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Influence of Conventional Tillage on Soil Adhesion, Plasticity and Cohesion of A Loamy Soil

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***Abstract* – Conventional tillage systems are performed over a long period for the production of a given crop. In convectional tillage, seedbeds are prepared well by clearing surface residues and the interruption of weed, insect and the breaking of root limiting soil layers. The influence of convectional tillage on soil adhesion, plasticity and cohesion in a loamy soil was investigated in this study. The study was conducted at Use Offot in Uyo Local Government Area. The soil in the study area was classified as loamy soil. The tillage implements which their influence were studied include 4-bottom disc plough and offset disc harrow. The soil adhesion, plasticity and cohesion properties were analyzed using tillage depths of 0-20 and 20-30 cm. The results show that the values of these properties were higher for the before tillage operation compared to the values of these properties for the after tillage operations. ANOVA and Turkey's tests indicate that there is no significant effect of conventional tillage on soil adhesion, plasticity and cohesion in a loamy soil.**

***Keywords* – Mechanical Properties, Loamy Soil, Conventional Tillage, Tillage Depth and Tractor.**

I. Introduction

Conventional soil tillage practices modify soil structure by changing both its physical and mechanical properties such as bulk density, porosity, moisture content and its penetration resistance.

All tillage practices no matter how little has an effect on the soil quality [1]. Since tillage fractures the soil, it disrupts soil structure, accelerating runoff and soil erosion. Soil-tool interaction is of much concern for this top soil stratum. Methods of classical soil mechanics are often applied to agricultural soil mechanics with little modification for studying soil deformation. Soil mechanics mostly deals with soil failure at shallow depth with the interaction of relatively low load. Classical soil mechanics deals with mainly on the response of soil to small displacements due to loading and its behavior up to failure, whereas tillage mechanics is concerned with the soil condition after failure [2].

Stated that tillage operation affects both soil resistance to penetration and its related indicators like moisture content and bulk density [3]. Because of this, it becomes very necessary to isolate the direct effect of tillage on cone index from its direct effect on water content as well as bulk density in different ways in order to allow better assessments. However, observed that in a good structured soil, root growth recorded higher penetrometer readings due to the inter aggregate spaces available for their growths [3]. Soil penetration is a measure of the ease at which an object can be pushed into the soil. Posited that the common indicators for determination of soil strength in tillage operations are bulk density and penetrometer resistance [4]. Conventional tillage involves three operations - primary, secondary and tertiary tillage [5]. Current concerns about environmental quality have questioned the sustainability of the conventional tillage practices which mainly accelerates soil organic matter breakdown [5] and destroys soil structure. Exposure of the soil surface and destruction of the soil structure in conventional tillage also increases the susceptibility of the soil, especially with heavy rainfall just after planting [6]. Posited that the important factors that influence the choice of the tillage system include soil aeration, management of crop residues, weed control, incorporation of fertilizers, timeliness for cultivation, cost and energy conservation; and that proper selection and utilization of tillage implements and systems means saving of environment and maximizing of returns [7].

The tillage practice that would have the least impact on the environment in a certain area and specifically the soil would thus be the most sustainable practice in that area [8]. A major advantage of conservation tillage is erosion control. Surface run-off can be virtually eliminated with no-tillage due to higher infiltration rates due to preferential flow paths created naturally. In most cases no-tillage (a conservation tillage practice) is such a practice because it improves soil quality, especially in the semi-arid Mediterranean climate. Confirmed this statement by using a quality indicator response technique [9]. No-tillage is a more sustainable system for the Mediterranean region but also in semi-arid areas and in some humid areas.

Stated that crop production and tillage usually lowers the organic matter content in soils [10]. Soil organic matter content is one of the most important soil properties and productivity indicators in agriculture, especially after the 20th century when sustainable agriculture became more important [10]. Organic carbon content is one of the factors which influences soil stability [11] because of its direct effect on the soil physical and chemical properties. One of the main reasons being that soil mixing and crushing (by conventional tillage) promote the decomposition and oxidation of organic matter [12].

This study focuses on the influence of conventional tillage on some soil properties in a loamy soil.

II. Materials and Methods

A. *Study Location*

The study area for this research work was in Use Offot, Uyo local government area of Akwa Ibom state, Nigeria. This region has its geographical coordinates to be 5° 03’ 4.57”N (latitude) and 7° 56’ 0.60”E (longitude). The average annual temperature for Uyo is 35^{0}C and there is about 502mm of rain in a year. Average humidity of the region is about 55%, and Uyo has the tropical monsoon climate.

B. *Tractor and Tillage Implements*

The specification of tractor used for the study is presented in Table I. Tillage implements used for evaluating the effects of tillage on soil mechanical properties included the 4-buttom disc plough and the offset disc harrow which are most commonly used for seed bed preparation in Akwa Ibom State and the study area. These implements were representative of the standard primary and secondary tillage implements. The implements were owned by the department of Agricultural Engineering, University of Uyo.

