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DETERMINATION OF WIND EROSION NEXT TO SHELTERBELTS

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Abstract

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The influence of shelterbelts on the erodibility of soil by wind was studied at three chosen shelterbelts of Southern Moravia, Czech Republic – near the shelterbelts in the cadastral areas of Dolní Dunajovice, Micmanice and Suchá Loz. Ambulatory measurements of wind velocity as so as soil sampling for soil humidity analyses, non-erodible and clay particles analyses were done during the year of 2006. Subsequently, real erodibility of soil by wind was determined at these three areas. Results of the measurements and calculations verify positive effect of shelterbelts consisted in wind velocity decreasing (at about 78% in average), soil humidity increasing (at about 102% in average) and soil resistance increasing (at about 70% in average) at the leeward side of the shelterbelts.

shelterbelt, wind erosion, wind velocity, non-erodible particles, clay particles, erodibility

Wind erosion damages the soil by reducing soil depth and by selectively removing clay and silt particles while leaving sand particles. Windbreaks or shelterbelts are strips of green (permanent trees) that shield against wind. These barriers control erosion by reducing the erosivity of the wind for some distance into the site. Barriers can also be used to cause deposition. Effectiveness of shelterbelts depends on their width, height, structure of wood and above all on porosity for air flow. Decrease in wind velocity means increase in air and soil humidity and decrease in soil loss. A dry surface soil is much more susceptible to wind erosion than is a moist surface (Toy et al., 2002).

The erodibility of soil by wind expresses mutual effect of wind, soil humidity and content of non-erodible soil particles. The study tries to find differences of the mentioned characteristics measured on the windward and leeward side of three chosen shelterbelts of Southern Moravia, Czech Republic.

MATERIAL AND METHODS

Characterization of chosen areas

The erodibility of soil by wind – wind velocity, soil humidity and content of non-erodible and clay soil particles – was studied on the windward and leeward side of the shelterbelts in the cadastral areas of Dolní Dunajovice, Micmanice and Suchá Loz. Below quoted characterization of the shelterbelts comes from Podhrázská et al. (2004):

Dolní Dunajovice (Fig. 1)

The shelterbelt with west – east aspect is 20 m high and 18 m wide. Canadian poplar (*Populus canadensis*) forms top part of the shelterbelt. Lower levels of the shelterbelt include European ash (*Fraxinus excelsior*), sycamore maple (*Acer pseudoplatanus*), Norway maple (*Acer platanoides*) and box elder (*Acer negundo*). Bush level contains Siberian pea tree (*Caragana arborescens*), black elder (*Sambucus nigra*) and wild rose (*Rosa canina*).

1: *Shelterbelts in the cadastral areas of Dolní Dunajovice (top left), Micmanice (top right) a Suchá Loz (left)*

Micmanice (Fig. 1)

The shelterbelt with south-southwest – north-northeast aspect is 14 m high and 7 m wide. Box elder (*Acer negundo*), sycamore maple (*Acer pseudoplatanus*), Norway maple (*Acer platanoides*) and European ash (*Fraxinus excelsior*) form main level of the shelterbelt. Bush level contains Siberian pea tree (*Caragana arborescens*). Also black elder (*Sambucus nigra*) and common privet (*Ligustrum vulgare*) occur in the shelterbelt sporadically.

Suchá Loz (Fig. 1)

The shelterbelt with west – east aspect is 22 m high and 4 m wide. It consists of two levels, where Canadian poplar (*Populus canadensis*) forms the upper level. In the lower level, pedunculate oak (*Quercus* robur), linden (*Tilia cordata*) and European ash (*Fraxinus excelsior*) occur. Bush level is formed from spindle tree (*Eonymus europaeus*), red dogwood (*Swida canguinea*), wild rose (*Rosa canina*) and hawthorn monospermous (*Crataegus monogyna*), sporadically also blackthorn (*Prunus spinosa*) occurs here.

