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Methods of erosion research induced by occurrence of strong wind

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Abstract

Wind is the most important factor for progress of wind erosion. Generally erosion research is quite difficult process, because it is discontinuous and it is difficult to monitor directly the erosive process. Hence, even impacts of erosion are explored – whether eroded soils or removed soil particles and substances fixed on them. Nowadays, wind erosion research is upgraded with new methods by which means it is possible to explore the wind erosion effectively. On the base of listing of deflametric methods of wind erosion research, a new-developed method is described.

Key words: deflameter, saltation, suspension

Introduction

Wind erosion research is focused on many factors influencing the formation and process of wind erosion. Atmospheric conditions (e.g. wind, precipitation and temperature), soil properties (e.g. soil texture, composition, and aggregation), land-surface characteristics (e.g. topography, moisture, aerodynamic roughness length, vegetation and non-erodible elements) or land-use practices (e.g. farming, grazing and mining) are studied.

Soil erosion data are generated through field experiments or in simulated conditions in laboratory. In practice, the results of experiments are used in erosion control. Field experiments are also used for verification of efficiency of erosion control measures.

Materials and methods

The success of measures taken against wind erosion of soil may be monitored by volumetric, pedological, morphometric, photogrammetric and historical, as well as by nivelation and vegetation growth methods. Besides these, wind erosion may be investigated using of number specific deflametric methods which focus mainly on the exact determination of the properties of deflates, i.e. particles carried by the wind. By analyzing eroded and blown soil with respect to granulation, structure, and nutrient content, the effect on wind erosion on the soil may be established. These methods may be divided more or less into field or laboratory methods.

The most important data to be obtained on a terrain concerns the quantity and quality of particles carried by the wind under different conditions, and at different heights above ground. Quantitative data on removal are required for determining the intensity of wind erosion and its relationship with other factors and conditions. Qualitative data are required for assessing the selective effect on the soil.

Accurate and reliable methods of measuring windblown sediment are needed to confirm, validate, and improve erosion models, assess the intensity of aeolian processes and related damage, determine the source of pollutants, and for other applications. The type of sampling apparatus and methods used in wind erosion field studies depend upon the specific objectives of the study (Zobeck et al., 2003).

Deflametric methods are the common used research methods for determination of amount of soil blowing by wind. Many samplers have been developed for measuring the material transported by wind. Aeolian sand samplers fall into two broad groups, those with horizontal sampling orifices and those with vertical sampling orifices. Samplers can be classified as either passive or active according to the way in which the air inside the sampler is exhausted. Passive samplers are more popular because they are easy to use and relatively inexpensive. Aeolian sand samplers can be stationary or rotating – the stationary samplers that are usually used in a wind tunnel are always oriented to a single direction, while the rotating samplers that are needed in field measurements are able to change their direction in response to the wind direction. Samplers can be designed as integrating samplers that collect aeolian sediment flux within a relatively greater layer or single-point samplers that collect sediment flux passing a small area (point). The integrated samplers can be either single-slot samplers or segmented samplers. The segmented samplers can collect the sediment flux at different positions respectively and are useful in studying flux profiles.

In later studies of wind erosion, Bagnold (1943) used a slotted collector with an opening 1,25 cm wide and 76 cm high to measure saltating grains and a buried ground trap to measure surface creep (Fig. 1).

Fig. 1 Bagnold collector (www.sensit.com)

The Cox sand catcher is adjusted to a height of 15 cm and have an opening at the top 1,5 cm wide (Fig. 2). As wind driven sand enters the sand catcher, the wind becomes obstructed by the vertical wall of the sand catcher, causing the sand particle to fall into the collection tube. This omni-directional catcher was designed by Bill Cox (www.sensit.com).

Fig. 2 Cox sand catcher (www.sensit.com)

Modified Wilson and Cook (MWAC – Fig. 3, Wilson et Cooke, 1980) and Big Spring Number Eight (BSNE – Fig. 4, Fryrear, 1986) samplers are used for sampling material at different heights in order to calculate the total mass transport associated to soil losses by wind erosion. The sampling efficiency of both traps depends on wind speed and particle sizes. Sampling efficiency of the MWAC remains constant but BSNE's efficiency decreases with wind speed, due to the higher stagnation pressure in the BSNE at higher wind speeds (Goossens, 2004). The stagnation pressure effect is higher for small particles, because they have lesser inertia and response time to changes in the air flow.

