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INFLUENCE OF CLIMATE CONDITIONS ON THE INTENSITY AND SPREADING OF WIND EROSION

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Abstract

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The influence of climate conditions on the intensity and spreading of wind erosion was considered in the area of South Moravia. For this purpose, 16 meteorological stations were selected on the basis of accessibility of required data, their adequate representativeness, homogeneity, and position of the stations. It was necessary to make the database of climatological factors (such as wind velocity, precipitation and air temperature) of the period of 1961–2003 for the analyses of climatological data. The climatological data was then evaluated for the periods of 1961–2003, 1961–1990, 1991–2000, and 1971–2000. Climatic erosion factor, which explains potential erodibility of soil by wind, was determined through the analyses of factors influencing the wind erosion. The assessment of influence of expected climate change on the intensity and spreading of wind erosion consists in the selection of suitable climatological model and climate change scenarios on the basis of ability to model the three climatological factors (wind velocity, precipitation and air temperature). Climate change scenarios were then applied on the data of the selected climatological stations and the assessment of changes in data sets and the comparative analysis of the outputs of the scenarios with measured data from the normal period of 1961–1990 were done. The climatic erosion factor was also determined from the altered data of the scenarios.

wind erosion, climatic erosion factor, climate change, climate change scenario

In nature, climatic factors do not always exercise a favourable effect, but in some cases they cause considerable damage or even catastrophes. A majority of these phenomena have an unfavourable effect because we are unable to control them. The primary cause of soil erosion is climatic phenomena.

Problem of erosion of agriculturally used soils requires proper attention because it has become a worldwide problem. Every year thousands square kilometres of agricultural soil lose on the Earth. Recently global climate change influences the soil erosion more and more.

The aim of the paper was to determine the influence of climate conditions on the intensity and spreading of wind erosion in the selected areas of Southern Moravia and consider the influence of expected climate change on the wind erosion.

MATERIAL AND METHODS

Wind erosion consists of a destruction of the soil surface through the mechanical force of wind (abrasion), of a carrying away of soil particles by wind (deflation) and of their depositing at another place (accumulation).

Wind erosion is influenced above all by these basic factors:

- meteorological factors – wind velocity, time of wind duration and occurrence frequency,
- pedological factors – soil structure and soil humidity.

The soil humidity is defined by the amount and distribution of precipitation and influenced by temperature, air humidity and wind, which define the evapotranspiration and loss of soil humidity. Wind erosion is dependent on the three main climatological (meteorological) factors – on wind, precipitation and air temperature. The influence of climate conditions on the intensity and spreading of wind erosion is well represented by the equation including all the mentioned climatological factors. Chepil et al. (1962) has called the equation the erosion climatic factor C. The erosion climatic factor C expresses the influence of the average soil surface humidity and the average wind velocity on the average soil erodibility by wind.

The changes of the erosion climatic factor influenced by the variability of meteorological factors that come from were monitored on the data coming from some climatological (meteorological) stations.

Characterization of meteorological stations

Data from 16 selected meteorological stations of Southern Moravia were used for the determination of the influence of climate conditions on the intensity and spreading of wind erosion (Tab. I). The meteorological stations were chosen on the basis of accessibility of required data, their adequate representativeness, homogeneity, and setting of the stations.

I: *Selected meteorological stations of Southern Moravia*

Meteorological station		Longitude	Latitude	Elevation (m)
Indicative	Name			
004	Žabčice	49°00‘44“	16°36‘03“	179
636	Kostelní Myslová	49°09‘36“	15°26‘21“	569
667	Moravské Budějovice	49°02‘58“	15°48‘30“	457
685	Nedvězí	49°38‘06“	16°18‘36“	722
686	Bystřice nad Pernštejnem	49°30‘54“	16°15‘00“	573
687	Velké Meziříčí	49°21‘14“	16°00‘31“	452
698	Kuchařovice	48°53‘00“	16°05‘00“	334
716	Protivanov	49°28‘38“	16°49‘54“	670
723	Brno-Tuřany	49°09‘35“	16°41‘44“	241
724	Pohořelice	48°58‘39“	16°31‘00“	183
725	Velké Pavlovice	48°54‘31“	16°49‘28“	196
749	Ivanovice na Hané	49°18‘32“	17°05‘22“	245
754	Staré Město u Uherského Hradiště	49°05‘30“	17°25‘54“	235
755	Strážnice	48°53‘57“	17°20‘17“	176
774	Holešov	49°19‘07“	17°34‘24“	223
777	Vizovice	49°13‘23“	17°50‘38“	315

Data concerning the wind velocity (average wind velocity in $m.s^{-1}$ at 2 p.m. during the vegetative period and average annual wind velocity in $m.s^{-1}$), amount of precipitation (month sum in mm) and air temperature (average air temperature in °C during the vegetative period) – all for the period of 1961–2003 – were necessary for the evaluation of the influence of climate conditions on the intensity and spreading of wind erosion.