Table I. Specification of Tractor Used.

Specification	Eicher 5660
Effective output (hp)	55
Type of engine	3-cylinder
Type of fuel	Diesel
Front tyres (size)	7.50-16
Rear tyres (size)	14.9-28

Specification	Eicher 5660
Fuel tank capacity(L)	60
Country of manufacture	India

C. *Soil Sampling and Experimental Layout*

At each of the sampling points, random spots were core sampled and augured at 0-30 cm depth with the aid of a dutch auger and bulked out to give a composite sample. The soil samples from different sampling points were, on each occasion, collected in polyethylene sample bags and labeled accordingly and the samples were taken to the laboratory for analysis. Laboratory methods of analysis were carried out on the soil samples for particle size distribution. The research field was measured, marked and mapped out with pegs to create a 50m by 50m dimension for the experiment. The experiment was conducted with the conventional tillage practices (primary and secondary tillage operations). The speed of the tractor used for the tillage operations was 7.5km/hr while the depth was 30cm which was achieved using the tractor quadrant. For each of the samples gotten, the auger was used. The ploughing depths were measured using a steel rule with the undisturbed surface taken to be the reference point.

D. *Determination of Soil Adhesion*

Samples collected from the field of experiment using the auger at various depths before and after the tillage operations were taken to the laboratory and the soil adhesion for each sample was determined. The direct shear test method was used for the test.

E. *Determination of Soil Plasticity*

The numerical difference between the liquid limit and the plastic limit is termed plasticity. Plasticity index is the range of water content where the soil exhibits plastic properties. The method employed to determine the liquid limit consist first of placing a soil-water paste in a standard cup. The paste is then divided into two halves. The moisture content at which the two halves flow is determined. The moisture content corresponds to the liquid limit. The plastic limit was determined by rolling a thread of soil to 3mm in diameter between the fingers and a glass plate.

F. *Determination Soil Cohesion*

The soil samples were collected in an air tight bag using the auger. These samples collected at various depths were taken to the laboratory for the test of the cohesiveness of the soil before and after the tillage operations. The direct shear test method was also employed for the test.

G. *Collection and Analysis of Data*

Data were collected from the various parameters tested. The data collected were analyzed using tables and statistical methods from which the effect of tillage operations on the mechanical properties of soil was judged. Results are expressed as mean and standard deviation using Statistical Package for Social Sciences (SPSS) and Ms Excel. Multiple comparisons of the data were done to compare the mechanical properties of the soil using the Tukey HSD. Analysis of variance (ANOVA) was also used to judge the effect of tillage operations on the soil mechanical properties.

III. Results and Discussion

A. *Soil Analysis*

The result of the soil analysis test carried out for the different sites worked on are presented in Table II.

Table II. Soil Textural Analysis.

	Soil Composition			
	Sand (%)	**Clay (%)**	**Silt (%)**	**Classification**
Use Offot	48	32	20	Loamy soil

The above soil analysis result was reached using the soil textural triangle after the laboratory test.

Table III. Experimental results on the influence of conventional tillage on the three properties.

Soil type	**Operation**	**Depth (cm)**	**Before**			**After**		
			SC	**SA**	**SP**	**SC**	**SA**	**SP**
Loamy soil	Ploughing	0-20	16.53	12.33	15.56	16.34	12.13	15.23
		20-30	16.57	12.24	16.47	16.28	11.79	15.44
	Harrowing	0-20	16.53	12.33	15.56	16.34	12.01	15.40
		20-30	16.57	12.24	16.47	16.04	11.75	15.34

SC = soil cohesion (kPa), SA = soil adhesion (kPa), SP = Soil plasticity (%).

B. *Influence of Tillage Operations on Soil Adhesion*

The influence of the tillage operation on soil adhesion property is judged from the results presented in Table III. ANOVA influence of tillage on soil adhesion is represented in table IV.

Table IV. Summary of ANOVA Influence of tillage operation on Soil Adhesion.

Soil Type	**Operation**	**Source**	**Type III Sum of Squares**	**Mean Square**	**Df**	**F**	**Sig**
Loamy soil	Ploughing	PS	0.317	1	0.317	0.400	0.545
		SD	0.139	1	0.139	0.175	0.687
		PS* SD	0.047	1	0.047	0.059	0.814
	Harrowing	HS	0.492	1	0.492	0.428	0.531
		SD	0.092	1	0.092	0.080	0.785
		HS * SD	0.022	1	0.022	0.019	0.894

PS = ploughing status, HS = harrowing status, SD = soil depth, PS*SD = interaction between ploughing status and soil depth, HS*SD= interaction between harrowing status and soil depth.

From Table IV, since the calculated values of probability, in all cases, are greater than 0.05 (i.e., 5% level of probability), it means that F-values are not significant which implies that the ploughing activity, harrowing activity, SD and PS*SD did not have any statistical significant impact on loamy soil. This result explains that the soil adhesion property remains the same despite the tillage operation carried out at the various depths considered.

