concerned area

The potential wind erosion threat to soils in the South Moravia region was determined by using the methodological procedure introduced by Janeček (2000; In: Podhrázská, 2008). Climatic regions and main soil units were categorized according to their exposure to wind erosion and were allocated a susceptibility factor, in which the lowest value indicates the lowest susceptibility to wind erosion. Soils were classified according to the content of clay particles within a 4-point system (0 = non-threatened, 2 = slightly threatened, 4 = threatened, 6 = most threatened).

For the climatic regions we reckoned only the first five numbers (code numbers 0–4) standing for “very warm, dry” up to “mildly warm, dry”. The risk categories were established from 6 (most hazardous) to 2 (least hazardous). Areas reaching into other climatic regions (code numbers 5–9) were classified as non-susceptible, however just from the viewpoint of climatic region, not from the viewpoint of soil conditions that were taken into account in all regions.

The resulting assessment of the potential wind erosion threat is then expressed by the weighted average of the product of individual factors and area representation of individual BPEJ codes (threat coefficient) in six categories (Tab. II).

Areas of wind erosion hazard were regionalized through a synthesis of the layers of climatic regions and soil characteristics into categories from 1 to 6 with the lowest number standing for the lowest wind erosion threat.

## II: Categories of wind erosion threat to cadastral areas

Category	Threat coefficient	Degree of threat
1	< 4	No threat
2	4.1–7	Susceptible soils
3	7.1–11	Slightly susceptible soils
4	11.1–17	Endangered soils
5	17.1–23	Severely endangered soils
6	> 23.1	Most endangered soils

## RESULTS AND DISCUSSION

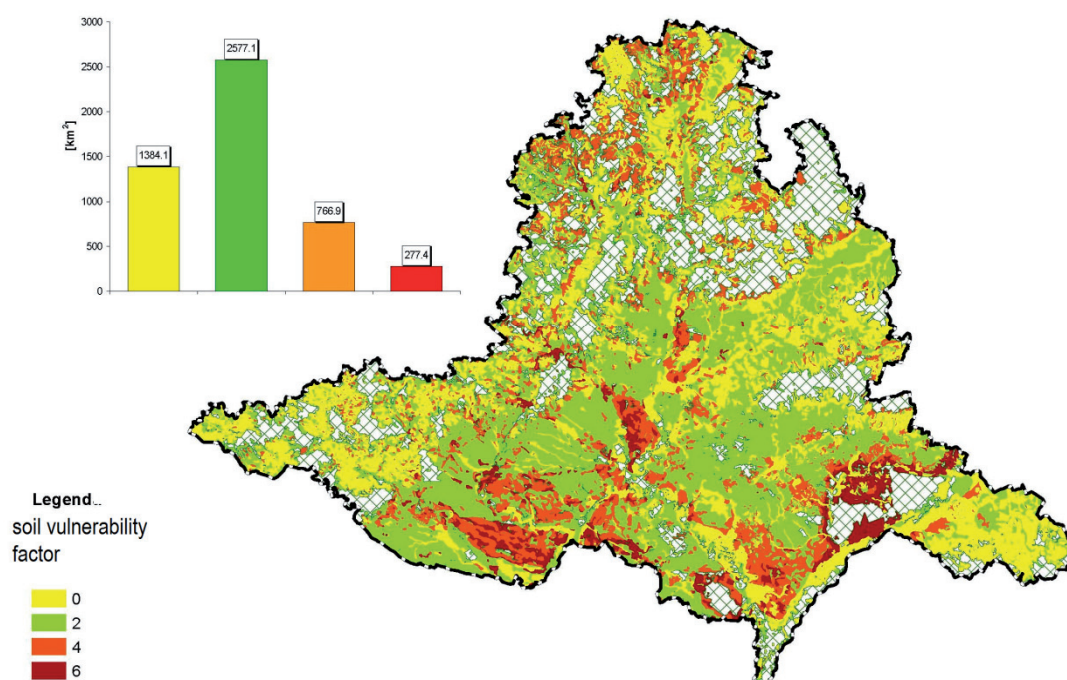
The above-described procedures were used to generate maps of wind erosion threat in the concerned territory in two following variants: soils threatened by wind erosion according to the existing boundaries of climatic regions and soils threatened by wind erosion according to the area representation of individual regions that have been newly delineated. For the period from 1901–1950, the isolines of individual climatic regions had been given by the BPEJ database. However, for the period from 1961–2000, the isolines had to be newly constructed based on the statistically processed data and the above-mentioned decision-making processes. The first maps created by this way was the map of soils categorized according to the factor of threat (Fig. 1) and two maps of climatic regions delineated on the basis of data processed for the periods 1901–1950 and 1961–2000 (Figs. 2 and 4).

