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IMPACT OF AGRICULTURAL MACHINERY PRACTICES ON THE DEGRADATION OF SOME CHARACTERISTICES OF CLAYEY SOILS

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ABSTRACT

Soil degradation resulted by agricultural machinery practices, was studies on some clayey soils (*Typic Haplotorrerts*) in the midwestern part of theNile Delta of Egypt. Measuring the compaction of soils was used as an indicator of soil degradation. Physical and micromorphological properties were characterized as parameters of soil compaction. Fissures, pores and matrices were measured as percentages of the projected images of thin sections. These were then used as indicators of soil compaction. Compaction tests were performed in both tilled and untilled soil.

Data revealed that tilled soil was compacted more than the untilled at the same moisture content. However, the top 20 cm was found to be more susceptible to compaction for both tillage treatments. Soil compaction progressively increased as the number of wheel traffic passes increased. Maximum compaction was attained with seven passes which indicated the virtual collapse of soil structure.

Micromorphological data showed no clear relation between porosity and the number of passes the soil was subjected to. This may be attributed to an insufficient numbers of tested samples. However, this soil which is a *Typic Haplotorrerts* has the capacity to recover rather quickly from such severe compaction because of its high content of smectitic clay, and the swelling and shrinking phenomenon that is characteristic of these soils.

Keywords : Soil degradation , soil compaction, clayey soils and Nile Delta.

INTRODUCTION

Machine traffic is an important consideration witch can affect soil conditions that, in turn, can influence plant growth. Soil compaction increases bulk density and reduces soil porosity witch can adversely affect soil aeration and soil –water relationships. The ultimate result is a significant reduction in root develompent and plant growth.

Long-term, intensive cultivation causes damage to soil structure (Greenland, 1977 and Russell, 1978). Omar (1983) studied compaction in four heavy clay soils in Egypt and concluded that the highest compaction was related to the exchangeable sodium percentage. Ghazy et al. (1986) reported that the main factors affecting the soil infiltration rate are moisture content and resistivity.

Weaver (1950) studied the compaction of a loamy soil caused by a pneumatic tires tractor He found that the maximum compaction in soil from tractor usage occurs in the range of 11 to 15 prcent moisture content. Free (1953) reported that the state of compaction is certainly a factor in seed germination. It affects the rate and extent of capillary movement of soil moisture, and also affects evaporation losses. The chemistry of plant nutrient availability and fertilizer use efficiency are influenced directly or indirectly by soil compaction.

Raney *et al* (1955) found that the zone of highest soil bulk density and lowest permeability is commonly just below the zone disturbed by normal tillage operations. Soane (1970), reported that machinery operations carried out on a wet filed induced a very dense subsoil. Voorhees et al. (1985) studied the soil and crop response to wheel traffic on highly productive soils of the northern Corn Belt of the USA, and found that the intensity and depth of compaction depend largely on the soil water content at the time of wheel traffic, and on total axle load. Little information which are available on the micromorphometry of man-induced compaction of subsurface layers often referred to plow pans, cultivated pans or traffic pans. A method for analyzing pores in thin sections of undisturbed soils by using electro-optical image analysis was developed by Pagliai et al. (1980). Jongerius (1982), reviewed the literature on soil micromorphological changes attributed to agricultural practices such as the influence of moving implements and machines on topsoil characteristics. McFowan et al. (1983) studied the continuity of soil pans and responses to wetting and drying. They reported on the preferred orientation and length of planar pores under barley, grass and fallow. Collins and Larey (1987) studied the micromorphology of compacted horizons in Irish tilled soils and observed that a platy structure is common in cultivation pans.

The purpose of this study was to observe changes in soil physical conditions in response to filed wheel traffic, and changes in the micromorophometric properties (i.e. porosity and pore size distribution) due to soil compaction.

MATERIALS AND METHODS

A none cultivated field in El-Bahira Governorate, in the mid-west of the Nile Delta was chosen for this study. A representative soil profile was exposed to a depth of 150 cm and the different soil horizons were descriped. Undisturbed and disturbed soil samples were collected for physical, chemical micromorphological and mineralogical analysis. According to U.S.D.A. (1998) the soil was classified as *Typic Haplotorrerts*. Description of soil profile, x-ray diffractorgram (Fig 1), and (Table 1) show some of the soil characteristices.

