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Effect of Tillage Operations on Soil Moisture Contents in the Southern Guinea Savanna Ecological Zone of Nigeria

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Abstract

An experimental farm plot was set up at the National Centre for Agricultural Mechanization (NCAM), kilometer 12 Ilorin-Idofian Road to investigate the effect of various agronomic operations (mound, ridge and plough tillage) on soil moisture content of varying depth intervals of 0 - 15 cm, 15 - 30 cm, 30 - 45 cm and 45 - 60 cm respectively. The experiment was conducted between year 2007 and 2009. Samples were taken on weekly basis from various depths using hand screw auger. The percentage moisture was determined by oven drying oil sample to a constant weight at the temperature of 105˚C. The difference between the initial weight and weight after oven drying was calculated and the percentage determined. Weekly data generated were grouped on monthly basis and the means calculated. Seasonal values were also calculated. ANOVA and the Post Hoc multiple comparison were employed to investigate variations in soil moisture content between tillage systems and within the four soil depths. The result showed mound tillage to be the driest and ridge was then wettest of all the tillage system considered. The difference between varying intervals of seach tillage became more pronounced between depth intervals of 0 - 15 cm and 15 - 30 cm. Generally, the result of ANOVA indicates seasonal variation in soil moisture between the three tillage methods at all depths considered. Again the result of the Pos Hoc multiple comparison shows that variation in soil moisture content between the 3 tillage systems in wet and in dry season in not significant because the p value > 0.05. Suggestions were made on the way forward towards achieving a self sufficient food production status.

Keywords

Agronomic Operation, Soil Moisture, Soil Depth, Oven Drying

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1. Introduction

A wide gap exists between food production and population growth in Nigeria [1]. Some of the reasons for this gap emanate from poor yield that resulted from climatic vagaries [2]. For Nigeria to be self sufficient in food production, efforts should be geared towards closing up this gap. Some of such efforts include investigating the various tillage operations as they affect some fundamentals of crop productions such as soil moisture in a rain fed ecological environment.

Tillage, the physical manipulation of the soil for preparation of seed beds among others affects crop growth and yields by changing soil structure and moisture removal pattern over the growing season [3]. Crop water requirement represents the amount of water crops needed to grow and yield optimally [4]. Plant removes water from available soil moisture through its roots. The energy plant used to extract water from the soil according to [5] is termed matric potential and the symptoms of stress and depression displayed by plant (wilting) under a strong matric potential is known as matric effect.

The ability of plant to remove water from the soil is stressed when the soil moisture is low, saline or both. In any case, low soil moisture brings crop performance into crises level in various ways.

Plant root cannot easily take nutrients from the soil without water. It is the evaporation of the water taken by the plant root that keeps it at correct working temperature otherwise plants would gain heat, shrivel and die. Moisture supply has been described by [6] as the usual limiting factor of crop yield. For instance, water and carbon dioxide are important components of photosynthesis a process where plants manufacture their food (carbohydrate).

Besides, water stress brings about a reduction in leaf water pressure which often results into stomata closure. This has a lot of implications for the exchange of water and gases (CO_2 and O_2) in and out of leaves (plant respiration) and on photosynthetic activities of plant as well. The wilting of plant consequent of low plant water drastically reduces the amount of leaf area exposed to sunlight for the process of photosynthesis. This present study is tailored to appraise the status of soil moisture at varying depth intervals among three tillage systems and established the tillage system(s) that is best suited for optimal crop yield in the southern guinea savanna ecological zone of Nigeria.

Tillage Operations, Soil Moisture Content and Yield

Tillage operations influence the available soil moisture and hence crop yield in diverse ways. [7] defined tillage as means of soil structure modification to favour agronomic process such as water infiltration among others. [8] examined the effect of four types of tillage operations on soil moistures and morphology and performance of 3 varietes of cotton in Golestan Province of Northern Iran. The results show that water storage capacity increases under no-till system. Low till cultivation leads to 695.8, 227.8 and 129.5 kg/ha increase in yield compared to disk, chisel/disk and mold/disk treatment.

[6] as cited in [3] described soil moisture as the limiting factor of crop yield. This assertion has been confirmed by findings of [8]-[10], among others. [9] investigated the influence of soil moisture and phosphate levels on root growth of corn. The result shows soil moisture having greater influence on root hair growth of maize crop. [8] performed a field experiment on the effect of different soil moisture conservation practices on evaporation and growth of young tea plant (camellia sinensis). The result suggest maximum plant of 6.16 m under T2 may be linked with conservation of high moisture content and more organic matter while the minimum height of 3.55 m observed in T1 may not be unconnected with less availability of moisture content in the soil. [10] studied the effect of soil moisture stress on the growth of *Corcliorus olitorius* L. in green house during summer at Tokyo, Japan. The result showed smaller growth in light moisture stress (60% - 50%) and acute moisture stress (40% - 30%) comparing to that of field capacity soil moisture. It was reported that pants were stunted under soil stress condition.

2. The Study Area

The map of the study area is shown in **Figure 1**. A research farm was set up at Nigerian Centre for Agricultural Mechanization (NCAM) located at Kilometer 12 Idofian-Ilorin Road, Kwara State Nigeria.