Meteorological factors influencing the wind erosion

Wind (velocity, direction, frequency and time of duration) is the most important climatological factor for the expansion of erosion processes. It affects negatively the soil surface with its kinetic energy, which frees, puts in motion and on the other place accumulates the soil particles under the influence of air drift intensity.

The amount and especially regular distribution of precipitation has propitious indirect effect on the decreasing of wind erosion intensity by the obtaining of moisture for the good vegetation state and preservation of soil humidity.

Air temperature is together with the precipitation the main factor that determines the climatic character of the region. The air temperature and its time behaviour have direct effect on the air humidity, on the evaporation of soil and transpiration of vegetation. The air temperature influences not only the soil humidity but also the quality and stage of grown plants. Consequently, the air temperature influences in the combination with the precipitation the erodibility of soil by wind.

Erosion climatic factor C

Erosion climatic factor C depends on the wind velocity and effective soil surface humidity. Chepil et al. (1962) presents the relationship for the erosion climatic factor by equations (1):

$$C = \frac{v^3}{(I_T + 60)^2} \times \frac{100}{1.9}, \qquad (1)$$

where C = erosion climatic factor, v = average annual wind velocity in the high of 10 m above the ground (mile per hour) and I_T = Thornthwaite's humidity index.

Erosion climatic factor C from the equation (1) expresses the loss of soil which can arise in the particular area as the percentage rate from the soil loss in Garden City, when the other factors of the two comparative areas are similar (Pasák et Janeček, 1971a).

The Thornthwaite's humidity index I_T can be substitute for Konček's humidity index I_Z (2):

$$I_Z = \frac{R}{2} + \Delta r - 10t - (30 + v^2), \qquad (2)$$

where R = sum of precipitation during the vegetative period (IV–IX) (mm), Δr = positive deviation of precipitation amount of three winter months (XII–II) from the value of 105 mm (mm) (negative values not reflected), t = average air temperature of vegetative period (°C), v = average wind velocity at 2 p.m. during the vegetative period ($m.s^{-1}$).

Maps of the Konček's humidity index for the whole vegetative period give the same image as the maps for Thornthwaite's humidity index. However, Konček's scale is three times more sensitive than the Thornthwaite's one (Konček, 1955).

The equation (1) for the determination of the erosion climatic factor in our conditions was modified to the following form (3) (Dufková, 2004):

$$C = \frac{5620.23 \times v^3}{(I_Z + 183.59)^2}, \qquad (3)$$

where v = average annual wind velocity in the high of 10 m above the ground ($m.s^{-1}$) and I_Z = Konček's humidity index.

Various soil types are differently threatened by wind erosion. Light soils with the content of clay soil particles 0–20% have the largest erodibility. Soils with the higher content of clay particles are threatened by wind erosion less (Pasák and Janeček, 1971b). Therefore the threatened areas of the Czech Republic by wind erosion were divided into six degrees according to the erodibility of soil depending on percentage content of soil particles < 0,01 mm (Tab. II) (Janeček, 1997). Map of soil types was used for delimiting of the areas. The criterion between light and medium soils, e.g. 20% content of clay particles, was chosen as the divided boundary line (Pasák, 1970).

II: *Degrees for evaluation of threat of soil by wind erosion (Janeček, 1997)*

Degree of threat		Erosion climatic factor C	% content of clay particles (< 0,01 mm)
I.	without treat	< 20	> 30
II.	very low	20–40	> 30
III.	low	20–40	20–30
IV.	medium	20–40	0–20
V.	high	> 40	> 30
		> 40	20–30
VI.	very high	> 40	0–20

Climate modelling

Modification of the climate data influencing the wind erosion, e.g. wind velocity, precipitation amount and air temperature, was done with two models – ECHAM4 and HadCM2 (Kalvová et al., 2002) with various climatic sensitivity and various emission scenarios. Altogether, four scenarios of climate change were used – four variants of future climate trend within 2050. Normal time period 1961–1990 was taken as the reference period. The short names of climate change scenarios EB1-low, EA2-high, HB1-low a HA2-high in Tab. III, IV a V mean using of the model E = ECHAM4, H = HadCM2, B1 = scenario with low emission of greenhouse gases (GHGs), A2 = with high emission of GHGs, low = low climatic sensitivity and high = high climatic sensitivity of the model.