C. *Influence of Tillage Operations on Soil Cohesion*

Table V shows the summary for ANOVA of the effect of the different tillage operations on soil cohesion at the two sampling depths obtained.

Table V. Summary of ANOVA Influence of tillage operation on Soil Cohesion.

Soil Type	Operation	Source	Type III Sum of Squares	Mean Square	Df	F	Sig
Loamy soil	Ploughing	PS	0.173	1	0.173	0.180	0.683
		SD	0.000	1	0.000	0.000	0.986
		PS* SD	0.007	1	0.007	0.008	0.932
	Harrowing	HS	0.389	1	0.389	0.051	0.827
		SD	0.051	1	0.051	0.007	0.937
		HS * SD	0.087	1	0.087	0.011	0.918

PS = ploughing status, HS = harrowing status, SD = soil depth, PS*SD = interaction between ploughing status and soil depth, HS*SD = interaction between harrowing status and soil depth.

From Table V, the statistical analysis result shows that the F-values are not significantly different. This implies that the tillage operations carried out on the different type of soil (loamy soil), does not affect the soil mechanical property (cohesion). The soil cohesion property remains the same before and after the soil tillage operations at the depths considered.

D. *Effects of Tillage Operations on Soil Plasticity*

The effect of the tillage operation on soil plasticity property is judged from the results presented in Table III. ANOVA effect of tillage on loamy soil plasticity is represented in Table VI.

Table VI. Summary of ANOVA Effect of tillage operation on Soil Plasticity.

Soil Type	Operation	Source	Type III Sum of Squares	Mean Square	df	f	Sig
Loamy soil	Ploughing	PS	1.387	1	1.387	1.463	0.261
		SD	0.368	1	0.368	0.388	0.551
		PS* SD	0.941	1	0.941	0.992	0.348
	Harrowing	HS	1.248	1	1.248	0.578	0.469
		SD	0.542	1	0.542	0.251	0.630
		HS * SD	0.706	1	0.706	0.327	0.583

PS = ploughing status, HS= harrowing status, SD = soil depth, PS*SD = interaction between ploughing status and soil depth, HS*SD = interaction between harrowing status and soil depth.

The summary for the ANOVA analysis of soil plasticity property from the table above shows that the F-values are not significant since the calculated values of probability, in all cases, are greater than 0.05 (i.e., 5% level of probability). The result gotten implies that the tillage operations (ploughing and harrowing) had no significant impact on the soil properties.

Using the multiple comparisons of the mean values of the soil mechanical properties, the results were also analyzed. The analysis is presented in the Tables below.

Table VII. Multiple Comparisons of mean values of Sand Soil Mechanical Properties before and after ploughing using Tukey HSD.

(I) F	(J) F	Mean Difference (I-J)	Sig.
ASA1	BSA1	-.2000	1.000
ASA2	BSA2	-.4500	1.000
ASC1	BSC1	-.1900	1.000
ASC2	BSC2	-.2900	1.000
ASP1	BSP1	-.1200	1.000
ASP2	BSP2	-1.2400	0.893

ASA1 = soil adhesion after ploughing at depth 0 - 20cm; ASA2 = soil adhesion after ploughing at depth 20 - 30cm; BSA1= soil adhesion before ploughing at depth 0 - 20cm; BSA2 = soil adhesion before ploughing at depth 20 - 30cm; SC = soil cohesion; SP = soil plasticity.

Table VIII. Multiple comparisons of mean values of Sand Soil Mechanical properties before and after harrowing using Tukey HSD.

(I) F	(J) F	Mean Difference (I-J)	Sig.
ASA1	BSA1	-.3200	1.000
ASA2	BSA2	-.4900	1.000
ASC1	BSC1	-.1900	1.000
ASC2	BSC2	-.5300	1.000
ASP1	BSP1	-.1600	1.000
ASP2	BSP2	-1.1300	1.000

ASA1 = soil adhesion after harrowing at depth 0 - 20 cm; ASA2 = soil adhesion after harrowing at depth 20 - 30cm; BSA1= soil adhesion before harrowing at depth 0 - 20cm; BSA2 = soil adhesion before harrowing at depth 20 - 30cm; SC= soil cohesion; SP= soil plasticity.

From Tables VII and VIII, it could be observed that all the values of calculated probability were greater than 0.05 (5% level of probability), This shows that their mean differences were not statistically significant. This indicates that the ploughing activity coupled with soil depth did not have any significant impact on soil properties considered.

IV. Conclusion

Primary and secondary tillage manipulation are the two different types of operations required for cultivation of any crop.

The tillage tools used in this study were a 4-buttom disc plough and off-set disk harrow. Measurements were made to determine the influence of conventional tillage operations on soil cohesion, soil adhesion, and soil plasticity in a loamy soil. The results show that the values of these properties were higher for the before tillage operation compared to the values of these properties for the after tillage operations but ANOVA and Turkey's tests indicate that there is no significant effect of conventional tillage on these properties in a loamy soil.

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