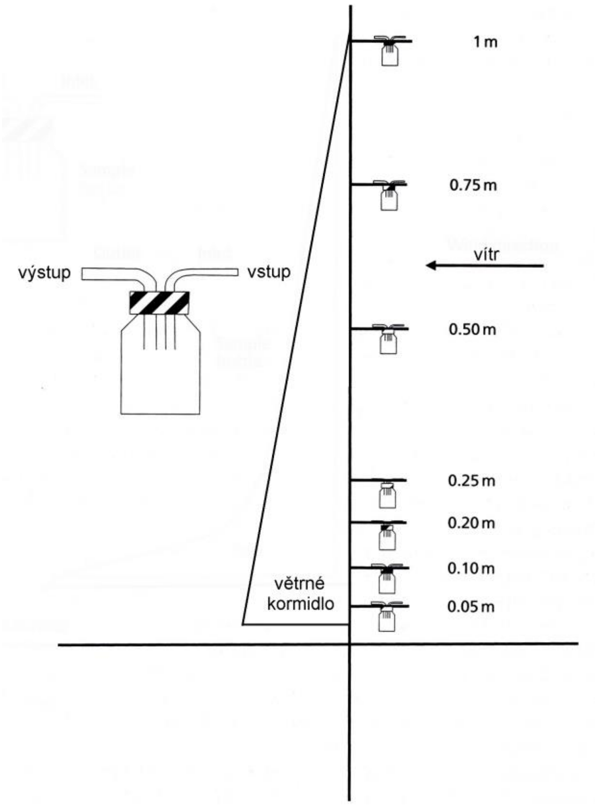

Fig. 3 Modified Wilson and Cook sampler (Toy et Foster, 2002)

Fig. 4 Big Spring Number Eight sampler (Zobeck et al., 2003)

Gillette et Stockton (1986) developed the Sensit (Fig. 5), which is a piezoelectric device that produces a signal upon impact of saltating soil particles. It has been used both in the open field and in wind tunnels. The instrument has proven useful for the determination of the threshold friction velocity at which erosion by wind starts.

Fig. 5 Sensit (www.sensit.com)

The Surface Creep Saltation sampler (Fig. 6) is a wind aspirated isokinetic sampler that samples airborne dust at the soil surface. The sampler is buried with the vertical sampling slot, the air exhaust, and the tail exposed to wind. Surface Creep Saltation sampler collects a sample of dust moving over the soil surface at heights of 3 mm, from 3 to 10 mm, and from 10 to 20 mm. Samples are collected in a divided canister with separate compartments for each height. These samplers operate at peak performance on a flat smooth soil surface (Stout et Fryrear, 1989).

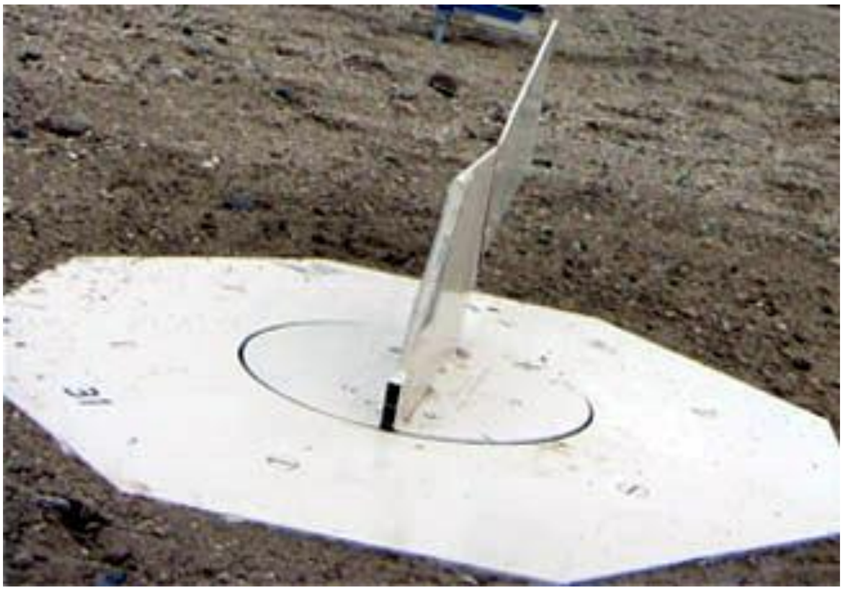

Fig. 6 Surface Creep Saltation sampler (www.fryreardustsamplers.com)

Saltiphon (Fig. 7) is a sensor for measuring the wind erosion according to the acoustic measuring principle. Dusted grains are counted and the digital output signal is registered by a datalogger (Goudie et al., 1999).