III: *Wind velocity, change in % (Kalvová et al., 2002)*

Model	ECHAM4		HadCM2	
Emission scenario	SRESB1	SRESA2	SRESB1	SRESA2
Climatic sensitivity	low	high	low	high
1	1.2	3.2	–0.6	–1.6
2	1.6	4.5	–1.8	–4.9
3	1.2	3.3	–0.8	–2.1
4	–1.3	–3.4	–0.6	–1.8
5	0.7	1.8	0.9	2.5
6	–0.1	–0.3	–0.1	–0.3
7	–1.8	–4.8	0.5	1.4
8	–3.5	–9.7	–0.2	–0.5
9	0.4	1.2	0.3	0.8
10	0.7	2.0	1.3	3.7
11	0.4	1.1	1.3	3.6
12	–0.9	–2.5	1.2	3.2
Year	–0.1	–0.3	0.1	0.3

IV: *Precipitation, change in % (Kalvová et al., 2002)*

Model	ECHAM4		HadCM2	
Emission scenario	SRESB1	SRESA2	SRESB1	SRESA2
Climatic sensitivity	low	high	low	high
1	3.1	8.6	–0.5	–1.4
2	4.6	12.6	–1.8	–4.9
3	3.1	8.4	1.3	3.6
4	–6.6	–18.0	1.9	5.2
5	3.3	9.0	0.3	0.7
6	–1.0	–2.7	1.0	2.8
7	–2.8	–7.8	–2.7	–7.4
8	–5.9	–16.1	–6.7	–18.3
9	3.8	10.3	–5.9	–16.0
10	–2.2	–6.2	7.9	21.7
11	2.0	5.4	3.5	9.6
12	–1.8	–4.9	2.7	7.5
Year	0.0	–0.1	0.1	0.3

V: *Average daily air temperature, aditive change in °C (Kalvová et al., 2002)*

Model	ECHAM4		HadCM2	
Emission scenario	SRESB1	SRESA2	SRESB1	SRESA2
Climatic sensitivity	low	high	low	high
1	1.4	3.8	1.0	2.6
2	1.6	4.4	1.1	2.9
3	1.2	3.4	0.7	1.9
4	1.1	2.9	0.5	1.4
5	0.7	2.0	0.5	1.4
6	0.7	2.0	0.7	1.8
7	1.1	2.9	0.8	2.2
8	1.3	3.6	1.1	2.9
9	0.9	2.6	1.3	3.5
10	1.0	2.6	1.1	2.9
11	1.2	3.2	1.0	2.7
12	1.0	2.8	1.2	3.4
Year	1.1	3.0	0.9	2.5

Proposed climate change scenarios were applied on the data from 16 selected meteorological stations and the results were compared with month averages of the standard climatological period 1961–1990. Obtained results were analysed with respect to the differences between measured data and individual scenarios for the evaluated climatological factors of the measured period.

Subsequently, the erosion climatic factor was calculated as from the data of present climate, as from the data of changed climate (by climate scenarios).

RESULTS AND DISCUSSION

Maximum wind velocity of the most areas is observed at the end of winter and at the beginning of the spring, when the arable soil is not protected by vegetation. The maximum wind velocity of the selected climatological stations of Southern Moravia was monitored in the normal period 1961–1990, on the contrary the minimum in the last decade 1991–2000. The wind velocity linear trend is not evidential in the area of the Czech Republic, despite the fact that statistically significant trends could be found in the time series of wind velocity of almost all the stations during all the studied periods (1961–2003, 1961–1990, 1991–2000 and 1971–2000). The used climatic scenarios suppose the largest differences of average daily wind velocity in the cold part of the year, when the negative effects of wind erosion does not occur because of the frozen soil surface (Streďanský, 1981), and then in summer, when the soil is protected by vegetation. The supposed change is not considerable in the other months of the year. From the total evaluation it is possible to expect that the wind velocity will not change and when the other factors influencing the wind erosion stay at the same level, the erodibility should not increase.

The trend of precipitation for the period of 1961–2003 expresses decreasing almost at all the studied stations. When only the normal period 1971–2000 or the last decade 1991–2000 is evaluated, the trend of average annual precipitation sums is increasing at all the stations. According to the climate change scenarios, the annual sum of precipitation will decrease a few or it will stay at the same level as at the present time. Observed or by the scenarios predicted changes in the annual course of precipitation are important. And just these changes could have the substantial negative impacts on the threat of soils by wind erosion, especially in the spring time.

The air temperature is the only climatic factor from the three analysed that gives clear idea about its trend in the future. All the climatic scenarios give the increase in the average air temperature during all the months. The increase confirms also the increasing linear trend of the average month air temperature for the monitored period 1961–2003 at all the analysed climatological stations. The air temperature influences the evapotranspiration and hereby also the soil humidity. Generally, it can be stated that the lower the soil humidity is, the larger the threat by wind erosion exists. It is evident that impact of expected climate change will appear in the significant spreading of soils threatened by wind erosion.

