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Influence Of Soil Compaction Caused By Tractor Passes On Soil Physical Properties

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Abstract: ***A 15x51m^2 field was manually cleared with cutlass and divided into three blocks of four plots each. The soil was compacted using a 35.5KN wheel tractor. The treatment consisted of 0,1,5,and 10 passes(wheel to wheel) of the tractor and were replicated three times. Soil physical properties were analyzed from core samples taken from each plot. This experiment was conducted on the Owerri soil precisely Uratta. This was done between the months of May and June 2018 Soil physical properties analyzed are the grain size analysis,cone index, dry bulk density, moisture content, soil porosity, water holding capacity, hydraulic conductivity and soil air. The results got showed that compaction affects the soil physical properties in so many ways. It results in poor nutrient and water uptake by plants and soil structure degradation which are reflected in the changes in soil physical properties. It also lowers the production potentials of the soil by exposing the soil to physio-chemical damages with a resultant poor nutrient uptake and poor growth and crop yield.***

Keywords: Soil compaction, tractor passes, soil physical properties, soil physio-chemical damages.

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I. INTRODUCTION

Soil compaction is the process of applying pressure to the agricultural soil thereby disturbing the soil texture and structure and thereby compressing the soil.

The compaction of soil can also be defined as an increase in its dry density, and the closer packing of solid particles or reduction in porosity. Modern cropping systems are based on agricultural machinery and this machinery is responsible for most of the soil compaction.

Vehicular traffic on agricultural mechanization i.e. a process by which any or all of the usual operations involved in agricultural production are carried out with mechanical assistance using either manually operated machinery or motorized and/ or automated machine units. The mechanization of crop production is increasing in most parts of the world. In many countries this trend is viewed with concern because of the compaction which results when wheels pass over soils used as a growing medium for crops (Soane, 1970; Barnes et al., 1971; Eriksson et al., 1974; Chancellor, 1976; Osuji, 1988; Ohu et al., 1991). Among the numerous studies carried out to determine the effects of wheel traffic on soils, parameters such as bulk density, soil strength, total porosity and hydraulic conductivity have been used as indicators of soil compaction (Gameda et al., 1988), with bulk density being the most used (Raghavan et al., 1978; De knipe et al., 1981; Voorhess et al., 1986; Cupta and Almares, 1987). Soil compaction is important in Agriculture as it reduces runoffs.The use of tractors in Agriculture makes agricultural practice less stressful etc. The mutual interaction between these parameters are affected by soil moisture content. As soil moisture content increases, the soil strength (cone index) decreases and dry bulk density increases (Taylor et al., 1981).

However, at a fixed moisture content a soil will have a higher strength at larger densities, which reflects the closer packing of solid particles. This compaction also alters the water content and movement in soils by modifying the void size distribution (Warkentin, 1971). This tends to reduce both the amount of water which is retained at low water suction pressure in the macropores, and the saturated hydraulic conductivity of the soil. Ide et al.(1984) found that the reduction in total porosity resulting from compaction would lead to a shortage of oxygen for plant roots while the reduction

in pore diameter would prevent the entrance of root tips and easy flow of gravitational water.

From the above review, it may be summarized that tractor passes on the soil result in:

- ✓ Poor nutrient and water up take by plants
- ✓ Soil structure degradation which are reflected in changes in soil physical properties such as dry bulk density, soil strength, soil porosity, permeability etc. with soil structure degradation, soil compaction due to traffic lowers the production potentials of the soil by exposing the soilto physio-chemical damages with a resultant poor nutrient uptake and poor growth and yield of crops. Although compaction is detrimental to plant growth, but it can be ameliorated (Mckyes, 1985) by any or all of the following:
  - Avoid high machinery contact pressure especially during repeated passes in fields.
  - Avoid moving on fields with machines when the top soil is moist, close to the "optimum" moisture content for compaction.
  - Avoid excessive slipping of tractor lives during field operations, which could double soil density changes under the same weight.
  - Manage cultural programs that leave healthy system of roots, and sufficient organic matter in the top soil.So in this work, it is intended to assess the interactions of soil properties as they area affected by tractor wheel traffic.