Fig. 7 Saltiphon (www.eijkelkamp.com)

The WITSEG sampler is a vertically integrating, passive type that follows an earlier design by Bagnold (1943) (Fig. 8). The WITSEG sampler is designed to measure the flux profile of blowing sand The cross-sectional area of the working section of the wind tunnel is 1,2×1,2 m (Dong et al., 2004).

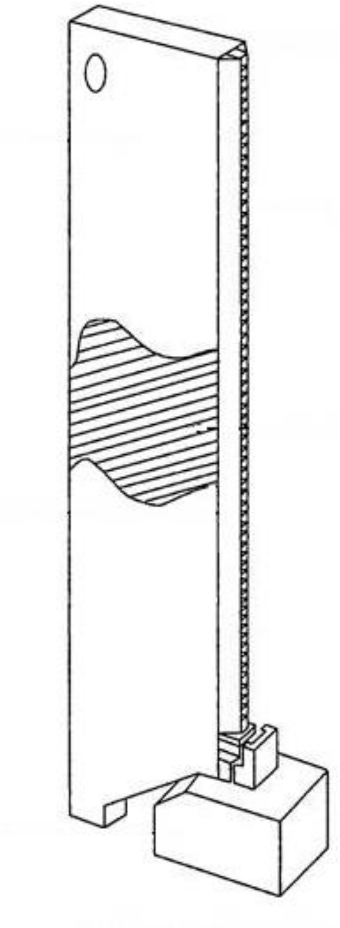

Fig. 8 WITSEG sampler (Dong et al., 2004)

Deflameter with active trap soil particles and time recording (Fig. 9) allows monitor the qualitative and quantitative properties including time recording of macroscopic and microscopic soil particles, carried by the wind. The term of the particle transport can be designated by deflameter. Also the number of soil particles is possibly to quantify and determine the size of it (Středová et al., 2012).

Fig. 9 Deflameter with active trap soil particles and time recording (Krmelová et al., 2012)

Soil particle catcher devices were developed to trap soil particles (Lackóová et al., 2013). With these devices it is able to measure the intensity of wind erosion at six different heights above the soil surface in one location (Fig. 10) or at three different heights in two places. It is possible to use them for six different places at the same time as well. The entrance hole through which the moving particles are trapped in the device has a dimension of 5x5 cm.

Fig. 10 Soil particle catcher devices (Lackóová et al., 2013)

On the basis of comparison of different measuring methods of the material transported by wind, new soil particle samplers called DEF1 and DEF1 were developed. They are described in the next part of the paper.

Results and Discussion

Deflameter DEF1 (Fig. 11) is intended for soil particles trapping at the heights of 0,5, 1,0 and 1,5 m above the ground. Deflameter DEF2 (Fig. 12) catches soil particles at the height from 0,15 to 0,30 m, depended on the depth of deflameter fitting in the ground. Plastic laboratory bottles with volume of 1 l are used for soil particles collecting. Bottles have an entrance opening in the front of their body and are placed at the supporting arms. Anti-blowing sloping sieve is installed into each bottle to prevent trapped soil particles blow out the bottle. Plastic wing fixed on the back of the bottle enables turning of the bottle with its entrance opening against prevailing wind direction.

