COMPARISON OF POTENTIAL AND REAL ERODIBILITY OF SOIL BY WIND

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Abstract

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Areas the most susceptible to wind erosion were chosen for the comparison of potential and real erodibility of soil by wind. All the areas are located in the Southern Moravia, the south-east of the Czech Republic. Ambulatory measurements of parameters required for wind erodibility determination were done during 2006 in three districts that are heavily endangered by wind erosion (districts of Breclav, Znojmo and Uherske Hradiste). Potential and real erodibility by wind was determined from wind velocity, soil humidity, content of clay and non-erodible soil particles. Potential soil loss does not go over the limit of the tolerable amount of soil loss 10 t.ha^{-1}.year^{-1} at any studied area, even though all the three areas belong to the ones strongly susceptible to wind erosion. On the other hand, the tolerable soil loss for real erodibility 1.4 g.m^{-2} was exceeded at two regions. Non-objectivity in the erodibility evaluation of heavy clay soils follows out of the results, as so as evident necessity of new knowledge concerning the determination of wind erosion intensity, because to date used equations come out of presumption that the more clay particles soil contains, the less susceptible to wind erosion is, which is inaccurate.

wind erosion, potential erodibility, real erodibility, heavy clay soils

Erodibility of soil by wind can be determined as a potential erodibility – hypothetical erosion that is typical for an area with specific conditions, as so as a real erodibility that can be observed and measured right in the field.

Wind erosion is a problem in many parts of the arid and semiarid world. Occurrence of soil erosion varies by season because of changing conditions within the year. Some times of the year are typically drier than are other times. Soil erodibility is greater during dry periods because increased soil moisture greatly reduces erodibility. Wind erosion causes soil-texture changes because fine articles are removed, decreases soil depth and fertility, decreases land productivity, causes abrasion of plants, sedimentation in ditches and on roadways, reduces visibility along roadways, and decreases water quality (Zobeck, 2001).

The variation in erodibility depends mainly on soil texture. Fine-textured soils (sandy and sandy loam soils) are typically highly erodible. Clay is the least erodible of the soil textures in the autumn but is about as erodible as a sandy loam, a soil considered to be highly erodible in spring (Skidmore, 1994). Exposed frozen clay soils that freeze-dries during the winter in the foothills of Bile Karpaty, Czech Republic, leaves soils highly erodible in late winter and early spring.

In the Czech Republic, wind erosion is a problem on about 26 % of agricultural soils of Bohemian part of the Czech Republic and 45 % on Moravian one.