Erodibility of soil by wind

The erodibility of soil by wind could be determined by the equation by Pasák (1970). The content of non-erodible and clay soil particles, soil humidity and wind velocity are parameters of the equation. Since wind velocity and soil humidity have to be determined directly in the field, these are the momentary figures (are real only for the moment for which they were specified) and we talk about determination of real momentary (actual) erodibility of soil by wind.

The erodibility equation expresses mutual effect of basic factors influencing the susceptibility of soil to wind erosion (1):

$$E = 22.02 - 0.72P - 1.69V + 2.64R, \qquad (2)$$

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 (2):

$$P = \frac{p}{c} \times 100, \quad (2)$$

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 (3) and (4) (Pasák, 1984):

$$V = \frac{V_O}{V_n}, \quad (3)$$

$$V_n = \frac{o}{2.4}, \quad (4)$$

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 (Jandák et al., 2001). The soil samples were taken from the flat smooth surface without the vegetation and its rests.

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

During the year of 2006 ambulatory measurements of wind velocity were done at the three chosen areas of Southern Moravia. The set for wind velocity measurement consisted of sensor W1 and transducer with current outputs 1WD420. The anemometer measured the wind velocity in the height of 20 cm above the soil surface (or vegetation cover when existing), 50 m from the shelterbelts on the windward as so as leeward side. The momentary wind velocity was measured automatically in the five-minute step during eight-hour period.

The maximum tolerable amount of soil loss is 1.4 g.m^{-2} per period of measurement (when wind occurs), i.e. 14 kg.ha^{-1} in the conditions of the Czech Republic (Pasák, 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

It was necessary to find out the content of non-erodible and clay 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 (Dolní Dunajovice 19. 04. 2006, Micmanice 04. 05. 2006 and Suchá Loz 29. 06. 2006). For that reason it is possible to determine the real momentary erodibility only in these terms.

The amount of non-erodible particles, i.e. particles bigger than 0.8 mm, was found out through the aggregate analysis; results can be found in Tab. I.

I: *Content of non-erodible soil particles*

Area	Shelterbelt side	% content of non-erodible soil particles
Dolní Dunajovice	windward	9.20
	leeward	16.19
Micmanice	windward	36.75
	leeward	53.46
Suchá Loz	windward	67.72
	leeward	68.01

The content of non-erodible soil particles is higher on the leeward sides of all chosen shelterbelts. According to Pasák (1970), it is possible to consider the amount of particles bigger than 0.8 mm in dry soil to be a decisive criterion for the assessment of the potential erodibility of soil by wind. Soils with the content of non-erodible particles more than 60 % can be considered as soils non-susceptible to wind erosion.

The determination of the momentary soil humidity and content of clay soil particles was necessary for relative soil humidity calculation.