3. Method of Study

Three farm plots measured 13 m by 10 m each designated ABC were prepared using different agronomic prac-

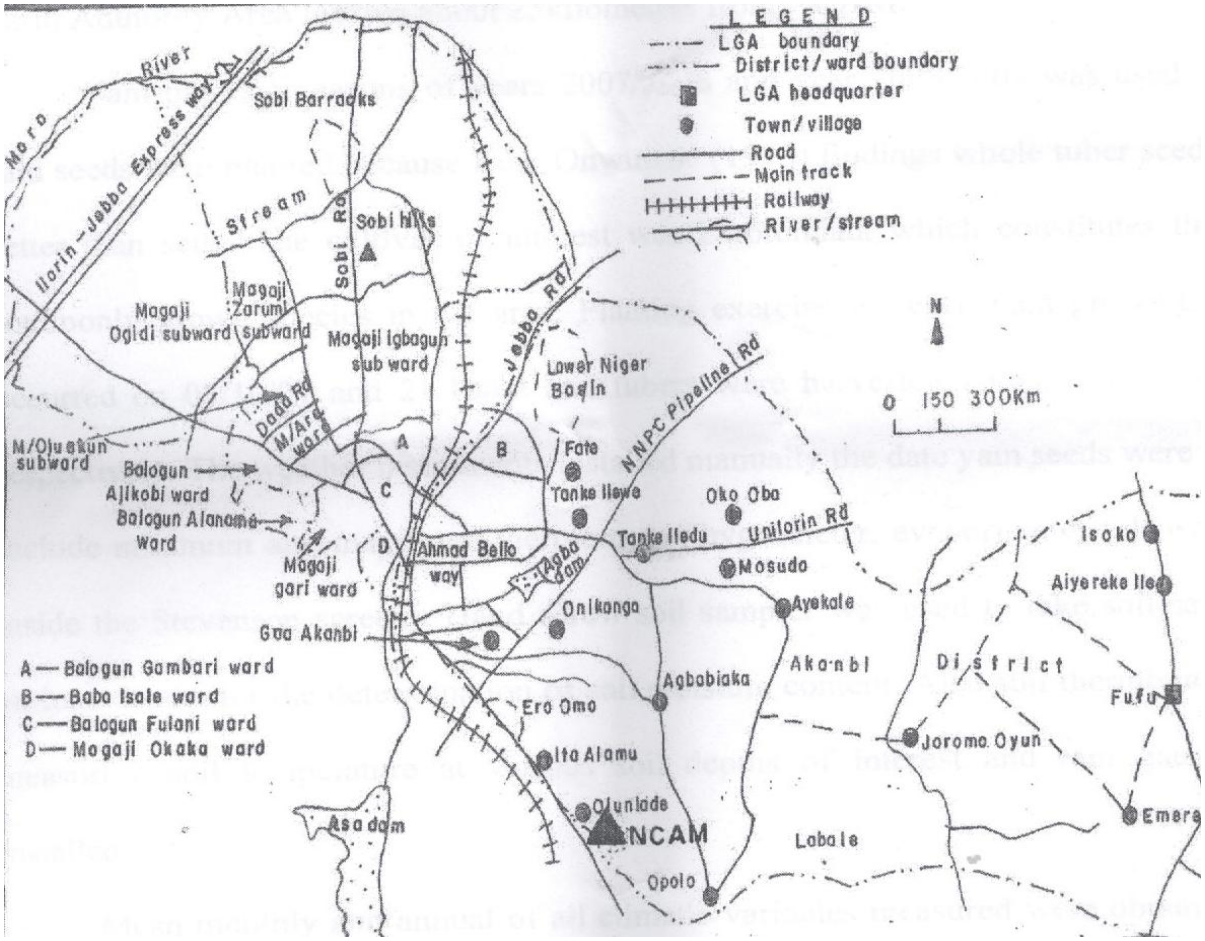

Figure 1. The map of ilorin south local government area showing NCAM the study area.

tices. Plot A was made up of 100 heaps prepared manually using hoe, B plot was ridged by tractor after harrowing while Plot C was only harrowed by tractor. The first two represent total tillage because the soil was deeply cultivated while Plot C where the soil was not well worked constitutes a partial tillage system. All together there are 3 sampling plots from which data were generated. The experiment was conducted 2007 through 2009. All plots were sited upland for easy comparison. Soil sample were taken on weekly basis from these various soil depths intervals of 0 - 15 cm, 15 - 30 cm, 30 - 45 cm and 45 - 60 cm respectively using hand screw soil urger. Each sample was weighed and recorded. The percentage moisture was determined by oven drying soil samples to a constant weight at 105˚C temperature. The difference between the initial weight and weight after oven drying was obtained and the percentage calculated.

The weekly data generated were grouped on monthly basis and the means for the period of study was calculated. Statistic tool of ANOVA was used to investigate the level of variations in soil moisture content between tillage systems at various depths and level of soil moisture variations between the two major seasons experienced in Nigeria. Dry season covers the period of November to April while rainy season starts in earnest in May and continues till October in the study area. Post HOC multiple comparison was carried out using Tukey test at 0.05 significant level to reveal which tillage method and what season is the soil moisture content different from the others.

4. Result and Discussion

Variations observed in soil moisture under different soil depth intervals among the three tillage system of mound, ridge and plough are presented and discussed under this session.

4.1. Variation in Soil Moisture among Tillage System

When the distribution of soil moisture with depths among the three tillage systems was considered, some pattern was observed. Generally soil moisture increased with depth in all the three tillage systems (See **Figures 2-4**).

Variation in soil moisture was most pronounced between the depth intervals of 0 - 15 and 15 - 30 cm. After this depth interval the difference in soil moisture was not much.

4.2. Variation in Soil Moisture at 0 - 15 cm Soil Depth Interval among Tillage Systems

Variation in soil moisture within the soil depth interval of 0 - 15 cm among the three tillage system is reflected in **Figure 5** (See also **Table A1**).

