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Soil erodibility calculations based on different particle size distribution measurements

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Abstract

In this study we focused on the factors affecting final outputs of the USLE (Universal Soil Loss Equation) model. In doing so, we conducted soil particle size measurements in different institutions (University of Debrecen, University of Szeged and Geographical Institute, Research Centre for Astronomy and Earth Sciences of the Hungarian Academy of Sciences) with a variety of methodologies (laser, aerometer and pipette methods) on various soil materials (sandy, loamy and clay). Statistical analyses of the eight examined soil samples have been shown some significant and some non-significant differences among the particle size measurements. This paper is aimed at i) to ascertain whether these significant differences in particle size measurements cause significant differences in soil erodibility calculations; and ii) to assess the amount of soil loss calculated by these K factors. The results suggest that regardless of the relatively small percentage between the smallest and the greatest K factor values, the amount of soil loss can be fairly high, especially when erosion occurs on a longer or steeper slope. In the present case, when we compare simulations results, the amount of soil loss is more important than the difference in percentage between the minimum and maximum values. Because the percentage of the difference can remain the same between the simulations, while the amount of soil loss increases way beyond soil loss tolerance limits.

Keywords: methods of particle size measurement, soil erodibility, USLE

Introduction

There has been a great deal of discussion about soils and their role in food production. Perhaps most importantly, soil is the main natural element from where the majority of the food for the human population originates. This topic becomes especially prescient because numerous scientists have declared that soil is a finite resource (Ángyán,

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J. 2001; Centeri, Cs. 2002; Centeri, Cs. *et al.* 2009, 2011, 2012; Madarász, B. *et al*. 2012). Therefore, understanding soil erosion in a more efficient and comprehensive way has a furthermost importance.

Soil stands in the focal point of soil erosion researches whose aims are primarily to protect this valuable resource (Kertész, Á. 1993; Szilassi, P. *et al.* 2006; Bádonyi, K. *et al.* 2008; Barczi, A. and Joó, K. 2009; Madarász, B. *et al*. 2011). When we are examining soil, it is done so from various points of view (Merinó, A. *et al.* 2004; Barczi, A. *et al.* 2009; Pető, Á. 2011; Fonseca, F. et al. 2012; Pető, Á. 2013; Kondrlová, E. *et al.* 2013). Soil erosion modelling is a useful tool for predicting potential amounts of soil loss (Rojas, R. *et al.* 2008; Heng, B.C.P. *et al.* 2011; Pradhan, B. *et al.* 2011). Soil erosion models must be examined *in situ* to obtain as much appropriate data as possible (Centeri, Cs. 2002; Centeri, Cs. *et. al.* 2009, 2011, 2012). Any additional data and research related to the increase of reliability of the models are most welcomed by model users (Madarász, B. *et al.* 2012). Soil particle size distribution is measured by various authors for various purposes (Su, Y.Z. *et al.* 2004). In the present case, the soil erodibility factor is analysed based on the liability of measuring an important input parameter, namely, the particle size distribution.

In the field of soil science, there has recently been a growing number of physically-based soil erosion models created and their application is rapidly increasing. As the input need of such physical models is much larger than those of the empirical models, any research investigating the reliability of factors affecting the final outputs of a model is valuable.

This research illustrates many effects of particle size measurements methods on soil erodibility factors of the USLE (Universal Soil Loss Equation) model. As particle size distribution is an important parameter for all other soil erosion models, these data can be used for other models as well (Giovannini, G. 2001).

Data and methods

Eight soil samples were chosen from seven different Hungarian locations of various soils (*Figure 1*). The samples represent a wide palette of soil textures and soil structures. In some cases there were no significant aggregating effects among the coarse particles. Other samples had higher clay contents with additional inorganic and humus colloids that resulted in more resistant aggregates (i.e. samples from the BOR, GFH and GAH).

Three institutions participated in the measurements and three methods were used. The codification of all information and basic geographical and other relevant parameters of the environment of the sample sites are available in *Table 1*.

