SOIL PHYSICAL EFFECTS OF SUGAR BEET HARVEST AND SLURRY SPREADING ON REGLULARLY MANAGED FIELDS

H.-J. KOCH[1], R. BRANDHUBER[2], N. STOCKFISCH[1], L. SCHÄFER-LANDEFELD[2]

[1]*Institut für Zuckerrübenforschung (IfZ), D-37079 GÖTTINGEN,* [2]*Bayerische Landesanstalt für Bodenkultur und Pflanzenbau, D-85316 FREISING*

ABSTRACT

In a field study, conducted on 11 conventionally managed fields in Germany, the effects of high axle loads (15 to 25 t) on soil physical properties were investigated. Soil texture classes ranged from loamy sand to silty clay loam. All sites were annually ploughed, one site was additionally subsoiled to 40 cm depth. In the context of common field operations either a sugar beet harvester (45 Mg total mass, 113 kPa average ground pressure) or a slurry spreader (30 Mg total mass, 77 kPa average ground pressure) was driven over the soils. Soil moisture conditions varied from 3.2 kPa (pF 1.5) to 32 kPa (pF 2.5) water tension during this pass. Soil cores were collected in a grid scheme at each site before and after the machine pass. Air filled porosity and air permeability at 6.2 kPa water tension (pF 1.8) was determined in these cores for two layers (topsoil and subsoil).

At most sites, a machine pass strongly affected topsoil properties with air filled porosity and air permeability being significantly decreased. The subsoil showed no changes or only minor signs of compaction. Only at the deeply fissured site, air filled porosity and air permeability were significantly reduced in the subsoil. The results show that using present-day heavy agricultural equipment does not necessarily lead to severe subsoil compaction. However, deeply fissured soils with an unstable subsoil structure are in serious danger of becoming severely compacted.

KURZFASSUNG

In einer Studie auf 11 Praxisfeldern in Deutschland wurde der Einfluss einer Überrollung mit schweren landwirtschaftlichen Maschinen (Zuckerrübenvollernter: 45 Mg Gesamtmasse, 113 kPa mittlerer Kontaktflächendruck; Gülleselbstfahrer: 30 Mg Gesamtmasse, 77 kPa mittlerer Kontaktflächendruck) auf physikalische Bodeneigenschaften untersucht. Alle Standorte (lehmiger Sand bis schluffig-toniger Lehm; Bodenwasserspannung bei Befahrung: 3,2 kPa (pF 1,5) bis 32 kPa (pF 2,5) waren in langjähriger Bewirtschaftung mit dem Pflug, ein Standort wurde ein Jahr vor der Befahrung auf 40 cm tiefgelockert. Vor sowie nach der Befahrung wurden Stechzylinder in einem Rasterschema in zwei Bodentiefen (Krume, Unterboden) gezogen. An diesen wurde das luftgefüllte

Porenvolumen und die Luftpermeabilität bei einer Wasserspannung von 6,2 kPa (pF 1,8) untersucht.

An den meisten Standorten beeinflusste die Befahrung die Bodeneigenschaften in der Krume deutlich: Das luftgefüllte Porenvolumen und die Luftpermeabilität nahmen signifikant ab. Der Unterboden zeigte keine oder nur schwache Zeichen von Verdichtung. Einzig am tief gelockerten Standort wurden signifikante Hinweise auf eine Unterbodenverdichtung entdeckt. Die Ergebnisse zeigen, dass der Einsatz praxisüblicher, schwerer Land-maschinen nicht zwangsläufig zu einer starken Verdichtung des Unter-bodens führen muss. Tiefgelockerte Böden mit einer instabilen Struktur sind demgegenüber ernsthaft gefährdet, wiederverdichtet zu werden.

ABRÉGÉ

Au cours d'une étude réalisée en Allemagne dans 11 champs agricoles, on a analysé l'influence, sur les propriétés physiques du sol, du passage de machinisme agricole lourd (intégrale de betteraves sucrières, masse totale 45 Mg, pression moyenne des surfaces en contact 113 kPa; épandeur de lisier autotracté: masse totale 30 Mg, pression moyenne des surfaces en contact 77 kPa). Tous les sites (d'un sol sableux à un sol argileux; tension de l'eau du sol comprise entre 3,2 kPa (1,5 pF) et 32 kPa (2,5 pF)) se trouvaient en exploitation à la charrue depuis de longues années, un site a été ameubli jusqu'à 40 cm de profondeur un an avant que les véhicules passent dessus. Avant et après leur passage on a prélevé des échantillons au moyen de vérins perforateurs appliqués selon un schéma en grille à deux profondeurs différentes (terre arable, sous-sol). En ces endroits, on a analysé le volume des pores remplis d'air et la perméabilité à l'air, ceci à niveau de tension de l'eau de 6,2 kPa (pF 1,8).