Due to the changed values of climatic factors, the size of areas classified as CR 0 (very warm, dry) increased, and the size of areas classified as CR 2

(warm, mildly dry), CR 3 (warm, mildly humid) and CR 4 (mildly warm, dry) decreased. The decrease of the last-mentioned regions resulted from the fact that a new region 1 was delineated in the territory (warm, dry), which originally had not occurred in South Moravia in the period 1901–1950. In general, the area of regions threatened by wind erosion (CR 0–4) increased from 82.9% of the concerned territory to 87.9%. Climatic regions 5–9 have no influence on the hazard of wind erosion.

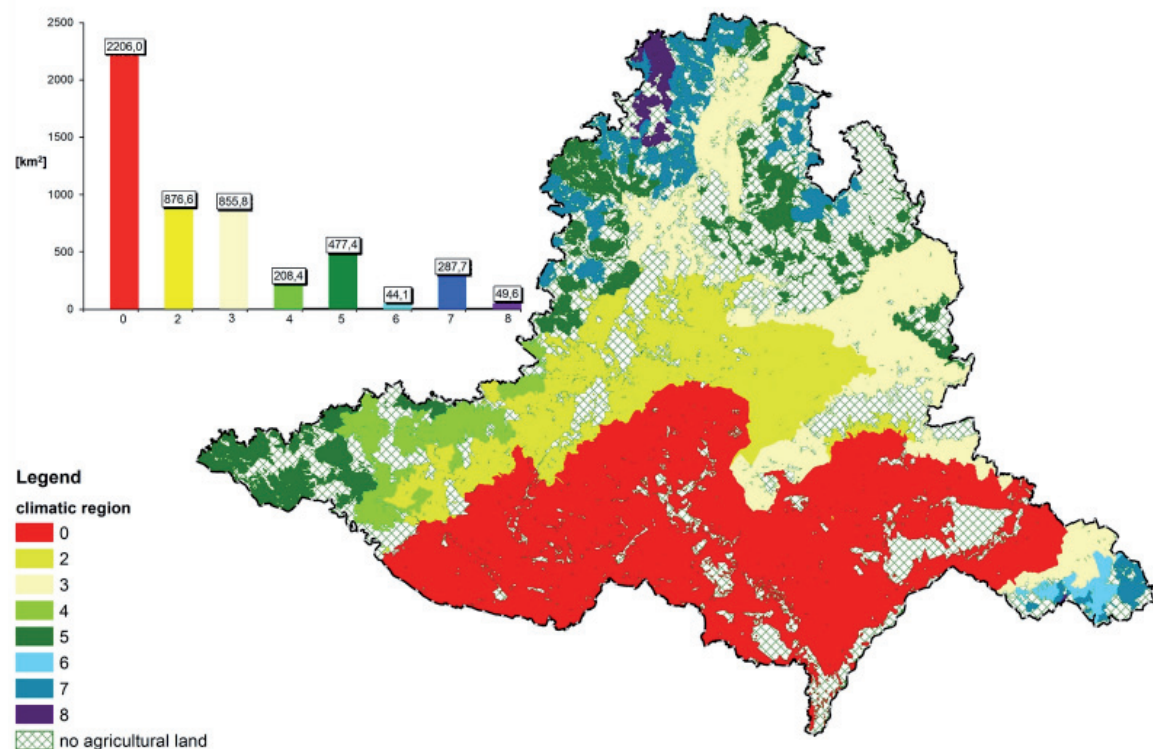
Climatic regions 0–4 were chosen for studying the wind erosion risks in the administrative region of South Moravia. Maps were created through a synthesis with the map of wind erosion threat to soils, delineating areas potentially endangered by wind erosion. Fig. 6 presents areas created according to the currently used data. Fig. 8 presents a map delineating areas endangered by wind erosion according to the newly created boundaries of climatic regions