At this soil interval, ridge tillage system recorded the highest soil moisture from January through December. This is followed closely by plough except in the month of February and June when higher values of 0.85% and 17.70% were observed in mound tillage as against 0.78% and 15.86% reported for plough tillage. Thus mound tillage environment remained the driest of the three tillage systems at this soil interval.

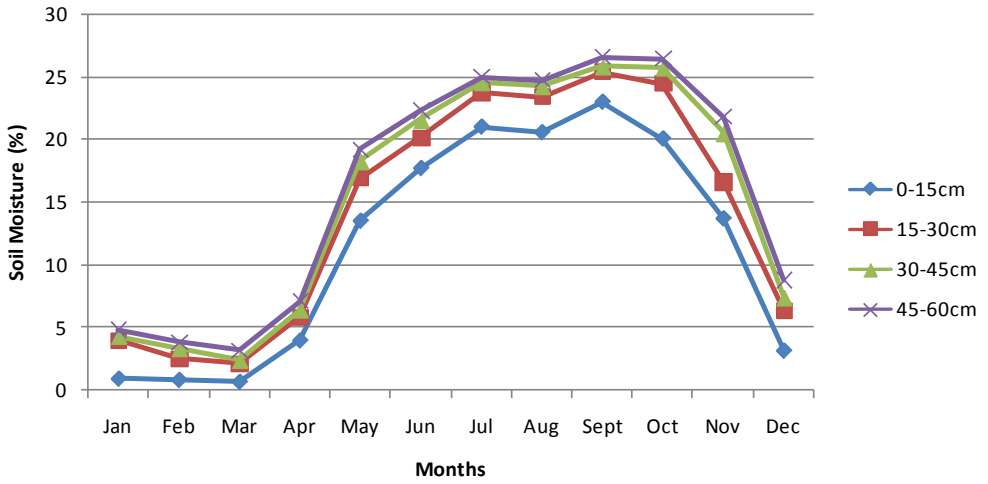

Figure 2. Variation in soil moisture at varying depth intervals in mound tillage system. Source: author's fieldwork 2014.

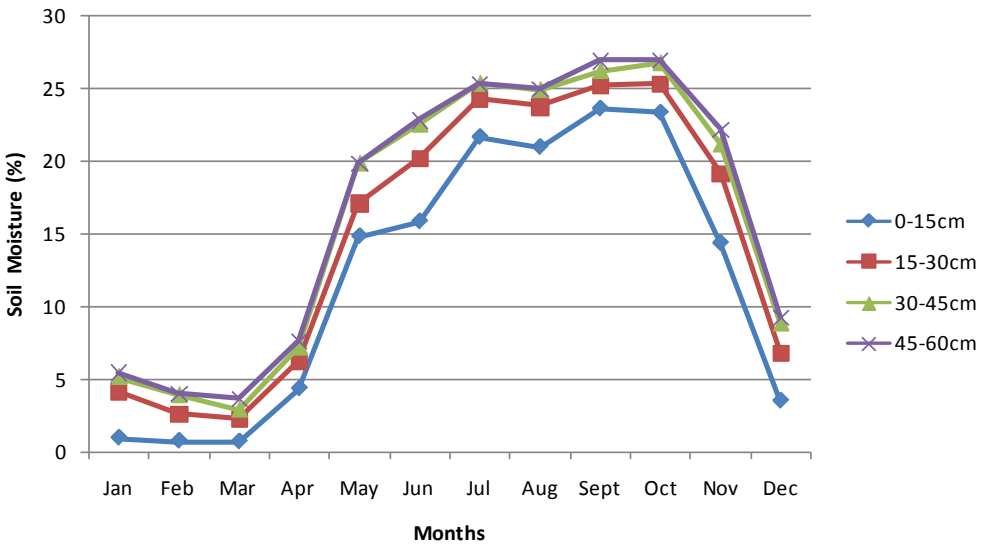

Figure 3. Variation in soil moisture at varying depth intervals in plough tillage system. Source: author's fieldwork 2014.

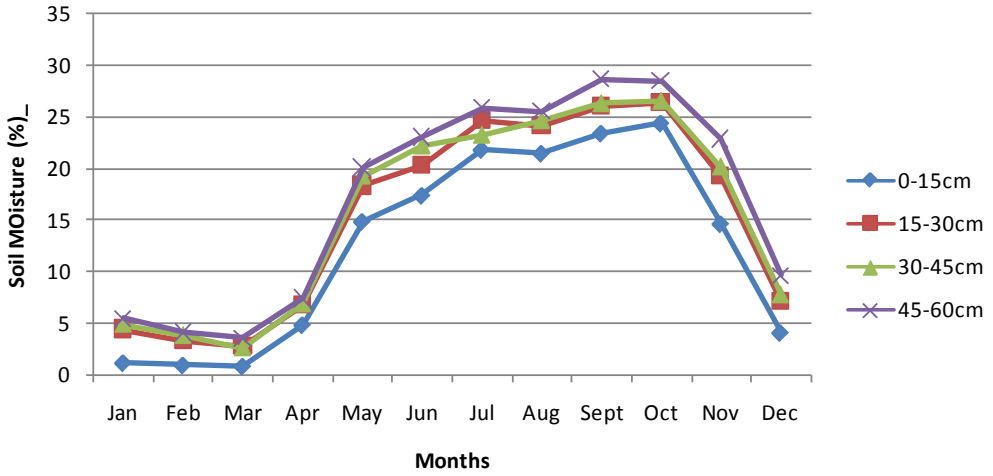

Figure 4. Variation in soil moisture at varying depth intervals in ridge tillage system. Source: author's fieldwork 2014.