Table 1. Codification of samples, sample sites and participating institutes

Code	Name of the participating institute
S	University of Szeged
D	University of Debrecen
F	Geographical Institute, RCAES HAS
Code	**Sample site information**
BOR	Börzsöny Mountains, mountain top
GAH	Gyöngyöstarján (Mátra Mountains)*
GFH	Gyöngyöstarján (Mátra Mountains)**
SZG	Szentgyörgyvár (Zala Hills)
TUR	Tura (Lowlands of Hatvan) ***
KMA	Kiskunmajsa (sandy lowland)
FES	Dabas (sandy lowland)
GAL	Galgahévíz (Lowlands of Hatvan) ***
Code	**Method of measurement**
A	Areometer
L	Laser method
P	Pipette method
P1	Pipette method, laboratory staff No. 1. (D)
P2	Pipette method, laboratory staff No. 2. (D)
Code	**Replicates**
1	Replicate 1
2	Replicate 2

*Lower third, **upper third of the slope.
***Along the Galga Stream

Measurements with the Laser Particle Sizer Analysette 22 MicroTech method

Sample preparation was carried out without OM (organic matter) takeout using sodium

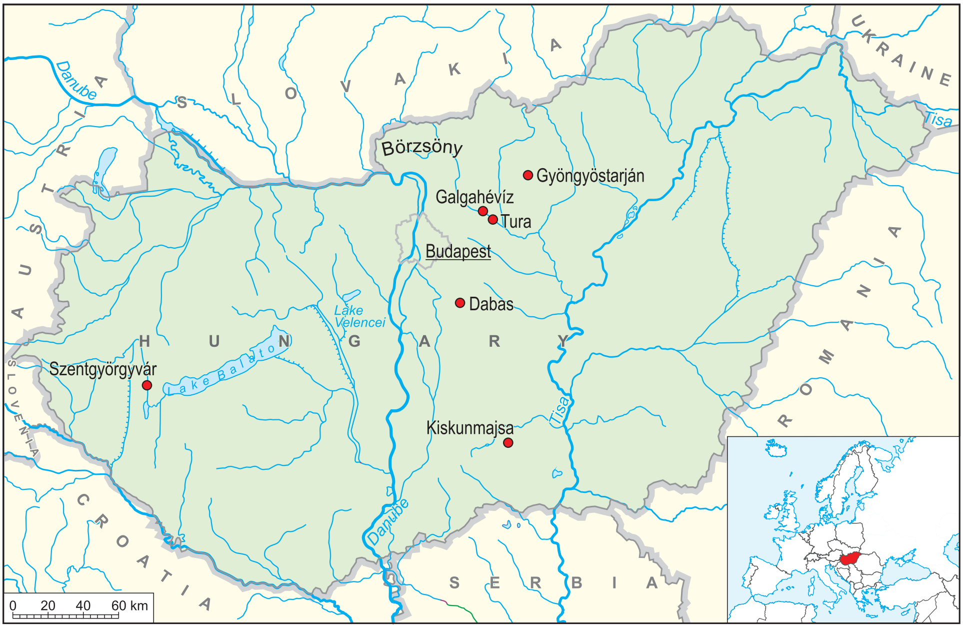

Fig. 1. Origin of the eight soil samples from seven locations, in Hungary

pyrophosphate in order to disperse the aggregates into elemental particles. 20 g of air dried soil was dispersed in 25 ml (0.5n) sodium pyrophosphate for 24 hours.

The suspension was leached through a 500 μm sieve and measured in a diffractometer Laser Particle Sizer Analysette 22 (Fritsch GmbH Germany). The measuring range of the used unit (MicroTec) was 0.1–670 μm. The coarse fractions (>500 μm) were determined by sieving. The measuring unit of "Analysette 22" contains a helium-neon laser below 5 mW and a wavelength of 655 nm. A Fourier lens then gathered the diffracted beams onto the detector.

The apparatus uses the Mie-theory (Mie, G. 1908) to calculate grain-sizes from the intensity of the diffracted laser light. The results were classified into 102 size classes. One measurement was an average of 180 scans of the sample therefore no repetitions were applied.

Determination of particle size distribution with the Köhn-pipette method

Measurements were carried out according to Buzás, I. (1993), using the Hungarian patent of particle size distribution (MSZ-08-0205-1978). The method needs soil sample preparation (i.e. organic matter removed with H_2O_2, sieved with Ø = 0.2 mm mesh size). A mortar was applied with water and continuous rubbing.

The finest fractions were poured into a sedimentation vessel. This procedure was repeated until there were no fine particles in the mortar in which the whole sample was then washed into the vessel.

The suspension was filled up to 1,000 ml with distilled water and 10 ml 0.2 M sodium-oxalate was added to prevent coagulation. The settling time was calculated at 10 cm below the surface. Finally, after the finest (<0.001 mm) fraction had settled, the pipetted samples were dried at 105 °C to determine their weight. Soils' particle size classes were expressed in percentage.

Determination of particle size distribution with the Aerometer method

This method is based on Stokes' law. Suspension is made from a 20–60 g sample. The moisture of the original sample is determined with gravimetry. To prevent coagulation, 0.5–1 g sodium-pyrophosphate is added to the suspension and then it is filled to 1,000 cm^3 with distilled water. The density of soil suspension measured at 30 s intervals for 24 hours by an aerometer (MSZ 14043/3: 1979; Buzás, I. 1993).