II. LITERATURE REVIEW

Soil compaction had been a very sensitive problem to agricultural production because it involves poor soil and water conservation and thus reduced crop growth and yield. In developing countries like Nigeria, mechanization is increasing and, although the vehicles used may be light, the low structural stability of many tropical soils combined with the high erosivity of rainfall together increase the chances of serious soil degradation by field traffic. Compaction from field traffic may occur in virtually all types of crop production (Soane and Van Ouiverkerk, 1981).

It modifies the pore volume and pore structure of the soil with changes in void ratio, total porosity, specific volume and dry bulk density. Changes in bulk volumetric properties may not be as important to plant growth as the associated increased strength and reduction of conductivity, permeability and diffusivity of water and air through the soil pore system (Soane, 1985; Boone et al., 1987; Guerif, 1988). The soil properties to measure in compaction studies must be chosen by the researcher. The properties must strongly influence the way in which the soil responds to applied loads and the likely importance of the measured changes in subsequent crop growth. Bulk density had found application for comparing growth of different varieties of crops (Hakansson, 1973, Raghavan et al., 1976) and for the comparison of the compacting effects of different wheel treatments over a range of soil types (Ljungara, 1977; Lamers et al., 1986). Changes in pore size distribution during compaction are important particularly with respect to large air-filled pores. Porosity and void ratio changes in a wide range of agricultural soils resulting from an applied mechanical stress have been reported by Larson et al.(1980) and Voinvail and Flocker (1991). Compaction reduces the diameter and continuity of pores and thus reduces the permeability and diffusion of gases and liquids in the soil (Grabble, 1971; Ball, 1979). The cone resistance that measures soil strength is an important parameter affected by compaction. Compaction increases soil strength which not only increases soil cutting forces and energy required but will also impede the growth of plant roots (Mckyes, 1985; Taylor et al., 1981).

All these soil properties mentioned above are usually affected by both soil type and soil moisture content (Mulqueen et al., 1980).

It is widely thought that second subsequent passes a wheel produce less compaction than that caused by the first pass. This depends on the initial soil strength and its distribution with depth (Soane et al., 1981). Modern systems of crop production are trending to increase both the number of pases and the loads carried on the wheels of agricultural vehicles especially in seed bed preparation, spraying and harvesting operations (Soane et al., 1982).

During fertilizer distribution, secondary cultivation and sowing, soil strength is generally low as a result of the loosening during primary cultivation and the soil is usually moist making tractor to cause appreciable compaction. Ljungars (1977) found that the soil moisture content and the number of wheel passes were the factors primarily responsible for the compaction resulting from seedbed traffic.

Compaction by wheel traffic was found by Raghavan et al.(1979) to delay germination and early growth of maize silage. Root distribution of maize has been found to be closely associated with both the number of passes and the contact pressure of types running over the soil either before or after seedling (Raghavan and Mckyes, 1978).

Many researches have used several numbers of wheel passes in their work Bonsu (1991) used 0,2,8 and 14 passes, Osuji (1988) used 0, 2,5, 10 and 15 passes and Ragharan et al.(1976) used 1, 5, 10 and 15 passes. Canarache et al.(1988) used 0,1,3,5, 10 , 20 and 30 passes and Daniel et al.(1988) used 0, 1,3,5 and 10 passes. In view of the fact that mechanization sequence is different in South Eastern Nigeria, 0, 1,5 and 10 passes of the tractor wheel were used in this work.

III. MATERIALS AND METHODS

In the analysis a 4-cylinder Steyr 768 tractor, hand operated auger, cutlasses, metre rule vibratory sieve materials and other relevant experimental apparatus as the affect different analysis were employed.

A piece of land at Umunahu, Uratta in Owerri was manually cleared using cutlass and piled. The soil was leveled by the use of rake and measured in three blocks of four plots each.The field measured 15x 51m^2.

The field was divided into three blocks, leaving a head land of 3m wide between blocks. Each plot measured 1x10m^2.