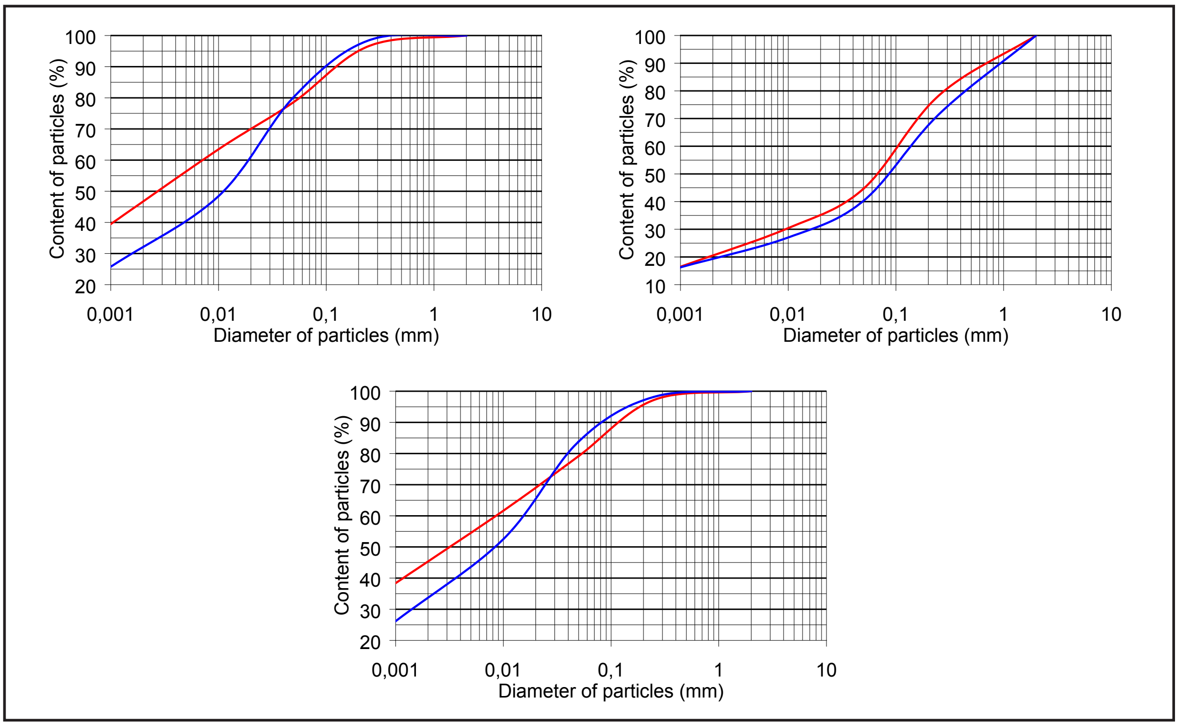
The momentary soil humidity, that was determined on the wind- and leeward sides of the three shelterbelts during wind velocity measurements, is higher on the leeward sides (Tab. II), which verifies positive effect of shelterbelt on increasing of humidity on the sheltered areas.

Decrease in wind velocity on the leeward side influences the increase in humidity of the air and soil, which prevents soil from loss. Moist soil is heavier than dry one and resists easily to wind. Humidity influences the soil erodibility directly through the cohesive forces between soil particles and indirectly through the surface crust formation. Crusting is a dense layer at the soil surface that can reduce wind erosion dramatically on fine-textured soils (Skidmore, 1994).

The content of clay soil particles (smaller than 0.01 mm) is lower on the leeward sides of the three shelterbelts (Fig. 2).

II: *Momentary soil humidity*

Area	Shelterbelt side	Momentary soil humidity in %
Dolní Dunajovice (19. 04. 2006)	windward	2.66
	leeward	4.70
Micmanice (04. 05. 2006)	windward	10.59
	leeward	24.05
Suchá Loz (29. 06. 2006)	windward	6.50
	leeward	13.10



2: *Texture analyses of the regions of Dolní Dunajovice (top left), Micmanice (top right) and Suchá Loz (left). Windward side = red line, leeward side = blue line.*

According to Skidmore (1994), the influence of soil humidity on the wind erodibility is important only in soils with small content of clay particles (in light sandy soils). The importance of the soil humidity decreases with increasing content of clay particles.

Wind velocity was measured by ambulatory methods in 50 meters from the shelterbelts on the wind- and leeward sides. The results of the measurements support the presumption of positive effect of shelterbelts on wind velocity reduction (Tab. III).

The dependency between wind velocity and soil erodibility is linear and statistically highly significant. The increasing in wind velocity by 1 $m.s^{-1}$ means increasing in loss of dry light soil in average by 15 $g.m^{-2}$ (Pasák, 1970).

After the required parameters are filled in the equation (1), the tolerable soil loss 1.4 $g.m^{-2}$ is exceeded at two regions – Dolní Dunajovice (wind- as well leeward side of the shelterbelt) and Micmanice (windward side) (Tab. IV).