Sur la plupart des sites, le passage des véhicules a influé notablement sur les caractéristiques de la terre arable: le volume des pores remplis d'air et la perméabilité à l'air diminuaient. Le sous-sol ne présentait que des signes faibles ou inexistants de compactage. Uniquement sur le site très ameubli sont apparus des indices significatifs de compactage du sous-sol. Les résultats montrent que l'emploi d'un machinisme agricole lourd ne doit pas forcément entraîner un fort compactage du sol. Les sols profondéments ameublis et à structure instable sont, eux, par contre, menacés par un nouveau compactage.

INTRODUCTION

During the last decades the mass of agricultural machinery has increased. At present, large wheel loads characterize machines such as self-propelled combine harvesters. Simultaneously, wide tires enabling low inflation pressure kept constant the mean ground pressure (TIJINK & VAN DER LINDEN 2000). This alleviated topsoil stress, while subsoil stress depends more on axle load than on contact pressure (HADAS 1994). Several studies confirmed that heavy machinery can lead to considerable compaction in the subsoil (HAKANSON & REEDER 1994, EHLERS et al. 2000). In many studies, however, wheeling conditions differed from actual field traffic in several respects.

The objective of this study was to investigate the effect of sugar beet harvest and slurry spreading with present-day machines characterized by high axle loads on soil physical properties.

1.- MATERIAL AND METHODS

The investigation was conducted on 11 conventionally managed fields with a long term history of annual mouldboard ploughing down to 20–30 cm depth in autumn. Thus, a moderate plough pan was developed on most sites. Site 1 was subsoiled to 40 cm depth and site 3 was left unploughed one year before starting the investigation. Soil texture classes ranged from loamy sand to silty clay loam. Soil water tension at time of machine passing was between 3.2 and 32 kPa (pF 1.5 to pF 2.5).

Machine passes took place in course of normal field operations of beet harvest (SH1: self propelled 6-row sugar beet harvester with hopper, fully loaded, approx. 45 Mg total mass, 113 kPa average ground pressure) and slurry spreading (SS: self propelled slurry spreader, approx. 30 Mg total mass, 77 kPa average ground pressure). Both machines were equipped with wide tires (80-105 cm) and with the rear wheels running offset from the front wheels. Thus, about 60 % of the field was trafficed by only one and 40 % by two or three wheels. On site 6 a 2-row tractor mounted sugar beet harvester was used (SH2: fully loaded, approx. 7 Mg total mass, 6 wheel passes).

Sampling was conducted before and after wheeling from topsoil (15-20 cm) and subsoil (38-43 cm) with 25–30 replicates each. Cores were taken in a grid scheme with alternating positions of sampling before and after machine pass. Sampling positions and positions of the wheel tracks were randomly oriented. Pore size distribution and air permeability at 6.2 kPa soil water tension (pF 1.8) were measured in the laboratory.

2.- RESULTS AND DISCUSSION

At most sites, a pass by the sugar beet harvester and the slurry spreader strongly affected topsoil properties: air-filled porosity and air permeability decreased significantly (Fig. 1). Only at sites 9 to 11 changes were slight, probably due to a soil water content lower than field capacity (pF > 1.8) at the time of wheeling. Sites 3 to 6 as well as sites 8 to 9 were characterized by relatively low values of air permeability even before wheeling. Despite these clear effects, compaction in the topsoil is thought to be of minor importance, because it mostly can be ameliorated by subsequent soil tillage.

The subsoil showed no or only minor signs of compaction (Fig. 2). Only at the deeply fissured site 1, which had been subsoiled one year before wheeling, a strong decrease in air filled porosity and air permeability was de-tected in subsoil layers. On sites 2 and 7 values of air permeability were di-minished by machine pass but remained above a "low" value (KMOCH 1966).

Results from the subsoils of sites 5 and 8 are remarkable because a slight decrease in air capacity was accompanied by an increase in air permeability. This might be explained by an increase in the number of earthworm burrows between the first and the second sampling, as it was observed at site 5 (time lag of 60 days between the two samplings). Additionally, wheel induced soil shearing and cracking cannot be excluded as a possible cause for these effects.