The presented maps and diagrams show that as compared with the previous period, the size of areas susceptible to wind erosion increased in 1961–2000 due to the changes of climatic factors. The square area of soils non-threatened by wind erosion decreased from nearly 40% of the total area surface to about 35%. The representation of susceptible sites decreased nearly by 5%. Slightly endangered sites increased nearly by two percent and threatened sites increased nearly by 5%. The share of severely endangered and most threatened climatic regions increased nearly by 2% and more.

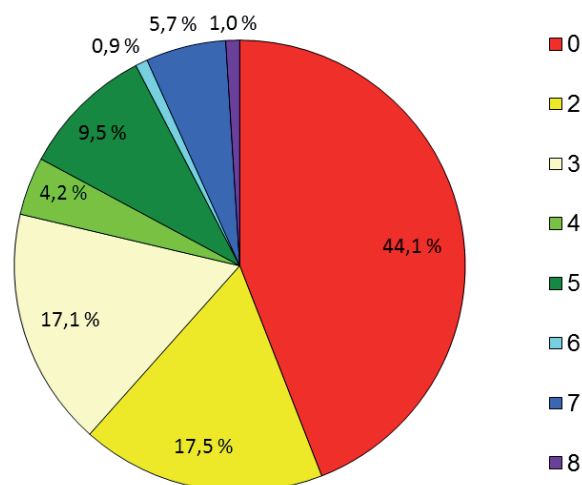


1: Categorization of wind erosion threat to soils based on their texture characteristics according to the main soil units (HPJ)





2: Map of climatic regions according to climatic characteristics processed for the period from 1901–1950

