

**USMANU DANFODIYO UNIVERSITY, SOKOTO
(POSTGRADUATE SCHOOL)**

**EFFECT OF TILLAGE PRACTICES AND IRRIGATION SCHEDULE
ON SOIL QUALITY AND PERFORMANCE OF SOME RICE
(*Oryza sativa* L.) VARIETIES IN SOKOTO, NIGERIA**

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to the Postgraduate School,
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(Soil Science)**

BY

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DEDICATION

This work is dedicated to late Prof. Abayomi George Ojanuga, who passed away at the verge of completion of the first year trial. May God Almighty grant him eternal rest, Amen.

CERTIFICATION

This thesis by ENJUGU, Achukwu Manasseh (ADM NO. 16310613004) has met the requirements for the award of the Degree of Doctor of Philosophy (Soil Science) of the Usmanu Danfodiyo University, Sokoto and is approved for its contribution to knowledge.

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TABLE OF CONTENTS

TITLE	
PAGE.....	i
DEDICATION.....	ii
CERTIFICATION.....	iii
ACKNOWLEDGEMENTS.....	iv
TABLE OF CONTENTS.....	vi
LIST OF FIGURES.....	xii
LIST OF TABLES.....	xii
ABSTRACT.....	xvi
CHAPTER ONE	
1.0 INTRODUCTION.....	1
1.1 Background to the study.....	1
1.2 Problem Statement.....	2
1.3 Justification of the Study.....	3
1.4 Objectives of the Study.....	4
1.5 Scope and Limitation of the Study.....	5
CHAPTER TWO	
2.0 LITERATURE REVIEW.....	6
2.1 Water Management in Lowland Rice Production.....	6
2.2 Water Management Strategies to Reduce Water Input.....	7
2.3 Electrochemical Changes in Flooded Lowland Rice.....	8
2.4 Environmental Impacts of Flooded and Drained Lowland Rice Fields.....	9
2.5 Tillage System.....	10
2.5.1 Tillage types and effects on soil physical properties.....	11
2.5.2 Effect of tillage on soil water retention characteristics.....	13
2.5.3 Effect of tillage on soil hydraulic conductivity.....	14
2.5.4 Effect of tillage on crop performance.....	14

2.6	Rice Production Systems in Nigeria and Commercially Released Varieties.....	15
2.7	Soils of the Study Area.....	19
2.8	Concept of Soil Quality.....	20
2.9	Soil Physical Quality Indicators.....	21
2.9.1	Bulk density.....	22
2.9.2	Soil porosity and pore size distribution.....	25
2.9.3	Soil water retention and transmission characteristics.....	26
2.9.4	Aggregation and aggregate stability.....	27
2.10	S-Index of Soil Physical Quality.....	29
 CHAPTER THREE		
3.0	MATERIALS AND METHODS.....	31
3.1	Experimental Location.....	31
3.2	Treatments and Experimental Design.....	31
3.3	Experimental Materials.....	32
3.4	Agronomic Practices.....	32
3.4.1	Nursery preparation.....	32
3.4.2	Land preparation.....	32
3.4.3	Transplanting and irrigation.....	33
3.4.4	Weed control.....	33
3.4.5	Fertilizer application.....	33
3.4.6	Pests and disease control.....	33
3.5	Determination of Plant Growth Attributes and Seed Quality.....	34
3.5.1	Plant height (cm).....	34
3.5.2	Number of tillers per plant.....	34

3.5.3	Days to 50% heading.....	34
3.5.4	Panicle length (cm).....	34
3.5.5	Percentage unfilled grain.....	34
3.5.6	Total dry matter (g).....	35
3.5.7	Number of off-types.....	35
3.6	Harvesting, Threshing and Winnowing.....	35
3.6.1	Grain yield (kg ha ⁻¹).....	35
3.6.2	1000 grain weight (g).....	35
3.7	Measurement of Soil Parameter.....	36
3.7.1	Particle size distribution.....	36
3.7.2	Total organic carbon.....	37
3.7.3	Total nitrogen.....	37
3.7.4	Soil pH.....	38
3.7.5	Available phosphorus.....	38
3.7.6	Exchangeable cation.....	38
3.7.7	Cation exchange capacity (CEC).....	38
3.7.8	Electrical conductivity.....	38
3.7.9	Bulk density.....	38
3.7.10	Saturated hydraulic conductivity.....	39
3.7.11	Total porosity.....	40
3.7.12	Aggregate stability.....	40
3.7.12.1	Dry Sieving.....	40
3.7.13	Soil water retention characteristics.....	41
3.7.14	Soil physical quality index (S).....	41

3.8	Irrigation Water Quality.....	42
3.8.1	pH.....	43
3.8.2	Electrical conductivity.....	43
3.8.3	Carbonate and bicarbonate.....	43
3.8.4	Chloride.....	43
3.8.5	Nitrate.....	43
3.8.6	Sulphate.....	43
3.8.7	Boron.....	43
3.8.8	Dissolved base cations.....	43
3.9	Data Analysis.....	44
CHAPTER FOUR		
4.0	RESULTS AND DISCUSSION.....	45
4.1	Some Physical and Chemical Properties of the Soils of the Study Area before onset of the Experiment.....	45
4.2	Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Physical Parameters at Harvest in 2018.....	48
4.3	Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Physical Parameters at Harvest in 2019.....	50
4.4	Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2018.....	53
4.5	Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2019.....	57
4.6	Effect of Tillage Practices, Irrigation Schedule and Depth on MWD and GMD of Aggregate in 2018 and 2019.....	60

4.7	Effect of Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties grown in 2018 Dry Season.....	64
4.8	Effect of Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties grown in 2019 Dry Season.....	68
4.9	Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50% Heading, Panicle length and Total Dry Matter in 2018 Dry Season at Kwalkalawa.....	73
4.10	Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50% Heading, Panicle length and Total Dry Matter in 2019 Dry Season in Kwalkalawa.....	78
4.11	Effect of Tillage Practices, Irrigation Schedule and Variety on One Thousand Grain Weight, Percentage Unfilled Grain, Number of Off-types and Grain Yield/ha in 2018 Dry Season at Kwalkalawa.....	82
4.12	Effect of Tillage Practices, Irrigation Schedule and Variety on One Thousand Grain Weight, Percentage Unfilled Grain, Number of Off-types and Grain Yield/ha in 2019 Dry Season at Kwalkalawa.....	86
4.13	Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m^3m^{-3}) in Dry Seasons at Harvest at Kwalkwalawa.....	90
4.14	Van Genutchen Parameters and Soil Physical Quality Index (S-index).....	94
4.15	Correlation Analysis.....	97
4.15.1	Correlation analysis for 2018 and 2019.....	97

4.16	Relationship between Observed and Fitted Water Content at Various Pressure Heads.....	100
4.17	Irrigation Water Quality Assessment of the Tube Wells.....	103
CHAPTER FIVE		
5.0	SUMMARY, CONCLUSION AND RECOMMENDATIONS.....	107
5.1	Summary.....	107
5.2	Conclusion.....	110
5.3	Recommendations.....	110
REFERENCES.....		112

LIST OF FIGURES

Figure 1:	Interaction between tillage practices and depth on aggregate size fractions in 2018.....	56
Figure 2:	Interaction between tillage practices and depth on aggregate size fractions in 2019.....	59
Figure 3:	Interaction between tillage practices and depth on MWD and GMD in both 2018 and 2019.....	63
Figure 4:	Relationship between measured and fitted volumetric water content at 0-10 cm depth under CT and RT.....	101
Figure 5:	Relationship between measured and fitted volumetric water content at 10-20 cm depth under CT and RT.....	102

LIST OF TABLES

Table 1:	Characteristics of some released rice varieties in Nigeria from 1958–2017.	18
Table 2:	General relationship of soil bulk density to root growth based on soil texture.....	24
Table 3:	S index ranges and their description.....	30
Table 4:	Physical and Chemical Properties of the Soils of the Study Area before onset of the Experiment.....	47
Table 5:	Effect of Tillage Practices, Irrigation Schedule and Depth on Bulk Density, Saturated Hydraulic Conductivity and Total Porosity after Harvest in 2018.....	49
Table 6:	Effect of Tillage Practices, Irrigation Schedule and Depth on Bulk Density, Saturated Hydraulic Conductivity and Total Porosity at Harvest in 2019...	52
Table 7:	Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2018 Dry Season.....	55
Table 8:	Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2019 Dry Season.....	58
Table 9:	Effect of Tillage Practices, Irrigation Schedule and Depth on Mean Weight Diameter and Geometric Mean Diameter in 2018 and 2019 Dry Season....	62
Table 10:	Effect of Tillage Practices, Irrigation Schedule on Plant Height of Rice Varieties grown in 2018 Dry Season at Kwalkwalawa, Sokoto state.....	65
Table 11:	Interaction between Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties at Harvest in 2018 Dry Season.....	67
Table 12:	Interaction between Irrigation Schedule and Rice Varieties on Plant Height at Harvest during 2018 Dry Season.....	67

Table 13:	Interaction between Tillage Practices, Irrigation Schedule and Rice Variety on Plant Height at Harvest during 2018 Dry Season.....	67
Table 14:	Effect of Tillage Practices, Irrigation Schedule on Plant Height of Rice Varieties grown in 2019 Dry Season at Kwalkwalawa, Sokoto state.....	69
Table 15:	Interaction between Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties at Harvest in 2019 Dry Season.....	72
Table 16:	Interaction between Irrigation Schedule and Rice Varieties on Plant Height at Harvest during 2019 Dry Season.....	72
Table 17:	Interaction between Tillage Practices, Irrigation Schedule and Rice Variety on Plant Height at Harvest during 2019 Dry Season.....	72
Table 18:	Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2018 Dry Season.....	76
Table 19:	Interaction between Tillage Practices, Irrigation Schedule and Variety on Number of Tillers during 2018 Dry Season.....	77
Table 20:	Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2019 Dry Season.....	80
Table 11:	Interaction between Irrigation Schedule and Variety on Number of Tillers during 2019 Dry Season.....	81
Table 22:	Effect of Tillage Practices and Irrigation Schedule on One Thousand Grain Weight (g), Percentage Unfilled Grain (%), Off-types and Grain Yield/ha (kg/ha) of Rice Variety during 2018 Dry Season.....	84

Table 23:	Interaction between Irrigation Schedule and Variety on Grain Yield/ha (kg ha^{-1}) During 2018 Dry Season.....	85
Table 24:	Effect of Tillage Practices, Water Management and Variety on One Thousand Grain Weight (g), Percentage Unfilled Grain (%), Off-types and Grain Yield (kg ha^{-1}) of Rice during 2019 Dry Season.....	88
Table 25:	Interaction between Irrigation Schedule and Variety on Grain Yield/ha (Kkg ha^{-1}) During 2019 Dry Season.....	89
Table 26:	Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m $^3m^{-3}$) in 2018 Dry Season.....	92
Table 27:	Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m $^3m^{-3}$) in 2019 Dry Season.....	93
Table 28:	Effect of Tillage Practices, Irrigation Schedule and Depths on RETC Outputs of Van-Genutchen Parameters and S-Index values.....	96
Table 29:	Matrix of Correlation between Paddy Yield, Tillage, Irrigation Schedule and Yield Components of Rice in 2018 Dry Season.....	98
Table 30:	Matrix of Correlation between Paddy Yield, Tillage, Irrigation Schedule and Yield Components of Rice in 2019 Dry Season.....	99
Table 31:	Description of each Tube-well Sample Point in the Field.....	105
Table 32:	Irrigation Water Quality Indicators in Tube-wells of the Study Area, showing Mean and Ranges.....	106

ABSTRACT

A study was conducted on the effect of tillage practices and irrigation schedule on soil quality and performance of some rice varieties grown in the dry seasons of 2018 and 2019 at Kwalkwalawa, Sokoto State. The treatments consisted of factorial combination of two tillage practices; conventional tillage (CT) and reduced tillage (RT), three irrigation water schedules (One day scheduling (W1), two days scheduling (W2) and three days scheduling (W3)) and three varieties of rice (FARO 44, FARO 60 and FARO 61). Treatments were laid in a split plot design replicated three times; tillage practice and irrigation water schedules were allocated to the main plots while varieties were allocated to the sub-plot. Data collected were subjected to analysis of variance and the results revealed a significantly ($P < 0.05$) effect of bulk density (BD) of RT is greater than CT, saturated hydraulic conductivity (SHC) and total porosity (TP) for CT is significantly ($P < 0.05$) greater than RT. Aggregate size fraction of 5-2 mm had significantly ($P < 0.05$) higher value for RT compared to CT, greater value of aggregate fractions for CT in both 0.25-0.005 mm and < 0.005 mm compared to RT. Mean weight diameter (MWD) and geometric mean diameter (GMD) showed that RT with W1 had higher value, which increases with depth. FARO 44 shows significant difference in 1000-grain weight and yield/ha (5835.85kg/ha in 2019) compared to the other two varieties. The RETC output shows significant difference in n and S-index was greater in RT. Measured and fitted RETC output were not close to 1:1 solid line, hence cannot predict with accuracy the hydraulic behavior of the soils. Electrical conductivity, total dissolved solids and sodium adsorption ratio were low, pH range between 7.12-7.32, carbonates, bicarbonates, magnesium and calcium levels were low while sodium is moderate, nitrates, sulphates, chlorides and boron were also low.

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Soil is a dynamic natural reservoir and source of plant nutrients that play key roles in terrestrial ecosystems. The primary function of soil to every agrarian is for the production of food, fodder, timbers, fibre and fuel (Lal and Shukla, 2004). Continuous and intensive soil cultivation has negative effects leading to accelerated soil erosion, nutrients depletion and degradation (Batione *et al.*, 2003, Abu and Abubakar, 2013). This is because continuous cultivation without returning crop residues to the soil after harvest, alter soil structure and increase the loss of soil organic matter which leads to rapid soil degradation. The increasing incident of soil degradation and the consequent impoverishment of soils have generated interest for proper understanding of soil characteristics and adoption of suitable conservation practice by farmers for sustainable crop production and maintenance of soil quality.

Soil quality degradation, which is defined as increasing inability of a soil to perform its ecosystem functions is manifested in persisting problems of erosion, compaction, acidification, organic matter losses, nutrient losses, desertification and chemical contaminations which reduce agricultural production capacity and food security (Larson and Pierce, 1991). Evaluating impact of agricultural practices on agro-ecosystem is essential for determining the sustainability of management systems (Liebig *et al.*, 2001). Soil quality is considered a key element for evaluating the sustainability of land management practices (Wander and Bollero, 1999; Carter, 2002). Numerous physical,

chemical and biological properties can be used as indicators for assessing the effect of ecosystem disturbance by human activity on soil quality (Gregorich *et al.*, 1994). Although these properties are interdependent, soil physical quality strongly affects water availability, nutrient adsorption, aeration, rooting ability and thus crop performance; therefore it plays a central role in studies on soil quality (Dexter, 2004a).

The study of soil response to different tillage systems and water management provides valuable information concerning the practices that can improve quality of these soils and hence the sustainability of crop production without any adverse environmental effect as integration of these two factors adopted may have considerable management of resources and for the optimization of crop yield.

1.2 Problem Statement

Rice is an important food crop that generates income for Nigerian farmers, especially small scale producers who sell a larger percentage of their total production and consume only a few and with the population of Nigeria on the increase, rice demand and consumption are also expected to increase (GAIN, 2016). Out of available 4.6 million hectares of land for rice production, only 1.7 million hectares are put into cultivation in the country (Nwachukwu *et al.*, 2008). The global trend in food and economic crises and continuous importation of rice from countries like India, Thailand, Vietnam, Pakistan and USA to developing countries, most especially Nigeria has negative effect on the domestic production and general economic development of such countries (Abbas *et al.*, 2018). In 2016, national rice demand was estimated at 6.3 million metric tons while domestic supply was put at 2.3 million metric ton (FMARD, 2016). The balance of 4 million metric tons is

expected to be filled by import, which is very detrimental to Nigeria`s economy because it portends a serious danger in terms of foreign exchange.

In the Savanna agro-ecology, crop production is increasing both in scope and intensity, where commonly crops grown includes maize, sorghum, rice, cowpea, groundnut, cotton, soyabean and vegetables (Odunze *et al.*, 2017). Average rice yield in Nigeria is put at 2.0 Mt ha⁻¹ far below the world`s average of 5.0 Mt ha⁻¹. The reasons for this low productivity is inadequate physical infrastructure, poor resources, in addition to low literacy level which limits the farmer`s ability to understand improved production technologies and fully utilize opportunities (Kasim *et al.*, 2014). Also, the continuous and intensive soil cultivation without proper soil and water management could lead to accelerated soil erosion, nutrients depletion and soil degradation (Abu and Abubakar, 2013; Odunze *et al.*, 2017).

For a sustainable rice production, proper soil and water management and use of improved rice varieties which are suitable for specific location should be encouraged.

1.3 Justification of the Study

Rice being the world`s second most widely grown cereal crop after wheat and presently more than half of the world`s population depends on it as a staple food. Approximately 3.7 million metric tons of rice was produced in 2018 in Nigeria, which meets only about 50% of its local demand and where production is mostly by small scale farmers who grow low yielding varieties coupled with inappropriate tillage practices. The consumption of rice has increased tremendously to 6.7 million metric tons in 2018, due to increasing humanitarian feeding of refugees caused by resurging Boko Haram (BH) attacks,

pastoralist-farmers clashes and coupled by the banning rice importation by the Federal Government, as all these, tends to encouraging domestic rice production (USDA, 2018). In Nigeria, there is virtually no person that does not consume rice except those on medical conditions e.g diabetic patients; in addition rice is used in the recipe of many traditional foods.

With the increase in world`s population and the effect of climate change in food production, the sustainable production of rice as a stable crop is threatened. However, with the development of wide range of rice varieties that can utilize less amount of water under controlled irrigation scheduling will go a long way to ensure a sustainable rice production system with good soil management.

Therefore, the need to study the effect of tillage practice and irrigation schedule on soil quality and performance of rice varieties in Sudan Savanna agro ecological zone for soil conservation management strategies and for sustainable rice production in the study area cannot be overemphasized.

1.4 Objectives of the Study

The main objective of this study was to evaluate the effect of tillage and irrigation schedules on soil quality indicators using suitable soil and water conservation methods that will support long time sustainable production without damage to soil resource base.

The specific objectives were to:

- i. determine the effects of tillage practices and irrigation schedules on soil quality;
- ii. determine the effect of tillage practices and irrigation schedule on the performance of rice varieties in Sokoto;

- iii. validate the applicability of retention curve (RETC) model in water retention study under two tillage practices and irrigation schedules and
- iv. evaluate the water quality of the tube-wells for irrigated rice production in the study area.