Before and after each treatment, a hand operated anger of core size 7.6 x 7.40m^2 was used to excavate the soil at

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different depths of 0-50cm, 5-100cm and 10-15cm for soil analysis and for the determination of soil physical properties.

A4-cylinder Steyr 768 tractor having two rear tires inflation pressure of 40psi with a weight of 35.5KN and tire size of 16.9/14-30 (6 ply rating) and this very tractor was to make passes on the field leaving a portion as control. The number of passes were 0, 1,5 and 10 replicated three times and the mean value recorded.

Samples of soil were taken in straight lines with the aid of the auger. Moisture content, Cone index etc were tested. The particles size distribution was done using vibratory sieve method. With mesh sizes 4.75mm, 2.36mm, 1.18mm, 950mm, 425mm, 212mm, 200mm, 150mm and 75mm arranged accordingly. Three samples were taken per plot.

The following soil physical properties were determined using standard laboratory methods on the soil core samples.

Soil analyses were performed on the different soil physical properties as seen below

SHEAR STRENGTH: Shear strength measurement was done using the following- Soil samples, shear box, successive loads etc. collected soil sample was prepared in a direct shear box, with load applied. the box was split into two parts, the lower part was fixed and the upper part was given a gentle increasing force. The soil specimen was removed for the shear box. This was repeated with different specimen. This was repeated in all the different plots.

HYDRAULIC CONDUCTIVITY (CONSTANT HEAD METHOD): Constant head was maintained by having a tap of water flowing constantly into the both. It was also constantly discharged so that the height, was maintained constant. The time within which discharge was collected was recorded.

POROSITY: Soil sample was collected into a funnel which was placed in a graced cylinder. The soil was put on top of cotton wool to act as sieve and water was poured into the cylinder through the funnel and the time taken for the water to drain and the amount of water drained and retained were recorded.

CONE INDEX (PENETRATION RESISTANCE): This was done at 60^0 tip cone penetration having a base area of 5x $10^{-4}m^2$ soil was put into a container and the cone allowed to touch it. The screw of this penetrometer was turned causing pressure on the tin and dial gauge's reading was recorded.

BULK DENSITY: A core sample of soil was got by driving the sample into the soil to a desired depth and then removed. Having known the volume of the sample, the mass, the dry bulk density was easily calculated.

MOISTURE CONTENT: The hand operated anger was used to excavated the soil to collect a soil sample. This natural soil was weighted and recorded. The soil was dried in an oven at the temp of 105^0 for 24 hours and was allowed to cool and it was re-weighted.The moisture content was calculated. This was replicated three times. It was allowed to cool before reviewing again to allow it to assume its normal weight because the soil is hydroscopic.

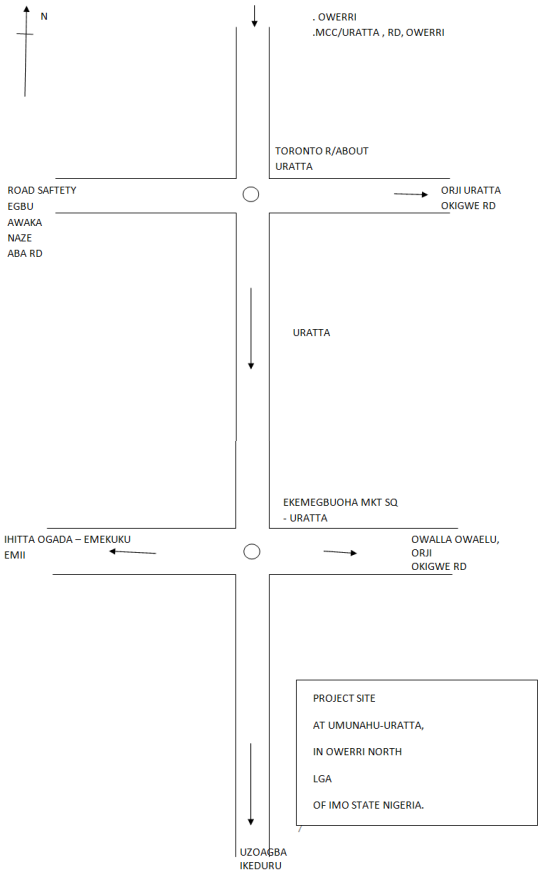
SOIL AIR: A milk tin was opened at one end and a volume was estimated by filling it with water and then pouring the water into a graduated cylinder. The empty tin was turned upside down and the open end was pressed firmly into the ground until the tin was filled with soil. It was later turned back and the soil was level to the brim of the tin with a ruler, $2300m^3$ of water was poured into a $500cm^3$ graduated cylinder. The soil was scrapped in the tin. Bubbles of air started escaping till no more air escaped.

