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Impact of the long-term straw supply on loess-derived soil structure

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A b s t r a c t. Keeping plant residues on the field and incorporating them instead of removing or burning them, is a well-known practice in soil and water conservation. One of the objectives of this management is to reduce the susceptibility of the soil surface to slaking and hence sealing. The non-removal of plant residues, starting in 1965, decreased the slaking of the soil surface after 10 years, which was clearly visible in March, 1976. To check whether the removal of plant residues affects only the top layer of a soil, undisturbed and disturbed samples of 4 horizons per profile were taken and analyzed in spring, 1999. Texture, saturated hydraulic conductivity, bulk density, pore size distribution, and aggregate stability (by means of a percolation test) as well as a few soil chemical parameters were determined. Almost no improvement of soil structural parameters was detected by keeping residues on the field. The susceptibility to slaking was the only parameter being significantly reduced. Against the expectations, this occurred on the plot where plant residues were removed.

K e y w o r d s: plant residues, slaking, soil structural properties, organic matter

INTRODUCTION

Covering the soil with plant residues is a well-known and recommended practice for conserving soil and water *eg* Schwertmann *et al.*, 1987; Boparai *et al.*, 1992; Lal and Stewart, 1995; Lamarca, 1996; Morgan, 1996; Pabin *et al.*, 2004 and affecting the microclimate within fields (Sharratt, 2002a, 2002b). Plant residues protect the soil surface against the splash effect of raindrops, and reduce the velocity of surface runoff and wind. Hence sealing (or crusting) of the soil surface is reduced, thereby infiltration is increased, soil loss is decreased or even stopped, and soil water is more effectively conserved (Sumner and Stewart, 1992). The long-lasting effect (over decades) of keeping plant residues on the field is thought not to be restricted to the soil surface, but to include at least the upper soil profile. Incorporating of plant residues reduces soil strength measured as penetration resistance (Valzano *et al.*, 2001), but increases aggregate stability measured by wet-sieving (Gerzabek *et al.*, 1995). Hence, increasing the soil organic matter content increases its stability and decreases soil surface sealing (Le Bissonnais and Arrouays, 1997).

In the mid 1960s, the Institute of Plant Nutrition, Technical University of Munich, started a field trial on the effect of keeping or removing plant residues of an agricultural cropland on the nutritional status of the soil and on crop yields. After 8-12 years, the soil surface of the plots with incorporated plant residues was much less sealed in springtime than that with removal of residues. This is demonstrated by photographs (Fig. 1) taken in March, 1976. The visual rating according to Boekel (1976) – 8=no slaking, 1 = very strong slaking - gave 7 and 5 for the plots with and without residues, respectively. Soil sampling of the plots down to 1 m without endangering the field trial was done in spring, 1999, after termination of the trial due to construction activities. The results on selected soil structural properties of two adjacent soil profiles with and without plant residues are reported and shortly discussed.

MATERIAL AND METHODS

The field trial was established within the campus area Weihenstephan (Freising) of the Technical University of Munich, Upper Bavaria (Germany), in about 1965, using plots (in 4 replicates) of 25 m^2 (3.33x7.5 m) with or without removing plant residues after each harvest, and was terminated at the end of 1998 due to construction activities. Soil and management were the same as described in Becher (2005). But there occurred a gradual change in the rotation