1.5 Scope and Limitation of the Study

The study covered both planting, field and laboratory analysis, where samples were taken at harvest for laboratory analysis for a period of two dry seasons of 2018 and 2019, respectively. This study was limited to a farmer`s field in Kwalkwalawa, along the Sokoto-Rima flood plain. The major limitation to this study was the unavailability of neutron probe and tensiometer for the *in situ* water measurements at varying pressure heads, rather than the use of laboratory determination of water by the use of pressure plate apparatus, which was very cumbersome, time consuming and affected by electricity fluctuations.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Water Management in Lowland Rice Production

Rice being a profligate user of water, uses 3000-5000 liters of water to produce one kilogram of paddy, which is about 2 to 3 times more than the quantity required to produce one kilogram of other cereals such as maize or wheat (Cantrell, 2002). Nigeria's present and future food security depends largely on irrigated rice production; as a result of continuous flooding of rice fields during rainy season, which drastically affects the yield. Until recently, the amount of water for irrigated rice has been taken for granted, but now the global water crises threatens sustainability of irrigated rice production (Gleick, 1993; Postel, 1997). Reasons for this are divers and location specific, but include decreasing water quality (chemical pollution and salinization), decreasing water resources (falling ground water tables, silting of reservoirs), and increased competition from other natural resource sectors; such as urban and industrial uses (Postel, 1997).

The scarcity of water, usage cost and resource development are on the increase. Therefore, farmers and researchers are faced with the challenges of reducing water use in rice production, increase its use efficiency and increase yield of paddy rice. A fundamental approach for achieving this is to start at the field level, where water and rice interact. For farmers that has no control over availability or distribution of water beyond their farm gates, the crucial question to address is; what are the available options to cope with decreasing water supply at the farm or field inlets? To answer this question, we have to study the flow of water into rice fields and understand where reduction in water use can be achieved without compromising yield. The quantum of water needed for growing rice is

determined by climate, soil, and water management factors. In tropical and subtropical climates, daily water requirement for meeting evapotranspiration, percolation and seepage losses vary from 5-12 mm/day depending on the season and related climate variability (ICAR, 2006). It has also been reported that the total water requirement to grow a mid-early (100-day duration) rice variety is estimated to be 800-1500 mm, which includes 250 mm water required for land preparation and 50 mm for nursery raising (ICAR, 2006). A typical evapotranspiration rates (water use) of rice fields are 4-5 mm d⁻¹ in the wet season and 6-7 mm d⁻¹ in the dry season, but can be as high as 10-11 mm d⁻¹ in subtropical regions (Tabbal *et al.*, 2002). During the crop growth period about 30-40 % of evapotranspiration losses are accounted for by evaporation (Bouman *et al.*, 2005).

2.2 Water Management Strategies to Reduce Water Input

Large reduction in water input can be potentially realized by reducing the unproductive seepage and percolation (SP) flows during the crop growth and idle periods. There are basically two ways to do so: (1) by increasing resistance to water flow in the soil and (2) decreasing hydrostatic pressure (depth) of the ponded water. The resistance to water flow can be increased by changing the soil physical properties. Cabangon and Tuong (2002) have shown the beneficial effects of an additional shallow tillage before land preparation to close cracks that cause rapid bypass flow at land soaking. Thorough puddling of tilt soil results in a good compacted plowed soil that reduces vertical water flow (Datta, 1981). Soil compaction using heavy machinery can decrease soil permeability in certain coarse textured soils (Harnpichitvitaya *et al.*, 2001). Researchers have experimented with introducing physical barriers underneath rice soils such as bitumen layers and plastic sheets (Garrity *et al.*, 1992). Though effective, most of these improvements are expensive and

beyond the financial means of resource-poor farmers. Reducing SP flows through reduced hydrostatic pressure can be achieved by water management. Instead of keeping the rice field continuously flooded with 5-10 cm of water, the flooded water depth can be decreased, the soil can be kept around saturation, or alternate wetting and drying regimes can be imposed. Under this management practices, hydrology of the soil changes from anaerobic under flooded conditions to alternate aerobic under drained or saturated regimes (Garrity *et al.*, 1992).

It is very important to alternate the scheduled of irrigation by skipping some days interval so as to save water and create aeration, which is applicable to alternate wetting and drying regimes.

2.3 Electrochemical Changes in Flooded Lowland Rice

Essential nutrients of most plants species are at maximal or near-maximal availability when soils are in the pH range of 5 to 6.5, and decreased both above and below this range (Landon, 1991). In acid soils, many plant species grow poorly due to low tolerance to high concentrations of hydrogen ions (H^+), and toxicities due to high levels of H^+ , Al, Fe, and Mn, and low levels of P, K, Ca, Mg, and micronutrients (Samonite, 2008). The populations or activities of beneficial microorganisms (e.g rhizobia and mycorrhizae) are also adversely affected by hydrogen ion toxicities (Howeler, 1991). Hydrogen ion toxicity damages plant roots; the roots become short, thickened, fewer, brown or dull gray. Root membranes are damaged, causing leakage of organic substrates and cations interference with ion transport (Samonite, 2008). Aluminum toxicity in soil solution is caused by low soil pH < 5 (IRRI, 2003). Aluminum accumulates at the root tips, where root cells divide and elongate. Excessive aluminum is toxic to cell walls, plasma membranes of younger and outer cells of roots, and the root symplasm (cytoplasm in plant cells,

interconnected by the plasmodesmata); resulting in root growth inhibition as the main symptoms of Al toxicity (IRRI, 2003). Aluminum toxicity also affects plasma membrane functions, thereby decreasing the influx of calcium, magnesium, and phosphorus. Manganese concentration in soil solution increases at low soil pH or when redox potential (ability of compounds to accept or donate electrons) is low, which occurs when soils are flooded (IRRI, 2003). Excessive amounts of manganese in the soil solution leads to high manganese uptake. High tissue manganese concentrations changes metabolic processes (e.g., enzyme activities and organic compounds), which cause toxicity symptoms such as chlorosis (photo-oxidation of chlorophyll) or necrosis (accumulation of oxidized phenolic compounds, e.g., anthocyanin) (IRRI, 2003).

The application of lime often alleviates low pH and problems caused by low pH. Lime increases pH by reducing the hydrogen ion concentration; that is, calcium ions from lime (CaCO_3) replace the hydrogen ions, which react with bicarbonates produced from the reaction of carbonate and water, to form water and carbon dioxide (Mitchel and Adams, 2002).

2.4 Environmental Impacts of Flooded and Drained Lowland Rice Fields

Submergence of soil promotes the production of methane by anaerobic decomposition of native and added organic matter. Lowland rice ecosystems have long being recognized as a source of methane – a greenhouse gas (Buresh *et al.*, 2005). United State Environmental Protection Agency (USEPA, 2004) estimated that lowland rice cultivation contributed 110 million tons of methane annually, which corresponds to 20% to the total annual global emissions of 550 million tons. Field measurements conducted since the early 1990s have shown large variations in methane emissions from the initial

estimates. This has allayed fears that rice ecosystems are major contributors to global warming (Wassman *et al.*, 2000).

The incorporation of organic materials such as straw during land preparations by conventional puddling can dramatically increase methane emissions (Buresh *et al.*, 2005). Burning of the straw can result in methane emissions comparable to those following incorporation of straw. Burning of straw is also an increasing environmental concern because it can adversely affect local air quality, leading to increases in respiratory problems. The management of straw by composting, mulching and early incorporation before soil submergence for puddling is some options to reduce methane emissions (Wassman *et al.*, 2000).

Temporary aeration of soil can reduce methane emission without adversely affecting rice yield, while potentially saving water, commonly with the use of alternate wetting and drying and scheduling of irrigation. Measurements of methane emissions are not available for aerobic rice, but the growth of lowland rice on unsaturated soil rather than submerged soil would markedly reduce emissions of methane.

2.5 Tillage System

Lal (1979) defined tillage as physical, chemical or biological soil manipulation to optimise conditions for seed germination, emergence and seedling emergence. Soil tillage is an important factor affecting soil physical properties and crop yield, and can contribute up to 20% of yield loss (Khurshid *et al.* 2006). In any agro ecological environment, the tillage system practiced is usually determined by the soil conditions, climate and type of crop to be grown. Tillage system affects sustainable use of soil resources through its influence on soil properties (Hammel, 1989). The proper use of tillage can improve soil related constraints, while improper tillage practices can cause a range of undesirable

processes, such as depletion of organic matter and fertility, destruction of soil structure, accelerated erosion, and disruption in cycles of water, organic carbon and plant nutrient (Lal, 1993 and Odunze *et al.* 2017).

2.5.1 Tillage types and effects on soil physical properties

Tillage has been shown to affect infiltration into the soil, evaporation from the soil surface (Schwartz, 2006), and drainage through the soil by altering the amount of surface residue as well as physical properties such as structure, compaction, pore connectivity and surface roughness. Tillage system can be broadly classified into conventional and conservational. Conventional tillage system, which involves the use of mould board plough with soil inversion, has been shown to cause undesirable side effects on soil properties (Opara-nadi, 1993; Abu and Abubakar, 2013). Soil becomes severely degraded by continuous cropping with conventional tillage due to increased soil erosion and soil organic matter oxidation (Zheng *et al.*, 2004 and Odunze *et al.* 2017).

Conservation tillage on the other hand, provides the best opportunity for halting degradation and for restoring and improving soil productivity (Lal, 1993). Conservation tillage involves management of surface residues (Odunze *et al.* 2017). No tillage, minimum or reduced tillage and mulch tillage are terms synonymous with conservation tillage or types of conservation tillage (Opara-Nadi, 1993; Ahn and Hintze, 1990).

Reports have shown that in most cases, elimination of tillage can increase bulk density and penetration resistance, soil water content, enhance infiltration, reduce runoff and erosion losses, as well as lower soil temperatures (Lal, 1979; Grant and Baily, 1994; Boehm, 2004; Wang *et al.*, 2007). Katsvairo *et al.* (2002) found lower penetration resistance, lower bulk density, and greater porosity on conventional and chisel till

treatments as compared with strip tillage during the vegetative stage of crop growth, but differences were not significant during their later reproductive stage. Licht and Al-Kaisi (2005) confirmed that penetration resistance is lower in Chisel than either strip tillage or no-till with differences in soil water storage during the vegetative stage. Annual disturbance and pulverization caused by conventional tillage produce a finer and loose soil structure as compared to no-tillage method which leaves the soil intact (Rashidi and Keshavarzpour, 2007). This difference results in changes in number, shape, continuity and size distribution of pores network, which controls the ability of soil to store and transmit air, water and agricultural chemicals. Conservation tillage methods often result in decreased pore space (Hill, 1990), increased soil strength (Bauder *et al.*, 1981) and stable aggregates (Horne *et al.*, 1992 and Castro *et al.*, 2004). The pore network in conservational tilled soil is usually more continuous because of earthworm and root channels and vertical cracks (Cannel, 1985). Therefore, while conservation tillage may reduce disruption of continuous pores, conventional tillage decreases soil penetration resistance and soil bulk density (Khan *et al.*, 1999).

Aggregation is frequently reduced by increasing tillage operations, with no-till having the greatest aggregate stability (Lal *et al.*, 1994). However, Raimbault and Vyn (1991) found no difference in aggregate size between conventional and chisel plow operations. The influence of tillage on porosity creates differences in hydraulic conductivity between tillage treatments. Increasing tillage results in a reduction of stable macropores for water conduction (Buczko *et al.*, 2006). Increased volume of macropores in reduced tillage treatments resulted in greater saturated hydraulic conductivity for a silt loam soil (Buczko *et al.*, 2006). Ankeny *et al.* (1990) examined the effect of both tillage and traffic on

saturated hydraulic conductivity and found that there was no significant tillage effect in non-traffic treatments but greater compaction in the chisel management, resulting in reduced hydraulic conductivity as compared with no-till. Muir (2007) explained that conservation tillage systems can be an important part of a sustainable agricultural system. There is therefore, a significant interest and emphasis on shift to conservation tillage methods for the purpose of controlling erosion process (Iqbal *et al.* 2005).

2.5.2 Effect of tillage on soil water retention characteristics.

Tillage practices have been shown to influence a number of components of hydrologic balance. Reports showed that tillage has effect on infiltration into the soil, evaporation from the soil surface (Schwartz, 2006), soil water retention and drainage through the soil by altering the amount of surface residue as well as physical properties such as structure, compaction, pore connectivity and surface roughness.

Most authors reported inconsistent or slight differences between no-tillage and conventional tillage in soil-water retention characteristics in the equivalent plough layer (Blanco-canqui *et al.*, 2004 and Fuentes *et al.*, 2004). Shukla (2003) measured large volumetric water contents at a given pressure head for the 0-10cm layer of no-tillage than conventional tillage. Difference in soil-water retention characteristics between the two tillage systems were mainly the result of modifications in both organic matter concentrations and bulk densities since soil texture was not significantly affected by tillage differentiation. Large amounts of surface mulch result in increased water content at saturation and generally larger water retention under low pressure heads for the 0-5cm soil layer. For high pressure heads the opposite occurs: more surface mulch results in less water retention ((Blanco-canqui *et al.*, 2004). In addition, higher bulk densities result in smaller

water retention for the low pressure heads and larger water retention for the high pressure heads (Reicosky *et al.*, 1981).

2.5.3 Effect of tillage on soil hydraulic conductivity

Tillage often results in the destruction or development of a new and more extensive pore system that changes hydraulic properties either by deteriorating or enhancing soil water transmission or storage (Bescansa *et al.*, 2006a). There is no consensus in literature regarding effect of tillage systems on saturated hydraulic conductivity (K_{sat}) (Datiri and Lowery, 1991). For instance, Wu *et al.* (1992) and Blanco-canqui *et al.* (2004) did not observe any significant differences in K_{sat} between the equivalent plough layer of conventional and no-tillage. However, while some researchers reported larger K_{sat} values in the equivalent plough layer of NT (Fuentes *et al.*, 2004), others reported smaller K_{sat} value when compared with CT (Hubbard *et al.*, 1994). The unsaturated hydraulic conductivity as a function of soil water pressure is similar under both tillage systems (Datiri and Lowery, 1991; Wu *et al.*, 1992; and Fuentes *et al.*, 2004). These contradictory results are probably due to the fact that effect of tillage on the hydraulic conductivity is mainly the result of two opposing factors: smaller total porosity in NT decreases the hydraulic conductivity whereas continuity and/ or a large number of macropores in NT increases the hydraulic conductivity compare to CT.

2.5.4 Effect of tillage on crop performance

Results on the effect of tillage systems on crop performance and yield have been quite variable. Lal and Dinkins (1979) reported that grain yield of maize and rice was significantly higher for no- till plots than for convectional tilled plots. Ike (1986) reported that mean maize grain yields and cotton lint yields under three tillage systems were not

significantly different. Wang *et al.* (2007) found that grain yields were always higher under no-tillage than conventional tillage and statistically higher in three of the four years of the study period. Nangju (1979) reported that tillage methods had a small but significant effect on cowpea emergence but not on soybean. Lal (1979) reported that tillage caused no significant differences in plant height in the initial stages but the differences between the no-tillage and conventional tillage increased with time with no-tillage treatment having taller plants and higher leaf area index. A study conducted under humid climate with heavier soils found a yield advantage to chisel tillage in two of four corn years and all four soybean years (Vetsch *et al.*, 2007). Vetsch *et al.* (2007) tested both long term and rotational tillage systems and confirmed significant yield reductions for no-till management with both crops. However, this study also applied economic analysis and reported that the yield reductions were not enough to effect overall economic return of no-till cropping system. A variety of reasons for reduced yield were given, but not verified, including less favourable temperature and/or moisture conditions and difficulty planting into previous crops' stubble.

These contrasting results of effect of tillage on crop performance and yields may be due to soil types and nature of the crop grown. For instance, soils of the Nigerian Savannas are different from those of the rain forest regions. Consequently, crop responses to tillage practices may not be similar in both regions. Aina (1979b) working at Ife, Nigeria, reported that while yields of cassava and maize were significantly affected by tillage, cowpea yield was not significantly affected.

2.6 Rice Production Systems in Nigeria and Commercially Released Varieties

The three main rice ecologies in sub-Saharan Africa are the rainfed upland, the rainfed lowland and the irrigated systems. The challenges and constraints in these rice

ecologies are enormous (Abo *et al.*, 2003). In addition, inter-linkages exist between the ecologies. This is true for water or nutrient flow from upland to lowland. Another fuzzy transition exists between rainfed and irrigated lowland. From about 8 million hectares of land under rice cultivation in sub-Saharan Africa, about 40 percent is located in the upland ecology, 37 percent in the rainfed lowland ecology and 14 percent in the irrigated ecology (Ukwunga and Abo, 2013).

In the upland ecology, farmers' yields usually range between 1 to 1.5 t ha⁻¹. This is caused by a host of abiotic and biotic stresses, such as low soil fertility, drought, and weed pressure and blast disease (Abo *et al.*, 2003; Ukwungwu *et al.*, 2009). The NERICA (New Rice for Africa) rice varieties such as NERICA 1 (FARO 55), NERICA 2 (FARO 56), NERICA 7 (FARO 57) and NERICA 8 (FARO 58) have made important headway in the upland ecology because of their better adaptation to the local stresses leading to higher and more stable yield and shorter growth duration. However, drought and soil fertility had limit attainable yields and potential grain yields from improved technology in the upland ecology which remains relatively small (Ukwunga and Abo, 2013).

In the rain fed lowland ecology, farmers can expect yields between 2.0 to 3.5 t ha⁻¹. This is largely due to better soil fertility and when combined with good water management, the yields can be as high as 6 t ha⁻¹. The National Cereal Research Institute (NCRI), Badeggi and other partners in rice development programmes in West Africa have developed a range of rice varieties suited for rain fed lowland and irrigation ecosystem. These popular improved lowland rice varieties include FARO 44 (Sipi), FARO 52 (WITA 4), FARO 57 (Tox 4008), FARO 60 (NERICA L – 19), FARO 61 (NERICA L – 34) and FARO 62

(NCRO– 49), (Ukwunga and Abo, 2013). Table 1 presents details of rice varieties released from 1958 to 2017.

The irrigated systems have the highest yield potential because of better water control and reliability. Attainable yields in these systems can be as high as 8 t ha⁻¹, and rice double cropping is often feasible in the irrigated systems but its development in Nigeria has been restricted by a lack of adequate machinery to prepare the land and harvest the crop on time (Ukwunga and Abo, 2013).

Table 1: Characteristics of some released rice varieties in Nigeria from 1958 – 2017.