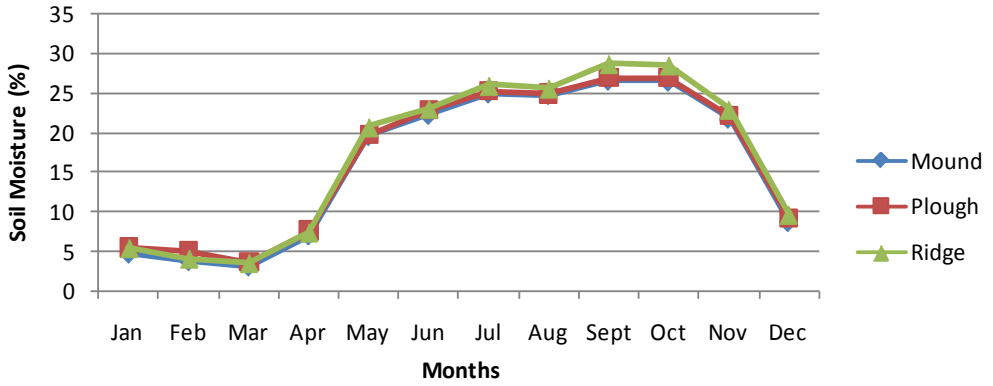

Figure 5. Variation in soil moisture at 0 - 15 cm soil depth interval among tillage systems. Source: author's fieldwork 2014.

4.3. Variation at 15 - 30 cm Soil Depth Interval among Tillage Systems

Figure 6 showed the variations in soil moisture that exist between the three tillage systems at soil depth interval of 15 - 30 cm (Also see **Table A2**).

The distribution of soil moisture at this soil depth interval resemble the pattern of distribution at 0 - 15 cm soil depth interval previously discussed above. The exception is that during the month of March, mound tillage recorded the highest percentage of soil moisture (2.20%) as against 2.13% and 2.18% observed in plough and ridge tillage systems. Mound tillage still maintained the driest condition while ridge tillage retained its wettest position. Variation in soil moisture between mound tillage and others became very pronounced in the month of November that marked the beginning of dry season in the area.

4.4. Variation at 30 - 45 cm Soil Depth Internal among Tillage Systems

The distribution of soil moisture among the three tillage systems at the soil depth interval of 30 cm - 45 cm is showed in **Figure 7** (see also **Table A3**).

At the soil depth of 30 - 45 cm, the pattern of variation in soil moisture among the three tillage systems changed. The plough tillage emerged the wettest as it observed the highest soil moisture content at this depth interval through the period under consideration. Mound tillage still observed the lowest percentage of soil moisture content. Highest Soil Moisture observed at this soil depth interval by plough tillage system might be attributable to the fact that the Soil of plough tillage is not well worked and it remained compacted thus slowing down the rate at which water infiltrates into the soil at the soil depth interval.

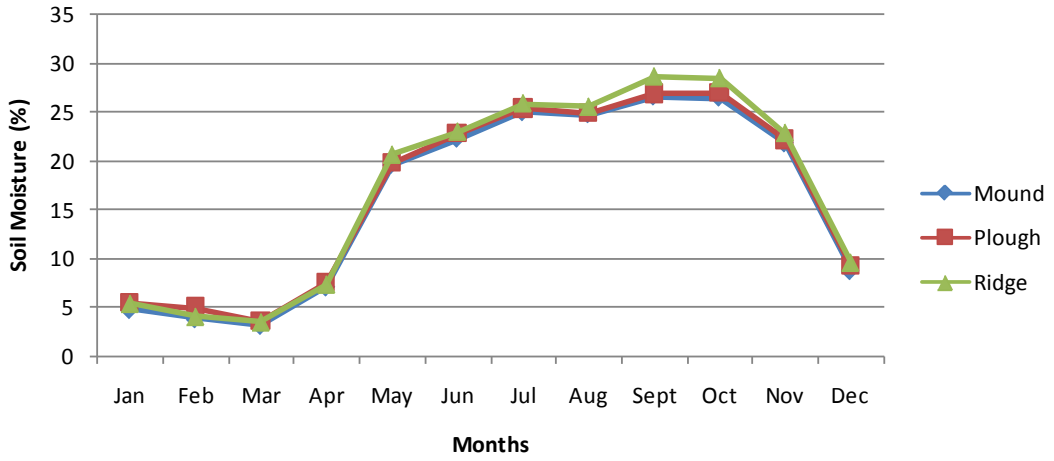

Figure 6. Variation in soil moisture at 0 - 15 cm soil depth interval among tillage systems Source: author's fieldwork 2014.