Description of the representative soil profile :

Location : 5 km North-west of Damanhour
Land use : Uncultivated
Parent material : alluvial sediments.
Topography : gently sloping, elevation: 5.5 m (a.s.l.)
Drainage : Moderately drained.
Classification : *Typic Haplotorrerts*.

Hor.	Depth cm	
Ap	0-30	Dark brown (10- YR 3/3, moist); clay loam; strong medium subangular blocky str.; sticky, plastic; strong effervescence with HCl; many fine $CaCO_3$ concretions; many fine to medium roots; diffused smooth boundary.
C_1	30-70	Dark brown (10 YR 3/3, moist); clay; strong, medium, subangular blocky str.; very sticky, very plastic; slickensides; slight effervescence with HCl; few fine $CaCO_3$ concretions; few fine to medium roots; diffused smooth boundary.
C_2	70-150	Dark brown (10 YR 3/3, moist); clay; strong, medium, subangular blocky str.; slickensides; very sticky, very plastic; slight effervescence with HCl; few fine $CaCO_3$ concretions; few fine roots.
	> 150	Water-table level. .

Fig. 1: X-ray diffractorgrams for the clay fraction (clay saturated with magnesium and treated with glycerine)

Table (1):Some physical, chemical, Micromorphological and mineral-ogical characteristics of the soil at the Experimental Field .

Characteristics	**Range in Values**
PH	7.9- 8.1
EC_e (dSm^{-1})	0.12 – 0.21
Particle size distribution	
Sand	17.0 – 21.0`
Silt	32.0 – 50.0
Clay	32.0 – 51.0
Texture	Silty clay loam to Clay
Cation exchange capacity (meq/100g)	33.0 – 51.0
Exchangeable sodium percentage (%)	3.7 – 32.0
Surface soil	
Salt accumulation	
Subsurface Soil	
Negligible lime accumulation	
Deep Layer	
Common slickensides	
Dominant clay mineral	
Montmoreilonite	

The experimental field, consisting of about five acres was divided into two parts. The first was tilled for seedbed preparation and the second was left untilled with no seedbed preparation.

Pretreatment for Seed Bed Preparation :

One) Three passes with a chisel plow fitted with five curved shanks 6 cm apart and at a 25- and 30-cm depth.

Two) Two passes with a subsoiler operating at 50-cm depth and 60-cm spacing. A 5-cm wide shank was used and raked on a 45-degree angle with 30-cm total width.

Three) One pass by a rotary tiller to cut, loosen and mix the soil up to 20-cm depth.

Four) The area was then flooded with water.

Both the tilled and untilled fields were flooded for two days until the soil moisture content reached filed capacity, after which the compaction treatments were implemented.

Compaction Treatments

Zero, one three, five, seven, nine and eleven passes with a 65-HP tractor (7500 kg weight) were conducted in both the tilled and untilled areas at different moisture contents. After each treatment the following measurements were taken :

One) Bulk density (wax mehtod).

Two) Soil resistivity (hand penetrometer).

Three) Soil sinkage under tractor tire.

Four) Infiltration rate (double-ring method).

Porosity Measurements :

Thin sections, with an average useful area of 12 cm^2, were prepared after impregnation of the dry undisturbed soil samples with polystyrene resin. Porosity was measured on the projected image of the thin sections using a digitizer combined with a Hewlett Packard 85 microcomputer. The reference lines had a constant distance of 2mm so that the intersections would facilitate the measurement of solid material, fissures and other pores.

RESULTS AND DISCUSSION

Filed Measurements:

Soil resistivity and land sinkage under tractor tires were the two parameters that were studied in the field for both tilled and untilled soil. The measurements were conducted at two moisture levels, i.e. 33 and 37 percent. (Table 2) shows that soil resistivety and land sinkage increased significantly in both tilled and untilled soil with increased number of tractor passes, and at both moisture levels. However, soil resistivity was higher and the land sinkage was less at the lower moisture content.