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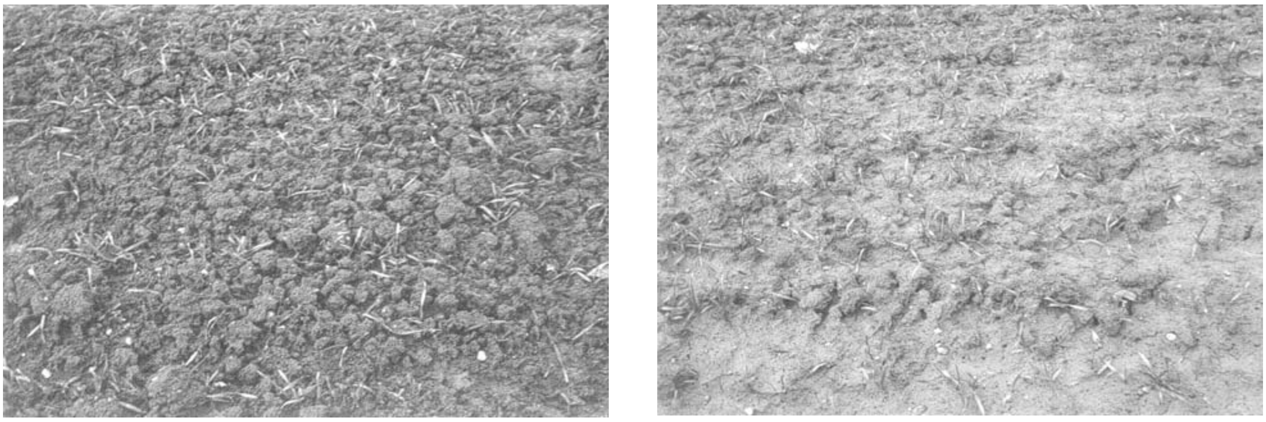

Fig. 1. Soil surface conditions in March, 1976, of the field trial on residue management carried out since *ca*. 1965 by the Institute of Plant Nutrition, Techn. Univ. Munich: a) close-up view of the residue plot, b) close-up view of the no residue plot

as well as in the management of the crop since 1976. In March, 1999, one pit was dug down to at least 1 m in the centre of only one replicate of plots either with residues kept (= residue plot) or residues removed (= no resi due plot), for profile sampling. Soil sampling, sample preparation and analyses were done as described by Becher (2005).

RESULTS AND DISCUSSION

The small differences in the basic soil properties (grain size distribution, pH and $C_{org.}$) (Table 1) determined in 1999, indicate that the soils of both plots are similar, although the no residue plot showed somewhat lower pH values and somewhat higher contents of $C_{org.}$. Considering the structural properties, only bulk density (ρ_b) and pore volume (P) of the Ap horizon of the residue plot are decreased and increased, respectively, as compared to the no residue plot (Table 1). The other three horizons of the residue plot show very similar or less favourable values than the horizons of the no residue plot. Keeping residues on plots seems to have weakly improved soil water characteristics (Fig. 2). The corresponding data in Table 1, however, do not confirm this. Considering ρ_b, P and field water capacity (FWC) together indicates a greater content of large pores (>10 μm) for the A_p horizon of the residue plot, but saturated hydraulic conductivity is lower on this plot. This means that pore continuity of the A_p horizon of the residue plot must be lower than that of the no residue plot.

Figures 1a and 1b show clear differences in slaking behaviour in spring, 1976. This visual finding cannot be confirmed by the values of aggregate stability determined as percolation volumes within 10 min (Table 1, Fig. 3). This measure characterizes the susceptibility to slaking, but not the dispersibility of soils (Mbagwu and Auerswald, 1999).

Table 1. Characteristic soil properties in 1999 of the field trial on plant residue incorporation carried out since 1965 by the Inst. of Plant Nutrition, Techn. Univ. of Munich

Soil property	Residue plot				No residue plot			
Horizons*	A_p	B_{v1}	IIB_{v2}	IIB_{v3}	A_p	B_{v1}	IIB_{v2}	IIB_{v3}
Depth (cm)	28	45	70	>100	28	52	70	>100
pH	6.41	6.43	6.36	6.39	6.24	6.26	6.24	6.32
$C_{org.}$ (% mass)	0.94	0.47	0.24	0.16	0.85	0.55	0.35	0.25
Clay (% mass)	22	30	19	16	20	31	25	20
Silt (% mass)	53	54	29	24	56	57	43	29
Sand (% mass)	26	16	53	60	25	12	32	51
ρ_b (g cm^{-3})	1.54	1.58	1.68	1.72	1.66	1.50	1.58	1.67
k_s (cm s^{-1})	5.13-3	1.83-2	2.41-3	1.07-3	9.89-3	1.64-2	9.95-3	4.05-3
P (% vol.)	52	48	43	46	44	46	47	44
FFC (% vol.)	33	36	30	29	32	35	35	30
PWP (% vol.)	21	26	18	16	22	24	22	17
PV (ml)	27.0	69.4	19.4	14.9	31.0	103.3	27.8	15.9