Calculation of soil erodibility values

Soil erodibility has been calculated with the following equation according to Schwertmann, U. *et al.* (1987):

$$K = 2.77 \cdot M^{1.14} \cdot 10^{-6} \cdot (12–OS) + 0.043 \cdot (A–2) + + 0.033 \cdot (4–D)$$

where M = (particle fraction between 0.063 mm and 0.002 mm [%] + particle fraction between 0.1 mm and 0.063 mm [%]) × (particle fraction between 0.063 mm and 0.002 mm [%] + particle fraction between 2.0 mm and 0.063 mm [%]) OS is the percentage content of organic substance (if $OS > 4\%$, $OS = 4\%$); A = aggregate category; D = category of permeability. In this case, $A = 2$ (soil aggregates are between 1–2 mm) and $D = 3$ (infiltration rate is between 10–40 cm·day^{-1}) (Schwertmann, U. *et al.* 1987).

Parametrization of the USLE model

We used USLE model to check whether the soil erodibility values calculated with the measured particle size distributions in different institutions with different methodologies have an effect on the amount of soil loss. The following parameters were in the calculation: R factor = 1,300 (MJ mm ha^{-1} h^{-1} y^{-1}), $LS = 3.5$, $C = 0.5$ and $P = 1$.

Research findings

Results of K factor calculations with USLE methodology based on the particle size distribution measurements from 3 institutions (University of Debrecen, University of Szeged and Geographical Institute, Research Centre for Astronomy and Earth Sciences of the Hungarian Academy of Sciences), using 3 methods (laser, pipette and aerometer). The resulting K factor calculations are shown in *Figure 2*.

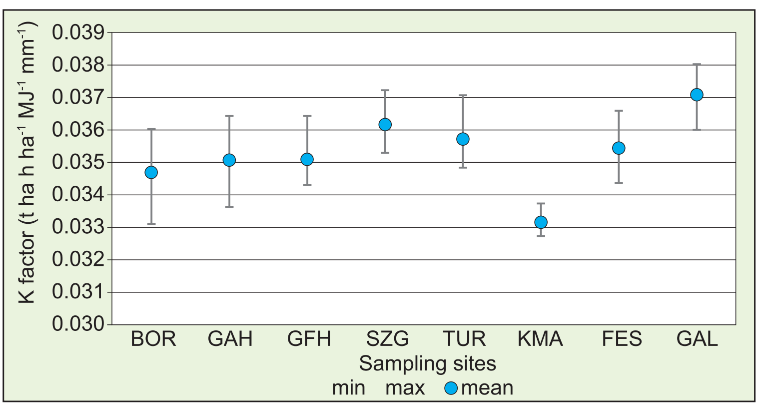

Fig. 2. Results of K factor calculations with USLE methodology including all 3 applied methods (laser, pipette and aerometer)

The calculated *K* factors (*Figure 2*) were used to calculate the amount of soil loss with the USLE model. The results of these calculations are in *Table 2*.

Based on the maximum and minimum values of soil loss calculations, the difference between these two values have been expressed in *Table 3* below. This *Table* shows the differences where the basis was the minimum value, so the percentage is expressing the difference of the maximum value compared to the minimum value (i.e. 6.1% means that the max. value is 6.1% higher than the min. value). The statistical ana-lyses proved that there were no differences in the measurements of the particle size distribution in case of KMA.

The differences between the amounts of soil loss calculated with the measured particle size classes resulted in very small (0.4%) difference bet-ween the smallest and the greatest amount of soil loss. The highest difference of the measured values was 6.1 percent, which can also be regarded as fairly low.

However, if we take into account the soil loss and not the percentage. We have to state that the amount of soil loss with the given parameterization is quite great, exceeding 70 t^{-1} ha^{-1} y^{-1}.

In the case, soil loss simulations on longer or steeper slopes, the difference between the smallest and the greatest amount of soil loss can grow to threefold. Therefore, this is a factor that must be considered as a tremendous increase in the amount of soil loss.