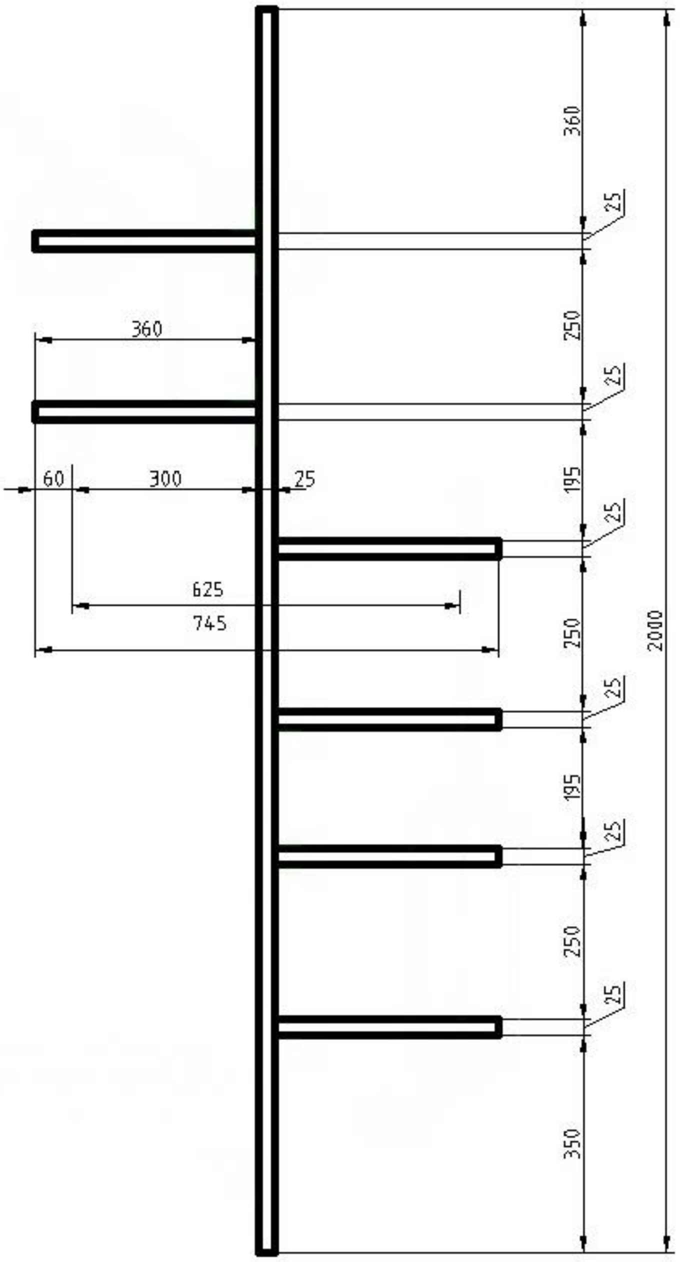

Fig. 11 General view of DEF1

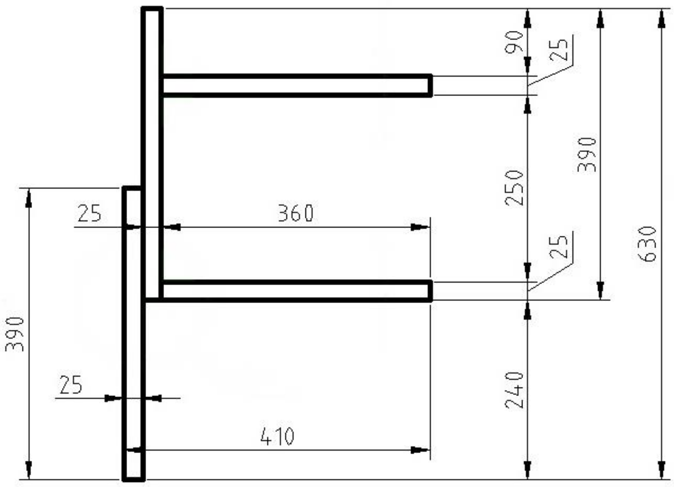

Fig. 12 General view of DEF2

Both types of deflameters were tested on light soils of Southern Moravia, Czech Republic – in Jevišovka (site A) and Hustopeče (site B). Soil particles trapped in the bottles of the deflameters were subject of analysis. They were washed out of bottles on filter paper using distilled water and drying they were weighed. Comparison of the amount of deflates from four heights of sites A and B for the period March to June 2013 is shown in Fig. 13. Site A has considerably lesser amount of trapped deflates than site B has. The reason is probably thicker vegetative cover (winter wheat) near deflameter that protected soil surface against wind effect.

New-developed deflameters have proven their efficiency. The most deflates were found in the lowest bottle, the least deflates in the highest one. Significant percentage of eroded soil particles (50–80 % of loose soil in total) moves by saltation, i.e. jumps when blown by wind up to height of 30 cm above the surface (Tatarko, 2001).
The question is how to evaluate the amount of trapped deflates per unit of area. Various research works suggest the same essentially – arrange more deflameters in network structure at enclosed experimental site (e.g. Fryrear, 1986; van Donk et Skidmore, 2003; Zobeck et al., 2003; Funk et al., 2004; Sterk et Goossens, 2007; Stout, 2007). However, they do not solve the problem how to prove that trapped soil particles do not come in from another area. This could

happened in case of very fine soil particles (< 50 μm) that move by suspension when they are blown high into the air. Actually, these fine particles are blown out hundreds and thousands kilometres from source of erosion. For that reason, any demarcation of experimental site has no function (e.g. sand from Sahara desert blown to Southern Moravia).