*Horizons according to German Soil Survey Manual (Anonymous, 1994); ρ_b – bulk density, k_s – geometric mean of saturated hydraulic conductivity *eg* 5.13-3 = 5.13 10^{-3}, P – pore volume, FWC – field water capacity, PWP – permanent wilting point, PV – percolated volume of water within 10 min after subtraction of volume for filling the system.

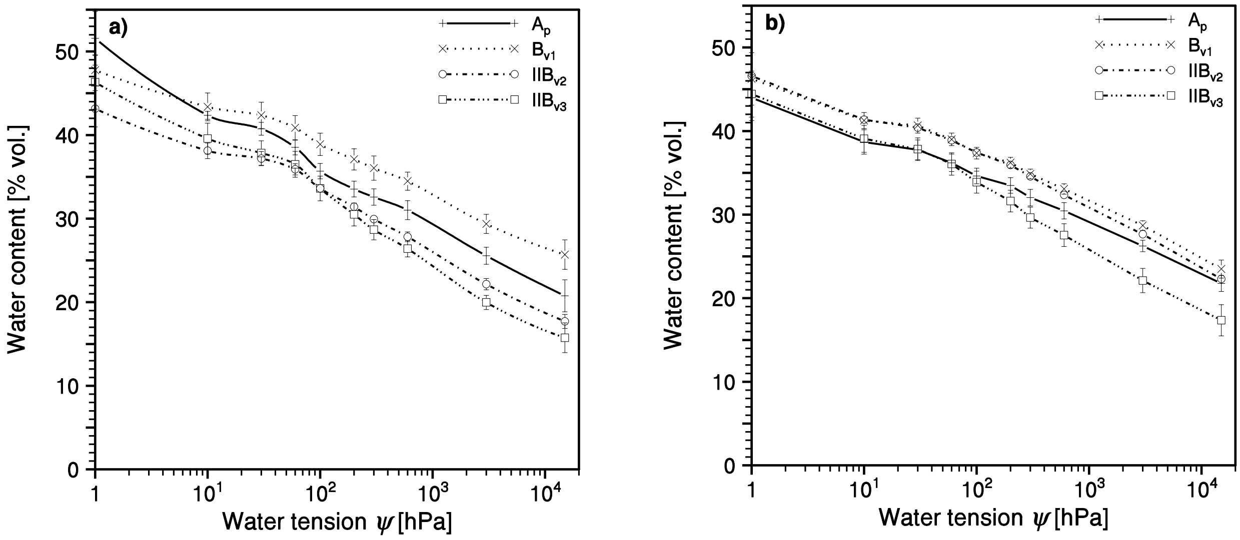

Fig. 2. Soil moisture characteristics for: a) the residue plot and b) the no residue plot.