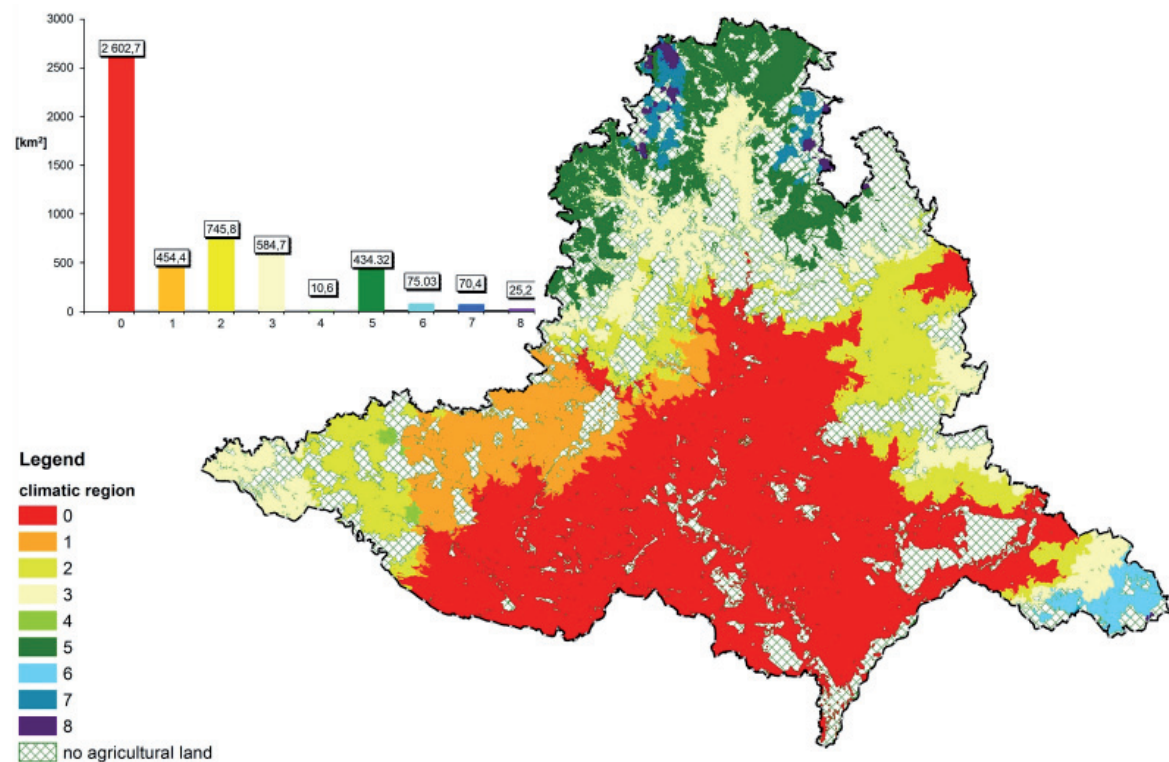


3: The percentage representation of climatic regions according to climate characteristics processed for the period from 1901–1950

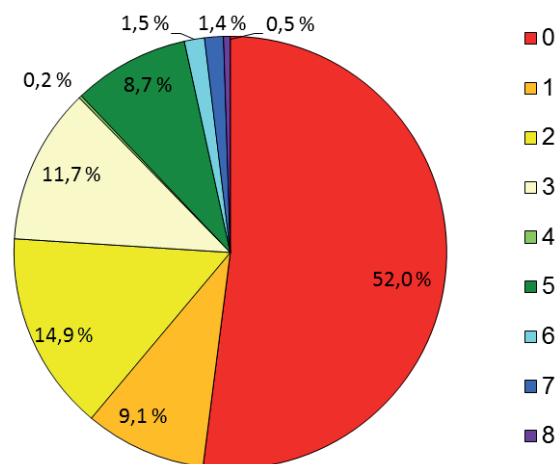
## CONCLUSION

Wind erosion and its consequences are in the Czech Republic still perceived as a marginal problem. Preference in solution is given to water erosion as required by the legislation of the European Union. Nevertheless, the risks of wind erosion will have to be taken into account too in connection with the development of climate.

The results of our research corroborate a shift in the values of some climatic factors, which may have a continuing trend. In any case, it will be necessary to reevaluate the approach to spreading wind erosion in the conditions of the Czech Republic and to pay more attention to a possible increase of its risks, harmful consequences and to prepare a concept for the solution of wind erosion control measures in the threatened regions.



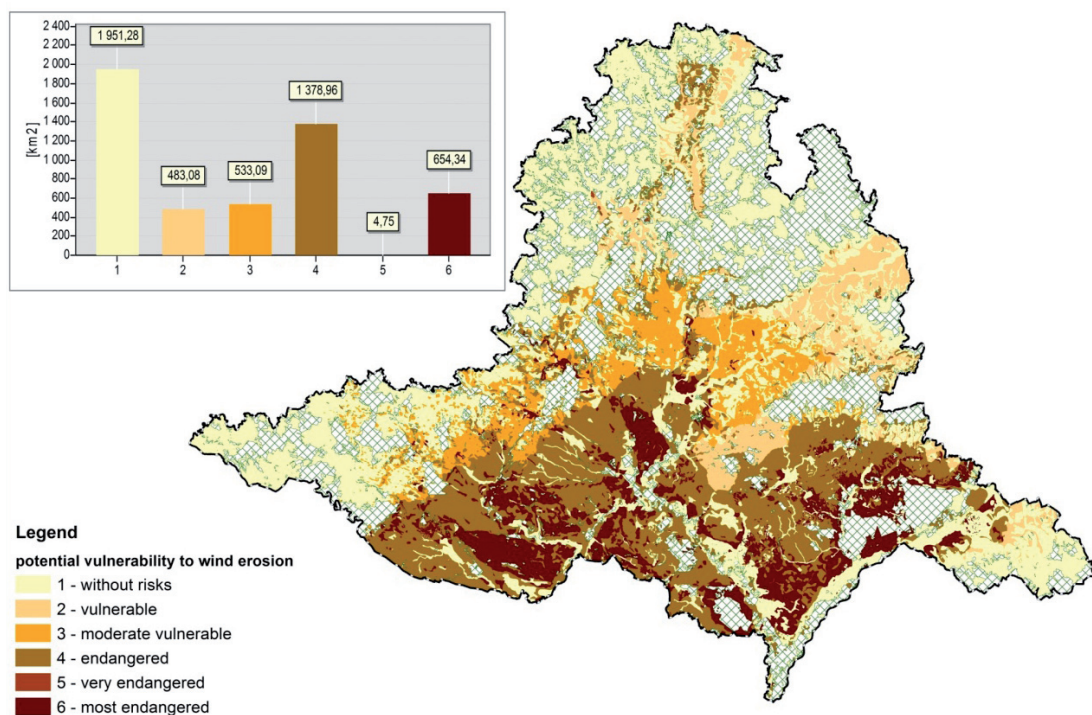
4: Map of climatic regions according to climatic characteristics processed for the period from 1961–2000