GRAIN SIZE ANALYSIS: This was done by weighing and noting the weights of the meshes and arranged in descending order of sizes. A known weight of dried soil sample was placed inside the mechanical shaker and timed for 2 mines. The meshes weighed again to know the amount of soil retained in each mesh.

HYDRAULIC CONDUCTIVITY: An undisturbed packed soil sample was placed on the cylindrical container with enough space below and above the soil pack. The cross-sectional area of soil pack or core A and the length L of the soil column was measured. One side of the soil column was sealed with paraffin wax to prevent passage of water down the sides of the soil column.

A known volume of water for a measured time was passed three the soil. The difference in head between two levels after the same measured time was measured.

DRY BULK(CORE TECHNIQUE METHOD): A sampler is known volume was used to collect a core sampler of known volume was used to collect a core sample of soil by driving it into the soil to depths of 0-5cm, 5-10cm and 10-15cm respectively at different times and then removed. After the sample was removed from the soil, the core was placed in a paraffin point-sized cream container and sealed. The core sample dimension was noted to be 7.6 x7.4cm^2 taken layer by layer along three profile pits due to the site. The soil was weighted wet and result noted as xgm. It was later over dried as 105^{0c} for 24 hours and allowed to cool, and was weighted dry, ygm.



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IV. RESULTS AND DISCUSSION

Sieve Diameter	0-5cm % Finner	5-10cm % Finner	10-15cm % Finner
4.75mm	100	100	100
2.36mm	99.95	99.95	99.99
1.18mm	99.70	99.80	98.24
850mm	96.65	98.10	94.91
425mm	54.55	63.00	51.3
212mm	43.35	41.05	40.36
200mm	3.85	4.85	5.10
150mm	0.15	1.91	2.07
75mm	0.02	0.05	0.06
Pan	0	0	0

Table1: Result of Sieve analysis of soil from the experimental plot

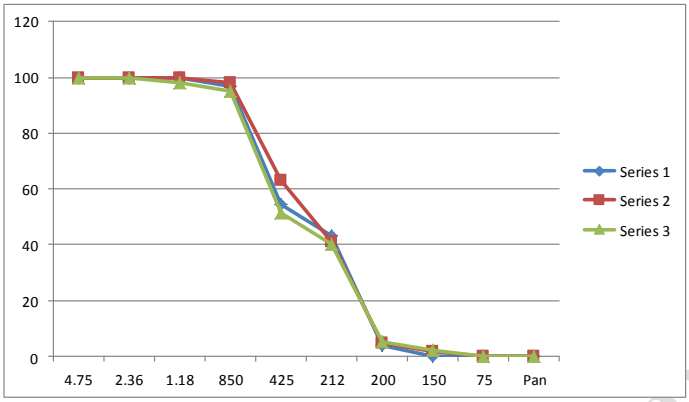

Figure 2: Sieve analysis of soil from the experimental plot

	T=0	T=1	T=5	T=10
0-5	0.35	0.89	2.55	7.45
5-10	0.77	1.12	2.93	8.23
10-15	1.16	1.81	5.45	8.96

Table 2: Effect of traffic density on Cone Index (Penetration resistance) (kg/cm^2)