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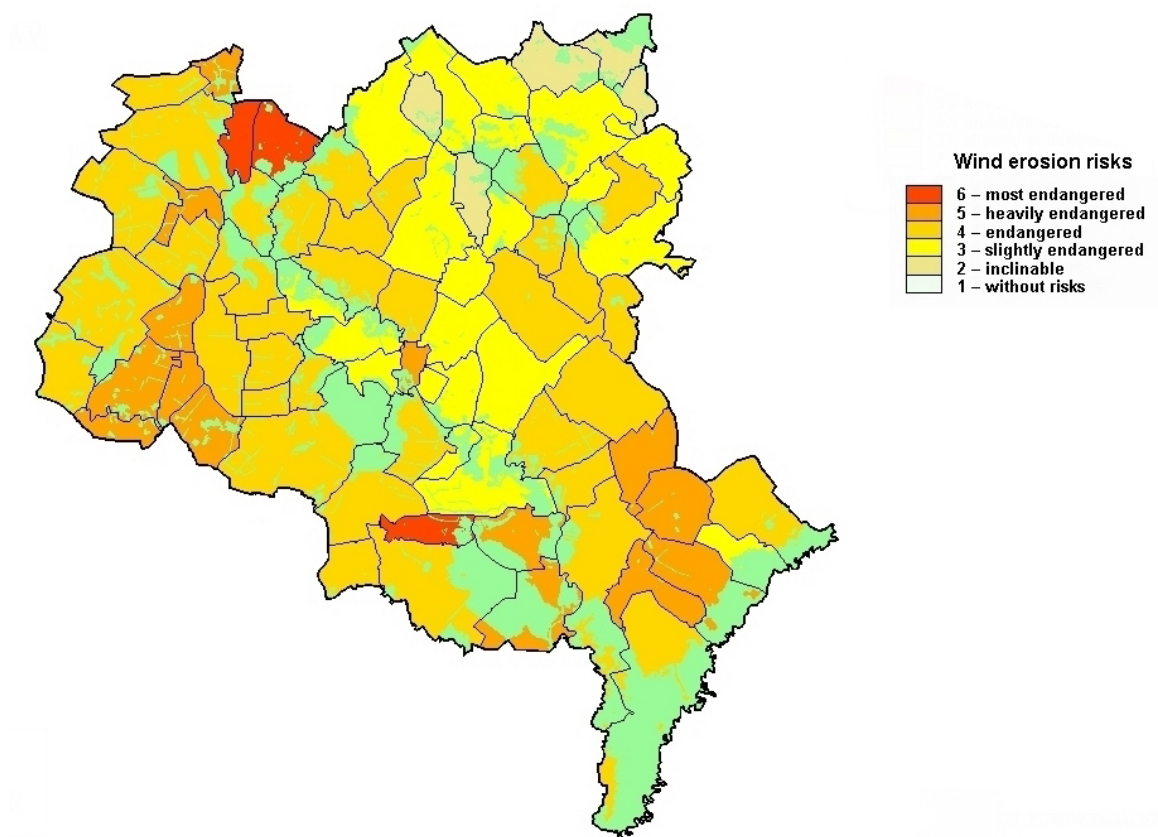
MATERIAL AND METHODS
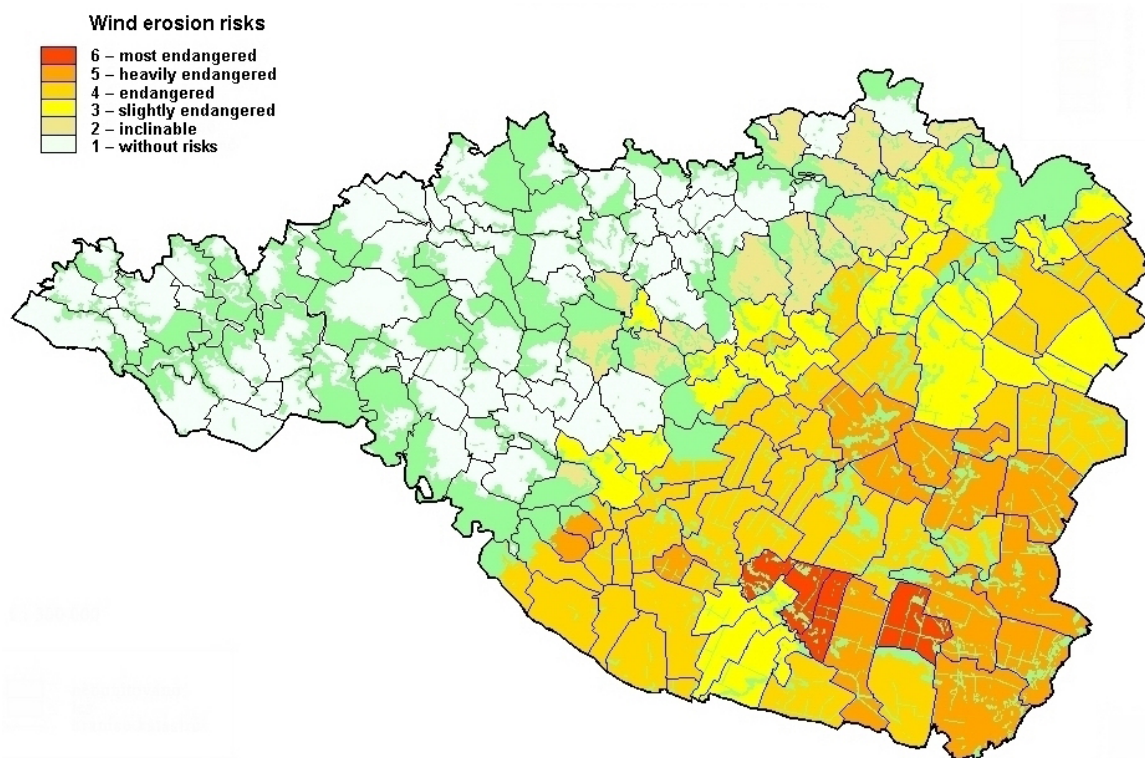
Characterization of chosen areas

Three representative areas of Southern Moravia that are – according to the Map of potential wind ero-

sion (VUMOP, 2000) – very susceptible to wind erosion are situated in the districts of Breclav, Znojmo and Uherske Hradiste. Below quoted characterization of the three chosen areas comes from Podhrazska et al. (2004):

• Dolni Dunajovice – district of Breclav (Fig. 1)
  - moderately undulating landscape,
  - sandy loam soils,
  - chernozems,
  - deep soils,
  - warm to temperate climate (average annual air temperature 9.3 °C),
  - dry climate (annual sum of precipitation 495 mm),
  - south-east wind direction (dry and strong in spring, causes wind erosion), north-west and east winds.