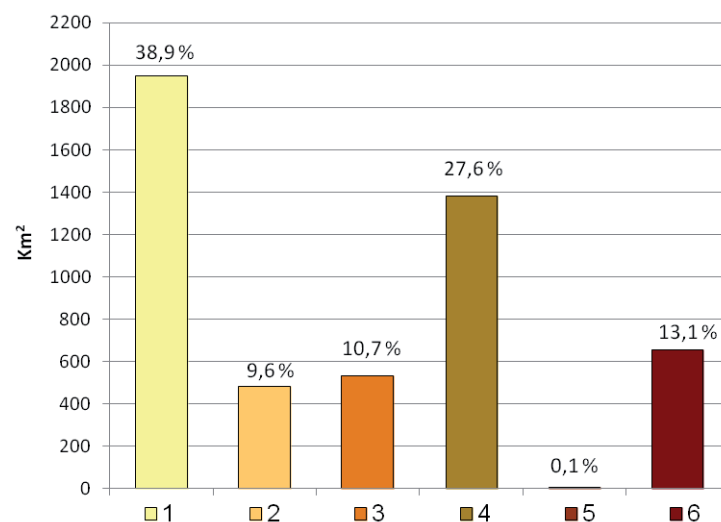
5: The percentage representation of climatic regions (CR) according to climate characteristics processed for the period from 1961–2000

## SUMMARY

Although the wind erosion is still considered as a marginal problem in the Czech Republic, recent studies show that it is necessary to deal with this phenomenon in more detail. Risk of wind erosion are connected mainly with the effects of climatic and soil factors and land use. Among the most vulnerable regions in the Czech Republic, endangered by wind erosion, belongs South Moravia. This is due to the intensity of farming and the occurrence of slightly erodible soils and climatic conditions, supporting the creation of erosion processes – the territory is mainly in dry and warm. In this study there was used a method to determine potential exposure of soil to wind erosion through the indexes of soil susceptibility to wind erosion in combination with the climatic characteristics of the area. Soils, situated in the area, were divided into 4 levels of vulnerability, according their selected soil characteristics. Using a digital database of soil characteristics in the investigated area there were