Conclusion

The analyses of the effects of particle size measurements methods proved that there can be considerable differences among the calculated soil losses if we use different par-

Table 2. Amount of soil losses calculated with the different K factors in using the results of the particle size distributions measured with different methods

Site code	Values	Soil loss, t^{-1} ha^{-1} y^{-1}	Site code	Values	Soil loss, t^{-1} ha^{-1} y^{-1}
BOR	Minimum Maximum Mean	76.2 81.0 78.9	TUR	Minimum Maximum Mean	80.2 83.4 81.3
GAH	Minimum Maximum Mean	77.4 81.9 79.8	KMA	Minimum Maximum Mean	75.4 75.8 75.4
GFH	Minimum Maximum Mean	78.9 81.9 79.9	FES	Minimum Maximum Mean	79.1 82.2 80.6
SZG	Minimum Maximum Mean	81.2 83.7 82.3	GAL	Minimum Maximum Mean	82.8 85.5 84.4

Table 3. Differences in the amount of soil losses calculated with the different K factors by using the results of the particle size distributions measured with different methods

Site code	$Values_{max}$ vs. $Values_{min}$, %	Site code	$Values_{max}$ vs. $Values_{min}$, %
BOR	6.1	TUR	3.9
GAH	5.7	KMA	0.4
GFH	3.7	FES	3.9
SZG	3.0	GAL	3.2

ticle size measurement methods to assess the soil erodibility factor and use these factors in the USLE model to calculate the amount of soil losses.

We therefore conclude that, the method of particle size measurement do have an effect on soil erodibility factors and thus, also on the amount of the calculated soil losses, regardless of the fact that in this study there were no analyses of significance on the soil erodibility and soil loss calculations.

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Changing Ethnic Patterns of the Carpatho–Pannonian Area from the Late 15th until the Early 21st Century

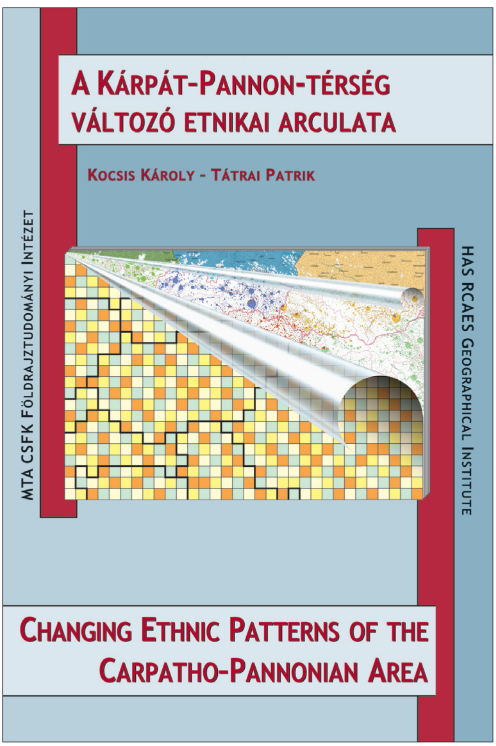
Edited by: Károly KOCSIS and Patrik TÁTRAI

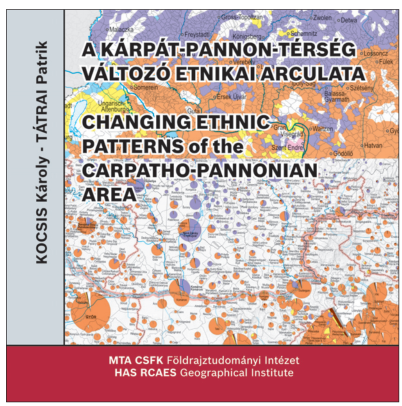
Hungarian Academy of Sciences, Research Centre for Astronomy and Earth Sciences
Budapest, 2013.

This is a collection of maps that visually introduces the changing ethnic patterns of the ethnically, religiously, culturally unique and diverse Carpathian Basin and its neighbourhood, the Carpatho-Pannonian area.

The Hungarian and English volume consist of three structural units. On the main map, pie charts depict the ethnic structure of the settlements in proportion to the population based on census data et the millennium. In the supplementary maps, changes of the ethnic structure can be seen at nine dates (in 1495, 1784, 1880, 1910, 1930, 1941, 1960, 1990 and 2001). The third unit of the work is the accompanying text, which outlines the ethnic trends of the past five hundred years in the studied area.

The antecedent of this publication is the „series of ethnic maps" published by the Geographical Research Institute of the Hungarian Academy of Sciences from the middle of the 1990's, which displayed each of the regions of the Carpathian Basin (in order of publication: Transylvania, Slovakia, Transcarpathia, Pannonian Croatia, Vojvodina, Transmura Region, Burgenland, Hungary). This work represents, on the one hand, the updated and revised version of these areas, and, on the other hand, regions beyond the Carpathian Basin not included on previous maps. Thus, the reader can browse ethnic data of some thirty thousand settlements in different maps.





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