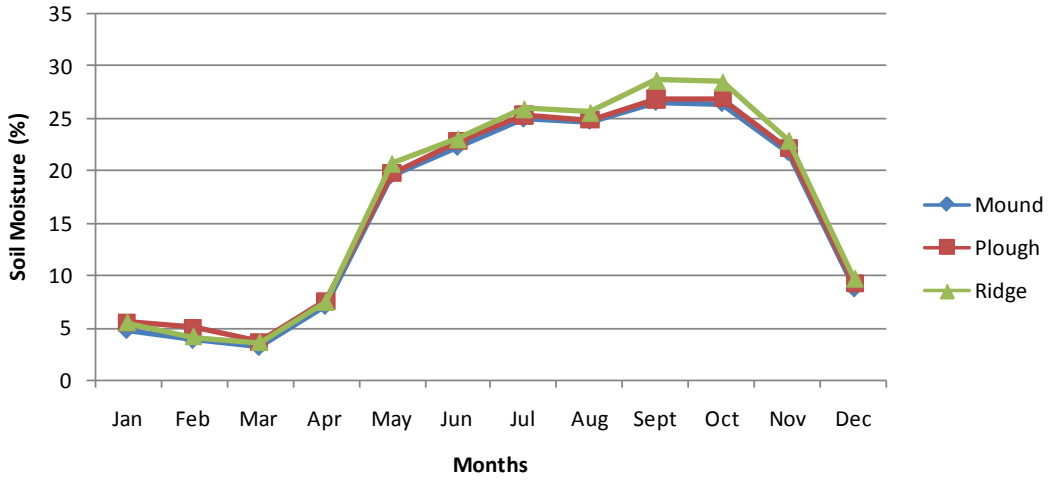

Figure 7. Variation in soil moisture at 0 - 15 cm soil depth interval among tillage systems. Source: author's fieldwork 2014.

4.5. Variation in Soil Moisture at 45 - 60 cm Depth among Tillage Systems

Figure 8 reflects the distribution of soil moisture at the soil depth intervals of 45 - 60 cm. At this soil depth interval the initial pattern of soil moisture distribution among tillage systems was re-established.

Ridge tillage became the wettest followed by plough and mound tillage systems. The exception of this is the month of March and April when plough system still retained highest value of 3.68% and 7.61% (see **Table A4**).

The lowest soil moisture content observed in plot under mound tillage may not be unconnected with the findings of [11]. Heat circulates within each heap of the mound tillage thus raising its temperature but horizontal transfer of heat occur in ridge tillage and so cooler than mound tillage. The implication of this is that evaporation is higher in mound tillage hence lowest soil moisture was reported under this tillage system.

4.6. Result of ANOVA and Post Hoc Multiple Comparisons

The descriptive statistics of seasonal variation in soil moisture between three different tillage systems at 0 - 15 cm soil depth showed that ridge tillage method in wet season has the highest mean soil moisture content of 20.58%. While mound tillage method in dry season has the lowest mean soil moisture content of 3.40%.

ANOVA summary **Table 1**, reveals that the between group mean square (the variation explained by the model) is 452.543, and the within group mean square (the variation unexplained) is 19.948. The F-ratio is 22.687 and the p-value < 0.05, this indicates that the seasonal variation in soil moisture between the three tillage method

at 0 - 15 cm depth is statistically significant. The table reveals that at least soil moisture content of one of the tillage method is different from the others.

Table 2 reflects the result of ANOVA summary for wet and dry season soil moisture between 15 - 30 cm soil depths. The between groups mean square (the variation explained by the model) is 460.626, and the within group mean square (the variation unexplained) is 22.928. The F-ratio is 20.090 and the p-value < 0.05, this indicates that the seasonal variation in soil moisture between the three tillage method at 15 - 30 cm depth is statistically significant. The table reveals that at least soil moisture content of one of the tillage method is different from the others.

ANOVA summary **Table 3** reveals that the between groups mean square (the variation explained by the model) is 461.516, and the within group mean square (the variation unexplained) is 25.544. The F-ratio is 18.067 and the p-value < 0.05, this indicates that the seasonal variation in soil moisture between the three tillage method at 30 - 45 cm depth is statistically significant. The table reveals that at least soil moisture content of one of the tillage method is different from the others.

ANOVA summary as presented in **Table 4** reveals that the between group mean square (the variation explained by the model) is 463.090, and the within group mean square (the variation unexplained) is 29.057. The

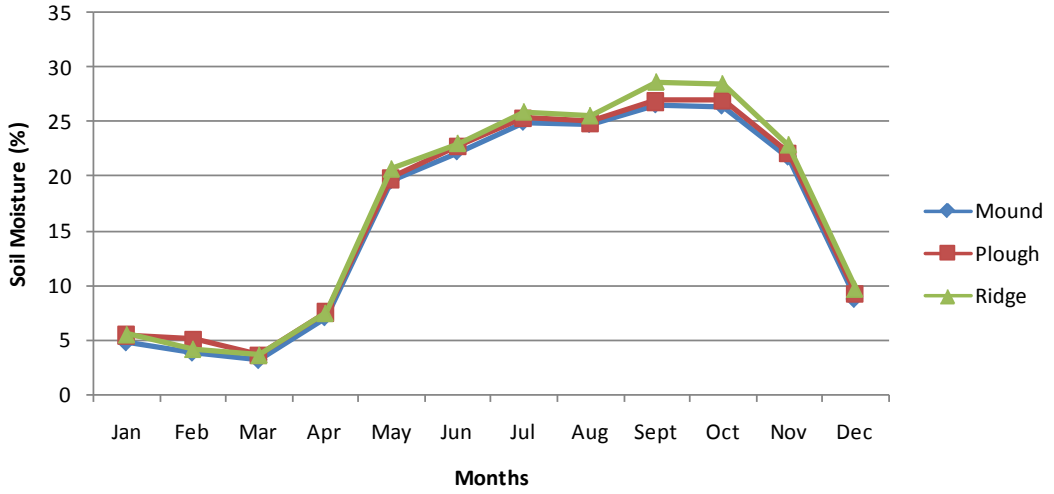

Figure 8. Variation in soil moisture at 0 - 15 cm soil depth interval among tillage systems. Source: author's fieldwork 2014.

Table 1. ANOVA for wet and dry season soil moisture between 0 - 15 cm.

Mound, Plough and Ridge	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2262.716	5	452.543	22.687	0.000
Within Groups	598.428	30	19.948		
Total	2861.144	35			

Source: author's computation 2014.

Table 2. ANOVA for wet and dry season soil moisture between 15 - 30 cm.