The effect of tillage on soil compaction throughout the soil was also studies by counting the number of blows needed to force the penetrometer through the soil in 5-cm increments. From the histograms shown in (figure 2), it can be concluded that as the number of tractor passes increased, soil compaction was increased in both tilled and untilled soils. However after nine passes compaction was found to be lower than for the other treatments. A probable explanation may be that this number of passes caused the virtual collapse of soil structure (pagliai et al., 1989).

Generally, the tilled soils showed lower resistivity (more compaction) than untilled soils. This relation became less pronounced with increased passes and actually reversed after nine passes. Both tilled and untilled treatments showed increased resistivity with depth.

Table (2):Changes in soil Resistivity and Land Sinkage of Tilled and Untilled Soil at two Moisture Levels as Affected by the Number of Wheel Passes.

No. of Passes	Soil Resistivity (Kg/cm 2)				Land Sinkage(cm)			
	Tilled (w_1)	Un-tilled	Tilled (w_2)	Un-tilled	Tilled (w_1)	Un-tilled	Tilled (w_2)	Un-tilled
Zero	1.17	1.40	1.97	2.30	-	-	-	-
1	1.53	1.59	2.66	2.70	4.50	3.50	5.00	2.75
3	1.82	2.05	3.32	3.50	6.50	3.80	5.50	3.90
5	2.05	2.36	3.57	3.95	7.25	6.25	7.00	5.20
7	2.34	2.99	4.27	4.24	7.60	7.25	7.25	5.50
9	3.11	2.30	4.18	4.30	10.70	9.45	7.50	6.25

Each value is the mean of four readings.
w_1 = 37 percent soil moisture content.
w_2 = 33 percent soil moisture content.

Figure (2):The Average Number of Blows to Penetrate 5 cm Soil Depth of Tilled and Untilled Soils under Different Traffic wheel Treatments.

Bulk density and infiltration rate measurements did not show any significant relationship with compaction (Table 3). This may be due to the unique behavior of vertisols. Shrinking, swelling and cracking of these soils when drying can induce irregular infiltration patterns. Consequently, bulk density was also affected. Swelling of these soils upon wetting closes the cracks, causing a kind of pedoturbation which directly affects the bulk density and infiltration rate.

Table (3):Changes in Bulk Density and Infiltration Rate of Tilled and Untilled Soil as Affected by the Number of Wheel Traffic Passes.

No. of Passes	Bulk Density (g/cm3)		Infiltration Rate (cm/day)		
	Tilled	Untilled	24 h	48 h	96 h
Zero	1.51	1.64	0.8	0.8	1.0
1	1.66	1.37	-	-	-
3	1.47	1.45	0.5	0.5	0.6
5	1.39	1.32	0.4	0.4	0.6
7	1.41	1.39	0.4	0.6	1.0
9	1.50	1.60	0.4	0.5	0.9

Each value is a mean of four readings.
Infiltration rates were measured on tilled soil only.

Micromorphological characteristics :
The results of microscopic investigation of the thin sections prepared from the undisturbed soil samples collected before implementing the different treatments can be summarized as follows:

Microstructure. Partially and moderately developed peds were found in the surface layer, but became strongly developed in the deep layers. Many channels and vughs (i.e. cavities) of medium to fine size, and few fissures were observed (plate 1). The microstructure type is channel to vugh in the surface layer which changes to fissures in the deep layers.

Mineral components. The coarse mineral fraction is fine to medium sand and well sorted quartz grains of subangular shape and randomly oriented.
There are also a few calcite crystals of fine sand size. The micromass is heterogenous, light brownish material consisting of clay, organic material and lime, with dotted to speckled crystallitic and gromostriated b-fabric.
The related distribution is open porphyric

Organic component. Amorphous fine organic materials of dark brownish color are impregnated in the fine material. There are some organic and cell residues of reddish color in the deep layers.