• Micmanice – district Znojmo (Fig. 2)
  - moderately undulating landscape,
  - sandy loam soils,
  - chernozems,
  - deep soils,
  - warm to temperate climate (average annual air temperature 8.8 °C),
  - dry climate (annual sum of precipitation 529 mm),
  - north-west and west wind direction, often also dry south-east winds.

• Sucha Loz – district Uherske Hradiste (Fig. 3)
  - highlands, foothills of Bile Karpaty, sloping relief,
  - heavy clay soils,
  - chernozems,
  - deep soils,
  - temperate climate (average annual air temperature 8.4 °C),
  - humid climate (annual sum of precipitation 800 mm),
  - east and south-east (north-west) winds.

Wind erosion risks
6 – most endangered
5 – heavily endangered
4 – endangered
3 – slightly endangered
2 – inclinable
1 – without risks

1: *Map of potential wind erosion, district of Breclav* (VUMOP, 2000)

2: *Map of potential wind erosion, district of Znojmo* (VUMOP, 2000)
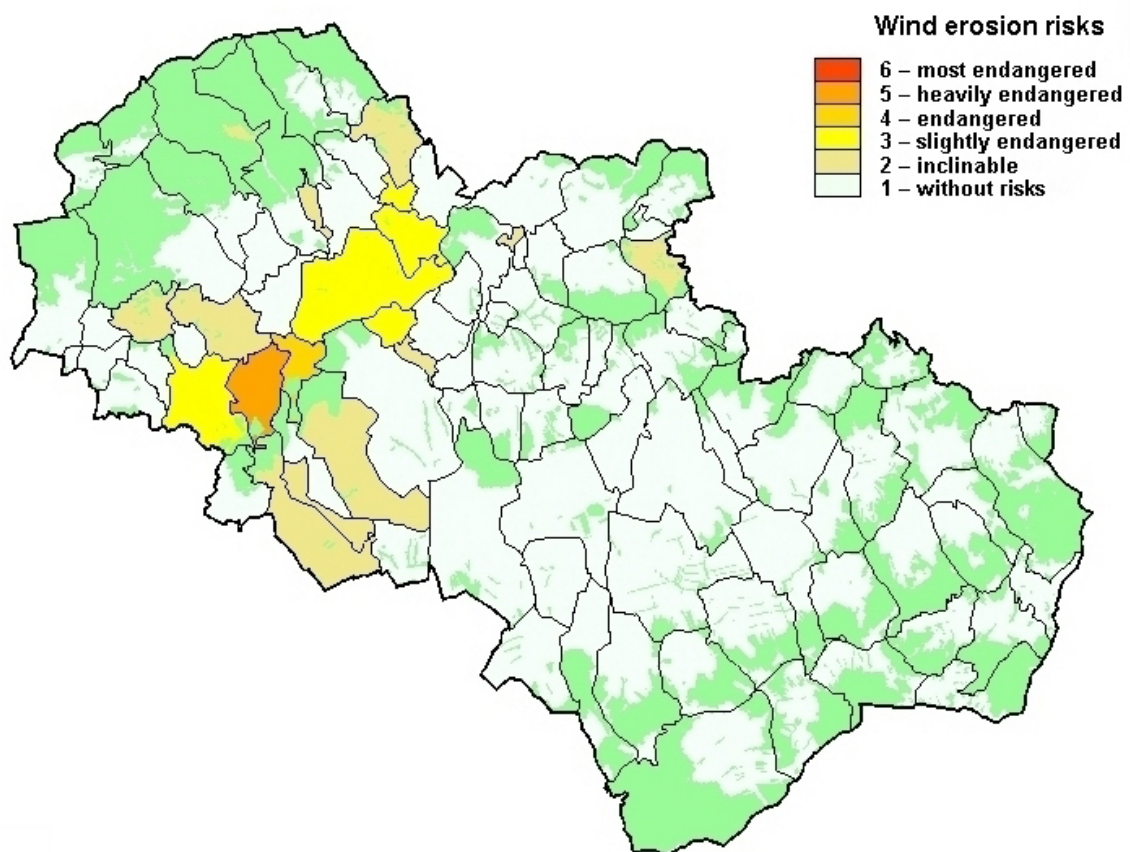
3: *Map of potential wind erosion, district of Uherske Hradiste* (VUMOP, 2000)