Mound Plough Ridge	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2303.128	5	460.626	20.090	0.000
Within Groups	867.853	30	22.928		
Total	2990.981	35			

Source: author's computation 2014.

Table 3. ANOVA for wet and dry season soil moisture between 30 - 45 cm.

Mound Plough Ridge	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	2307.580	5	461.516	18.067	0.000
Within Groups	766.331	30	25.544		
Total	3073.911	35			

Source: author's computation 2014.

Table 4. ANOVA for wet and dry season soil moisture between 45 - 60 cm.

	Sum of Squares	Df	Mean Square	F	Sig
Between Groups	2315.449	5	463.090	15.937	0.000
Within Groups	871.706	30	29.057		
Total	3187.155	35			

Source: author's computation 2014.

F-ratio is 15.937 and the p-value < 0.05, this indicates that the seasonal variation in soil moisture between the three tillage method at 45 - 60 cm depth is statistically significant. The table reveals that at least soil moisture content of one of the tillage method is different from the others.

Generally all the tables of ANOVA discussed however did not reveal which tillage method and what season is the soil moisture content is different from the others. To reveal this, Post Hoc multiple comparisons is carried out using Tukey test at 0.05 significant levels (see **Tables A5-A8**).

Variation in soil moisture content between the three tillage methods in wet season is not significant because the p-value > than 0.05. Also, the variation in soil moisture content between the three tillage methods in dry season is not significant because the p-value > 0.05. However, statistically there is a difference in the seasonal variation in soil moisture content between the three tillage methods.

5. Summary and Conclusion

Mound tillage system remained the driest and ridge was the wettest at all depth intervals considered. The exception of this occurred at soil depth interval of 30 - 45 cm when plough tillage recorded highest value. Also the difference in soil moisture between varying depths was more pronounced between the soil depth intervals of 0 - 15 cm and 15 - 30 cm. In conclusion, further studies should examine the implications of the above findings on various crops produced in the Southern guinea savanna ecological zone of Nigeria. This calls for studying the root system of these crops and having adequate information on crop water requirement for effective planning, design, implementation and monitoring irrigation agriculture towards adequate food production in the Southern guinea eco zone of Nigeria.

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Appendix

Table A1. Seasonal variation in soil moisture at 0 - 15 cm soil depth interval (2007-2009).

Tillage System	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mound	0.95	0.85	0.70	3.99	13.15	17.70	20.99	20.55	22.97	20.05	13.70	3.18
Plough	0.99	0.78	0.73	4.38	14.84	15.86	21.66	20.97	23.61	23.33	14.37	3.53
Ridge	1.12	0.89	0.78	4.81	14.86	17.39	21.85	21.49	23.44	24.42	14.64	4.05

Table A2. Seasonal variation in soil moisture at 15 - 30 cm soil depths interval (2007-2009).

Tillage System	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mound	4.04	2.56	2.20	5.91	16.96	20.17	23.77	23.45	25.39	24.45	16.62	6.44
Plough	4.19	2.64	2.3	6.24	17.12	20.19	24.27	23.76	25.24	25.33	19.19	6.80
Ridge	4.43	3.30	2.8	6.78	18.39	20.35	24.72	24.24	26.16	26.45	19.28	7.14

Table A3. Seasonal variation in soil moisture at 30 - 45 cm soil depths interval (2007-2009).

Tillage System	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mound	4.35	3.37	2.44	6.44	18.25	21.54	24.55	24.24	25.81	25.72	20.49	7.41
Plough	5.20	3.95	2.96	7.22	19.86	22.53	25.33	24.90	26.21	26.75	21.17	8.87
Ridge	4.92	3.82	2.68	6.89	19.31	22.23	23.27	24.68	26.33	26.58	20.20	7.77

Table A4. Seasonal variation in soil moisture at 45 - 60 cm soil depth interval (2007-2009).

Tillage System	Jan	Feb	Mar	April	May	June	July	Aug	Sept	Oct	Nov	Dec
Mound	4.80	3.86	3.18	7.10	19.60	22.27	24.97	24.77	26.57	26.46	21.79	8.77
Plough	5.48	4.05	3.68	7.61	19.89	22.84	25.37	24.95	26.90	26.95	22.20	9.24
Ridge	5.49	4.16	3.60	7.45	20.10	23.05	25.94	25.59	28.68	28.51	22.92	9.68

Dry season Nov-April; Wet season May-Oct.

Table A5. Multiple comparisons for soil moisture between 0 - 15 cm depth.