The values of erosion climatic factor grow up during the studied period of 1961–2003 what theoretically means the increasing of potential threat of soil by wind erosion (Tab. VI). The increasing trend is the most apparent at the stations of warm and dry areas. Also climate change scenarios predict the increase in values of erosion climatic factor (Tab. VII).

VI: *Potential threat of soil by wind erosion on the basis of the comparison of maximum values of erosion climatic factor C for the analysed time periods and on the basis of the clay particles content in the soil (found out from the map of prevailing soil types in the Czech Republic)*

Station	Clay particles (%)	1961–2003	1961–1990	1991–2000	1971–2000
004	> 60	51.3	10.8	17.9	17.9
636	30–45	20.1	20.1	8.1	20.1
667	30–45	7.9	5.3	7.9	7.9
685	30–45	45.2	45.2	31.9	45.2
686	30–45	11.6	6.7	11.6	11.6
687	20–30	15.1	7.5	15.1	15.1
698	30–45	184.6	184.6	48.1	184.6
716	45–60	52.8	23.7	52.8	52.8
723	30–45	48.1	48.1	41.4	48.1
724	> 60	7.9	5.8	7.9	7.9
725	30–45	54.8	7.1	25.6	25.6
749	30–45	4.4	4.0	3.3	3.3
754	10–20	68.1	32.6	68.1	68.1
755	10–20	44.6	20.1	44.6	44.6
774	30–45	8.4	5.2	8.4	8.4
777	> 60	1.6	1.6	1.3	1.5

VII: *Maximum values of erosion climatic factor modified by climate scenarios*

Station	1961–1990	EB1-low	EA2-high	HB1-low	HA2-high
004	10.8	12.7	17.7	12.7	17.2
636	20.1	22.4	27.7	22.9	29.1
667	5.3	6.1	8.1	6.1	8.0
685	45.2	50.5	61.6	51.5	65.6
686	6.7	7.3	8.8	7.5	9.3
687	7.5	8.3	10.0	8.5	10.6
698	184.6	219.1	309.0	219.0	304.3
716	23.7	26.5	31.8	26.6	32.8
723	48.1	56.9	79.6	57.0	78.9
724	5.8	6.8	9.4	6.7	9.1
725	7.1	8.3	11.6	8.3	11.2
749	4.0	4.6	6.1	4.5	5.9
754	32.6	38.0	51.5	37.9	50.6
755	20.1	22.8	28.7	23.2	30.4
774	5.2	5.9	7.7	5.9	7.7
777	1.6	1.7	2.1	1.8	2.1

Climate conditions have substantial influence on the intensity and spreading of wind erosion especially in the dry areas of Southern Moravia. Thus, negative impacts of climate change will appear at first in these areas. Therefore at least from the beginning the humid areas with higher elevation will be spare from the negative impacts of warming. In the future it must be taken into account that threat of soil by wind erosion will extend into the areas heretofore not threatened by wind erosion. The wind erosion is dependent also on the soil type. And if it is impossible to influence the climate process, then it should try to prevent the soil degradation and change of its structure state.

SOUHRN

Vliv klimatických podmínek na intenzitu a rozšíření větrné eroze

Vliv klimatických podmínek na intenzitu a rozšíření větrné eroze byl posuzován na území jižní Moravy. K tomuto účelu bylo vybráno 16 klimatologických stanic, a to na základě dostupnosti požadovaných dat, jejich dostatečné reprezentativnosti, homogenity a polohy stanice. K analýzám klimatických údajů bylo potřeba vytvořit databázi klimatických prvků (rychlost větru, atmosférické srážky a teplota vzduchu) za období 1961 až 2003. Klimatické údaje byly následně vyhodnoceny, a to zvlášť pro období 1961–2003, 1961–1990, 1991–2000 a 1971–2000. Po analýzách faktorů ovlivňujících intenzitu a rozšíření větrné eroze, byl stanoven erozně klimatický faktor, který vyjadřuje potenciální ohroženost půdy větrem. Posouzení vlivu očekávané klimatické změny na větrnou erozi započalo výběrem vhodných klimatických modelů a scénářů klimatické změny na základě schopnosti modelovat všechny tři klimatické prvky (rychlost větru, atmosférické srážky a teplotu vzduchu), pokračovalo aplikací scénářů klimatické změny na staniční data vybraných klimatologických stanic a bylo dovršeno posouzením změn datových souborů po použití scénářů klimatické změny a srovnávací analýzou výstupů ze scénářů s naměřenými údaji pro normálové období 1961–1990. Navíc byl stanoven erozně klimatický faktor z dat pozměněných scénáři klimatické změny.

větrná eroze, erozně klimatický faktor, klimatická změna, scénář klimatické změny

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