Determination of soil erodibility by wind

Wind erosion occurs when the forces applied to the soil by wind are greater than the resistance of the soil to these forces. The forces are directly a function of the environmental conditions at a particular location where wind erosion is occurring. Wind erosion is a function of the amount of sediment produced by detachment processes and the transport capacity of the wind. The factors such as wind, soil humidity and content of non-erodible soil particles determine wind erodibility (Toy et al., 2002).

As above mentioned, it is possible to determine potential and real erodibility of soil by wind. It is necessary to know in the field measured wind velocity and soil humidity for real erodibility determination which are the momentary figures; real erodibility then could be called momentary (actual) erodibility.

Potential erodibility of soil by wind

For the potential erodibility of soil by wind it is possible to use a relation by Pasak (1970) where the erodibility of different soil classes depends on the content of clay particles in the soil (1):

$$E = 875.52 \times 10^{-0.0787M}, \tag{1}$$

where E = erodibility of soil by wind (t.ha^{-1}.year^{-1}), M = content of clay particles in the soil (%).

The equation was derived from the experiments in the aerodynamic tunnel from the values of soil loss in g.m^{-2} during 15-minute exposure to wind velocity of 15 m.s^{-1}. The presumption of winds causing erosion is included in the equation for practical determination of potential wind erosion. It is assumed that winds causing erosion occur four days a year – two days in spring, two days in autumn when the soil is not covered by vegetation.

The content of clay particles (smaller than 0.01 mm) was determined by texture analyses, by pipette method (Jandak et al., 2001).

The tolerable amount of soil loss is for the shallow soils (up to 30 cm of depth) 1 t.ha^{-1}.year^{-1}, for medium-shallow soils (30–60 cm) 4 t.ha^{-1}.year^{-1} and for deep soils (over 60 cm) 10 t.ha^{-1}.year^{-1} (Podhrazska et Dufkova, 2005).

Real erodibility of soil by wind

The real momentary erodibility of soil by wind could be determined by the equation by Pasak (1970). The content of non-erodible particles, soil humidity and wind velocity are parameters of the equation and they have to be determined directly in the field.

The erodibility equation expresses mutual effect of basic factors influencing the susceptibility of soil to wind erosion (2):

$$E = 22.02 - 0.72P - 1.69V + 2.64R, \tag{2}$$

where E = erodibility of soil by wind (g.m^{-2}), P = content of non-erodible particles of soil (soil particles larger than 0.8 mm) (%), V = relative soil humidity (%) and R = wind velocity by soil surface (m.s^{-1}).

The amount of non-erodible particles in dry soil can be considered as an important criterion for the determination of the potential erodibility of soil by wind. The amount of non-erodible soil particles was found out through the aggregate analysis, by the sifting of the average dry soil sample from the soil surface through a sieve with meshes of 0.8 mm. The content of non-erodible particles in the soil was calculated from the equation (3). Soils with the content of non-erodible particles more than 60 % can be considered as soils non-susceptible to wind erosion (Pasak, 1970).

$$P = \frac{p}{c} \times 100, \tag{3}$$

where P = content of non-erodible soil particles (%), p = soil sample weight after its sieving through the sieve with meshes of 0.8 mm (g), c = weight of the dry soil sample before the sieving (g).

The relative soil humidity was calculated from momentary one. Relative soil humidity was determined by equation (4) and (5) (Pasak, 1984):

$$V = \frac{V_O}{V_n}, \tag{4}$$

$$V_n = \frac{o}{2.4}, \tag{5}$$

where V = relative soil humidity (%), V_O = momentary soil humidity (%), V_n = non-available water (%) and o = content of clay particles (%).

Gravimetric method was used for the determination of the momentary soil humidity (Jandak et al., 2001). The soil samples were taken from the flat smooth surface without the vegetation and its rests.

During the year of 2006 ambulatory measurements of wind velocity were done at the three chosen areas of Southern Moravia. The anemometer measured the wind velocity in the height of 20 cm above the soil surface. The momentary wind velocity was measured automatically in the five-minute step.