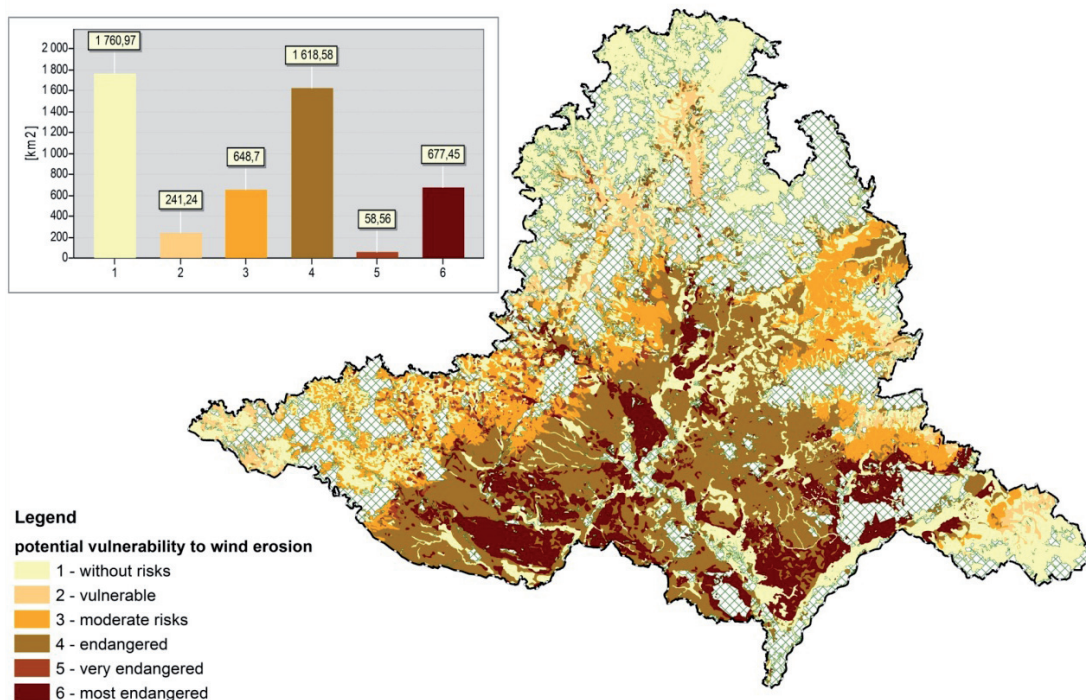


6: The up-dated synthetic map of areas endangered by wind erosion in the administrative region of South Moravia (synthesis of maps 1 and 2)

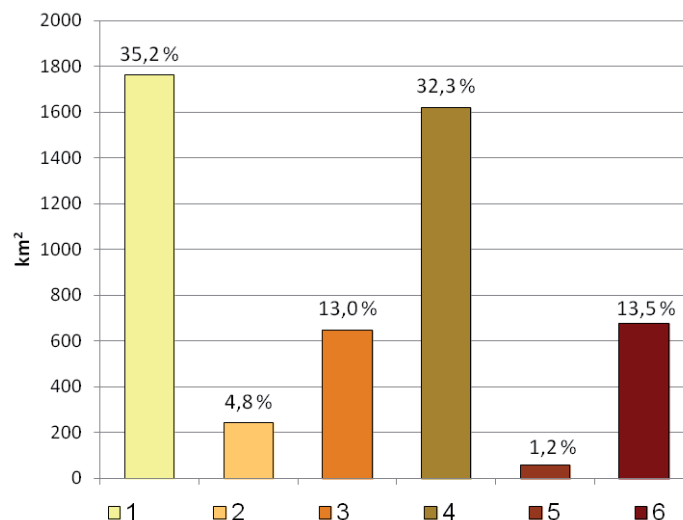


7: The percentage representation of areas endangered by wind erosion in the administrative region of South Moravia according to the threat category 1-6 (1901-1950)

subsequently created polygons defining the different susceptibility of soils to erosion? To evaluate the climatic characteristics there was used the method of climatic regionalization, based on the evaluation of the area by the temperature and humidity characteristics. As the climatic regions were determined by using the values from the years 1901–1950, there was performed a new regionalization of climate data by using values from the years 1961 to 2000. To determine the new climatic regions there was used technical range of climatic data processed in a grid network 10 x 10 km. Technical data series are based on the station CHMI networks and are designed for grid points outputs of regional climate model ALADIN – Climate / CZ. Statistical data processing 1961–2000 and their expert evaluation led to the creation of polygons representing the new spatial determination of climatic regions in the South Moravian Region.



8: The up-dated synthetic map of areas endangered by wind erosion in the administrative region of South Moravia (synthesis of maps 1 and 4)



9: The percentage representation of areas endangered by wind erosion in the administrative region of South Moravia according to the threat category 1-6 (1961-2000)

By the synthesis of layers of climatic regions and soil characteristics for the two analysed periods (1901-1950 and 1961-2000) there were regionalised areas vulnerable to wind erosion, in categories 1-6. From the performed analysis results that through the changes in climate factors in the years 1961-2000 the area very dry, respectively dry and warm (CR 0-3) was spread in comparison with the previous period, i.e. the area threatened by wind erosion was extended from 78.7% of the area up to 87.7%. In combination with the soil properties and their level of risk to erosion the areas slightly vulnerable to most endangered increased by 8.5%.

#### Acknowledgement

This paper was written under support of the research project no. MA NAAR QJ122054.