Variety	Old Variety Name	Ecology	Year of Release	Growth Duration	Potential yield (t/ha)
FARO 3	Agbede 16/56	UPLAND	1958	95-120	1.5-2.5
FARO 11	OS-6	SS	1966	110 – 122	1.5-2.5
FARO 12	SML-140/10	SS	1969	145-155	2.0-3.5
FARO 29	BG90-2	IS & SS	1984	120 – 130	3.0-4.0
FARO 35	ITA 212	IS	1986	120 – 135	5.0-8.0
FARO 36	ITA 222	IS	1986	120-135	5.0-8.0
FARO 37	ITA 306	IS	1986	120-135	5.0-8.0
FARO 44	SIPI 692033	IS & SS	1992	110 – 120	4.0-8.0
FARO 46	ITA 150	Upland	1992	115 – 120	2.0-3.0
FARO 48	ITA 301	Upland	1992	123	2.0-3.0
FARO 49	ITA 315	Upland	1992	120	2.0-3.0
FARO 51	CISADANE	IS & SS	1998	145-150	3.0- 8.0
FARO 52	TOX 3100-44-12-3-3 (WITA 4)	IS & SS	2001	125-130	3.0-5.0
FARO 53	ITA 321	Upland	2002	115 – 120	2.0-3.0
FARO 55	WAB 450-1-B-P36-HB (NERICA 1)	Upland	2003	100-105	2.0-3.0
FARO 56	WAB 450-11-1-P31-HB(NERICA 1)	Upland	2005	100 – 105	2.0-3.0
FARO 57	TOX 4004-43-1-2-1	IS & SS	2005	120-135	6.0-8.0
FARO 58	NERICA 7	Upland	2011	100 – 110	3.0-4.0
FARO 59	NERICA 8	Upland	2011	100 – 110	3.0-4.0
FARO 60	NERICA-L 19	IL	2011	100 – 115	3.0-5.0
FARO 61	NERICA-L 34	IL	2011	100 – 115	4.0-6.0
FARO 62	NCRO 49	SS	2011	120 – 125	3.0-5.0
FARO 66	ART351:12-2-B-5-B	IL	2017	120 – 125	6.7
FARO 67	ART350:10-2-1-B	IL	2017	120 – 125	6.7

Source: NACGRAB, 2017

FARO=Federal Agricultural Research Oryza. IL = Irrigated Lowland, SS = Shallow Swamp, IS = Irrigated Swamp

2.7 Soils of the Study Area

Soil series is the smallest unit of soil classification in the USDA soil taxonomy system, and according to Noma (2005), the soils of the study area was classified as Rima series. The USDA order of classification of Rima series followed this trend; Order Inceptisols, suborder aquepts, great group Endoaquepts, sub-group Aeric Endoaquepts, family level of the soil fit into a fine silty over clayed, mixed, non acidic, isohyperthermic Aeric Endoaquepts. Soils of Rima series are very deep, poorly drained loamy soils developed on Gande micaceous deposits over stratified Argungu floe and Kurukuru deposits of the floodplain. They occupy the flat to gently sloping swells and splays in the floodplain where water table rises to about 46cm in the rainy season.

Noma (2005) observed that the texture of these soils is commonly silt loam in the surface and subsurface horizons grading into contrasting materials of loamy sand, sandy loam, clay loam and clay textures in the substratum. Soil structure is medium to strong subangular blocky structure in the surface and subsurface (cambic) horizon when dry, changing to single grained or massive below. The soils are porous and permeable as indicated by bulk density and porosity values. Bulk density is in the range of 1.19 to 1.46MgM⁻³ while porosity ranged from 45% to 55%. Higher bulk density values were obtained in the subsurface horizons than in the surface horizons due to compaction by tillage operation and animal movement in the dry season. Malgwi *et al.* (2000) observed the same phenomenon in a Typic Trophaquent studied at Samaru, Zaria from soils of similar conditions. A bulk density value of this range is considered suitable for most crops causing no serious hindrance to root penetration or seedling emergence.

Noma. (2005) also measured infiltration rate at 6.09cm/hr at Rima series. This further attests to the moderately rapid permeability of the soils to water, a constraint to

irrigation development on the soils. FAO (1987) indicated that optimum infiltration rates for gravity irrigation are between 0.7 to 3.5cm/hr, which shows that the soils are not very suitable for gravity irrigation.

2.8 Concept of Soil Quality

Larson and Pierce (1991) defined soil quality as the capacity of soil to function within the ecosystem. Arshad and Coen (1992) defined soil quality as the sustaining capability of a soil to accept, store and recycle water, mineral and energy for production of crops at optimum levels while preserving a healthy environment. Gregorich *et al.* (1994) defined soil quality as a composite measure of both soil's ability to function and how well it functions relative to a specific use or degree of fitness of soil for a specific use. Similarly, Soil Science Society of America Ad Hoc Committee on soil quality opined that soil quality is the capacity of a reference soil to function, within natural or managed ecosystem boundaries to sustain plant and animal productivity, maintain or enhance water and air quality and to support human health and habitation. Karlen *et al.* (1997) brought out five functions of soil as:

- ❖ Sustaining biological activities, diversity and productivity;
- ❖ Regulating and partitioning water and solute flow;
- ❖ Filtering, buffering, degrading, immobilizing and detoxifying organic and inorganic materials including industrial and municipal by-products and atmospheric deposition;
- ❖ Storing and recycling nutrients and other elements within the earth biosphere and
- ❖ Providing support of socio-economic structures and protection for archeological treasures associated with human habitations.

The concept of soil quality emerged in literature in the early 1990s (Doran and Safely, 1997; Wienhold *et al.*, 2004), but concerns on soil quality are new because early scientific activities acknowledged the importance of categorizing soil type and soil properties in relation to land or soil use, especially for agricultural purpose (Carter *et al.*, 1997). Soil quality measurement is considered important for the assessment of extent of land degradation, amelioration and for identifying management practices which promotes sustainable land use (Carter and Rennie, 1982; Lal, 1993; Campbell *et al.*, 1998 and Roldan *et al.*, 2003). In general, soil quality consists of three main aspects i.e. physical, chemical and biological qualities.

2.9 Soil Physical Quality Indicators

The physical quality of an agricultural soil refers primarily to the soil-strength, fluid transmission and storage characteristics in the crop root zone (Topp *et al.*, 1997; Reynolds *et al.*, 2002). Soil physical quality affects both chemical and biological processes in the soil and, therefore plays a central role in the studies on soil quality (Dexter, 2004a). An agricultural soil with good physical quality maintains a good structure, holds crop upright, resists erosion and compaction, allow unrestricted root growth and proliferation of soil flora and fauna, while permitting the correct proportions of water, dissolved nutrients and air for both maximum crop performance and minimum environmental degradation (Topp *et al.*, 1997; Reynolds *et al.*, 2002).

The indications of soil quality are properties, processes and characteristics that can be measured to monitor changes in the soil (USDA-NRCS, 1996). Not all the soil properties can be regarded as soil quality indicators; as such the scientific relevance of an

indicator of soil quality was suggested by Paris *et al.* (2005) which depends upon the following conditions:

- ❖ Good correlation with the beneficial soil functions;
- ❖ Helpfulness in revealing ecosystem processes;
- ❖ Comprehensibility and utility for land managers and
- ❖ Cheap and easy to measure.

The commonly use physical indicators to assess soil function and quality (USDA-NRCS, 2008) includes:

- ❖ Bulk density;
- ❖ Soil porosity and pore Size distribution;
- ❖ Soil water retention and transmission characteristics and
- ❖ Aggregation and aggregate stability.

2.9.1 Bulk density

Bulk density is the ratio of mass of solid to the total volume (solids and pore together) of the soil (Lal and Shukla, 2004). Bulk density reflects the soil's function for structural support, water and solute movement and soil aeration. High bulk density is an indicator of low soil porosity and compaction (Arshad *et al.*, 1996). It may cause restriction to root growth, and poor movement of air and water through the soil. Compaction can result in shallow plat rooting and poor plant growth. Further, by reducing water infiltration into soils, compaction can lead to increased runoff and erosion from sloping land or waterlogged soils. Arshad *et al.* (1996) described various bulk density values which affect plant growth in different textural classes (Table 2).

Soil bulk density depends on natural soil characteristics such as texture, organic matter content, soil structure (Cassel, 1982; Chen *et al.*, 1998) and gravel content (Frazen *et al.*, 1994). Bulk density varies between and within the year due to the action of several processes e.g freezing and thawing (Blevins *et al.*, 1983; Unger, 1991), settling by desiccation and kinetic energy of rainfall (Cassel, 1982) and loosening by root action and animal activity.

Land use and crop management practices also influence soil bulk density. For example, continuous cultivation and removal or burning of residues increase soil bulk density, while continuous cropping and addition of organic amendments lowers soil bulk density (USDA-NRCS, 1996). Jiao *et al.* (2011) observed that re-vegetation had a positive effect on soil bulk density by decreasing soil bulk density values.

Table 2: General relationship of soil bulk density to root growth based on soil texture

Soil Texture	Ideal Bulk Densities (g/cm ³)	Bulk Densities That May Affect Root Growth (g/cm ³)	Bulk Densities That Restrict Root Growth (g/cm ³)
Sands, Loamy Sands	<1.60	1.69	>1.80
Sandy Loam, Loam	<1.40	1.63	>1.80
Sandy Clay Loam, Clay Loam	<1.40	1.60	>1.75
Silts, Silt Loam	<1.30	1.60	>1.75
Silt Loam, Silty Clay Loam	<1.40	1.55	>1.65
Sandy Clay, Silty Clays and Some Clay (35-45%)	<1.10	1.49	>1.58
Clays (>45% clay)	<1.10	1.39	>1.47

Source: Arshad *et al.* (1996)

2.9.2 Soil porosity and pore size distribution

Generally, soil pores can be expressed in two ways i.e quantitative and qualitative characterization (Adonis-Habib, 1985). Quantitatively, soil pores can be expressed as total porosity; which is the ratio of soil fluid volume (air and water) divided by the total volume. It is commonly calculated as unity minus the fraction of bulk density by particle density (Hillel, 1998). Total porosity is sometimes partitioned into microporosity and macroporosity (Bonneau and Levy, 1982).

Total porosity varies with structure and texture. It tends to be lower in coarse-textured than fine-textured soils and decreased when soil is poorly aggregated (Adonis-Habib, 1985). Qualitatively, soil scientists have divided soil pores into macro- and micropores according to their diameter. Macropores are large tubes involved in soil drainage and aeration, while micropores serve to retain water after drainage has taken place. Macropores are associated with movement of excess water by gravimetric potential. On the other hand, micropores relate to unsaturated flow and matric potential (Hillel, 1982; Meriaux, 1982).

Furthermore, Nimmo (1997) and Meriaux (1982) divided porosity into textural (intra-aggregate) and structural porosity (inter-aggregate). Textural porosity means very fine pores which results from size, shape and disposition of mineral particles in elementary assemblies. Structural porosity corresponds to large pores existing between aggregates (gap porosity) and clods influenced by tillage, climate and biological activities; it is the most dynamic part of porosity and commonly used to study soil structural changes after tillage (Guerif *et al.*, 2001). Tisdale and Oades (1982) noted that aggregates need to contain enough pores to remain aerobic and enough small pores to hold plant-available water. Macroporosity (structural porosity) is sensitive to variation in cultivation practices and can

increase under no-till management (Elliot and Coleman, 1988). These large pores play an important role in allowing roots; gas and water penetration into the soil (Perret *et al.*, 1999).

In agricultural lands, soil compaction is one of the environmental factors that adversely affect soil function. Heavy vehicles used for tillage and other operations can compact the soil, resulting in increased soil bulk density, a decreased in total porosity and a change in the pore size distribution. Rasmussen (1999) reported differences in total porosity at topsoil and subsoil layers with varied types of tillage practices. Also, Shipitalo *et al.* (2000) found that total porosity often increased with the adoption of reduced tillage compaction with conventional land which simultaneously resulted in an increased in total porosity of the organic soil.

2.9.3 Soil water retention and transmission characteristics

The amount of water absorbed before surface runoff starts and the amount of water a particular soil supply to maintain optimum plant growth is strongly determined by soil water content (Kamara *et al.*, 1992). A parameter often used to describe soils` ability to supply plants with the water they need is the available water capacity (AWC). Available water capacity is the amount of water a soil can store that is available for use by plants (Lipsius, 2002). It is defined as water held between field capacity (FC) and the water content at permanent wilting point (PWP). Field capacity represents the upper limit of water available to plants and equilibrium pre-saturated soil samples with a matric potential value between -10kPa and -33kPa for light to heavy textured soils respectively (Jury *et al.*, 1991). While permanent wilting point is represented by the lower limit of plant available water which is retained by soil particles with -1500kPa matric potential value. Soil texture especially clay content, porosity, pore size distribution and soil organic matter content have

been reported to influence FC (Lal and Shukla, 2004), where all the aforementioned soil characteristics have a positive influence on FC (Lal, 1979). Permanent wilting point is primarily determined by the amount and nature of clay (Lal, 1979b); the PWP is higher in soils with high clay content. It is higher in 2:1 expanding clay minerals than the 1:1 fixed lattice non expanding clay minerals.

The availability of soil moisture to plants is a function of water input, moisture retention and root depth of a given soil, which is governed by the inherent soil properties and management practices. Earlier works revealed that soil moisture retention and plant available water were affected by various management practices. Alliaume *et al.* (2010) reported 17% reduction in plant available water on cropped fields compared to their fallow pairs; the higher retention in undisturbed plots was attributed to high organic matter contents. The high organic matter stored in forest soil resulted in high amount of water retained at FC when associated with lower content observed in arable land (Wahren *et al.*, 2009). Also, higher soil moisture content was observed under conservation tillage than conventional tillage systems (Ohiri *et al.*, 1990; Khan *et al.*, 1999). Liebzig and Doran (1999) indicated that organic matter application improves water holding capacity of the soil.

2.9.4 Aggregation and aggregate stability

Aggregation is defined as the process whereby individual soil particles are joined into compound particles, clusters or aggregates (Sullivan, 2004). Aggregation is an important indicator for the soils` overall quality (Boix-fayos *et al.*, 2001). It has potential benefits on soil moisture status, nutrients dynamics, tilth maintenance and erosion reduction (Kemper and Rosenau, 1986). The term aggregate stability is used by soil physicists to refer

to the ability of the bonds of the aggregation to resist stress upon exposure (Rohoskova and Valla, 2004). In determining the stability of soil aggregates, soil physicists generally subject samples of aggregates to artificially induced forces designed to simulate phenomena which are likely to occur in the field (Hillel, 1980). Resistance of soil solids to the mechanical abrasion arising from the two forces of destruction i.e water and air for long has been used to measure stability of aggregates. The technique for aggregate stability analysis is described by Kamper and Rosenau (1986). Wet sieving technique discussed by Angers and Mehuys (1993) and dry sieving by White (1993) are the common methods employed to simulate aggregate resistance to water and wind erosion respectively.

Numerous factors affect stability of soils (Kay, 1997), most of which can be broadly grouped into two: endogenous and exogenous factors. The endogenous factors are those that are due to inherent soil properties. These factors include soil characteristics such as texture, clay mineralogy and nature of exchangeable cations, and quantity and quality of humus fractions (Lal and Shukla, 2004). The exogenous factors that affect soil aggregate stability include weather, biological processes, land use and management. Soil management or land use has been reported to influence soil aggregate stability (Six *et al.*, 2000).

Pinheiro *et al.* (2004) found that soil surface aggregates of >2mm fractions formed (50%) soil under no-tillage compared with animal traction (35%) and conventional tillage (30%). He also observed that soil organic carbon (SOC) was higher under no-tillage than conventional tillage. Gajic *et al.* (2006) reported that conversion of forest to continuous cropping by conventional cultivation significantly decreased the water stability of soil aggregates in the plough horizon. Also, Adesodun and Odejimi (2010) reported that mean weight diameter (MWD) was significantly higher in un-cultivated land, whereas, addition of compost to the cultivated land improved stability of the soil.

It has been reported that soil organic matter and clay content are the main soil properties affecting soil aggregation, as they bind individual particles (Fryrear *et al.*, 1994). Any practices that reduce organic matter and disturbed clay particles reduce soil aggregation.

2.10 S-Index of Soil Physical Quality

Efforts have been made for quite sometimes to quantify the soil physical environment, but one parameter found sensitive to a particular soil may not be suitable for another. At the moment, to integrate major physical indicators that influence soil quality, a unified soil physical quality index (S) had been proposed by Dexter (2004a). S-index is defined as the shape value or inclination of the soil water retention curve (SWRC) at the inflection point. This curve must be plotted as the logarithm to base e of the water potential against the gravimetric water content (KgKg^{-1}). The symbol S had been used because it is a measure of the slope of the water retention curve therefore, a measure of soil structure (particularly, the microstructure). It was suggested that the use of soil physical properties for the quantification of soil physical quality be called S-theory. It was also proposed that the index S provides a scale that can be used to compare easily the physical quantity of different soils or the effects of different soil management systems (Dexter, 2004b).

Though it is possible to obtain values of S from the slope at the inflection point by measuring directly on a graph, the moisture retention data can be fitted into a mathematical function and the slope at the inflection point of the SWRC is calculated from the estimates of the parameters of the used function. The Van Genuchten (1980) function is one of the most frequently used and in many studies; their parameters can be described from pedotransfer functions. Pedotransfer functions (PTF) to estimates SWRC have been widely developed and used in temperate climate soils (Tormena *et al.*, 1999) and to certain extent

for Brazilian tropical soils. Table 3, present a table on the categories of the S index of soil quality. Garg *et al.* (2009) concluded that different management practices that led to decreased bulk density and increase in organic carbon content, available water capacity resulted in larger values of S.

Table 3: S index ranges and their description

S Index Range	Description
$S < 0.002$	Very poor
$S \geq 0.002 \leq 0.035$	Poor
$S > 0.035$	Good

Source: Dexter (2004b)

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Experimental Location

The experiment was conducted in a farmer`s field, near the Usmanu Danfodiyo University Teaching and Research Farm, Kwalkwalawa, Sokoto State in the dry season of 2018 and 2019. The coordinates of the area were taken using global positioning system (GPS) model Garmin etrex 20.0 as (N13⁰05.963”E005⁰12.650” and 252m asl). The soils of the study area are classified as Aeric Endoaquepts at subgroup level in the USDA Soil Taxonomy System (USDA, 2014) which correlated with Gleyic Cambisols in the World Reference Base (FAO, 2015) and Rima series (Noma, 2005). The area experiences a long dry season from October to May and a short rainy season from June to September. The dry season consists of a cold dry spell (Harmattan) roughly from November to February, followed by a hot dry spell from March to May. The rainfall is erratic, small in quantity and uneven distribution with peak in August and temperature fluctuates roughly between 40⁰C maximum and 15⁰C minimum (Noma, 2005).

3.2 Treatments and Experimental Design

The treatments consisted of factorial combination of two tillage systems (Conventional tillage (CT); which involves cutting, inverting, puddling and leveling the field plots and reduced tillage (RT); which involves puddling and leveling of the plots all with local hoes, shovels and rake), three irrigation schedules (one day, two days and three days irrigation scheduling, which were carried out from one week after transplanting to hard dough stage) and three rice varieties (FARO 44, 60 and 61).

The treatments were laid in a split plot design replicated three times. Tillage system and irrigation schedule was allocated to the main plots, while varieties were allocated to the sub-plots. Field observations and measurements were made for two consecutive seasons (dry) using the same experimental design and field layout.

3.3 Experimental Materials

High yielding foundation seeds of rice which were commercially released were obtained from National Cereals Research Institute, Baddegi, Niger State. The varieties were: FARO 44, 60 and 61. The characteristics of the varieties were shown in Table 1.

3.4 Agronomic Practices

3.4.1 Nursery preparation

A nursery bed was established for the three rice varieties (FARO 44, 60 and 61) around the edge of the experimental field. Each seed was treated with seed dressing chemical (Apron star ® 50 DS), which contains metalaxyl-M 20% w/w, difenoconazole 2% w/w and thiamethoxam 20% w/w. It was used at the rate of 3.0 kg of seed per 10g sachet of chemical to protect the seeds from soil borne fungi and insect pests. The nurseries were established on 12/2/18 and 09/2/19.