Pedofeatures. Many calcitic nodules of clear boundaries and rounded to ellipsoidal shape are observed. A few calcite hypocoating of pores, and coarse compound calcitic nodules are found in the deep layers. Some iron and manganese compounds having clear boundaries and brown to black color are also identified in the deepest layer.
All of these micromorphological descriptions are based on the terminology introduced by Bullock et al, (1984).

Micromorphometric Measurements

The total area of fissure, pores, and matrices expressed as percent of total area of the thin sections, and the average length of intersections of the reference line with each of the studied units, were calculated for each slide to determine the effect of wheel traffic compaction on the micromorphologic characteristics.

Total prosity

The mean values of pores of each shape group (fissures and other pores_ and their sum (total porosity), expressed as a percentage of the total area of the thin section occupied by pores are reported in (Table 4). Fissures, the dominant pore type in Vertisols, are more susceptible to compaction than the other types of pores. Therefore, the data in (Table 4) showed a decrease in the percentage of fissure with increased number of passes (pagliai et al., 1989).

The variation in total porosity (fissures and other types of pores) can be attributed to the physical stresses such as shrinkage and swelling of montorillontic clay, which is dominant in Vertisols (pagliai et al., 1980 and El-Araby et al., 1987). Another important factor affecting the relation between porosity and the number of passes is the heterogeneity of the soil materials. From the data in (Table 5) it is apparent that there is a considerable variation within a few centimeters (thin section area).

Plate (1): Photograph of Thin Section Taken at 30 to 70 cm Depth showing Fissures, Strongly Developed peds, Sorted Grains and Lime Nodules. C.p. 113x.

Table 4. Changes in the Pore Size Distribution and Total porosity of Soil as Affected by the Number of wheel Traffic Passes.

No. of Passes	Fissure	Pores %	Matrix	Fissure	Pores mm	Matrix
0	5.3	3.3	91.3	0.19	0.23	2.22
3	5.0	6.3	88.6	0.50	0.19	2.28
5	3.6	9.5	86.9	0.29	0.63	2.28
7	6.3	6.3	87.9	0.75	0.15	1.73
9	1.5	7.7	91.0	0.12	0.21	1.90

The results obtained by field measurements clearly show the increase in soil resistivity and land sinkage with increased number of traffic passes. However, the data obtained by the investigation of thin sections prepared from undisturbed soil samples collected from different tillage treatments, did not show such a relationship. The micromorphometric measurements show no clear relation between porosity and the number of passes the soil subjected to.

Table (5):Micromorphometric Characteristics of Thin Section Taken at the 20 to 30 cm Depth from Tilled Soils After Seven wheel Traffic passes.

Zone No.	Pores	Fissures ………………………%………………………	Matrix
1	2.50	1.9	95.7
2	12.1	0.4	87.5
3	4.8	0.4	94.3
4	15.6	0.9	88.7
5	30.7	0.1	69.2
6	12.2	0.1	87.7
7	11.9	2.2	85.9
8	25.6	0.3	74.9
9	8.9	1.2	90.0
10	16.8	0.3	82.9
Mean	14.1	0.8	85.7

CONCLUSIONS

Tilled soil was subjected to greater compaction than untilled soil at the same moisture content with increasing number of wheel traffic passes. The top 20 cm of soil was more susceptible to compaction in both tillage treatments. Field measurements showed that soil resistivity and land sinkage increased significantly in both tillage treatments as the number of wheel traffic passes increased. However, soil resitivity was higher and the land sinkage was lower at the lower moisture content. Changes in bulk density and infiltration rate in both tilled and untilled soil as affected by the number of wheel traffic passes were variable and did not show any consistent relationship with compaction. It is likely that this was due to the unique shrinking, swelling and cracking of Vertisols that caused highly variable effectes on bluck density and water infiltration. Fissures are the most dominant pore type in Vertisols, and are more susceptible to compaction than other types of pores. Results showed a decrease in the percentage of fissures as the number of wheel traffic passes increased. The micromorphometric measurement showed no clear relationship between soil porosity and the number of wheel traffic passes that the soil was subjected to.

