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IMPACTS OF WATER EROSION ON SOIL PHYSICAL PROPERTIES

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Abstract

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The aim of the paper is to determine the effect of water erosion on maximum capillary water capacity, bulk density, soil airiness, total porosity and minimal air capacity. For this purpose, 13 plots located in South Moravia were selected. Each plot was divided into three positions. The first one, eluvial, was located on the top of the slope. These were always flat and water erosion did not occur there. The second one was midslope position where soil was damaged by water erosion. Soil washed down from the midslope position was accumulated in the third one. It has been found that water erosion has a statistically significant effect on minimal air capacity of topsoil, and on bulk density and airiness of subsoil. Variance analysis showed less variance of values referring all characteristics beyond these: the minimal air capacity of the midslope position damaged by erosion regarding topsoil; and maximum capillary water capacity, soil airiness and porosity regarding the subsoil.

Keywords: soil, physical properties, water erosion, soil degradation, porosity, bulk density, capillary water capacity

INTRODUCTION

Together with water and air, soil is a major natural resource for life on Earth. It provides a large variety of goods and services (Verheijen *et al.*, 2009), particularly in relation to biodiversity, soil biota, plant composition, runoff control, water-holding capacity, carbon sequestration and ecosystem productivity (Van Oost *et al.*, 2000). Consequently, soil degradation is one of the most important threats to soil productivity and human welfare (Pimentel *et al.*, 1976). Soil erosion is a major cause of soil degradation as it involves removal of the most fertile topsoil where organic matter and nutrients are concentrated (Li *et al.*, 2009). Soil erosion is considered to be one of the greatest threat jeopardizing food safety and environmental health, and it results in environmental and economical damages (Pimentel, 2006). Erosion causes degradation and loss of soil resources, damage to agricultural production, eutrophication of surface waters, floods, and damage to infrastructure (Blanco-Canqui and Lal, 2010; Pimentel, 2006). The issue of soil erosion is very serious throughout the whole Europe.

Given that in most cases, the rate of erosion occurring in agricultural areas is higher than the rate of soil formation (Verheijen *et al.*, 2009), several reports (e.g. Boardman, 2006) have highlighted a decrease in soil quality in many areas worldwide. This in part explains increases in production costs, declining crop yields, and farmland abandonment in the worst cases (Montgomery, 2007).

Physical properties of soils are largely air and moisture conditions in soil together with its compaction. The optimum amount of air and water is essential for the vitality of soil organisms, and also right functioning of the chemical properties, proper crop growth and sufficient yield (Lal, 1976; Qamar *et al.*, 2005; Javeed, 2013). Quine and Zhang (2002) reported that water erosion is a major factor affecting the spatial variability of soil properties and production. The on-site effects of accelerated soil erosion on crop productivity are due to a multitude of interacting factors e.g. reduction in rooting depth, decline in plant-available water reserves, decrease in soil fertility, and adverse soil physical conditions (Ebeid *et al.* 1995)

High porosity and low bulk density is convenient to microorganisms and fungi. Such soil is richer in micro-roots contributing to greater stability of the soil which is therefore less susceptible to water and wind erosion (Ievers rand Hamilton, 1993). Authors (Packer and Hamilton, 1993) found that increased bulk density also increases the quantity of soil washed off. This is caused by disruption of the stability of soil due to excessive compaction and subsequent adverse physical, biological and chemical properties impaired by compaction. Also, the authors Ebeid *et al.* (1995) indicate that soils damaged by erosion have a higher bulk density and the soils with higher density are erosion prone. This is related to the content of air and water. In erosion-damaged soils, the contents were the lowest, especially the maximum water holding capacity (Ebeid *et al.*, 1995). Nizeymana and Olson (1988) found smaller porosity at erosion-damaged soils. The authors also found lower available water capacity at erosion damaged soil. Shift in soil grain size composition is also significant. Authors Stone *et al.* (1985) reported soil damaged by erosion contained by up to 10 % clay (< 0.002 mm).

The aim of the presented study is to find out effect of water erosion on disruption of selected physical properties of soil on plots damaged by erosion.

METHODS

Samples were taken from 13 plots located in South Moravia. Sampling sites are drawn on the Fig No. 1. For the purpose of the study, sloping land with chernozem was selected. Selected plots were divided into three parts – the first eluvial slope position located on the platform was not damaged by erosion; the second position was translocation in the middle of the slope always damaged by water erosion; and the third position located in accumulation part of the slope where washed off sediments from translocation part were accumulated.

Samples were taken from topsoil at the depth of 5–25 cm and subsoil at the depth of 30–50 cm. Kopecký's sampling tubes (100 cm^3) were used to take samples for physical analysis. Physical properties were determined and evaluated using standard methods according to Zbíral *et al.* (2010). 8 sampling tubes were taken from each sampling site.

All plots were planted with maize in time of sampling. Samples were always taken after harvest and before tillage.

Results were assessed statistically. Descriptive statistics was carried out and single-factor ANOVA was done to investigate the effects of water erosion on physical properties.