3.4.2 Land preparation

The entire field was cleared of shrubs, pre-wetted and sprayed with 3.0 litre ha⁻¹ of a systemic herbicide before onset of the experiment. Soil samples were collected for the determination of some soil physical and chemical properties from both disturbed and undisturbed soils before imposing the treatments. The tillage was incorporated as per the treatment, followed by the construction of basins and water channels. The main plot size for

each tillage was $4\text{m} \times 10.2\text{m}$ (40.8m^2), the sub-plot sizes within the main plots was $4\text{m} \times 3\text{m}$ (12m^2) and net plot was $3\text{m} \times 2.5\text{m}$ (7.5m^2)

3.4.3 Transplanting and irrigation

The entire plot was flooded with water and the rice seedlings after being wetted over night from the nursery were transplanted after 28 days of its establishment, using transplanting rob at inter and intra row spacing of $20\text{cm} \times 20\text{cm}$ apart, using two seedling per stand. Immediately after transplanting, the field was sprayed with pendimethalin at the rate of 1.2ai/Kg ha^{-1} and irrigation water was maintained for one week all through the field before imposing of the irrigation scheduling according to the treatment.

3.4.4 Weed control

Weeding was done at 3 and 6 WAT using local hoe followed by hand pulling of weeds in the plots as the need arises which assisted to maintain weed free plots.

3.4.5 Fertilizer application

Fertilizer was applied through broadcasting at the recommended rate of 100, 40 and 40 Kg, N, P_2O_5 and K_2O per ha^{-1} respectively. 40 Kg of nitrogen and full dose of phosphorous and potassium were applied at 2WAT using NPK 15:15:15: while a split dose of 30 Kg N ha^{-1} was applied at 6WAT and the balance of 30 Kg N ha^{-1} was applied during panicle initiation using Urea (46%) as a source of N.

3.4.6 Pests and disease control

Birds were controlled by using nets and no incidence of disease and rodents was recorded.

3.5 Determination of Plant Growth Attributes and Seed Quality

3.5.1 Plant height (cm)

The height of five randomly tagged plants were measured and recorded from each net plot at 3, 6, 9 WAT and prior to harvest. This was achieved by measuring the plant from ground level to the tip of the newly opened leaf using a plastic measuring ruler and the average value was computed and recorded.

3.5.2 Number of tillers per plant

The number of tillers of tagged plants were counted prior to harvesting and the mean was recorded.

3.5.3 Days to 50% heading

Rice is regarded to have headed when the panicles are clearly visible. The days to 50% heading were recorded when 50% of the panicles were visible.

3.5.4 Panicle length (cm)

This was determined at harvest by measuring the length of five (5) randomly sampled panicles from each net plot with a ruler from the base of the first primary spike to the tip of the panicle and the mean value was computed and recorded.

3.5.5 Percentage unfilled grain

The empty spikelets were counted from the 5 randomly selected panicles selected at harvest from each net plot. The average was taken for all panicles and the percentage of unfilled grains was calculated. The empty seeds was designated as sterile while the remaining seeds were considered as normal seeds (Nagato and Chaudhry, 1969).

3.5.6 Total dry matter (g)

Total dry matter was determined by harvesting five plants per plot at random in the net plot from the base of the stem, oven dried to a constant weight at 70°C and the mean was computed.

3.5.7 Number of off-types

All plants that differed in conformity from the original variety planted in each net plot were counted and recorded as off-types. This counting was based on the differences in plant height, leaf colour and arrangement and the panicle colour and length.

3.6 Harvesting, Threshing and Winnowing

The crop was harvested at physiological maturity when the entire plants had turned yellow and the grain fully filled and at hard dough stage. The plants within the net plot were cut at ground level and bundled into sheaves. Each net plot harvested was threshed by putting into polythene sack and beaten with sticks. The paddy collected for each net plot was cleaned by winnowing, sun-dried and weighed using a sensitive electronic weighing balance.

3.6.1 Grain yield (kg ha⁻¹)

The harvested panicles from each net plot were threshed and the paddy winnowed and weighed using a sensitive electronic weighing balance and the yield expressed in tons per hectare.

3.6.2 1000 grain weight (g)

A randomly selected 1000 seeds were counted from the harvest of each net plot and weighed using a sensitive electronic weighing balance.

3.7 Measurement of Soil Parameter

After the land clearing, both disturbed and undisturbed soil samples were collected at 0-10 and 10-20cm depths at the experimental site. The samples collected were used to determine some soil physical and chemical properties before onset of the experiment and at the end of each season`s experiment, disturbed soil samples were collected at the same depths for some soil physical properties and water retention determination.

3.7.1 Particle size distribution

Particle size distribution of the less than 2 mm fine earth fraction was determined using Boyoucou method as described by Gee and Bauder (1986). Fifty grams of sieved soil was weighed into plastic bottle, 100ml of sodium hexametaphosphate (Calgon) was added into the bottle and the mixture placed on a mechanical shaker and agitated for 10 minutes. The mixed sample was then transferred into one-litre capacity measuring cylinder and made up to mark one litre with water. The suspension was stirred with a plunger before inserting the hydrometer. The hydrometer reading after 40 seconds was recorded for determining silt content, and the second reading after 2 hours was recorded to determine the clay content. The temperature of the suspension at first and second hydrometer readings was recorded and used for the correction of hydrometer readings. The value of 0.36 was added for any degree above 20⁰C or removed for any degree of temperature below 20⁰C. The particle size were calculated as follows:

$$\% \text{ (Clay + Silt)} = \frac{\text{Corrected 40 seconds hydrometer reading}}{\text{Weight of soil taken}} \times 100$$

$$\% \text{ Clay} = \frac{\text{Corrected 2 hours hydrometer reading}}{\text{Weight of sample taken}} \times 100$$

% Silt = % (clay +silt) - % clay

% Sand = 100 - % (clay +silt)

3.7.2 Total organic carbon

The soil organic carbon was determined by the Walkley-Black wet oxidation method (Nelson and Sommers, 1982). One gram of 2 mm sieved soil sample was weighed into a 250 ml conical flask and 5 mls of 1N potassium dichromate ($K_2Cr_2O_7$) solution was added and the flask gently swirled. 10 mls of concentrated sulphuric acid (H_2SO_4) was added into the flask and allowed to stand for 30 minutes. Then 100 mls of distilled water was added and allowed again to cool for 30 minutes, the organic carbon (OC) was determined by titrating this digest with 0.5N ferrous ammonium sulphate [$(NH_4)_2SO_4.FeSO_4.6H_2O$] to a red (maroon) end point. The organic carbon content was calculated using the formula below:

$$OC (\%) = \frac{(Blank\ titre - Actual\ titre) \times 0.3 \times m \times f}{Weight\ of\ air\ dried\ soil\ taken}$$

Where f = correction factor = 1.33

$$m = \text{concentration of } FeSO_4 = \frac{\text{Concentration of } K_2Cr_2O_7 \times \text{Volume of } K_2Cr_2O_7}{Blank\ titre}$$

$$OC (g/Kg) = OC (\%) \times 10$$

3.7.3 Total nitrogen

Total nitrogen was analyzed by micro Kjeldahl digestion method (Bremner and Mulvancy, 1986). One gram of soil was digested for 2 hours with concentrated H_2SO_4 and catalyst to raise the temperature and hasten the reaction respectively. The mixture was transferred into a 100 ml volumetric flask and made to mark. Ten ml of the digest was transferred into a distillation flask and 10 ml of NaOH was added. Twenty ml of 2% Boric acid was transferred into a conical flask and was introduced to the bottom of the distillation condenser. The digest was distilled and 50 ml of the distillate was collected which was then titrated with 0.05N H_2SO_4 to pink end point. The nitrogen content was calculated by the formula:

$$N (\%) = \frac{0.014 \times (\text{Titre value} - \text{Blank titre value}) \times NA \times \text{Vol. of digest} \times 100}{\text{Weight of soil} \times \text{Aliquot taken}}$$

Where NA = concentration of acid used

$$N (\text{g/kg}) = N (\%) \times 10$$

3.7.4 Soil pH

Soil pH was determined potentiometrically in 1:2.5 soil to solution ratio using glass electrode in a coleman metric IV pH meter, in distilled water and in CaCl₂ as detailed by Mclean (1982).

3.7.5 Available phosphorus

Extractable P was determined colorimetrically using spectrophotometer as described by Olsen and Sommers (1982).

3.7.6 Exchangeable cation

Exchangeable bases were determined by extraction with neutral 1.0N ammonium acetate (NH₄OAc) (Anderson and Ingram, 1993), calcium (Ca) and magnesium (Mg) were determined using the atomic absorption spectrophotometer while potassium (K) and sodium (Na) in the extract were determined with flame photometer.

3.7.7 Cation exchange capacity (CEC)

CEC was determined by neutral (pH 7.0) NH₄OAc saturation method (Anderson and Ingram, 1993).

3.7.8 Electrical conductivity

Electrical conductivity was determined in a 1:2.5 soil water ratio using a Wheatstone bridge at 25°C (Udo *et al.*, 2009).

3.7.9 Bulk density

Bulk density was determined by gravimetric method (Blake and Hartge, 1986). The undisturbed cores were taken from the field and placed in the oven to dry at 105°C for

24hours. The oven dried weights were obtained and used in the calculation of bulk density expressed as a ratio of the mass of dried soil to its total volume (solid and pores together)

$$\rho_b = \frac{M_s}{V_t}$$

Where M_s = mass of oven dried soil (g)

V_t = volume of soil, which is equivalent to the volume of core ring (cm^3)

3.7.10 Saturated hydraulic conductivity

Laboratory determination of saturated hydraulic conductivity (K_s) was made with undisturbed soil cores by the constant head permeameter method (Klute and Dirksen, 1986) using the laboratory permeameter (ICW Eijkelkamp Agrisearch N0.09.02.). The core rings containing soil were saturated overnight, but this was done by first covering, blunt end of the ring with a muslin sheath (nylon cloth) which was held in place by means of a rubber band to prevent soil loss. The core rings were then secured to a plastic container after it was held in place by a special mesh and clamp to fit the core. This was then inserted into the permeameter after a constant head had been established. A small tube initially filled with water was used as a junction between inside of the plastic holder and water in the permeameter, which aids water flow into burette. A chosen volume of water collected in the burette was taken at the time of flow via a stop watch. The heights of water both inside and outside the ring holder were measured by means of the meter bridge as the hydraulic head difference. Darcy's law for inflow of water in soils was applied for computing K_s after measuring volume of flow through the soil column, V , in time t , of known area, A and with hydraulic head difference, H as shown below:

$$K_s = VL/At\Delta H$$

Where, V=volume of water collected, (cm³); A=Cross sectional area of the soil column, cm² (equivalent to area of core); L= length of soil column, (cm); t= time (s) and ΔH=change in hydraulic pressure head, (cm).

3.7.11 Total porosity

Total porosity was evaluated by core method (Ibitoye, 2008). A saturated undisturbed soil core was weighed, volume of core determined and thereafter oven dried at 105⁰C for 24hours. The total pore space is the volume of the water at soil saturation obtained from its mass using the following equations:

$$\text{Total porosity } (f) = \frac{\text{Total pore volume}}{\text{Bulk soil volume}} \times 100$$

$$\text{Where; pore volume} = \frac{\text{Mass of water loss (Weight at saturation-Oven dried weight)g}}{\text{Density of water (1 g/cm3)}}$$

3.7.12 Aggregate stability

The disturbed soil sample was passed through a 5mm sieve, while the aggregate stability was determined by dry sieving methods as described by Van Bavel (1950) as modified by Kemper and Rosenau (1986)

3.7.12.1 Dry Sieving

Two hundred grams of bulk soil from the 5mm sieve was weighed and transferred into nest of sieves consisting of diameters 2.0 mm, 0.25 mm and 0.005 mm. The nest of sieves was placed on a mechanical shaker and shaken for 2 minutes after which the weight of soil retained in each sieve was determined.

Aggregate size distribution was calculated as the proportion of soil retained in each sieve as:

$$\text{Aggregate size distribution} = \frac{\text{Weight of soil retained in a sieve}}{\text{Total weight of soil taken}}$$

While the mean weight diameter (MWD) and geometric mean diameter (GMD) was calculated as follows:

$$\text{MWD}_{\text{dry}} = \sum_{i=1}^n w_i x_i$$

x_i = The mean diameter of the class (mm)

w_i = the proportion of each size class with respect to the total sample

$$\text{GMD}_{\text{dry}} = \exp\left[\frac{\sum_{i=1}^n w_i \log x_i}{\sum_{i=1}^n w_i}\right]$$

w_i = weight of aggregate of each size class (g)

$\log x_i$ = logarithm of the mean diameter of the size classes.

3.7.13 Soil water retention characteristics

The soil moisture retention characteristics for the undisturbed core samples were measured using pressure plate extractors (Klute, 1986). The moisture content of the soil was evaluated at -2, -5, -10, -33, -100, -500, -1000 and -1500 kPa. The saturated moisture content of the soil was determined by equilibrating the soil on the tension table without suction (i.e. at 0 kPa). The available water holding capacity (AWHC) was calculated as the difference between moisture content at field capacity (FC) at -33 kPa and permanent wilting point (PWP) at -1500 kPa.

3.7.14 Soil physical quality index (S)

The S as proposed by Dexter (2004a) was computed using the constants values that were simulated by RETC Model for Mualem-van Genuchten parameters from the equation below as;

$$S = -n(\theta_{sat} - \theta_{res}) \left[\frac{2n-1}{n-1} \right]^{\left[\frac{1}{n}-2 \right]}$$

Where θ_{sat} is saturated soil moisture content (m^3m^{-3}), θ_{res} is residual moisture content (m^3m^{-3}) or moisture content at permanent wilting point (PWP), and n is Mualem-van Genuchten equation parameters (Van Genuchten, 1980; Mualem, 1986).

The retention curve (RETC) model is a widely used computer program developed at the US Salinity Laboratory for estimating parameters of the retention curve and hydraulic conductivity functions of unsaturated soils (Van Genuchten *et al.*, 1991). While the retention curve (often also called the soil water characteristic curve) characterizes the energy status of the soil water, the unsaturated hydraulic conductivity function describes the ability of the porous medium to conduct water. The RETC model uses the parametric model of Van Genuchten (1980) to represent the soil water retention curve and the theoretical pore-size distribution model of Mualem (1976) to either predict the unsaturated hydraulic conductivity function from observed soil water retention data or to use the obtained data in the fitting procedure. The Van Genuchten retention function (Van Genuchten, 1980) has been very popular in the field of soil physics and water conservation management.

3.8 Irrigation Water Quality

Water from the tube wells were sampled in plastic bottles for laboratory analysis. The following parameters were determined: pH, electrical conductivity (EC), carbonates and bicarbonates, chlorides, nitrates, sulphates, boron and dissolved base cation (Ca, Mg, K and Na). Sodium adsorption ratio (SAR) and total dissolved solids (TDS) were determined by calculation. All water quality parameters were determined according to FAO (1985) standard procedures as described below:

3.8.1 pH

The pH of irrigation water was determined directly with a glass electrode on a pye unicam model 290 MK pH meter.

3.8.2 Electrical conductivity

The electrical conductivity was read directly using conductivity meter.

3.8.3 Carbonate and bicarbonate

The carbonate and bicarbonate were determined by the rapid titration method

3.8.4 Chloride

Silver nitrate and potassium chromate were used in determining the chloride contents of irrigation water.

3.8.5 Nitrate

The distillation and titration methods of Bremner (1965) were applied for nitrate determination.

3.8.6 Sulphate

The sulphate content of irrigation water was determined turbidimetrically.

3.8.7 Boron

Azomethine-H was used to develop the colour for B determination, and concentration was read using Spectrophotometer 20.

3.8.8 Dissolved base cations

Atomic Absorption Spectrometer (AAS) was used to determine Ca and Mg while Flame photometer was used to read K and Na in the irrigation water

3.9 Data Analysis

All crop data collected and data on soil bulk density, total porosity, aggregate stability and water retention were subjected to analysis of variance (ANOVA) using SAS (Statistical Analysis System) software version 9.3 (SAS, 2011). Significant means were compared using Duncan Multiple Range Test (DMRT) (Gomez and Gomez, 1984). While water retention data was used in the RETC model to bring out the Van Genuchten parameters to calculate the soil quality index and the water quality data were analyzed by descriptive statistics in form of ranges and means (Agbenin, 1995).

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Some Physical and Chemical Properties of the Soils of the Study Area before onset of the Experiment.

Some physical and chemical properties of the soils of the study area are shown on Table 4. The results obtained shows that sand content decreased with increase in depth within the range of 0-20 cm depth, silt content increased with depth while there was no change in clay contents across the two depths. This shows that there was no clay illuviation across the two depths and the textural class of the soils is mainly clay loam across the two depths.

The bulk density of the soils increased with increasing depth from 1.39 gcm^{-3} in 0-10 cm to 1.42 gcm^{-3} in 10- 20 cm, respectively. These values were within the range for clay loam soils which will not restrict root growth (Arshad *et al.*, 1996).

Soil pH measured in both water and CaCl_2 slightly increased with depth, but with neutral acidity at both depths. These values agree with the claim of Reich *et al.* (2001) and Mohammed (2012) that most of the sub-Saharan West African soils are having a pH range of slightly acidic to moderately alkaline. The range is within the favorable limit for which plants` nutrients are available (Weil and Brady, 2016).

The value of organic carbon, total nitrogen and available phosphorus were all very low across the two depths. All the above values confirm that the soils are inherently low in fertility status (Lombin, 1987; Odunze, 2003). This may be attributed to cultivation intensity that persisted in the area for a long time, which resulted in the continuous mining

of soil nutrients. Low to medium organic matter content in tropical soils (including fadama) is common as observed by the work of Awode *et al.* (2008).

The Ca and Mg values were considered low while Na was high based on the rating of Esu (1991). The results were in disagreement with the findings of Mohammed (2012). This values obtained may be as a result of continuous irrigation of the soil with irrigation water that may have relatively higher value of Na, which may precipitate both Ca and Mg in the exchange sites over time (FAO, 1985). Based on the ratings of Esu (1991), the K values were high at the surface 0-10 cm and low in 10-20 cm depths. The variation in these values may be attributed to the slow immobilization of K ions within the soil depths from top to bottom and it could have been adsorbed at the exchange site. The neutral acidic nature of soils at both depths, enhanced its availability Mohammed (2012).

The CEC was low using the rating of Esu (1991). Tropical soils are characterized by low to medium CEC values because of the abundance of kaolinite clay; which contributes barely little to the exchange capacity of such soils, which was also in agreement with the finding of Mohammed (2012). Weil and Brady (2016) are of the opinion that the contribution of organic matter to the total CEC of the soil is much higher than that of clay as a result of the low value of organic carbon in the study area, the CEC value is also low.

Table 4: Physical and Chemical Properties of the Soils of the Study Area before onset of the Experiment.

Parameters	0-10 cm value	10-20cm value
Sand (gkg^{-1})	290	270
Silt (gkg^{-1})	370	390
Clay (gkg^{-1})	340	340
USDA Textural Class	Clay loam	Clay loam
Bulk Density (gcm^{-3})	1.39	1.42
pH (H ₂ O)	7.00	7.20
pH (0.01M CaCl ₂)	6.70	6.80
Organic Carbon (gkg^{-1})	9.80	5.50
Total Nitrogen (gkg^{-1})	1.40	0.80
Available Phosphorus (mg/kg)	4.42	4.28
Exchangeable Bases (Cmol/kg)		
Calcium (Ca^{2+})	1.32	1.04
Magnesium (Mg^{2+})	3.56	2.81
Sodium (Na^{+})	0.32	0.84
Potassium (K^{+})	0.40	0.20
CEC	5.08	6.88

4.2 Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Physical Parameters at Harvest in 2018.