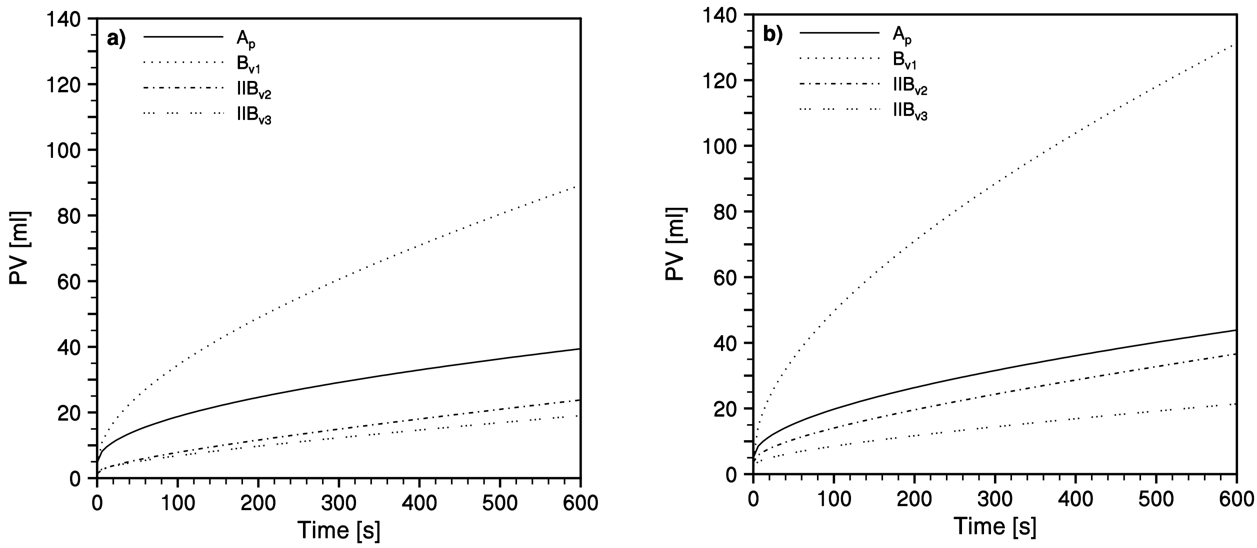

Fig. 3. Mean cumulative water volumes percolated (PV) within 10 min through aggregate (1-2 mm) samples from: a) the residue plot and b) the no residue plot.

The higher values of percolation volume (PV) for the B_{v1} horizons indicate the aggregates of the no residue plot seem to be less susceptible to slaking. Fitting cumulative percolation volumes y versus time x (shown in Fig. 3) for each horizon resulted in the general regression equation:

$$y = a + b\sqrt{x} + c\,x, \qquad (1)$$

where: the intercept a is a measure for the water volume entering the system and the interaggregate pores and being initially partly sorbed by the dry aggregates (1-2 mm), and the coefficients b and c indicate the stability of the aggregates when becoming fully saturated and being sheared later on by the percolating water, respectively. The higher a the higher is the amount of interaggregate pores and the more stable are the aggregates against the forces produced by the sudden wetting. The higher the resulting y the less susceptible to slaking are the aggregates during the percolation process.

The unexpected results indicate that there are no significant differences between the differently managed plots. The former manager of the field trial pointed out that the sampled plots belonged to two different subplots of a former calcium cyanamide trial carried out since 1932 (Hunnius, 1954). This may have resulted in the lower pH values and higher $C_{org.}$ contents of the no residue plot which probably produced the higher slaking resistance for depths >30 cm. The effect of the quality of soil organic matter on structural properties is confirmed by Roberson *et al.* (1991), Ball *et al.* (1996), and Grant *et al.* (2001). These authors found correlations between the amount and composition of carbohydrates and soil structural properties. The findings of Ball *et al.* (1996) were valid only for the long-lasting trial (22 years), but not for the relatively short-lasting one (9 years). On the other hand, Chaney *et al.* (1985) state that the increase in $C_{org.}$ does not reduce soil slaking. As demonstrated by the results of Alberts *et al.* (1987) and Packer *et al.* (1992), the large temporal variability of soil structural parameters within and between years induced by changing weather and soil conditions, renders difficult or even prevents to relate structural properties like pore size distribution and aggregate stability to other soil properties like C_{org}. This is especially true if several years pass between visual observation and soil sampling.

CONCLUSIONS

1. The removal of plant residues during a period of about 10 years increased the slaking of the soil surface, which was clearly visible in 1976.

2. This optical finding, however, could not be confirmed by soil properties determined about 20 years later, in 1999.

3. Both the change in soil management and crop rotation since 1976 and the effect of a former field trial started on the same plots in 1932, obscure the effect of the residue management on soil structural properties.

4. The plot with residues kept has lower $C_{org.}$ contents than the plot without plant residues, which showed also a higher slaking resistance being the only soil structural property affected by the residue management at the end of the trial.

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