1: *Sampling sites*

I: *Descriptive statistics – topsoil*

		Maximum capillary water capacity (% vol.)	Bulk density ($g*cm^{-3}$)	Soil airiness (% vol.)	Total porosity (% vol.)	Minimal air capacity (%)
Eluvium	Average	34,12	1,54	15,08	40,63	4,41
	Median	34,61	1,56	11,28	40,12	3,69
	Variability	12,71	0,02	72,23	26,48	6,26
	Min.	24,57	1,24	5,99	31,69	1,05
	Max.	40,02	1,78	32,98	53,44	8,78
Midslope position	Average	33,96	1,54	14,34	39,46	5,39
	Median	34,56	1,55	11,52	39,25	5,88
	Variability	11,64	0,01	65,83	21,47	12,51
	Min.	25,49	1,26	2,99	31,22	1,40
	Max.	39,31	1,73	32,98	53,44	15,26
Aluvium	Average	35,39	1,51	18,64	41,77	7,13
	Median	35,62	1,55	20,36	41,22	7,22
	Variability	12,17	0,02	81,56	47,28	15,62
	Min.	28,49	1,24	1,23	10,25	0,55
	Max.	41,22	1,72	33,25	52,70	15,22

II: *Descriptive statistics – subsoil*

		Maximum capillary water capacity (% vol.)	Bulk density ($g*cm^{-3}$)	Soil airiness (% vol.)	Total porosity (% vol.)	Minimal air capacity (%)
Eluvium	Average	37,75	1,53	26,91	42,80	5,02
	Median	36,27	1,53	29,33	41,22	4,32
	Variability	50,25	0,00	38,28	25,87	7,87
	Min.	24,77	1,43	10,18	16,33	1,08
	Max.	53,15	1,73	36,17	49,55	10,47
Midslope position	Average	35,68	1,49	28,65	40,68	6,61
	Median	35,97	1,50	29,62	43,22	6,86
	Variability	15,00	0,01	21,94	18,34	14,20
	Min.	28,79	1,25	18,52	31,22	0,52
	Max.	42,55	1,59	37,85	51,22	14,55
Aluvium	Average	34,98	1,55	22,12	41,30	5,72
	Median	34,79	1,55	26,21	40,15	5,80
	Variability	16,03	0,01	76,99	19,89	14,23
	Min.	28,67	1,25	6,34	34,25	0,30
	Max.	45,78	1,73	33,24	55,48	16,45

III: *ANOVA statistics ($\alpha < 0,05$)*

	Maximum capillary water capacity (% vol.)	Bulk density ($g*cm^{-3}$)	Soil airiness (% vol.)	Total porosity (% vol.)	Minimal air capacity (%)
Value P – topsoil	0,14352	0,40463	0,06406	0,19892	0,00215
Value P – subsoil	0,05514	0,00511	0,00012	0,18248	0,13216

RESULTS AND DISCUSSION

In all three positions (eluvial, midslope and accumulation position), physical conditions are disturbed – bulk density, total porosity and minimal air capacity. The average value of bulk density for eluvial position is 1.54 g * cm^{-3} which is very above the limit (1.45 g * cm^{-3} for the conditions). In the midslope position, the value is the same. The value found in the position of accumulation is lower (Tab. I).The total porosity is below the limit at all three positions. The average value of total porosity measured was 40.63 % vol. at eluvial position, 39.46 % vol. at midslope position, and 41.77 % vol. at position of accumulation. The worst value was measured in the midslope position where water erosion occurred. This is consistent with findings of authors Nizeymana and Olson (1988), who found disrupted total porosity of places affected by water erosion. It is probably related to the changes in the grain size composition caused by washing off the smallest particles of soil (Stone *et al.*, 1985). The minimum air capacity is also significantly below the limit at all three positions – average value 4.41 % at eluvial position, 5.39 % at midslope position, and 7.13 % at position of accumulation. The best value was achieved in the accumulation position.

Beyond minimum air capacity, where the lowest variance is found at eluvial position, analysis of variance revealed that all other properties have the lowest variance of measured values just in the midslope position. This is probably due to a certain homogenization of the soil environment caused by erosion (Stone *et al.*, 1985; Lal, 1995) even though statistically significant affection of these properties by water erosion has not been found.

To determine effect of erosion on physical properties, the single factor analysis ANOVA was carried out. As drawn in the table III, erosion has affected only minimal air capacity regarding topsoil ($P = 0{,}00215$, $\alpha = 0{,}05$).

The physical condition of the subsoil is unfavourable as well. Average value of the maximum capillary water capacity of eluvium was 37.75 % vol. Therefore, the limit of 36 % vol. was exceeded (Tab. II). Bulk density is impaired at all three positions. There were measured mean values * 1.53 g cm^{-3} at eluvium, 1.49 g * cm^{-3} at the midslope, and 1.51 g * cm^{-3} at the position of accumulation. The total porosity was also disrupted in all three slope positions. The worst mean value (40.68 % vol.) was measured at the subsoil in the midslope position (Tab. II). It is interesting that the best value of the minimum air capacity (6.61 % – Tab. II) was achieved at subsoil in the midslope position.

The analysis of variance was carried out even for the subsoil. The analysis found the lowest variance of the measured values at the maximum capillary water capacity, soil airiness and total porosity (Tab. II). There is probably also a certain homogenization of the soil environment due to runoff of fine soil particles caused by water erosion (Stone *et al.*, 1985; and Lal, 1995).

However, single factor analysis ANOVA has shown that regarding subsoil, water erosion has a statistically significant effect only on the bulk density and soil airiness (Tab. III)

CONCLUSION

Regading topsoil, it was found that the water erosion has a statistically significant effect only on minimal air capacity. However, analysis of variance found that regarding erosion damaged midslope positions, the variance of the measured values of the maximum capillary water capacity, bulk density and total porosity is lower than in the eluvial and accumulation position of the slope. This is probably due to a certain homogenization of the soil in these parts due to water erosion leading to leaching of fine grain fraction.

Regarding the subsoil, statistically significant effect of water erosion on the bulk density and soil airiness was confirmed. As in the case of topsoil, lower variance of maximum capillary water capacity, soil airiness and total porosity was detected at the areas damaged by water erosion.

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