Table 5 shows the data on the effect of tillage practices, irrigation schedule and depth on soil bulk density (BD), saturated hydraulic conductivity (SHC) and total porosity (TP) after harvest in 2018 cropping season. The result showed that BD and SHC were not significantly influenced by both tillage practices. However, conventional tillage was observed to significantly ($P<0.05$) affects TP than reduced tillage. Irrigation schedule was also found to significantly ($P<0.05$) affects BD. Irrigation at one day and two days interval significantly ($P<0.05$) gave higher values of BD than irrigation at three days interval. It was also observed that irrigation schedule did not significantly affect SHC and TP of the soils. The BD and SHC were not significantly influenced by depth. However, it was found out that TP was significantly ($P<0.05$) lower at the 10-20cm depth than at 0-10cm.

The high total porosity in CT may be attributed to it relatively lower bulk density compared to RT. Several scientists have reported that high bulk density is among the stronger indicator of low soil porosity and high compaction (Arshard *et al.*, 1996; Liebig and Doran, 1999). Enjugu, (2014) also observed no significant difference between two tillage treatments in the values for bulk density and saturated hydraulic conductivity in the first year on a two years trial for soil physical properties at Samaru. This also agrees with the findings of Elijah (2016) in a soil quality improvement study of conservation agriculture in Zaria.

There was no interaction between the tillage, water management and depth among all the soil bulk density, saturated hydraulic conductivity and total porosity of the soil in the first year (2018) of this study.

Table 5: Effect of Tillage Practices, Irrigation Schedule and Depth on Bulk Density, Saturated Hydraulic Conductivity and Total Porosity at Harvest in 2018.

Treatment	BD(gcm ⁻³)	SHC (cms ⁻¹)	TP (%)
Tillage Practice (T)			
CT	1.40	0.37	37.86a
RT	1.41	0.32	36.28b
LOS	NS	NS	*
SE(±)	0.008	0.028	0.360
One days schedule (W1)	1.42a	0.33	38.17
Two days schedule (W2)	1.42a	0.35	36.70
Two days schedule (W3)	1.38b	0.35	36.34
LOS	*	NS	NS
SE(±)	0.009	0.035	0.440
Depths (D)			
0-10 cm	1.40	0.38	37.32a
10-20 cm	1.41	0.31	36.83b
SE(±)	0.008	0.028	0.036
Interaction			
T × W	NS	NS	NS
T × V	NS	NS	NS
W × V	NS	NS	NS
T × W × V	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error and NS= Not significant, BD=Bulk density, SHC= Saturated hydraulic conductivity, TP= Total porosity and LOS= Level of significance.

4.3 Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Physical Parameters at Harvest in 2019.

The data on the effect of tillage practices, irrigation schedule and depth on BD, SHC and TP in 2019 cropping season are presented in Table 6. It was observed that RT practice significantly ($P<0.05$) gave higher BD than CT. Conventional tillage practice significantly ($P<0.05$) gave higher values for SHC and TP than RT practice. Irrigation schedule also significantly ($P<0.05$) affects BD, SHC and TP in 2019 cropping season. Irrigation at three days interval significantly ($P<0.05$) gave higher values of BD than the other irrigation schedules. However, irrigating at one day interval significantly ($P<0.05$) gave higher values of SHC and TP than the other irrigation schedules. The BD and TP were not significantly influenced by depth. However, it was found that SHC was significantly ($P<0.05$) higher at the 0-10cm depth than at 10-20cm.

The results obtained for the BD values were in agreement with the findings of Enjugu (2014) after two years trial in Samaru. This agrees with the findings of Boehm (2004) and Osunbitan *et al.* (2005). Rashidi and Keshavarrzpou (2007) observed that annual disturbance and pulverization caused by conventional tillage produce a finer and loose soil structure as compared to no-tillage and reduced tillage methods which favor increase in BD.

Saturated hydraulic conductivity value observed under CT management may be due to a larger number of macro pores which enhanced the rate of conductivity. Enjugu (2014) and Buczko *et al.* (2006) observed that increase in volume of macropores in CT treatment resulted in greater SHC. Similarly, Khan *et al.* (2010) found that tillage had significant effect on SHC. The maximum mean value was observed in CT while the minimum value

was observed in NT. Ogunwole *et al.* (2001) reported a decrease in SHC with compaction on soils at Samaru. Osunbitan *et al.* (2005) and Enjugu (2014) also reported a decrease in SHC with depth, which is in consistence with the findings of this study.

The low total porosity in RT may be attributed to its high bulk density compared to CT. Liebig and Doran (1999) have documented that high bulk density is a strong indicator of low soil porosity and high compaction.

Table 6: Effect of Tillage Practices, Irrigation Schedule and Depth on Bulk Density, Saturated Hydraulic Conductivity and Total Porosity at Harvest in 2019.

Treatment	BD(gcm ⁻³)	SHC (cms ⁻¹)	TP (%)
Tillage Practice (T)			
CT	1.40b	0.39a	37.86a
RT	1.42a	0.33b	36.28b
LOS	*	*	*
SE(±)	0.005	0.001	0.399
Irrigation schedule (W)			
One day schedule (W1)	1.40b	0.50a	38.17a
Two days schedule (W2)	1.41ab	0.32b	36.70b
Three days schedule (W3)	1.42a	0.28c	36.34b
LOS	*	*	*
SE(±)	0.006	0.001	0.489
Depths (D)			
0-10 cm	1.40	0.40a	38.31
10-20 cm	1.41	0.33b	37.30
	NS	*	NS
SE(±)	0.005	0.001	0.039
Interaction			
T × W	NS	NS	NS
T × V	NS	NS	NS
W × V	NS	NS	NS
T × W × V	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, BD=Bulk density, SHC= Saturated hydraulic conductivity, TP= Total porosity and LOS= Level of significance.

4.4 Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2018.

Table 7 shows the data on the effect of tillage practices, irrigation schedule and depth on aggregate size fraction after harvest in 2018 cropping season. It was observed that RT practice significantly ($P < 0.05$) gave higher 5-2mm fraction of aggregate than CT practice. Conventional tillage practice significantly ($P < 0.05$) gave higher values for 2-0.25mm, 0.25-0.005mm and < 0.005 mm fractions of aggregate than RT. Irrigation schedule was also found to significantly ($P < 0.05$) affects all the aggregate size fractions. Irrigation at one day and two days interval significantly ($P < 0.05$) gave higher values of aggregate size fractions than irrigation at three days interval. The aggregate size fraction were significantly ($P < 0.05$) influenced by depth, where it was found that aggregate size fractions were significantly ($P < 0.05$) higher at the 10-20cm depth than at 0-10cm.

The observed differences in the different aggregate separates between the two tillage and irrigation schedule may be as a result of the degree of soil disturbances and the variation in timing of the water application among the treatment combination, this made the CT with one day irrigation schedule ease of removal and being dislodged. Oades (1984) observed that macro and micro aggregates depends on organic matter for stability against destructive forces caused by quick wetting. Aggregates were more disrupted in CT compared to RT according to Mrabet (2002). The decline in the size of the aggregates due to tillage could be attributed to mechanical disruption of macro aggregates which may have exposed soil organic matter previously protected against oxidation. This result is similar to the findings of Elijah (2016).

Significant interaction between the tillage and depth were noted among all the aggregate size fractions across all the separates as depicted in Figure 1.

Table 7: Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2018 Dry Season.

Treatment	5-2 mm	2-0.25 mm	0.25-0.005 mm	<0.005 mm
Tillage Practice (T)				
CT	0.21b	0.42a	0.51a	0.058a
RT	0.22a	0.41b	0.48b	0.048a
LOS	*	*	*	*
SE(±)	0.0018	0.0044	0.0021	0.0020
Irrigation schedule (W)				
One day schedule (W1)	0.22a	0.42a	0.50a	0.059a
Two days schedule (W2)	0.21b	0.42a	0.49b	0.053b
Three days schedule (W3)	0.21b	0.41b	0.48c	0.048c
SE(±)	0.0022	0.0054	0.0024	0.0024
Depth				
0-10 cm	0.18b	0.39b	0.46b	0.024b
10-20 cm	0.24a	0.45a	0.52a	0.083
SE(±)	0.0018	0.0044	0.0021	0.0020
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	**
W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS= Level of significance.

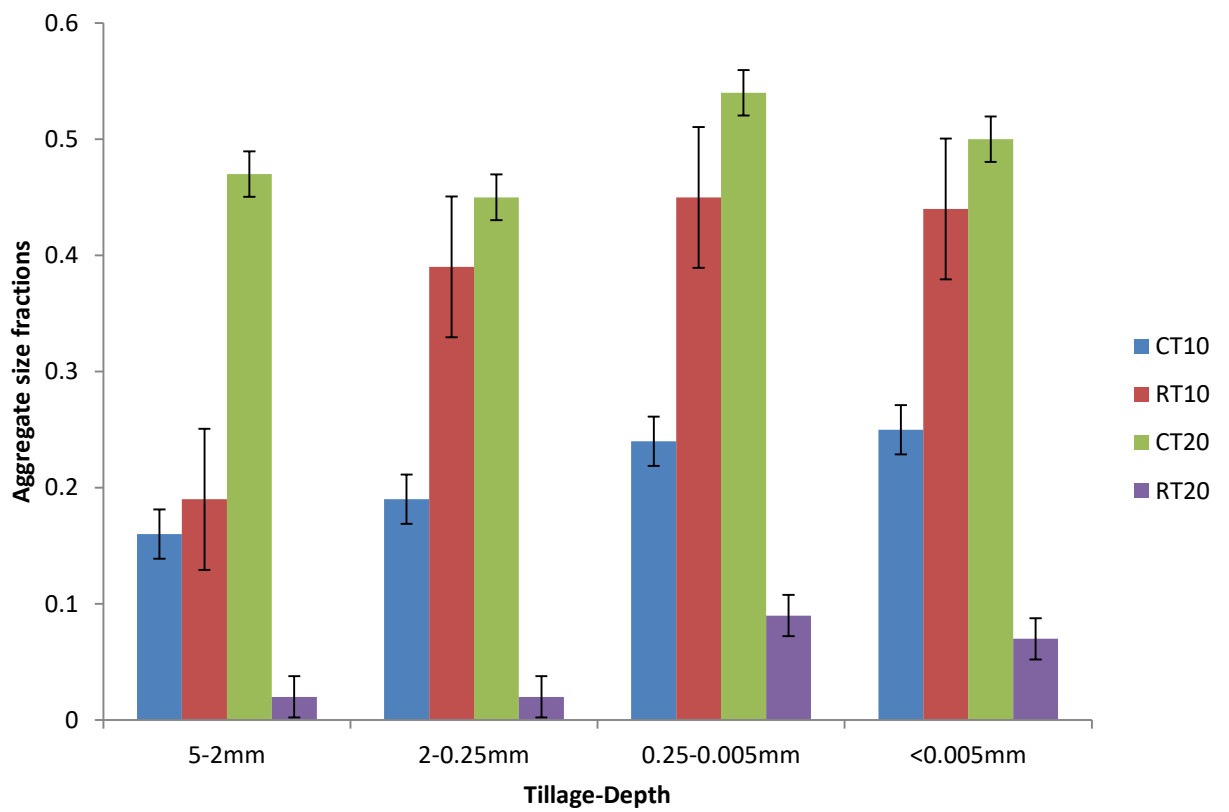


Figure 1: Interaction between tillage practices and depth on aggregate size fractions in 2018

4.5 Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2019.

The data on the effect of tillage practices, irrigation schedule and depth on aggregate size fraction after harvest in 2019 cropping season are presented in Table 8. It was observed that RT practice significantly ($P < 0.05$) gave higher 5-2mm fraction of aggregate than CT practice. Conventional tillage practice significantly ($P < 0.05$) gave higher values for 0.25-0.005mm and < 0.005 mm fractions of aggregate than RT. Irrigation schedule was also found to significantly ($P < 0.05$) affects all the aggregate size fractions. Irrigation at one day and two days interval significantly ($P < 0.05$) gave higher values of aggregate size fractions than irrigation at three days interval. The aggregate size fraction were significantly ($P < 0.05$) influenced by depth, where it was found that aggregate size fractions were significantly ($P < 0.05$) higher at the 10-20cm depth than at 0-10cm.

There was a significant decrease in values of aggregate size fractions of both the CT and RT in 2019. Significant interaction effect between the tillage and depth was observed among all the aggregate size fractions in 2019 except < 0.005 mm aggregate fraction which does not show interaction effect (Figure 2). This consistent trend in the variation of all the aggregates may be as a result of the degree of disruption of all the aggregates fractions both in CT and RT, with CT been more pronounced in the second year due to continuous disturbance of those soils without subsequent addition of organic matter that will boost the bond strength of those soils. Enjugu (2014) and Elijah (2016) also observed a steady increase in aggregate size fraction over a two year tillage research in Samaru.

Table 8: Effect of Tillage Practices, Irrigation Schedule and Depth on Aggregate Size Fractions in 2019 Dry Season.

Treatment	5-2 mm	2-0.25 mm	0.25-0.005 mm	<0.005 mm
Tillage Practice (T)				
CT	0.20b	0.41	0.50a	0.055a
RT	0.21a	0.41	0.47b	0.043b
LOS	*	NS	*	*
SE(±)	0.0021	0.0050	0.0026	0.0025
Irrigation schedule (W)				
One day schedule (W1)	0.21a	0.42a	0.49a	0.055a
Two days schedule (W2)	0.21a	0.41b	0.49a	0.045b
Three days schedule (W3)	0.20b	0.40c	0.48b	0.047ab
LOS	*	*	*	*
SE(±)	0.0026	0.0062	0.0032	0.0034
Depth				
0-10 cm	0.18b	0.38b	0.45b	0.022b
10-20 cm	0.24a	0.44a	0.52a	0.077a
LOS	*	*	*	*
SE(±)	0.0021	0.0050	0.0026	0.0025
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	NS
W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS= Level of significant.

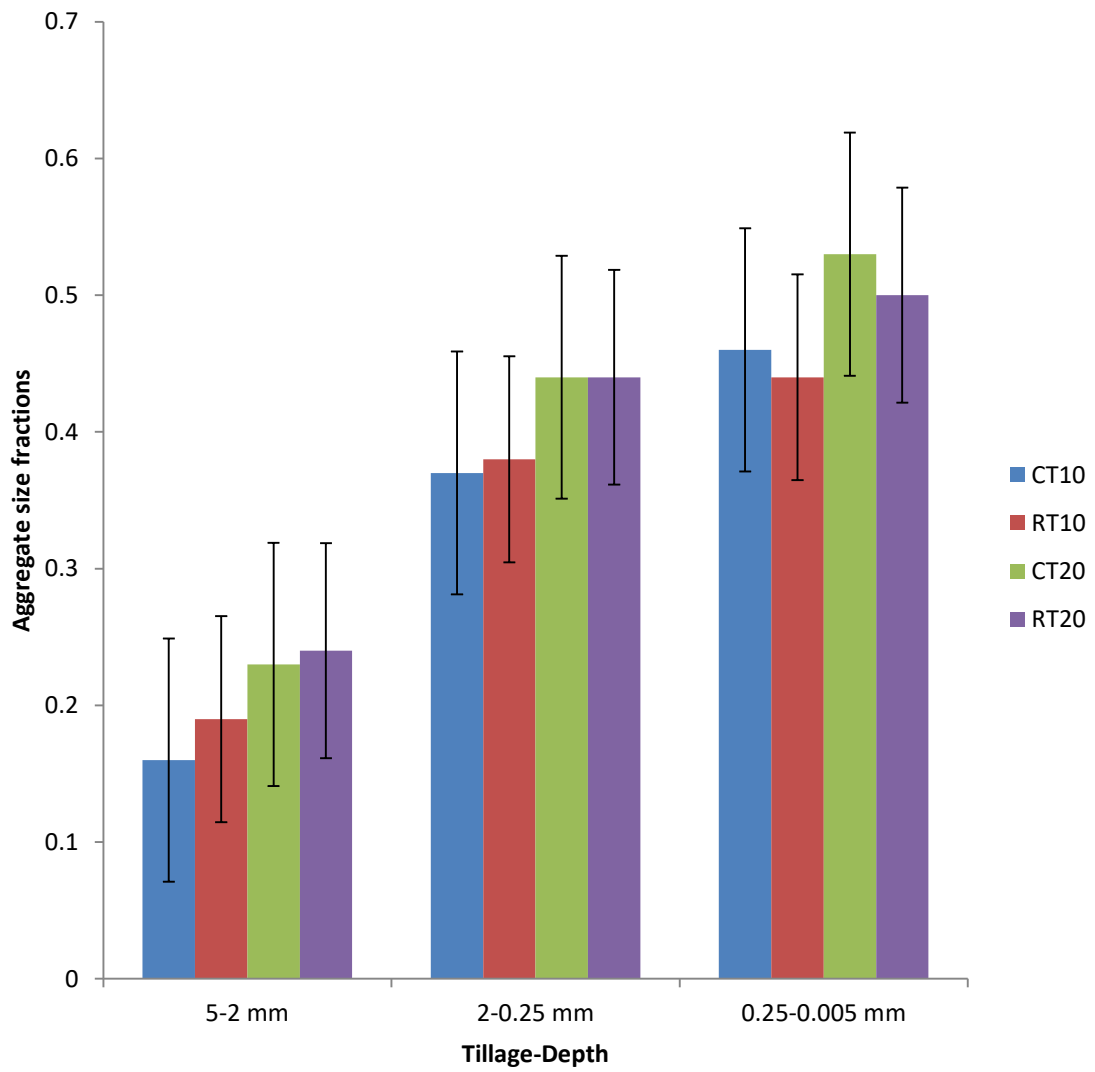


Figure 2: Interaction between tillage practices and depth on aggregate size fractions in 2019

4.6 Effect of Tillage Practices, Irrigation Schedule and Depth on MWD and GMD of Aggregate in 2018 and 2019.

The mean weight diameter (MWD) and geometric mean diameter (GMD) were significantly affected by tillage (Table 9) in the two years of this study. In 2018, a significant difference ($P < 0.05$) was noticed in tillage with RT showing significantly higher value for MWD and GMD. The irrigation schedules also shows a significant increase in values of both the MWD and GMD, where one day irrigation schedule recorded the highest value while three days irrigation schedule had the least.

Significant increase in MWD and GMD across the two depths increased with increasing depth in 2018, and there was significant interaction effect between tillage and depth among the MWD and GMD of the aggregate in 2018 (Fig. 3)

A similar trend in MWD and GMD were also observed in 2019 (Table 9). This trend shows a gradual decrease in the value of both MWD and GMD for the two tillage systems across the two years. This shows the decrease of the stability of the soil to various tillage operations. Unger (1991) reported that an increase in MWD and GMD is its ability to withstand erosion. The MWD and GMD increased as the depth of sampling increases indicating that the deeper the soil, the less vulnerable the soil will be exposed to erosion. Oguike and Mbagwu (2009) observed that tillage with traditional hoeing and clean weeding together with reduced organic matter content, as in the case of this trial field may explain the low value of MWD and GMD observed under CT compared to the RT tillage practices. Fuentes *et al.* (2011) and Enjugu (2014) also reported that soil with conventional tillage plus reduced organic matter had a low MWD and GMD compared to soil with no-tillage plus

residue, which indicates that despite the incorporation of residues, there was a negative effect on soil stability with tillage.