REFERANCES

Bullock, P., N. Fedoroff, A. Jongerius, G. Stoops, and T. Tursina (1984). Handbook for soil thin section description. Waine Research publications. London, England.

Collins, J.F. and F.J. Larney (1987). Micromorphological observation of compacted horizons (cultivated pans) from various horizons in Irish tilled soils. In Proc. Int. Conf. On Micromorphology (France).

El-Araby, A., Z. El- Haddad and M. El-Ansary (1987). Subsoiling in some heavy clay soils of Egypt. Soils and Tillage Research, 9:207-216.

Free, G.R. (1953). Traffic soles. Agric . Eng., 34:528-531.

Ghazy, A., M. Tayel and M. Omar (1986). Moisture and resistivity, the main factors affecting infiltration studies. Egypt. J. Soil Sci., 26: 275-281.

Greenland, D.J. (1977). Soil damage by intensive arable cultivation: Temporary or permanent. Philosophical Transactions of the Royal Soc. Of London, 281: 193-208.

Jongerius, A. (1982). The role of micromorphology in agricaltural research. P. 111-138. In Soil Micromorphology. London, England.

McGowan, M., S.R. Wellings and C.J. Fry (1983). The structural improvement of damaged clay subsoil. J. Soil Sci., 34:233-248.

Omar, M.S. (1983). The relation between compaction and production. Egypt. J. Siol Sci., 23:259-266.

Pag1iai, M., G. Guidi and M. La Marca (1980). Macro and micromor-phometric investigation on soil-dextran interaction. J. Soil Sci., 31: 493-504.

Pagliai, M.,M, Pezzarossa, M.Mmazzonicini and E.Bonari (1989). Effect of tillage on porosity and microstructure of a loamy soil. Soil Technology, 2: 345-358.

Raney, W.A., T.W. Edminister and W.H. Allawy. (1955). Current status of research in soil compaction. Soil Sci. Soc. Amer. Proc., 19: 423 – 428.

Ressel, E. (1978). Arable Agriculture and soil deterioration.

Russel, E. (1978). Arable agriculture and soil deterioration. In proc. 11th Int. Cong. Soil Sci., June 19-27.

Soane, B.D. (1970). The effects of traffic and implements on soil compaction. J. Proc. Inst. Agric. Eng., 25 (3): 115 -126.

U.S.D.A. (1998). “Keys to soil taxonomy” Soil Survey Staff. Handbook, English Edition.

Voorhees, W.B., W. Nelson and G. Randall (1985). Soils and crop response to wheel traffic on heavy productive soil of the northern corn Belt. In Proc. Int. Conf. On soil Dynamics, 5:1120-1131.

Weaver, H.A. (1950). Tractor use effects on volume weight of Davidson loam. Agric. Eng., 31: 182-183.

أثر ممارسة الميكنة الزراعية على تدهور بعض خواص الأراضى الطينية

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أجريت الدراسة بهدف التعرف على مدى تغير بعض خواص التربة التى تدهورت بالاندماج كنتيجة لممارسة الميكنة فى العمليات الزراعية المختلفة و وذلك من خلال تقدير بعض خواص التربة الطبيعية والكيميائية والمنرالوجية والميكرومورفولوجية وذلك فى حالتى التربة المجهزة وغير المجهزة للزراعة.

وقد وجد أن تصنف هذه الأرض طبقا للتقسيم الأمريكى عام 1998 هو *Typic Haplotorrerts* هذا وقد روعى ثبات نسبة الرطوبة عند إجراء معاملات الاندماج المختلفة. وقد أوضحت الدراسة الحلقية أن التربة التى جهزت للزراعة أكثر عرضة للاندماج كنتيجة لمرور الجرارات الزراعية عن التربة التى لم يتم تجهيزها.

وأوضحت الدراسة الميكروسكوبية للعينات الممثلة للمعاملات المختلفة أن العلاقة بين الاندماج والمسامية الكلية وكذلك التوزيع الحجمى لم تكن واضحة كنتيجة لخصائص تلك الأراضى والتى تنتفخ بالترطيب وتنكمش وتتشقق بالتجفيف.