The maximum tolerable amount of soil loss, it means the average soil loss with 60%-content of non-erodible particles, is 1.4 g.m^{-2}, i.e. 14 kg.ha^{-1} in the conditions of the Czech Republic (Pasak, 1970). The amount of tolerable soil loss comes from the necessity of the sustentation of soil fertility and from demand not to harm notably young plants by salting soil particles and by baring of plants roots.

RESULTS AND DISCUSSION

Potential erodibility of soil by wind

The content of clay particles in the soil was necessary to find out for the potential erodibility calculation. Texture curves / analyses of the three studied regions are at the Fig. 5.
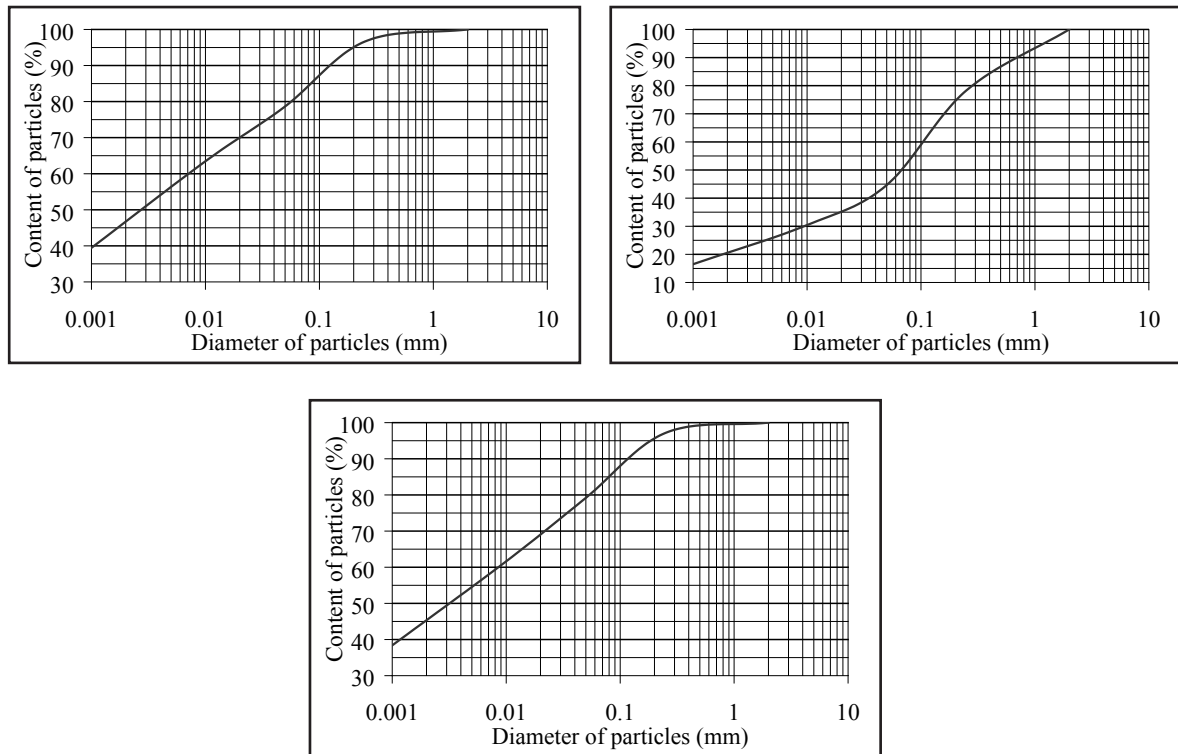
5: *Texture analyses of the regions of Dolni Dunajovice (top left), Micmanice (top right) and Sucha Loz (left)*

The potential erodibility of soil by wind is calculated according to the equation (1), see Tab. I.

I: *Potential erodibility of soil by wind at the chosen areas of Southern Moravia*

Area	Potential erodibility (t.ha^{-1}.year^{-1})
Dolni Dunajovice	0.01
Micmanice	3.52
Sucha Loz	0.01

The tolerable amount of soil loss depends on the soil depth. All the studied areas have deep soils then the tolerable soil loss is 10 t.ha^{-1}.year^{-1}. It follows from the Tab. I that the potential loss of soil does not go over the limit at any studied area, even though all the three areas belong to the ones strongly susceptible to wind erosion. The reason could be the higher content of clay particles in the soil. As Pasak (1984) states, the more clay particles soil contains, the less susceptible to wind erosion is.