The variation of MWD and GMD and soil depth could be probably due to reduced soil disturbance, redistribution of residues and homogenization effect of plowing (Tan *et al.*, 2004)

Table 9: Effect of Tillage Practices, Irrigation Schedule and Depth on Mean Weight Diameter and Geometric Mean Diameter in 2018 and 2019 Dry Season.

Treatment	2018		2019	
	MWD	GMD	MWD	GMD
Tillage Practice (T)				
CT	1.09b	0.80	1.08b	0.79b
RT	1.15a	0.82	1.14a	0.81a
LOS	*	NS	*	*
SE(±)	0.001	0.008	0.001	0.003
Irrigation schedule (W)				
One day schedule (W1)	1.13a	0.82a	1.12a	0.81a
Two days schedule (W2)	1.12b	0.81b	1.11b	0.80b
Three days schedule (W3)	1.11c	0.80c	1.11b	0.80b
LOS	*	*	*	*
SE(±)	0.001	0.001	0.001	0.003
Depth				
0-10 cm	1.09b	0.78b	1.08b	0.77b
10-20 cm	1.15a	0.84a	1.15a	0.83a
LOS	*	*	*	*
SE(±)	0.001	0.008	0.001	0.003
Interaction				
T × W	NS	NS	NS	NS
T × D	**	**	**	**
W × D	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS= Level of significant.

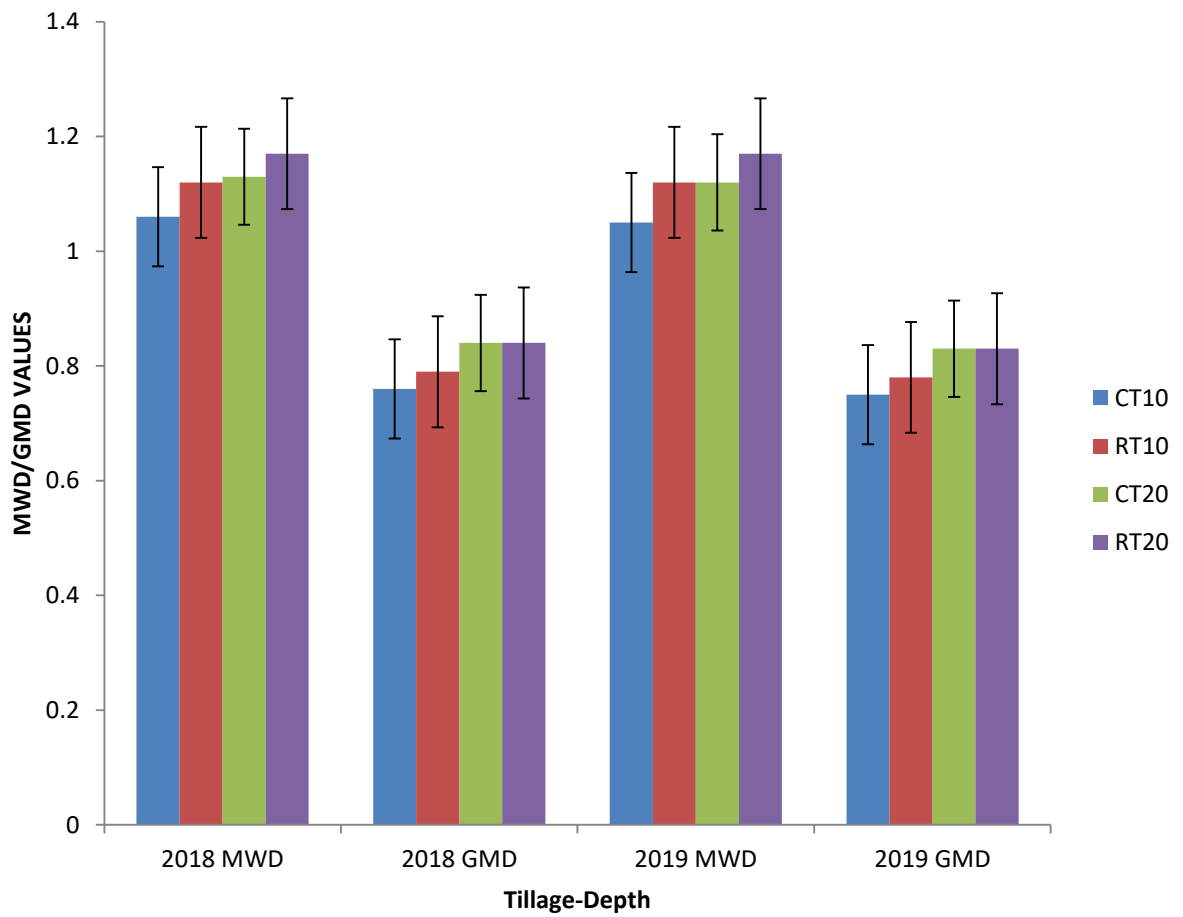


Figure 3: Interaction between tillage practices and depth on MWD and GMD in both 2018 and 2019

4.7 Effect of Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties grown in 2018 Dry Season.

The data in Table 10 shows the effect of tillage practices and irrigation schedules on plant height of rice varieties grown in 2018 dry season at Kwalkwalawa, Sokoto state. The result showed that there was no significant difference in plant height as affected by tillage practices at 3,6 and 9 weeks after transplanting (WAT). However, it was observed at harvest that CT practice significantly ($P<0.05$) gave taller plants than RT practice. Irrigation schedule also significantly ($P<0.05$) influenced plant height of rice. Irrigating rice at one day interval significantly ($P<0.05$) produced taller plants at 6 and 9 WAT than the other irrigation schedules, but there was no significant difference in plant height of rice at 3 WAT and at harvest. It was noted that the rice varieties differ significantly ($P<0.05$) in plant height. FARO 60 significantly ($P<0.05$) produced taller plants at 3, 6, 9 WAT and at harvest, than FARO 44 and FARO FARO 61 varieties.

The difference between plant height prior to harvest in the two tillage operations may be due to well pulverization of the soil and efficient utilization of available nutrients to the plant roots that manifested in the plant height. The differences in plant height observed in the irrigation schedule may be as a result of shortage of irrigation water to meet up the crops physiological requirements that showed in the growth pattern of the crops, knowing that rice is a profligate user of water (Cantrell, 2002). The significant ($P<0.05$) difference in plant height at different stages of the rice plant between the three varieties may be as a result of variation in the genetic constituents of each of the varieties from the Breeder, with little or no environmental influence.

Table 10: Effect of Tillage Practices, Irrigation Schedule on Plant Height of Rice Varieties grown in 2018 Dry Season at Kwalkwalawa, Sokoto state.

Treatment	Plant Height (cm)			
	3WAT	6WAT	9WAT	Harvest
Tillage Practice (T)				
CT	24.08	55.15	73.77	104.21a
RT	24.03	54.34	73.10	101.96b
LOS	NS	NS	NS	*
SE(±)	0.172	0.105	0.290	0.288
Irrigation schedule (W)				
One day schedule (W1)	23.93	56.19a	74.46a	104.86
Two days schedule (W2)	24.43	54.67b	72.62b	103.26
Three days schedules (W3)	23.81	53.38c	70.24c	101.13
LOS	NS	*	*	NS
SE(±)	0.211	0.129	0.355	0.353
Variety (V)				
FARO 44	24.17ab	49.31c	67.66c	103.52b
FARO 60	24.39a	64.02a	83.47a	111.23a
FARO 61	23.60b	50.91b	69.19b	94.49c
LOS	*	*	*	*
SE(±)	0.211	0.129	0.355	0.353
Interaction				
T × W	NS	NS	NS	*
T × V	NS	NS	NS	NS
W × V	NS	NS	NS	**
T × W × V	NS	NS	NS	*

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard error, NS= Not significant, **= Highly significant, *= Significant and LOS= Level of significant

These results are similar to the findings of Ojo *et al.* (2018) in a plant height evaluation of some rice varieties. Similarly, Alhassan (2014) observed significant ($P < 0.05$) differences in plant height of rice at different stages of growth and attributed it to variation in the weed management practices.

There was a Significant ($P < 0.05$) interaction effect between tillage and irrigation schedule; irrigation schedule and varieties; and tillage, irrigation schedule and varieties all at plant heights prior to harvest. There was significant interaction effect between tillage and irrigation schedule (Table 11) of plant height at harvest. Conventional tillage in combination with one day irrigation schedule produced significantly taller plants, followed by RT and one day irrigation schedule. Both CT and RT with two days irrigation schedule were similar, while the interaction between RT and three days irrigation schedule was the least in plant height.

Similarly, a highly significant interaction ($P < 0.01$) effect between irrigation schedule and varieties is presented in Table 12. Irrespective of the irrigation schedule, FARO 60 had significantly taller plants compared to the other varieties. This was followed by FARO 44 with one day irrigation schedule while FARO 61 with three days irrigation schedule was the least.

Considering the interactions between the three treatment factors on plant height at harvest in 2018 (Table 13). The tallest plants were observed from plots sown with FARO 60 and enjoyed CT with one day irrigation schedule (114.7 cm) while FARO 61 with RT and three days irrigation schedule (90.00 cm) had the shortest plants.

Table 11: Interaction between Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties at Harvest in 2018 Dry Season.

Tillage Practice	Irrigation Schedule		
	W1	W2	W3
CT	108.87a	103.60c	101.86cd
RT	106.8b	102.17c	97.3e
SE±		0.499	

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, CT=Conventional Tillage, RT=Reduced Tillage, SE±=Standard error, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

Table 12: Interaction between Irrigation Schedule and Rice Varieties on Plant Height at Harvest during 2018 Dry Season.

Variety	Irrigation Schedule		
	W1	W2	W3
FARO 44	108.87c	103.60d	101.87d
FARO 60	114.73a	111.40b	110.70b
FARO 61	97.07e	95.30e	94.37ef
SE±		0.611	

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, SE±=Standard error, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

Table 13: Interaction between Tillage Practices, Irrigation Schedule and Rice Variety on Plant Height at Harvest during 2018 Dry Season.

Tillage Practice Rice Variety	W1		W2		W3	
	CT	RT	CT	RT	CT	RT
FARO 44	108.87bc	106.80d	103.60e	102.17e	101.87e	97.83f
FARO 60	114.73a	111.70b	111.40b	110.27bc	110.70b	108.63cd
FARO 61	97.07f	93.40h	95.30g	96.80fg	94.37gh	90.00i
SE±			0.865			

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, SE±=Standard error, CT=Conventional Tillage, RT=Reduced Tillage, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

4.8 Effect of Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties grown in 2019 Dry Season.

The effect of tillage practices and irrigation schedule on plant height of rice varieties grown in 2019 dry season at Kwalkwalawa, Sokoto state is presented in Table 14. The results showed that tillage practices did not significantly affect plant height of rice varieties at 3, 6 and 9 WAT. However, CT practice significantly ($P < 0.05$) produced taller plants than RT practice at harvest. Irrigation schedule also significantly ($P < 0.05$) influenced plant height of rice. Irrigating rice at one day interval significantly ($P < 0.05$) produced taller plants at 9 WAT and harvest than the other irrigation schedules, but there was no significant difference in plant height of rice at 3 and 6 WAT. It was noted that the rice varieties differ significantly ($P < 0.05$) in plant height. FARO 60 significantly ($P < 0.05$) produced taller plants at 6 and 9 WAT and at harvest, than FARO 44 and FARO 61 varieties.

Significant interactions existed between tillage and irrigation schedule; irrigation schedule and variety; and tillage, irrigation schedule and variety all at plant height at harvest in 2019, just as it was in 2018, respectively.

Table 14: Effect of Tillage Practices, Irrigation Schedule on Plant Height of Rice Varieties grown in 2019 Dry Season at Kwalkwalawa, Sokoto state.

Treatment	Plant Height (cm)			
	3WAT	6WAT	9WAT	Harvest
Tillage (T)				
CT	25.20	56.54	75.98	107.33a
RT	25.41	56.02	75.26	105.12b
LOS	NS	NS	NS	*
SE(±)	0.120	0.267	0.300	0.281
Irrigation schedule (W)				
One day irrigation (W1)	25.89	57.80	80.53a	108.96a
Two days irrigation (W2)	25.41	56.36	74.65b	106.37b
Three days irrigation (W3)	24.62	54.68	71.62c	103.32c
LOS	NS	NS	*	*
SE(±)	0.147	0.327	0.368	0.345
Varieties (V)				
FARO 44	25.22	51.09b	69.81b	106.61b
FARO 60	25.69	65.20a	85.61a	114.39a
FARO 61	25.00	52.55b	71.44b	97.65c
LOS	NS	*	*	*
SE(±)	0.147	0.327	0.368	0.345
Interaction				
T × W	NS	NS	NS	*
T × V	NS	NS	NS	NS
W × V	NS	NS	NS	**
T × W × V	NS	NS	NS	*

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant, *= Significant and LOS= Level of significant

The difference between plant height at harvest in the two tillage operation in the 2019 dry season, may be due to well pulverized soil and efficient utilization of available nutrients by the plant in the CT compared to the RT. The differences in plant height observed in the irrigation schedules may also be as a result of shortage of irrigation water to meet up the crops physiological requirement that showed in the growth pattern of the crops, knowing that rice is a profligate user of water Cantrell (2002). The significant differences in different stages of the crop plant height between the three varieties may be as a result of variation in the genetic constituents of each of the varieties. These results also corroborate the findings of Ojo *et al.* (2018). Similarly, Alhassan (2015) observed significant difference in plant height of rice at different stages of growth and attributed it to variation in the weed management practices.

Table 15 represents the interaction between tillage and irrigation schedule on plant height at harvest in 2019. Conventional tillage in combination with one day irrigation schedule had taller plants (110.92 cm) while RT with three days irrigation schedule had the least value (102.16 cm) of plant height at harvest. Conventional tillage in combination with one day irrigation schedule produced significantly taller plants, followed by RT and one day irrigation schedule. Both CT and RT with two days irrigation schedule were similar, while the interaction between RT and three days irrigation schedule had the least in plant height.

A highly significant interaction ($P < 0.01$) effect between irrigation schedule and varieties are presented in Table 16. Irrespective of the irrigation schedule, FARO 60 had significantly taller plants compared to the other varieties. This followed by FARO 44 with

one day irrigation schedule while FARO 61 with three days irrigation schedule had the least value.

Interaction between the three treatments factors on plant height at harvest in 2019 (Table 17). The tallest plants were observed from plots sown with FARO 60 and enjoyed CT with one day irrigation schedule (118.60 cm) while FARO 61 with RT and three days irrigation schedule (95.67 cm) had the shortest plants.

Table 15: Interaction between Tillage Practices and Irrigation Schedule on Plant Height of Rice Varieties at Harvest in 2019 Dry Season.

Tillage Practice	Irrigation Schedule		
	W1	W2	W3
CT	110.92a	106.57b	104.49c
RT	106.99b	106.18b	102.16d
SE(±)	0.487		

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, SE±=Standard error, CT=Conventional Tillage, RT=Reduced Tillage, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

Table 16: Interaction between Irrigation Schedule and Rice Varieties on Plant Height at Harvest during 2019 Dry Season.

Irrigation Schedule	Rice Variety		
	FARO 44	FARO 60	FARO 61
W1	111.82c	117.45a	97.60f
W2	105.98d	113.90b	99.23f
W3	102.03e	111.82c	96.12fg
SE(±)	0.597		

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, SE±=Standard error, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

Table 17: Interaction between Tillage Practices, Irrigation Schedule and Rice Variety on Plant Height at Harvest during 2019 Dry Season.

Rice Variety	W1		W2		W3	
	CT	RT	CT	RT	CT	RT
FARO 44	112.87ab	110.77c	106.63d	105.33d	104.00e	100.07e
FARO 60	118.60a	116.30a	114.53ab	113.27ab	112.90ab	110.73c
FARO 61	101.30f	93.90gh	98.53g	99.93f	96.57g	95.67gh
SE(±)	0.844					

Means followed by the same letter(s) within the column are not significantly different at 5% level of probability using DMRT, SE±=Standard error, CT=Conventional Tillage, RT=Reduced Tillage, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

4.9 Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2018 Dry Season at Kwalkalawa.

The effect of tillage practices, irrigation schedule on number of tillers, days to 50 % heading, panicle length and total dry matter of rice variety are presented in Table 18. There was a significant ($P<0.05$) difference with tillage practices. Conventional tillage practice was observed to significant ($P<0.05$) produced higher number of tillers, days to 50% heading and total than RT practice in 2018 dry season at Kwalkalawa. The application of water at one day interval significant ($P<0.05$) gave higher number of tillers and total dry matter (g) than the other irrigation schedules. However, irrigating at 3 days interval significant ($P<0.05$) gave higher values of days to 50% heading than the other irrigation schedules in 2018 dry season at Kwalkalawa. Panicle length was not significantly affected by irrigation schedules in 2018 dry season at Kwalkalawa. The varieties were observed to differ significant ($P<0.05$), it was recorded that FARO 44 significant ($P<0.05$) produced higher number of tillers than the other varieties in 2018 dry season at Kwalkalawa, while FARO 60 was also observed to significant ($P<0.05$) gave higher values of days to 50% heading, panicle length and total dry matter than the other varieties used in the experiment in 2018 dry season at Kwalkalawa.

Significant difference was observed between CT and RT on days to 50 % heading, with CT taking more number of days to reach 50 % heading than the RT. A significant difference was also noticed in the irrigation schedule with respect to days to 50 % heading, showing a delay in heading with a corresponding delay in water application, where three days irrigation schedule having more days to reach 50 % heading while one day irrigation schedule being the least. A corresponding variation was observed in days to 50 % heading

with the three varieties, with FARO 44 and FARO 61 being at par (84.00) while FARO 60 having a delayed days to 50 % heading. The extended days to 50 % heading in CT may be as a result of high evapotranspiration rate in CT, where RT conserved more water for plants utilization and enhanced the phenological development compared to CT. The difference in days to 50 % heading between the three varieties has to do with the varietal differences between the three varieties. Contrary to these findings Manasseh *et al* (2018) observed no significant difference between three rice varieties on their days to 50 % heading in his studies on maxicrop effect on rice yield at Jega, Kebbi state.

The panicle length was not significantly affected by tillage practice and irrigation schedule. But significant difference in panicle length was well pronounced with differences in varieties, where FARO 60 had a significantly longer panicle (30.79) compared to FARO 44 and 61, which were at par.

A similar trend was observed in total dry matter (TDM) as presented in Table 18 with CT having significantly higher TDM compared to RT. Following the irrigation schedule, a consistent trend of increase in TDM with corresponding increasing days of irrigation, with one day irrigation schedule having more TDM and three days irrigation schedule was the least. There was also a variation in TDM with varieties, where FARO 60 had more value of TDM, followed by FARO 44 while FARO 61 was the least. The more the water the more the rate of crop transpiration, which helps in crop physiological activities and hence the production of more TDM.