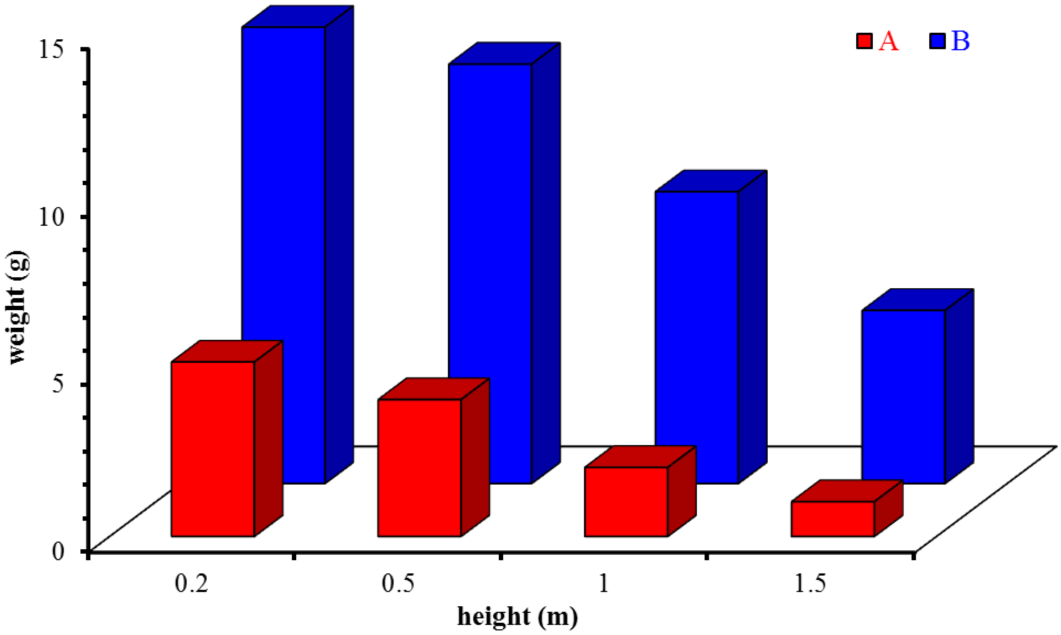

Fig. 13 Amount of deflates trapped by deflameters in various heights from sites Jevišovka (A) and Hustopeče (B)

Conclusion

New types of deflameters were developed and they proved their efficiency. Deflameters are able to catch wind-blown soil particles, however it is not possible to make their quantification per unit of area, as they are trapped in the open (non-bordered) space.

Field deflametric methods of wind erosion research are usually used for validation of wind erosion models or verification of wind erosion intensity calculation on the basis of equations. Others research works (e.g. van Donk et Skidmore, 2003; Funk et al., 2004; Skidmore et al., 2006; Buschiazzo et Zobeck, 2008) describe this in detail.

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Summary

Vítr je nejdůležitější klimatický faktor pro rozvoj procesů větrné eroze. Působí na povrch půdy svou kinetickou energií, kterou uvolňuje a uvádí do pohybu a jinde opět ukládá jednotlivé částice půdy vlivem síly vzdušného proudu. Výzkum eroze obecně je docela složitý proces, eroze je totiž jev přerušovaný a těžko se podaří sledovat přímo erozní děj. Z tohoto důvodu se zkoumají až následky eroze, ať již samotné erodované půdy nebo z nich odstraněná zemina a na ni se vážící látky. Výzkum větrné eroze je v dnešní době obohacován o stále nové metody, pomocí nichž lze větrnou erozi zkoumat efektivněji. Příspěvek uvádí výčet deflametrických metod sloužících k výzkumu větrné eroze. Na jejich základě byl vytvořen nový typ deflametru, který byl testován na lehkých půdách lokalit Hustopeče a Jevišovka. Deflametr se prokázal jako funkční – je schopen odchytit větrem odnášené půdní částice, nelze však provést jejich kvantifikaci na jednotku plochy, protože k odchytu půdních částic dochází v otevřeném prostoru.

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