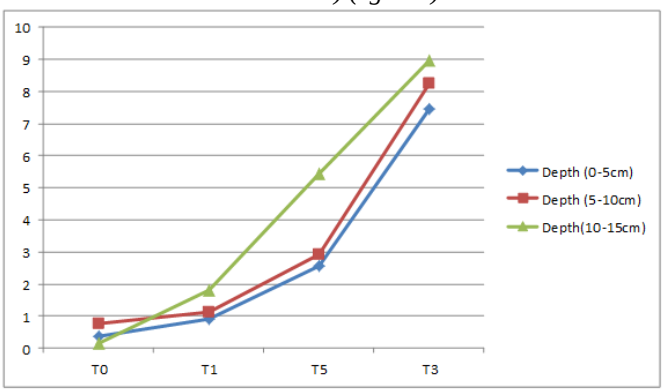

Figure3: Effect of traffic density on Cone Index (Penetration resistance) (kg/cm^2)

Depth (cm)		1	5	10	
0-5	0.124	0.070	0.056	0.045	
5-10	0.340	0.340	0.285	0.141	0.116
10-15	0.440	0.440	0.353	0.230	0.126

Table 3: Effect of traffic density on Hydraulic Conductivity (m/s)

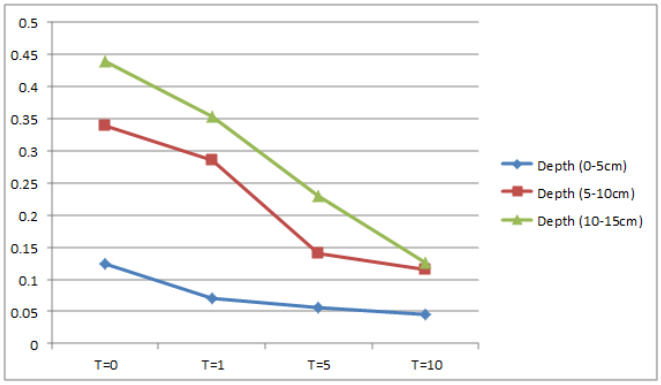

Figure 4: Effect of traffic density on Hydraulic Conductivity (m/s)

Depth (cm)	0	1	5	10
0-5	7.03	7.95	8.90	9.03
5-10	9.34	9.3	12.32	15.96
10-15	10.90	11.64	13.45	14.9

Table 4: Effect of traffic density on soil porosity

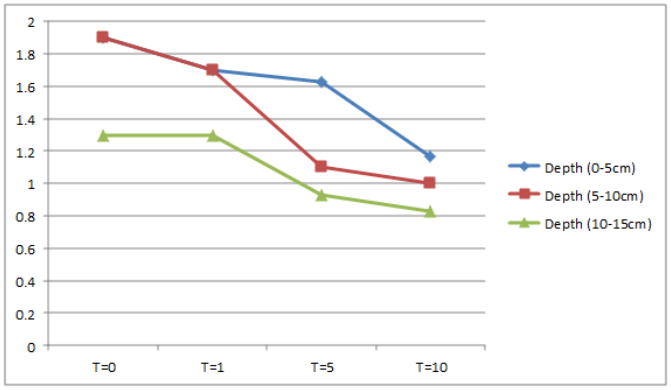

Figure 5

Depth (cm)		1	5	10
0-5	1.9	1.70	1.63	1.17
5-10	1.9	1.70	1.10	1.0
10-15	1.30	1.30	0.93	0.83

Table 6: Effect of traffic density on soil porosity

	0	1	5	10
0.4	6.0	8.5	16.5	28
0.8	14	16	27	39
1.2	20.5	22.5	34.9	46.8
1.6	25.3	27.5	39.9	52.3
2.0	29.0	31.3	45	56.6
2.4	30.8	33.4	46	59.7
2.8	30.5	33.4	47.6	61.7
3.2	30.5	33.4	47.6	62.7
3.6	30.5	33.4	47.6	62.7

Table 6: Effect of traffic density on soil porosity Strain, 6 Proving ring dial (cm)