A highly significant ($P < 0.01$) interaction effect existed between the tillage, irrigation schedule and variety on number of tillers of the rice plant (Table 19). FARO 44

with CT and one day irrigation schedule had more tiller numbers (68) while FARO 60 with three days irrigation schedule under RT was the least (52)

Table 18: Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2018 Dry Season.

Treatment	Number of Tillers	Days to 50 % heading	Panicle length (cm)	Total dry matter (g)
Tillage (T)				
CT	61.00a	89.00a	28.06	49.06a
RT	58.00b	87.00b	27.85	47.59b
LOS	*	*	NS	*
SE(±)	0.026	0.093	0.759	0.189
Irrigation schedule (W)				
One day schedule (W1)	63.00a	84.00c	28.75	51.49a
Two days schedule (W2)	59.00b	88.00b	27.99	48.72b
Three days schedule (W3)	56.00c	92.00a	27.11	44.76c
LOS	*	*	NS	*
SE(±)	0.032	0.114	0.929	0.232
Variety (V)				
FARO 44	62.00a	84.00b	26.82b	47.54b
FARO 60	57.00c	97.00a	30.79a	54.50a
FARO 61	59.00b	84.00b	26.24b	42.93c
LOS	*	*	*	*
SE(±)	0.032	0.114	0.929	0.232
Interaction				
T × W	NS	NS	NS	NS
T × V	NS	NS	NS	NS
W × V	NS	NS	NS	NS
T × W × V	**	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS=Level of significant

Table 19: Interaction between Tillage Practices, Irrigation Schedule and Variety on Number of Tillers during 2018 Dry Season.

Tillage Practice Rice Variety	W1		W2		W3	
	CT	RT	CT	RT	CT	RT
FARO 44	68.00a	65.00b	63.00d	59.00g	59.00g	55.00j
FARO 60	60.00f	57.00h	59.00g	56.00i	55.00j	52.00l
FARO 61	64.00c	62.00e	59.00g	57.00h	57.00h	54.00k
SE±			0.079			

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT, SE±=Standard error, CT=Conventional Tillage, RT=Reduced Tillage, W1=One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

4.10 Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2019 Dry Season at Kwalkalawa.

Tillage practice effect on irrigation schedule and variety on number of tillers, days to 50 % heading, panicle length and total dry matter is presented in Table 20. A similar trend was observed in 2019 as was in 2018 results, with little or no variation on some parameters. Conventional tillage had significantly more tillers in 2019 than RT. The trend in irrigation schedule also shows that one day irrigation schedule was significantly higher in number of tillers than two days irrigation schedule, while three days irrigation schedule was the least. For varieties, FARO 44 had significantly higher number of tillers, followed by FARO 61 and FARO 60 was least. This similar trend observed in both years in the number of tiller in tillage practices, irrigation schedule and variety was in agreement with the results of Manasseh *et al.* (2018) and Ojo *et al.* (2018).

Days to 50 % heading was significantly influenced by the tillage practices, taking CT more days to reach 50 % heading compared to RT. Considering irrigation schedule, one day irrigation schedule significantly shortens the days to 50 % heading compared to the other two irrigation applications. All the three varieties show a significant decrease in days to 50 % heading in 2019 compared to 2018 with FARO 60 taking longer period than the other varieties which were at par. The variation in 50 % heading may be as a result of high evapotranspiration rate in CT, where RT conserved more water for the plants utilization and prolonged the physiological maturity in RT than CT. The difference in days to 50 % heading between the three varieties could be due to varietal differences between the three varieties. Contrary to these findings Manasseh *et al* (2018) observed no significant

difference between three rice varieties in days to 50 % heading in his studies on maxicrop effect on rice yield at Jega, Kebbi state.

The panicle length shows no significant difference between tillage and irrigation schedule. Significant difference in panicle length was observed with difference in three rice varieties, where FARO 60 had significantly longer panicle, followed by FARO 61 and FARO 44 being the least.

A similar trend was observed in total dry matter (TDM) also (Table 20) with CT having significantly higher TDM than RT. In the irrigation schedule, a consistent trend of increase in TDM with corresponding increasing days of irrigation, with one day irrigation schedule having more TDM and three days irrigation schedule had the least. There was also a variation in TDM with varieties, where FARO 60 had more value of TDM, followed by FARO 44 while FARO 61 was the least. The more the water the more the rate of the crop transpiration, which helped in crop physiological activities and the production of assimilates which resulted in more total dry matter Kamara *et al* (2003).

A highly significant interaction effect existed between irrigation schedule and variety on number of tillers (Table 21). FARO 44 and one day irrigation schedule had more tiller numbers (69) while FARO 60 with three days irrigation schedule under RT was the least (52) which is the same as in 2018.

Table 20: Effect of Tillage Practices, Irrigation Schedule and Variety on Number of Tillers, Days to 50 % Heading, Panicle length and Total Dry Matter in 2019 Dry Season.

Treatment	Number of Tillers	Days to 50% heading	Panicle length (cm)	Total dry matter (g)
Tillage Practice (T)				
CT	61.00a	88.00a	29.34	49.84a
RT	58.00b	86.00b	28.43	48.31b
LOS	*	*	NS	*
SE(±)	0.076	0.100	0.043	0.198
Irrigation schedule (W)				
One day schedule (W1)	65.00a	81.00c	31.28	52.67a
Two days schedule (W2)	59.00b	86.00b	28.58	49.51b
Three days schedule (W3)	54.00c	92.00a	26.81	45.04c
LOS	*	*	NS	*
SE(±)	0.093	0.124	0.053	0.243
Variety (V)				
FARO 44	62.00a	82.00b	27.20c	48.31b
FARO 60	57.00c	96.00a	31.12a	55.23a
FARO 61	59.00b	82.00b	28.34b	43.68c
LOS	*	*	*	*
SE(±)	0.093	0.124	0.053	0.243
Interaction				
T × W	NS	NS	NS	NS
T × V	NS	NS	NS	NS
W × V	**	NS	NS	NS
T × W × V	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS=Level of significant

Table 21: Interaction between Irrigation Schedule and Variety on Number of Tillers during 2019 Dry Season.

Irrigation schedule	Rice Variety		
	FARO 44	FARO 60	FARO 61
W1	69.00a	61.00d	65.00b
W2	62.00c	58.00f	59.00e
W3	55.00g	52.00i	54.00h
SE(±)		0.161	

Means followed by the same letter(s) are not significantly difference at 5% level of probability using DMRT, SE±=Standard error, W1= One day irrigation schedule, W2= Two days irrigation schedule, W3= Three days irrigation schedule and LOS= Level of significant

4.11 Effect of Tillage Practices, Irrigation Schedule and Variety on One Thousand Grain Weight, Percentage Unfilled Grain, Number of Off-types and Grain Yield/ha in 2018 Dry Season at Kwalkalawa.

Table 22 shows the data on the effect of tillage practice and irrigation schedule on one thousand grain weight, percentage (%) unfilled grain, number of off-types and the grain yield/ha of rice varieties grown in 2018 dry season at Kwalkwalawa. Significant difference was observed between CT and RT in the values of 1000 grain weight, where CT had higher value compared to RT. The one day irrigation schedule was significantly higher than the two days irrigation schedule in the value of 1000 grain weight, while three days irrigation schedule was the least. A significant difference was also noticed among the rice varieties with respect to 1000 grain weight, where FARO 44 had significantly higher value of 1000 grain weight, followed by FARO 60 while FARO 61 was the least.

There was no significant difference in percentage unfilled grain between the two tillage systems, but significant difference in percentage unfilled grain was observed with the irrigation schedule, where three days irrigation schedule had significantly higher values of percentage unfilled grain, followed by two days irrigation schedule and one day irrigation schedule had the least value. The varieties also exhibited significant differences in the percentage unfilled grain, where FARO 60 had a significantly higher value, followed by FARO 44 while FARO 61 was the least. The only significant difference existed among the three varieties in the number of off-types, with FARO 44 and 60 having the highest numbers (2.0) while FARO 60 was is least.

The result of grain yield/ha shows that significant difference was observed between tillage, irrigation schedule and variety, where conventional tillage had significantly higher grain yield/ha compared to RT. There was an increase in grain yield with corresponding

increase in water application, where one day irrigation schedule had significantly higher grain yield compared to the other two irrigations. The varieties also show significant variation in grain yield/ha, with FARO 44 having a significantly higher grain yield/ha, followed by FARO 60 and then FARO 61. These observed differences in yield and yield attributes between tillage, irrigation schedule and variety may be as a result of good soil preparation, less weed competition and available water for the production of assimilates. The yield and yield parameters were favored in CT and one day irrigation schedule than other treatment combinations due to the fact that CT may have less weed competition than RT and one day irrigation schedule does not sufficiently allowed the growth of weed to compete for nutrients, water, light and space with rice, this enables rice to efficiently utilized the available nutrients and water. Oloro (2002) reported that water saving irrigation with good cultivation practice can increase rice yields and yield parameters in Madagascar.

Abu and Malgwi (2012) reported higher values of 1000 grain weight, blank grain percentage and grain yield/ha in an experiment conducted at Talata Mafara, as a result of higher water application and shortened irrigation frequencies. This also agreed with the findings of Manasseh *et al.* (2018) and Ojo *et al.* (2018) in a yield evaluation trial of rice at Jega, in Kebbi state.

There was also a highly significant interaction effect between irrigation schedule and variety on grain yield/ha in 2018 (Table 23). FARO 44 and one day irrigation schedule had the highest grain yield/ha while FAROs 44, 60 and 61 with three days irrigation schedule gave the least and were similar statistically.

Table 22: Effect of Tillage Practices and Irrigation Schedule on One Thousand Grain Weight (g), Percentage Unfilled Grain (%), Off-types and Grain Yield/ha (kg/ha) of Rice Variety during 2018 Dry Season..

Treatment	1000-Grain wt (g)	% Unfilled grain	Off-types	Grain yield (kg/ha)
Tillage Practice (T)				
CT	27.06a	8.76	2.00	3843.92a
RT	26.00b	9.07	2.00	3663.71b
LOS	*	NS	NS	*
SE(±)	0.074	0.111	0.268	26.284
Irrigation schedule (W)				
One day schedule (W1)	30.16a	5.42c	2.00	5021.36a
Two days schedule (W2)	27.08b	8.25b	2.00	4092.18b
Three days schedule (W3)	22.33c	13.08a	2.00	2147.91c
LOS	*	*	NS	*
SE(±)	0.091	0.135	0.328	32.191
Variety (V)				
FARO 44	28.18a	9.16b	2.0a	3905.12a
FARO 60	26.67b	9.69a	2.0a	3756.76b
FARO 61	24.72c	7.90c	1.0b	3599.57c
LOS	*	*	*	*
SE(±)	0.091	0.135	0.328	32.191
Interaction				
T × W	NS	NS	NS	NS
T × V	NS	NS	NS	NS
W × V	NS	NS	NS	**
T × W × V	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS=Level of significant.

Table 23: Interaction between Irrigation Schedule and Variety on Grain Yield/ha (kg ha⁻¹) During 2018 Dry Season.

Irrigation schedule (W)	Rice Variety		
	FARO 44	FARO 60	FARO 61
W1	5410.05a	4942.35b	4711.67c
W2	4055.20d	4148.63d	4072.72d
W3	2250.10e	21.79.30e	2014.33e
SE(±)		55.756	

Means followed by the same letter(s) are not significantly difference at 5% level of probability using DMRT, SE±=Standard error, W1= One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

4.12 Effect of Tillage Practices, Irrigation Schedule and Variety on One Thousand Grain Weight, Percentage Unfilled Grain, Number of Off-types and Grain Yield/ha in 2019 Dry Season at Kwalkalawa.

There was a consistent trend in the result of tillage, irrigation schedule and variety on one thousand grain weight, percentage (%) unfilled grain, number of off-types and the grain yield/ha with the values obtained in 2018 of the same parameters (Table 24). Significant difference was observed between CT and RT in the values of 1000 grain weight, where CT had higher value compared to RT. The one day irrigation schedule was significantly higher than the two days irrigation schedule in the value of 1000 grain weight, while three days irrigation schedule was the least. A significant difference was also observed with variation in the rice varieties, where FARO 44 had significantly higher value of 1000 grain weight, followed by FARO 60 while FARO 61 was the least.

There was no significant difference ($P>0.05$) in percentage unfilled grain between the two tillage systems, significant difference in percentage unfilled grain was observed with a decrease in irrigation as in 2018, where three days irrigation schedule had significantly higher values of percentage unfilled grain, followed by two days irrigation schedule and one day irrigation schedule was the least. The varieties also exhibited significant differences in the percentage unfilled grain, where FARO 60 had a significantly higher value, followed by FARO 44 while FARO 61 was the least.

There was no significant difference ($P>0.05$) in the number of off-types among the three varieties with respect to tillage and irrigation schedule. However, significant difference was observed between tillage, irrigation schedule and varieties with respect to grain yield/ha. Conventional tillage had significantly higher grain yield/ha compare to RT, there was an increase in grain yield with corresponding increase in water application, where

one day irrigation schedule had significantly higher grain yield compared to the other two irrigation schedules. Varieties also show significant variation in grain yield/ha, with FARO 44 having a significantly higher grain yield/ha, followed by FARO 60 and then FARO 61. These observed differences in yield and yield attributes between tillage, irrigation schedule and variety may be as a result of good soil preparation, less weed competition, available water for the production of assimilates as well as the variation in the genetic make-up of each variety.

This consistent trend in the one thousand grain weight, percentage (%) unfilled grain and the grain yield/ha also agrees with the results obtained by Manasseh *et al.* (2018) and Ojo *et al.* (2018) in a yield evaluation trial of some rice varieties in Jega, Kebbi State. Alhassan (2015) also reported a significant increase in yield of FARO 44 in a multi-location trial conducted at Talata Mafara and Kadawa in Kano State on the effect of weed management practices, seeding method and seed rate.

Highly significant interaction effect existed between irrigation schedule and variety on grain yield/ha in 2019 (Table 25). FARO 44 and one day irrigation schedule had the highest yield/Ha (5835.85 Kg/ha) while FARO 61 with three days irrigation schedule was the least (2163.60 kg/ha).

Table 24: Effect of Tillage Practices, Water Management and Variety on One Thousand Grain Weight (g), Percentage Unfilled Grain (%), Off-types and Grain Yield (kg/ha⁻¹) of Rice during 2019 Dry Season.

Treatment	1000-Grain wt (g)	% Unfilled grain	Off-types	Grain yield (kg/ha)
Tillage Practice (T)				
CT	27.85a	5.96	1.00	4139.50a
RT	26.87b	6.09	1.00	3943.99b
LOS	*	NS	NS	*
SE(±)	0.082	0.129	0.113	29.331
Irrigation schedule (W)				
One day schedule (W1)	31.39a	3.94c	1.00	5470.17a
Two days schedule (W2)	27.96b	5.91b	1.00	4358.12b
Three days schedule (W3)	22.73c	8.63a	1.00	2296.93c
LOS	*	*	NS	*
SE(±)	0.100	0.158	0.138	35.924
Variety (V)				
FARO 44	29.05a	6.34b	1.00	4185.33a
FARO 60	27.54b	6.85a	1.00	4036.84b
FARO 61	25.49c	5.35c	1.00	3903.04c
LOS	*	*	NS	*
SE(±)	0.100	0.158	0.138	35.924
Interaction				
T × W	NS	NS	NS	NS
T × V	NS	NS	NS	NS
W × V	NS	NS	NS	**
T × W × V	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, SE±=Standard Error, NS= Not significant, **= Highly significant and LOS=Level of significant.

Table 25: Interaction between Irrigation Schedule and Variety on Grain Yield/ha (Kgha⁻¹) During 2019 Dry Season.

Irrigation schedule	Rice Varieties		
	FARO 44	FARO 60	FARO 61
W1	5835.85a	5367.83b	5206.83c
W2	4321.12de	4414.55d	4338.70d
W3	2399.03f	2328.15f	2163.60g
SE±		62.221	

Means followed by the same letter(s) are not significantly difference at 5% level of probability using DMRT, SE±=Standard error, W1= One day irrigation schedule, W2= Two days irrigation schedule and W3= Three days irrigation schedule.

4.13 Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m^3m^{-3}) in Dry Seasons at Harvest at Kwalkwalawa

Table 26 present results of soil water content at various matric potentials at harvest in 2018 which was significant between the two tillage operations only at lower matric potentials between 0 KPa to -5KPa, where RT was significantly higher than CT. There was significant increase in water retention among all the matric potentials with increasing days to irrigation, where one day irrigation schedule retained more water compared to the others, except at -100KPa and -500KPa, where all the water retention were similar ($0.27 \text{ m}^3\text{m}^{-3}$) and ($0.26 \text{ m}^3\text{m}^{-3}$), and at -1000KPa, where three days irrigation schedule had significantly higher values and one and two days irrigation schedules were at par ($0.021 \text{ m}^3\text{m}^{-3}$). Among the two depths considered, soil moisture retention increased with corresponding increase in depth of soil sampling in the various matric potentials considered, except at -10KPa and -33KPa where both values of moisture retention were the same. This could be linked to high organic content and greater dry aggregate stability observed in RT. This was supported by Lal and Shukla (2004) and Alliaume *et al.* (2010) who reported increase in moisture retention as organic matter and structural stability increases. Soil organic matter positively improves soil moisture retention especially at high tensions. This is because as the soil begins to dry, characteristics of surface soil particles become more important than the pore geometry (Lipsius, 2002).

Also, from the result in Table 27, there was a significant difference ($P < 0.05$) in water retention among the various matric potentials between the two tillage systems. Reduced tillage had significantly higher values compared to CT, except at -100KPa matric

potential where CT was significantly higher than RT. At matric potentials of -33, -100 and -500 KPa, both RT and CT were similar in water retention values.

A consistent trend of increase in water retention among all the matric potentials with corresponding increase in water application was observed, where one day irrigation schedule retained more moisture compared to two days schedule while three days schedule was the least with their corresponding matric potentials. A significant difference in moisture contents among the two depths was significant at low matric potential, where moisture contents increased with depth. But from -5KPa to -1500Kpa, there was no significant difference between moisture contents among the various matric potentials for the two depths, except at -100Kpa where it increased with an increase in depth.

Lower soil moisture retention capacity under CT relative to RT could be linked to higher saturated hydraulic conductivity based on the effect of tillage operations and the degree of soil disturbance. This finding corroborates Arshad *et al.* (1999), who observed that soil water retention and storage capacity was higher under no-tillage compared to conventional tillage.

Table 26: Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m^3m^{-3}) in 2018 Dry Season.