Dependent Variable: Mound, Plough and Ridge							
	(I) Group	(J) Group	Mean Difference (I - J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Tukey HSD	Mound Wet Season	Plough Wet Season	−0.75000	2.57860	1.000	−8.5931	7.0931
		Ridge Wet Season	−1.28000	2.57860	0.996	−9.1231	6.5631
		Mound Dry Season	15.40000*	2.57860	0.000	7.5569	23.2431
		Plough Dry Season	15.16500*	2.57860	0.000	7.3219	23.0081
		Ridge Dry Season	14.91333*	2.57860	0.000	7.0703	22.7564
	Plough Wet Season	Mound Wet Season	0.75000	2.57860	1.000	−7.0931	8.5931
		Ridge Wet Season	−0.53000	2.57860	1.000	−8.3731	7.3131
		Mound Dry Season	16.15000*	2.57860	0.000	8.3069	23.9931
		Plough Dry Season	15.91500*	2.57860	0.000	8.0719	23.7581
		Ridge Dry Season	15.66333*	2.57860	0.000	7.8203	23.5064
	Ridge Wet Season	Mound Wet Season	1.28000	2.57860	0.996	−6.5631	9.1231
		Plough Wet Season	0.53000	2.57860	1.000	−7.3131	8.3731
		Mound Dry Season	16.68000*	2.57860	0.000	8.8369	24.5231
		Plough Dry Season	16.44500*	2.57860	0.000	8.6019	24.2881
		Ridge Dry Season	16.19333*	2.57860	0.000	8.3503	24.0364
	Mound Dry Season	Mound Wet Season	−15.40000*	2.57860	0.000	−23.2431	−7.5569
		Plough Wet Season	−16.15000*	2.57860	0.000	−23.9931	−8.3069
		Ridge Wet Season	−16.68000*	2.57860	0.000	−24.5231	−8.8369
		Plough Dry Season	−0.23500	2.57860	1.000	−8.0781	7.6081
		Ridge Dry Season	−0.48667	2.57860	1.000	−8.3297	7.3564
	Plough Dry Season	Mound Wet Season	−15.16500*	2.57860	0.000	−23.0081	−7.3219
		Plough Wet Season	−15.91500*	2.57860	0.000	−23.7581	−8.0719
		Ridge Wet Season	−16.44500*	2.57860	0.000	−24.2881	−8.6019
		Mound Dry Season	0.23500	2.57860	1.000	−7.6081	8.0781
		Ridge Dry Season	−0.25167	2.57860	1.000	−8.0947	7.5914
	Ridge Dry Season	Mound Wet Season	−14.91333*	2.57860	0.000	−22.7564	−7.0703
		Plough Wet Season	−15.66333*	2.57860	0.000	−23.5064	−7.8203
		Ridge Wet Season	−16.19333*	2.57860	0.000	−24.0364	−8.3503
		Mound Dry Season	0.48667	2.57860	1.000	−7.3564	8.3297
		Plough Dry Season	0.25167	2.57860	1.000	−7.5914	8.0947

*The mean difference is significant at the 0.05 level.

Table A6. Multiple comparisons for soil moisture between 15 - 30 cm depth.

Tukey HSD						
(I) Group	(J) Group	Mean Difference (I - J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mound Wet Season	Plough Wet Season	−0.28667	2.76456	1.000	−8.6953	8.1220
	Ridge Wet Season	−1.02000	2.76456	0.999	−9.4287	7.3887
	Mound Dry Season	16.07000*	2.76456	0.000	7.6613	24.4787
	Plough Dry Season	15.47167*	2.76456	0.000	7.0630	23.8803
	Ridge Dry Season	15.07667*	2.76456	0.000	6.6680	23.4853
Plough Wet Season	Mound Wet Season	0.28667	2.76456	1.000	−8.1220	8.6953
	Ridge Wet Season	−0.73333	2.76456	1.000	−9.1420	7.6753
	Mound Dry Season	16.35667*	2.76456	0.000	7.9480	24.7653
	Plough Dry Season	15.75833*	2.76456	0.000	7.3497	24.1670
	Ridge Dry Season	15.36333*	2.76456	0.000	6.9547	23.7720
Ridge Wet Season	Mound Wet Season	1.02000	2.76456	0.999	−7.3887	9.4287
	Plough Wet Season	0.73333	2.76456	1.000	−7.6753	9.1420
	Mound Dry Season	17.09000*	2.76456	0.000	8.6813	25.4987
	Plough Dry Season	16.49167*	2.76456	0.000	8.0830	24.9003
	Ridge Dry Season	16.09667*	2.76456	0.000	7.6880	24.5053
Mound Dry Season	Mound Wet Season	−16.07000*	2.76456	0.000	−24.4787	−7.6613
	Plough Wet Season	−16.35667*	2.76456	0.000	−24.7653	−7.9480
	Ridge Wet Season	−17.09000*	2.76456	0.000	−25.4987	−8.6813
	Plough Dry Season	−0.59833	2.76456	1.000	−9.0070	7.8103
	Ridge Dry Season	−0.99333	2.76456	0.999	−9.4020	7.4153
Plough Dry Season	Mound Wet Season	−15.47167*	2.76456	0.000	−23.8803	−7.0630
	Plough Wet Season	−15.75833*	2.76456	0.000	−24.1670	−7.3497
	Ridge Wet Season	−16.49167*	2.76456	0.000	−24.9003	−8.0830
	Mound Dry Season	0.59833	2.76456	1.000	−7.8103	9.0070
	Ridge Dry Season	−0.39500	2.76456	1.000	−8.8037	8.0137
Ridge Dry Season	Mound Wet Season	−15.07667*	2.76456	0.000	−23.4853	−6.6680
	Plough Wet Season	−15.36333*	2.76456	0.000	−23.7720	−6.9547
	Ridge Wet Season	−16.09667*	2.76456	0.000	−24.5053	−7.6880
	Mound Dry Season	0.99333	2.76456	0.999	−7.4153	9.4020
	Plough Dry Season	0.39500	2.76456	1.000	−8.0137	8.8037

*The mean difference is significant at the 0.05 level.

Table A7. Multiple comparisons for soil moisture between 30 - 45 cm depth.