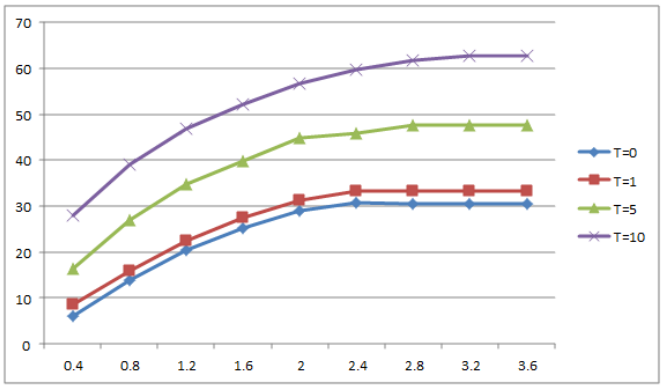

Figure 6: Effect of traffic intensity on soil shear strength

The results obtained from this experiment were represented in tables and figures as shown below.

A. RELATIONSHIP BETWEEN SOIL PROPERTIES AND WHEEL TRAFFIC

- ✓ *GRAIN SIZE ANALYSIS:* The results got from this research is represented in table 4.1. The percentage finner varied with the Sieve diameter and has no significant difference with the number of wheel passes because as the traffic density increased, the soil was more depressed than crushed.

Looking closely at the graph of percentage finner against sieve diameter at different soil depths, Figure 4.2 showed that the percentage finner varied slightly with soil depth.

The deeper the soil, the more finner the soil grain. From the fig. 2, it was observed that the curves for 0-5cm, 5-10cm and 10-15cm soil depth took the same pattern as observed by Asoegwu,(1987).

- ✓ *CONE INDEX:* The penetration resistance of the soil varied directly with the number of tractor wheel passes (Table 2). Increase in traffic intensity, increased the Penetration Resistance. From the result obtained from this research, the cone Index was maximum (8.96kg/cm^2) in the 10 passes treatment and at soil depth of 10-15cm whereas the lowest value of cone Index (0.35kg/cm^2) was obtained in the 0 pass treatment at 0-5cm soil depth. Figure 3 it could be said that the cone index increases with traffic density and soil depth.

We therefore, conclude that compaction increases soil strength which also increases soil cutting forces and energy required and as such impede plant root growth. This is in consonance with the previous research work. (Mckyes, 1985; Taylor et al., 1981).

- ✓ *DRY BULK DENSITY:* The traffic density has a significant effect on the Dry Bulk Density of a soil sample. It has found application for comparing growth of different varieties of crops- (Hakansson 1973, Bagharan et al., 1976) and for the comparison of the compacting effects of different wheel treatment over a range of soil types. Increase in traffic intensity, increases the pressure and thereby reducing the volume of the pores resulting in increased density at constant soil mass .
- ✓ *HYDRAULIC CONDUCTIVITY (PERMEABILITY):* Permeability decreased with traffic density and increased with soil depth according to Bonsu (1991).
- ✓ *SOIL POROSITY AND WATER HOLDING CAPACITY:* It is evident from Table 4.4 that the porosity decreased as the soil depth increased. This observation is true with Larson et al.,(1980), Voinvail and Flocker (1961).
- ✓ *CONE INDEX AND DRY BULK DENSITY:* The cone index and dry bulk density have the same pattern of growth under axle wheels. (Tables 2 and 3). From these tables, we saw that cone index increased with increased Dry Bulk Density at different soil depths. From this, we could confirm that compaction governs both cone index and dry Bulk Density of a soil. This result is similar with Bonsu (1991) and Asoegwu (1987).
- ✓ *PROVING RING AND STRAIN:* The result on proving ring dial and strain has a direct relationship with each other. (Figure 6). This figure illustrates the curves of proving ring dials and strain at different traffic density. The curves have the same pattern but different values of proving Ring dials for different traffic density at the same strain. (Table 6). from this table, we observe that the proving ring dial was lowest (6mm) at 3.6% strain in the 10 passes treatment.

V. CONCLUSION AND RECOMMENDATION

From the results so far got, it is found out that soil compaction as a result of farm vehicular traffic affects soil physical properties. It affects the soil structure and stability.

A more concise result would have been got if a roller wheel was used instead of the tire type of tractor so that more area of soil would have been compacted, and this would have increased the tractor weight on the soil.

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