Real erodibility of soil by wind

It was necessary to find out the content of non-erodible particles, soil humidity and wind velocity for determination of real momentary erodibility of soil by wind.

The wind velocity measurements and soil sampling was done at each locality only one time – in spring time of the year of 2006 (Dolni Dunajovice 19. 04. 2006, Micmanice 04. 05. 2006 and Sucha Loz 29. 06. 2006). For that reason it is possible to determine the real momentary erodibility only in these terms.

After the required parameters are filled in the equation (2), the tolerable soil loss 1.4 g.m^{-2} is exceeded at two regions – Dolni Dunajovice and Micmanice (Tab. II).

II: *Real erodibility of soil by wind at the chosen areas of Southern Moravia (with average wind velocity)*

Area	P (%)	V (%)	R (m.s^{-1})	E (g.m^{-2})
Dolni Dunajovice	9.20	0.10	1.45	19.06
Micmanice	36.75	0.83	4.14	5.08
Sucha Loz	67.72	0.25	0.40	0.00

When the maximum wind velocity per monitored period is fill in the equation (2), the real erodibility of soil by wind increases (Tab. III).

III: *Real erodibility of soil by wind at the chosen areas of Southern Moravia (with maximum wind velocity)*

Area	P	V	R$_{max}$ (m.s^{-1})	E$_{max}$ (g.m^{-2})
Dolni Dunajovice	9.20	0.10	2.66	22.25
Micmanice	36.75	0.83	7.48	13.91
Sucha Loz	67.72	0.25	1.25	0.00

All the applied methods for the determination of soil erodibility by wind depend above all on the evaluation of clay particles content with very good results for the areas with light sandy soils and typical behaviour of weather during the year. Great difficulties arise by evaluation of erodibility on heavy soils in the areas, where the erosion evidently works, but it is not possible to detect it through the computational techniques, as it is right in the area Sucha Loz.

The apparent necessity of new knowledge concerning the determination of wind erosion intensity follows from quoted results not only for mentioned heavy soils.

The determination of potential or real (actual) erodibility of soil by wind is more complicated than the determination of erodibility by water. Literature presents many possible calculations and determinations, however their disadvantage is that they work often with single factors participating on wind erosion formation. For all that, it is possible to use some of them in practise. A lot of calculation exists, majority of them is based on determination of wind velocity, soil humidity or clay particles content.

The problem of wind erosion seems to be not as interesting as water erosion is, probably due to its non-comparatively smaller spreading. For all that, it is necessary to pay attention to the problem of the wind erosion and solve it generally under the terms of complete care of landscape.

SOUHRN

Srovnání potenciální a skutečné erodovatelnosti půdy větrem

Ke srovnání potenciální a skutečné erodovatelnosti půdy větrem byly vybrány lokality, které splňují základní předpoklady vzniku větrné eroze a větrná eroze byla na těchto lokalitách skutečně prokázána. Všechny lokality se nacházejí na území jižní Moravy – v okresech Břeclav, Znojmo a Uherské Hradiště. Během roku 2006 probíhala na těchto lokalitách ambulantní měření parametrů potřebných ke stanovení erodovatelnosti půdy větrem (rychlost větru, vlhkost půdy, obsah jílnatých a neerodovatelných částic v půdě). Byla stanovena a porovnána erodovatelnost půdy potenciální a skutečná (aktuální), vycházející z naměřených okamžitých dat přímo v terénu. Potenciální odnos půdy větrem nepřesahoval ani na jedné lokalitě přípustnou mez 10 t.ha^{-1}.rok^{-1}, a to i přesto, že všechny tři lokality jsou řazeny do oblastí silně ohrožených větrnou erozí. Oproti tomu skutečná erodovatelnost půdy větrem 1,4 g.m^{-2} byla překročena na dvou lokalitách. Z výsledků vyplývá neobjektivnost hodnocení ohroženosti půd těžkých a zřejmá potřeba nových poznatků týkajících se stanovení intenzity větrné eroze, protože doposud používané vzorce vycházejí z předpokladu, že čím více jílnatých částic půda obsahuje, tím méně je náchylná k větrné erozi, což neplatí.

větrná eroze, potenciální erodovatelnost, skutečná erodovatelnost, těžké půdy

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