Tukey HSD						
(I) Group	(J) Group	Mean Difference (I - J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mound Wet Season	Plough Wet Season	−0.91167	2.91801	1.000	−9.7871	7.9637
	Ridge Wet Season	−0.38167	2.91801	1.000	−9.2571	8.4937
	Mound Dry Season	15.93500*	2.91801	0.000	7.0596	24.8104
	Plough Dry Season	15.12333*	2.91801	0.000	6.2479	23.9987
	Ridge Dry Season	15.63833*	2.91801	0.000	6.7629	24.5137
Plough Wet Season	Mound Wet Season	0.91167	2.91801	1.000	−7.9637	9.7871
	Ridge Wet Season	0.53000	2.91801	1.000	−8.3454	9.4054
	Mound Dry Season	16.84667*	2.91801	0.000	7.9713	25.7221
	Plough Dry Season	16.03500*	2.91801	0.000	7.1596	24.9104
	Ridge Dry Season	16.55000*	2.91801	0.000	7.6746	25.4254
Ridge Wet Season	Mound Wet Season	0.38167	2.91801	1.000	−8.4937	9.2571
	Plough Wet Season	−0.53000	2.91801	1.000	−9.4054	8.3454
	Mound Dry Season	16.31667*	2.91801	0.000	7.4413	25.1921
	Plough Dry Season	15.50500*	2.91801	0.000	6.6296	24.3804
	Ridge Dry Season	16.02000*	2.91801	0.000	7.1446	24.8954
Mound Dry Season	Mound Wet Season	−15.93500*	2.91801	0.000	−24.8104	−7.0596
	Plough Wet Season	−16.84667*	2.91801	0.000	−25.7221	−7.9713
	Ridge Wet Season	−16.31667*	2.91801	0.000	−25.1921	−7.4413
	Plough Dry Season	−0.81167	2.91801	1.000	−9.6871	8.0637
	Ridge Dry Season	−0.29667	2.91801	1.000	−9.1721	8.5787
Plough Dry Season	Mound Wet Season	−15.12333*	2.91801	0.000	−23.9987	−6.2479
	Plough Wet Season	−16.03500*	2.91801	0.000	−24.9104	−7.1596
	Ridge Wet Season	−15.50500*	2.91801	0.000	−24.3804	−6.6296
	Mound Dry Season	0.81167	2.91801	1.000	−8.0637	9.6871
	Ridge Dry Season	0.51500	2.91801	1.000	−8.3604	9.3904
Ridge Dry Season	Mound Wet Season	−15.63833*	2.91801	0.000	−24.5137	−6.7629
	Plough Wet Season	−16.55000*	2.91801	0.000	−25.4254	−7.6746
	Ridge Wet Season	−16.02000*	2.91801	0.000	−24.8954	−7.1446
	Mound Dry Season	0.29667	2.91801	1.000	−8.5787	9.1721
	Plough Dry Season	−0.51500	2.91801	1.000	−9.3904	8.3604

*The mean difference is significant at the 0.05 level.

Table A8. Multiple comparisons for soil moisture between 45 - 60 cm depth.

Tukey HSD						
(I) Group	(J) Group	Mean Difference (I - J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
Mound Wet Season	Plough Wet Season	−0.37667	3.11217	1.000	−9.8426	9.0893
	Ridge Wet Season	−1.20500	3.11217	0.999	−10.6710	8.2610
	Mound Dry Season	15.85667*	3.11217	0.000	6.3907	25.3226
	Plough Dry Season	15.39667*	3.11217	0.000	5.9307	24.8626
	Ridge Dry Season	15.22333*	3.11217	0.000	5.7574	24.6893
Plough Wet Season	Mound Wet Season	0.37667	3.11217	1.000	−9.0893	9.8426
	Ridge Wet Season	−0.82833	3.11217	1.000	−10.2943	8.6376
	Mound Dry Season	16.23333*	3.11217	0.000	6.7674	25.6993
	Plough Dry Season	15.77333*	3.11217	0.000	6.3074	25.2393
	Ridge Dry Season	15.60000*	3.11217	0.000	6.1340	25.0660
Ridge Wet Season	Mound Wet Season	1.20500	3.11217	0.999	−8.2610	10.6710
	Plough Wet Season	0.82833	3.11217	1.000	−8.6376	10.2943
	Mound Dry Season	17.06167*	3.11217	0.000	7.5957	26.5276
	Plough Dry Season	16.60167*	3.11217	0.000	7.1357	26.0676
	Ridge Dry Season	16.42833*	3.11217	0.000	6.9624	25.8943
Mound Dry Season	Mound Wet Season	−15.85667*	3.11217	0.000	−25.3226	−6.3907
	Plough Wet Season	−16.23333*	3.11217	0.000	−25.6993	−6.7674
	Ridge Wet Season	−17.06167*	3.11217	0.000	−26.5276	−7.5957
	Plough Dry Season	−0.46000	3.11217	1.000	−9.9260	9.0060
	Ridge Dry Season	−0.63333	3.11217	1.000	−10.0993	8.8326
Plough Dry Season	Mound Wet Season	−15.39667*	3.11217	0.000	−24.8626	−5.9307
	Plough Wet Season	−15.77333*	3.11217	0.000	−25.2393	−6.3074
	Ridge Wet Season	−16.60167*	3.11217	0.000	−26.0676	−7.1357
	Mound Dry Season	0.46000	3.11217	1.000	−9.0060	9.9260
	Ridge Dry Season	−0.17333	3.11217	1.000	−9.6393	9.2926
Ridge Dry Season	Mound Wet Season	−15.22333*	3.11217	0.000	−24.6893	−5.7574
	Plough Wet Season	−15.60000*	3.11217	0.000	−25.0660	−6.1340
	Ridge Wet Season	−16.42833*	3.11217	0.000	−25.8943	−6.9624
	Mound Dry Season	0.63333	3.11217	1.000	−8.8326	10.0993
	Plough Dry Season	0.17333	3.11217	1.000	−9.2926	9.6393

*The mean difference is significant at the 0.05 level.

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