In general, these results agree well with recent studies conducted under comparable machinery conditions reported by DISERENS et al. (1998), GYSI et al. (1999), RADFORD et al. (2000), ARVIDSSON (2001) and SOMMER et al. (2002). In these studies, a single pass of heavy machinery caused only slight alterations of the subsoil structure.

Fig. 1: Median values of air capacity (pores > 50 µm in diameter) and air permeability at pF 1.8 (field capacity) in topsoil (15-20 cm) as affected by sugar beet harvest (SH1, SH2) and slurry spreading (SS).
, **, * = significance of changes due to the machine pass as indicated by Mann-Whitney-U test, ns = not significant; pF-value at time of passing.*

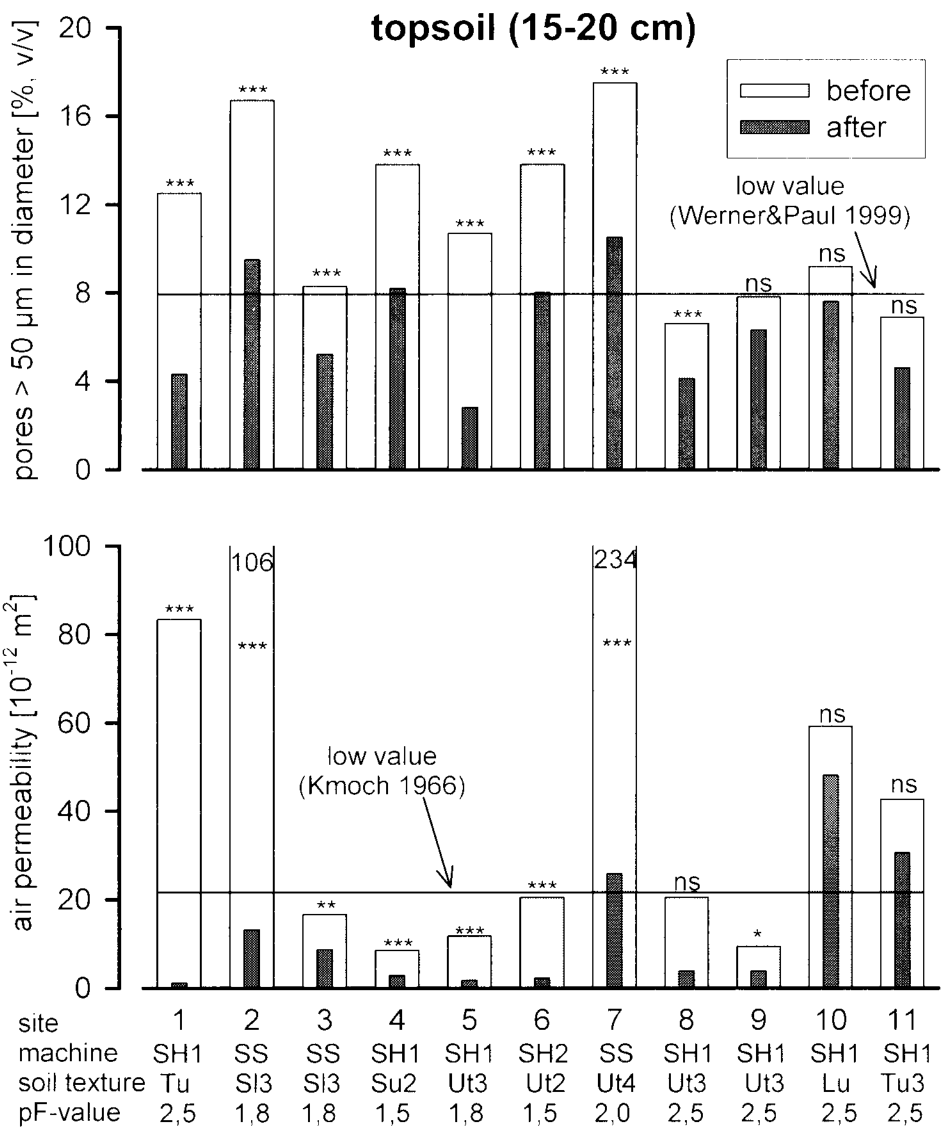
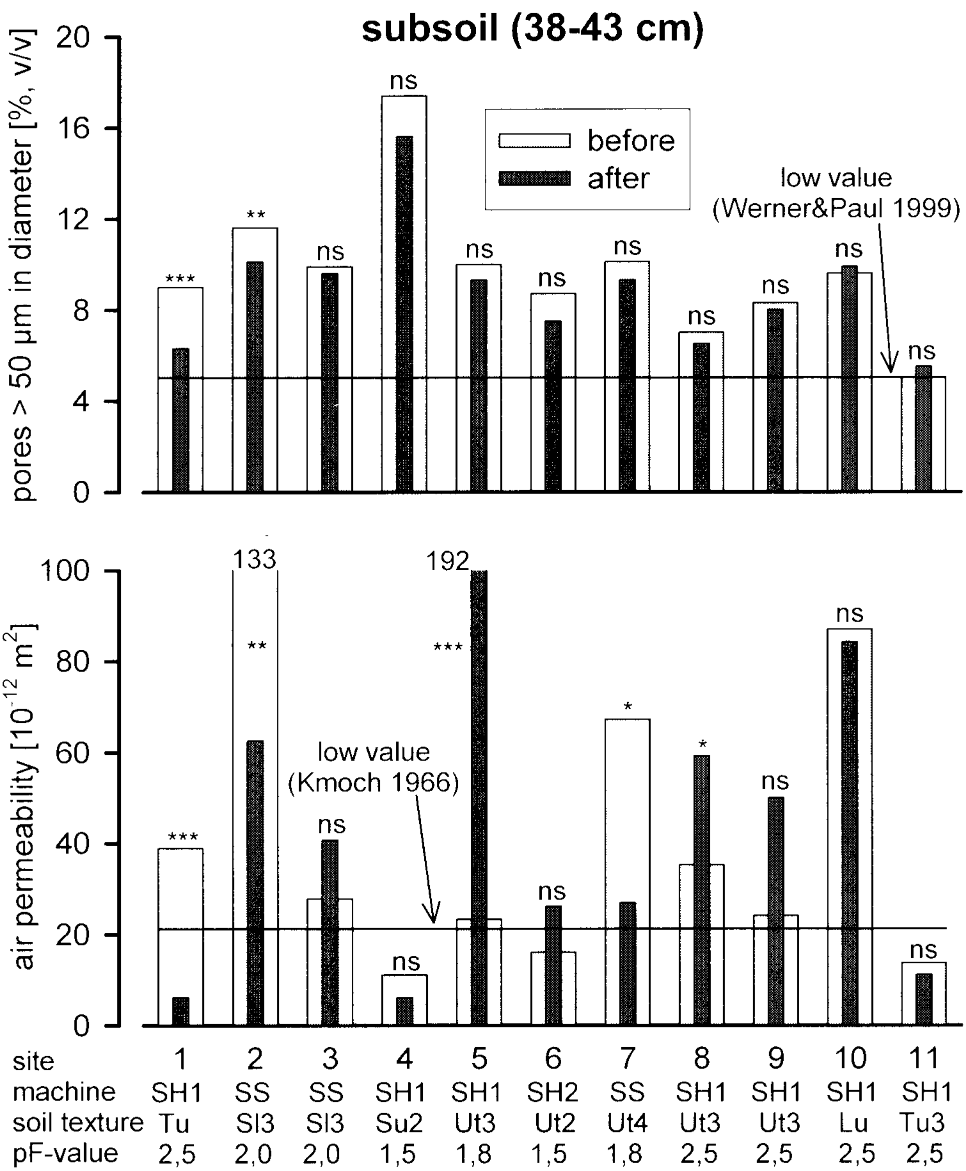


Fig. 2: Median values of air capacity (pores > 50 µm in diameter) and air permeability at pF 1.8 (field capacity) in subsoil (38-43 cm) as affected by sugar beet harvest (SH1, SH2) and slurry spreading (SS).
, **, * = significance of changes due to the machine pass as indicated by Mann-Whitney-U test, ns = not significant; pF-value at time of passing.*



CONCLUSION

- Present-day heavy agricultural equipment does not necessarily lead to severe subsoil compaction. Even if the soil is wet, the effect of a single pass on soil properties seems to be slight.

- However, these slight changes may add up with repeated passes of heavy machines over years.
- Especially soils with little potential for self-restoration as well as deeply fissured soils with an unstable subsoil structure are in serious danger of becoming compacted.

The risk of soil structure degradation due to heavy farm machinery needs to be reduced by: wide tires, low inflation pressure, radial instead of bias-ply carcass, offset wheels, conservation tillage (SOMMER et al. 2002).

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