## REFERENCES

- CABLÍK, J., JŮVA, K., 1963: *Erosion control of soils* (in Czech). 1st edition, Prague: SZN Praha, 324 pp.
- DUFKOVÁ, J., ROŽNOVSKÝ, J., POKLADNÍKOVÁ, H., 2005: Application of climate change scenarios on meteorological elements affecting wind erosion (in Czech). *Meteorologické zprávy*, 58, 2: 47–50. ISSN 0026-1173.
- FUKALOVÁ, P., ROŽNOVSKÝ, J., CHUCHMA, F., 2009: Analysis of periods with no precipitation in the conditions of the current and future climate in South Moravia (in Czech). In: *The XVII poster day with international participation "Transport of water, chemicals and energy in the soil-plant-atmosphere system"*. Bratislava: ÚH and GFÚ SAV Bratislava, p. 118–128. ISBN 978-80-89139-19-4.
- JANEČEK, M., TIPPL, M., PIVCOVÁ, J., VETIŠKOVÁ, D., 2000: *Methods for restricting the degradation of soils by erosion and erosion control systems. Maps of the potential water and wind erosion threat to agricultural soils in the Czech Republic* (in Czech). Output from the project No. NAZV EP7057. Prague: VÚMOP Praha-Zbraslav. Available online [www.sowac-gis.cz](http://www.sowac-gis.cz).
- KUBEŠ, J., 1996: Biocentres and corridors in a cultural landscape. A critical assessment of the "territorial system of ecological stability". *Landscape and Urban Planning*, 35, 3: 231–240. ISSN 0169-2046.
- MAŠÁT, K. et al., 2002: *Methodology for the delineation and mapping of classified soil ecological units* (in Czech). Prague: VÚMOP, 113 s. ISBN 80-238-9095-6.
- ROŽNOVSKÝ, J., 2007: Current development of weather and its influence on the growing of field crops (in Czech). In: *Proceedings from the 24th evaluation seminar "System for oilseed rape production, system for sunflower production"*. Hluk 21–22 Nov. 2007. Prague: SPZO s. r. o. and Dolňácko, a. s., p. 277–285. ISBN 978-80-87065-03-7.
- PODHRÁZSKÁ, J. et al., 2008: *Optimization of functions of shelterbelts on agricultural land*. Methodics. Brno: RISWC, 38 pp. ISBN 978-80-904027-1-3.
- STEHLÍK, O., 1983: *Potential soil erosion in the Czech Socialist Republic* (in Czech). Map. Brno: Geografický ústav ČSAV, Praha: Geodetický a kartografický podnik.
- STŘEDOVÁ, H., ROŽNOVSKÝ, J., STŘEDA, T., KRMELOVÁ, P., 2012: Assessing temperature and precipitation extremes in some arid zones of the Czech Republic (in Czech). In: *Život na venkově a trvale udržitelné zemědělské hospodaření v prostředí extrémních projevů sucha*. Prague: Ministry of Agriculture, p. 43–50. ISBN 978-80-87577-11-0.
- ŠVEHLÍK, R., 1996: *Wind erosion of soils in southern Moravia* (in Czech). Uh. Brod: CICERO plus, 108 s. ISBN N.
- TOMAN, F., 1994: Possible impact of anticipated climate changes on the erosion threat to soils (in Czech). In: *Klimatická změna a zemědělství*. Proceedings UAKE VŠZ Brno, p. 50–52.

## Address

Ing. Jana Podhrázká, Ph.D., Research Institute for Soil and Water Conservation, Lidická 25/27, 602 00 Brno, Czech Republic, Ing. Filip Chuchma, Czech Hydrometeorological Institute, Kroftova 1, 616 67 Brno, Czech Republic, Ing. Tomáš Středa, Ph.D., Department of Applied and Landscape Ecology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, Ing. Hana Středová, Ph.D., Department of Applied and Landscape Ecology, Mendel University in Brno, Zemědělská 1, 613 00 Brno, Czech Republic, e-mail: [podhrazska.jana@vumop.cz](mailto:podhrazska.jana@vumop.cz), [filip.chuchma@chmi.cz](mailto:filip.chuchma@chmi.cz), [streda@mendelu.cz](mailto:streda@mendelu.cz), [hana.pokladnikova@seznam.cz](mailto:hana.pokladnikova@seznam.cz)