When the maximum wind velocity per monitored period is fill in the equation (1), the real erodibility of soil by wind increases (Tab. V).

The primary purpose of the shelterbelts is a protection of land against soil loss. However, shelterbelts have other positive effects such as influence on temperature and humidity increasing, influence on evaporation and evapotranspiration decreasing, influence on dew forming or yield increasing. Optimal shelterbelts affect an area on windward side with the length of 10x shelterbelt's height and area on leeward side with length of 20–25x shelterbelt's height. The important influence of shelterbelt on the landscape occurs in arid climate. The influence is not so evident in humid climate.

III: *Wind velocity by shelterbelts*

Area	Shelterbelt side	Wind velocity in $m.s^{-1}$	
Dolní Dunajovice	windward	average	1.45
		minimum	0.19
		maximum	2.66
	leeward	average	0.51
		minimum	0.19
		maximum	1.25
Micmanice	windward	average	4.14
		minimum	1.72
		maximum	7.48
	leeward	average	0.55
		minimum	0.19
		maximum	1.13
Suchá Loz	windward	average	0.40
		minimum	0.19
		maximum	1.25
	leeward	average	0.07
		minimum	0.01
		maximum	0.41

IV: *Real erodibility of soil by wind E by chosen shelterbelts of Southern Moravia (P = content of non-erodible soil particles, V = relative soil humidity, R = average wind velocity)*

Area	Shelterbelt side	P (%)	V (%)	R ($m.s^{-1}$)	E ($g.m^{-2}$)
Dolní Dunajovice	windward	9.20	0.10	1.45	19.06
	leeward	16.19	0.23	0.51	11.31
Micmanice	windward	36.75	0.84	4.14	5.08
	leeward	53.46	2.13	0.55	0.00
Suchá Loz	windward	67.72	0.25	0.40	0.00
	leeward	68.01	0.60	0.07	0.00

V: *Maximum real erodibility of soil by wind E_{max} by chosen shelterbelts of Southern Moravia (P = content of non-erodible soil particles, V = relative soil humidity, R_{max} = maximum wind velocity)*

Area	Shelterbelt side	P	V	R_{max} ($m.s^{-1}$)	E_{max} ($g.m^{-2}$)
Dolní Dunajovice	windward	9.20	0.10	2.66	22.25
	leeward	16.19	0.23	1.25	13.27
Micmanice	windward	36.75	0.84	7.48	13.91
	leeward	53.46	2.13	1.13	0.00
Suchá Loz	windward	67.72	0.25	1.25	0.00
	leeward	68.01	0.60	0.41	0.00

Mentioned measurements and calculations validate positive effect of shelterbelts on wind velocity reduction, on soil humidity increasing and also on resistance to soil loss on leeward side.

Shelterbelts should be constructed in a net system to carry out soil-protective role. Correct placement in the landscape supposes the knowledge of wind direction in the period of peak wind velocity (Podhrázská et Dufková, 2005).

SOUHRN

Stanovení větrné eroze v působnosti větrolamů

Vliv větrolamů na erodovatelnost půdy větrem byl posuzován u třech vybraných větrolamů jižní Moravy – u větrolamu v katastru obce Dolní Dunajovice, Micmanice a Suchá Loz. Během roku 2006 probíhala u těchto větrolamů ambulantní měření rychlosti větru a zároveň odběr vzorků půdy ke stanovení půdní vlhkosti, obsahu neerodovatelných a jílnatých částic v půdě. Následně byla na těchto lokalitách stanovena skutečná erodovatelnost půdy větrem. Výsledky měření a výpočtů potvrzují pozitivní účinek větrolamů spočívající v redukci rychlosti větru (v průměru o 78 %), ve zvýšení vlhkosti půdy (v průměru o 102 %) a ve zvýšení odolnosti půdy (v průměru o 70 %) na straně závětrné.

větrolam, větrná eroze, rychlost větru, neerodovatelné částice, jílnaté částice, erodibilita

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