Treatments	0kPa	2kPa	5kPa	10kPa	33kPa	100kPa	500kPa	1000kPa	1500kPa
Tillage (T)									
CT	0.36b	0.31b	0.31b	0.30	0.30	0.27	0.26	0.021	0.012
RT	0.37a	0.33a	0.33a	0.30	0.30	0.27	0.26	0.022	0.012
LOS	*	*	*	NS	NS	NS	NS	NS	NS
SE(±)	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.002
Irrigation schedule (W)									
One day schedule (W1)	0.38a	0.35a	0.34a	0.33a	0.31a	0.27	0.26	0.021b	0.014a
Two days schedule (W2)	0.37b	0.34b	0.32b	0.32b	0.30b	0.27	0.26	0.021b	0.011c
Three days schedule (W3)	0.35c	0.33c	0.32b	0.31c	0.29c	0.27	0.26	0.022a	0.013b
LOS	*	*	*	*	*	NS	NS	*	*
SE(±)	0.002	0.002	0.002	0.002	0.002	0.001	0.001	0.001	0.001
Depth (cm)									
0-10 cm	0.36b	0.33b	0.33a	0.32	0.30	0.27b	0.26b	0.021b	0.012b
10-20 cm	0.37a	0.34a	0.32b	0.32	0.30	0.28a	0.27a	0.022a	0.013a
SE(±)	0.001	0.001	0.001	0.003	0.003	0.003	0.002	0.002	0.002
Interaction									
T × W	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × D	NS	NS	NS	NS	NS	NS	NS	NS	NS
W × D	NS	NS	NS	NS	NS	NS	NS	NS	NS
T × W × D	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT, NS=Not significant, CT=Conventional Tillage, RT=Reduced Tillage, SE±=Standard error, kPa=Kilo pascal and LOS= Level of significant.

Table 27: Effect of Tillage Practices, Irrigation Schedule and Depth on Soil Moisture Retention Characteristics (m^3m^{-3}) in 2019 Dry Season.

Treatments	0kPa	2kPa	5kPa	10kPa	33kPa	100kPa	500kPa	1000kPa	1500kPa
Tillage practice (T)									
CT	0.36b	0.33b	0.32b	0.32b	0.31	0.28	0.27	0.036a	0.018b
RT	0.38a	0.35a	0.34a	0.34a	0.31	0.28	0.27	0.032b	0.022a
LOS	*	*	*	*	NS	NS	NS	*	*
SE(\pm)	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.003
Irrigation schedule (W)									
One day irrigation (W1)	0.38a	0.35a	0.34a	0.34a	0.32a	0.28	0.27	0.043a	0.02a
Two days schedule (W2)	0.38a	0.34b	0.33b	0.32b	0.30c	0.28	0.27	0.028c	0.018c
Three days schedule (W3)	0.35b	0.33c	0.32c	0.32c	0.31b	0.28	0.27	0.029b	0.020b
LOS	*	*	*	*	*	NS	NS	*	*
0-10 cm	0.37b	0.34b	0.33	0.33	0.31	0.27b	0.27	0.028b	0.020
10-20 cm	0.38a	0.35a	0.33	0.33	0.31	0.29a	0.27	0.039a	0.020
LOS	*	*	NS	NS	NS	*	NS	*	NS
SE \pm	0.002	0.002	0.002	0.001	0.001	0.001	0.001	0.003	0.003
Interaction									
T \times W	NS	NS	NS	NS	NS	NS	NS	NS	NS
T \times D	NS	NS	NS	NS	NS	NS	NS	NS	NS
W \times D	NS	NS	NS	NS	NS	NS	NS	NS	NS
T \times W \times D	NS	NS	NS	NS	NS	NS	NS	NS	NS

Means followed by the same letter(s) are not significantly different at 5% level of probability using DMRT, NS=Not significant, CT=Conventional Tillage, RT=Reduced Tillage, SE \pm =Standard error, kPa=Kilo pascal and LOS= Level of significant.

4.14 Van Genuchten Parameters and Soil Physical Quality Index (S-index)

Table 28 shows the effect of tillage systems and irrigation schedule of the study using the RETC Output model for Van Genuchten parameters and the values of S-index.

The data showed that there was no significant difference ($P>0.05$) in residual moisture content (θ_r) between the two tillage systems. Significant difference was observed in irrigation schedule, with three days irrigation schedule having the least value of θ_r , while one and two days irrigation schedule values were the same.

Considering saturated water content (θ_s) and inverse of air entry point (α), there was no significant difference between both tillage, irrigation schedule and depths, except in θ_s values in irrigation schedule, where both one and two days irrigation schedule were at par (0.44) while three days irrigation schedule was the least.

The curve fitting parameters (n) shows significant difference between tillage, irrigation schedule and depths. Conventional tillage had significantly higher n than RT, both one and two days irrigation schedule had similar (1.01) values of curve fitting parameters while three days irrigation irrigation schedule had the highest value. The value of n decreased with increasing depths, with 10-20 cm having smaller values compared to 0-10 cm, respectively.

Absence of variation in values of the θ_r , θ_s and α obtained in the study area may be as a result of the short duration of the trial period (two years), while the significant differences between the two tillage systems, water management and depths on the value of n may be as a result of variation in cultivation intensities between the two tillage operations were the same field was consistently maintained for the period of the study. These results

corroborate the finding of Enjugu (2014) in two years studies of tillage and Van Genuchten parameters of soils in Samaru. But contrary to this findings, Poreska *et al.* (2006) and Evett *et al* (1999) reported significant differences in the values of Van Genuchten parameters in different types of soils under different managements and attributed the differences to variation in their physical and chemical properties, with the content of particle size fractions playing the greatest role.

Soil physical quality index (S-index) significantly varied between the two tillage systems (Table 28). The S-index value was greater in RT compared to CT. S-index increased with increase soil depth, though it was not statistically different. From these findings, the value of S-index in the study area was in the range of 0.023 to 0.025, which by grouping of Dexter (2004b) is considered to be a moderately suitable for optimal root growth.

Table 28: Effect of Tillage Practices, Irrigation Schedule and Depths on RETC Outputs of Van-Genuchten Parameters and S-Index values

Treatment	θ_r	θ_s	α	n	S-Index
Tillage Practice (T)					
CT	0.083	0.44	0.012	1.03a	0.023b
RT	0.083	0.44	0.011	1.01b	0.025a
LOS	NS	NS	NS	*	*
SE(\pm)	0.0025	0.025	0.002	0.125	0.0003
Irrigation schedule (W)					
One day schedule (W1)	0.084a	0.44a	0.011	1.01b	0.025
Two days schedule (W2)	0.084a	0.44a	0.011	1.01b	0.024
Three days schedule (W3)	0.082b	0.43b	0.011	1.04a	0.024
LOS	*	*	NS	*	NS
SE(\pm)	0.0035	0.030	0.004	0.135	0.0003
Depths (D)					
0-10 cm	0.084	0.44	0.011	1.03a	0.024
10-20 cm	0.084	0.44	0.011	1.01b	0.025
LOS	NS	NS	NS	*	NS
SE(\pm)	0.0025	0.025	0.002	0.125	0.0003
Interaction					
T \times W	NS	NS	NS	NS	NS
T \times V	NS	NS	NS	NS	NS
W \times V	NS	NS	NS	NS	NS
T \times W \times V	NS	NS	NS	NS	NS

Means followed by the same letter(s) within the same column are not significant at 0.05 level of probability, RT=Reduced tillage, CT= Conventional tillage, NS= Not significant, SE \pm =Standard error, θ_r = Residual moisture content, θ_s =Saturated moisture content, α =Inverse of air entry point, n= Curve fitting parameters and S=Soil physical quality index and LOS=Level of significant.

4.15 Correlation Analysis

4.15.1 Correlation analysis for 2018 and 2019

The result of correlation analysis between paddy yield, soil parameters, water retention and yield components of rice in 2018 and 2019 are shown in Table 29 and 30. In 2018, paddy yield was found to be significantly and positively correlated with tiller number ($r=0.757^{**}$), 1000-grain weight ($r=0.929^{**}$) and total dry matter ($r=0.533^*$) while the tiller number was significantly and positively correlated with 1000-grain weight ($r=0.778^{**}$) and paddy yield ($r=0.757^{**}$), there was also a significant and positive correlation between soil physical quality index (S) with mean weight diameter ($r=0.705^{**}$) and geometric mean diameter ($r=0.521^{**}$) respectively.

No correlation was observed between tiller number with mean weight diameter and geometric mean diameter, panicle length with 1000-grain weight, TDM, paddy yield and moisture content at 1,500kPa.

In 2019, paddy yield significantly and positively correlated with tiller number ($r=0.875^{**}$), panicle length ($r=0.832^{**}$), 1000-grain weight ($r=0.938^{**}$) and TDM ($r=0.562^*$). Soil physical quality index (S) also shown a significant and negative correlation with moisture content at 1,500kPa ($r=-0.648^{**}$) while positive correlation with MWD ($r=0.712^{**}$) and GMD ($r=0.545^*$).

Table 29: Matrix of Correlation between Paddy Yield, Tillage, Irrigation Schedule and Yield Components of Rice in 2018 Dry Season.

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	-0.072	1.000								
3	0.778**	0.126	1.000							
4	0.271	0.433	0.598**	1.000						
5	0.757**	0.121	0.929**	0.533**	1.000					
6	-0.051	-0.123	-0.228	-0.160	-0.180	1.000				
7	-0.021	0.109	-0.019	0.096	-0.083	0.659**	1.000			
8	0.083	-0.176	-0.010	0.058	-0.057	0.275	0.174	1.000		
9	0.088	-0.151	-0.005	0.048	-0.069	0.303	0.211	0.920**	1.000	
10	-0.070	-0.139	0.009	0.018	-0.011	0.323	0.205	0.705**	0.521*	1.000

** significant at 1% * significant at 5% 1. Tillers number 2. Panicle length 3. One thousand grain yield 4. Total dry matter 5. Paddy yield 6. Moisture Content 33 at kpa 7. Moisture content at 1,500 kPa 8. Mean weight diameter (MWD) 9. Geometric mean diameter 10. S (Soil physical quality index)

Table 30: Matrix of Correlation between Paddy Yield, Tillage, Irrigation Schedule and Yield Components of Rice in 2019 Dry Season.

	1	2	3	4	5	6	7	8	9	10
1	1.000									
2	0.487*	1.000								
3	0.864**	0.554*	1.000							
4	0.382	0.832**	0.632**	1.000						
5	0.875**	0.631**	0.938**	0.562*	1.000					
6	-0.093	-0.016	-0.227	-0.158	-0.184	1.000				
7	-0.005	0.127	-0.026	0.144	-0.056	0.535	1.000			
8	0.042	0.084	-0.012	0.053	-0.058	0.316	0.573	1.000		
9	0.041	0.071	-0.007	0.050	-0.065	0.326	0.366	0.926**	1.000	
10	-0.047	-0.042	0.012	0.019	-0.018	0.371	-0.648**	0.712**	0.545*	1.000

** significant at 1% * significant at 5% 1. Tillers number 2. Panicle length 3. One thousand grain yield 4. Total dry matter 5. Paddy yield 6. Moisture Content 33 at kpa 7. Moisture content at 1,500 kPa 8. Mean weight diameter (MWD) 9. Geometric mean diameter 10. S (Soil physical quality index)

4.16 Relationship between Observed and Fitted Water Content at Various Pressure Heads

Measured water retention data at various pressure heads was inputted in to RETC computer programme which predicted other water retention values (fitted values). The measured and fitted water retention values were compared to validate the applicability and suitability of RETC for studies of hydraulic properties of soils in the study area. The results obtained at 0-10 cm and 10-20 cm depths for the three irrigation schedules are presented in Fig. 4.5 and 4.6 respectively. As seen from the figures, both the measured and the fitted values at all depths and various irrigation schedules were not close to the 1:1 solid line, except at 10-20 cm depth with one day irrigation schedules with coefficient of determination value of 0.733, while all the rest had a value of <0.60 , showing weak and positive values.

All these point to the fact that RETC with lower precision cannot predict the hydraulic behavior of the soil under both tillage practices at all the studied depths. But contrary to these findings, Abu and Abubakar (2013) measured the coefficient of determination of >0.97 in a Soil in Northern Guinea Savana Alfisols and proved the validity of application of RETC for predicting the hydraulic properties of the soil in the study area.

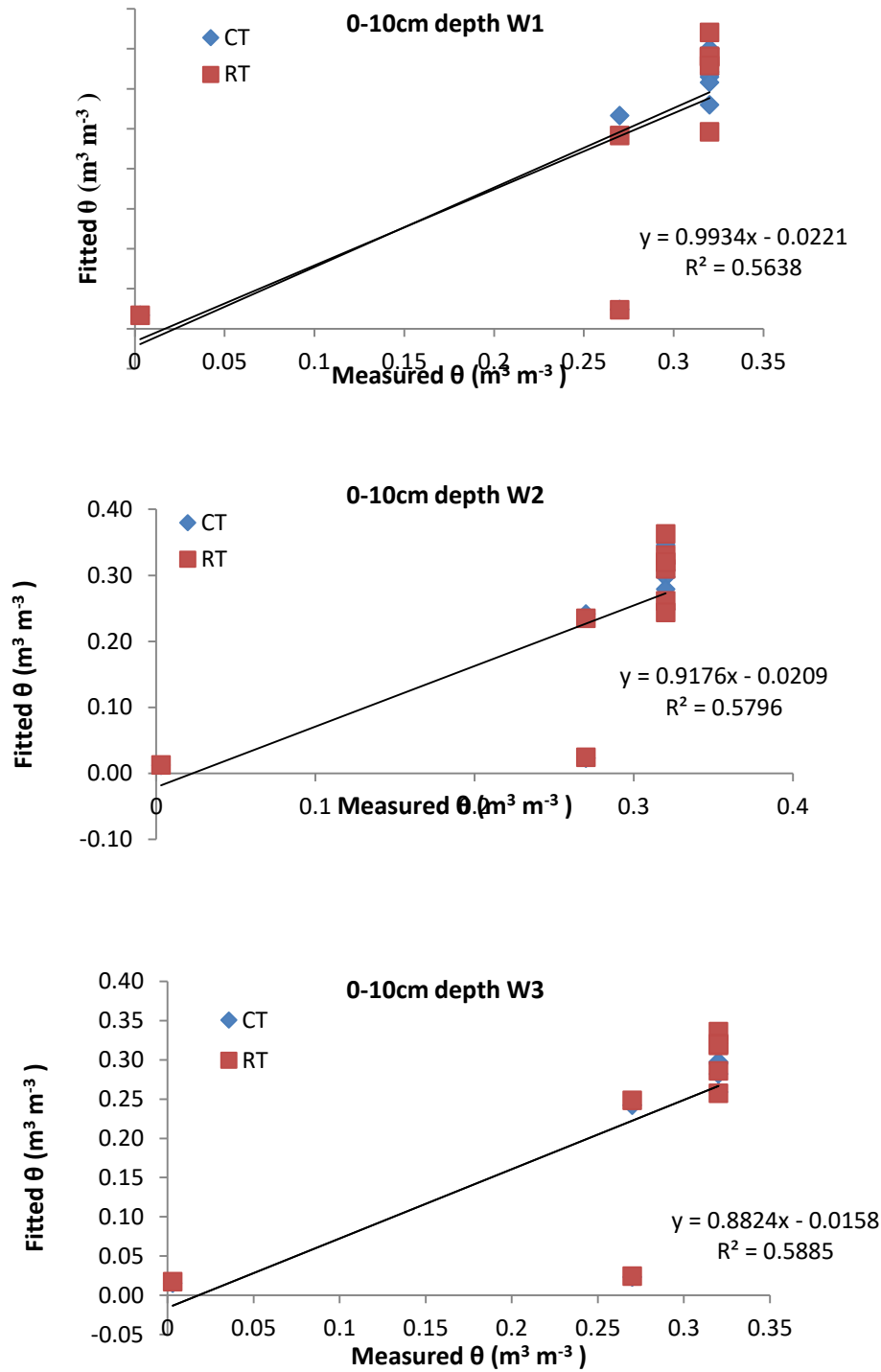


Figure 4: Relationship between measured and fitted volumetric water content at 0-10 cm depth under CT and RT.

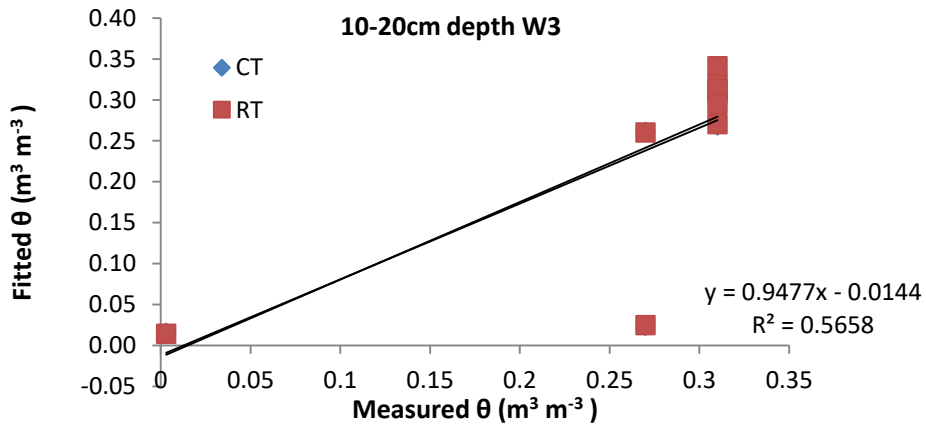
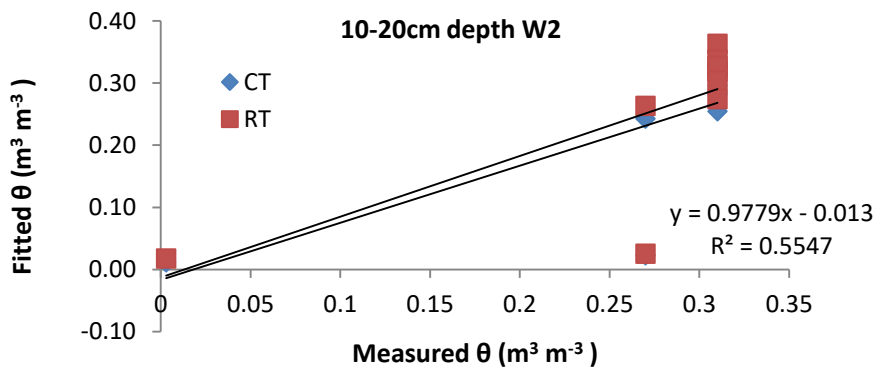
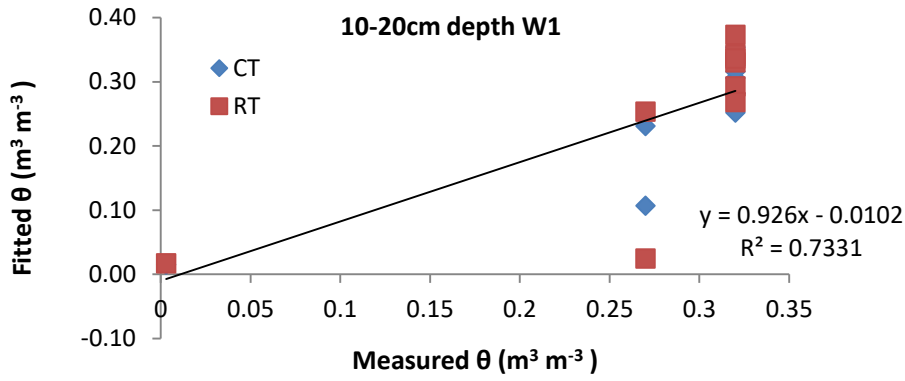


Figure 5: Relationship between measured and fitted volumetric water content at 10-20 cm depth under CT and RT.

4.17 Irrigation Water Quality Assessment of the Tube Wells

The coordinate of each of the three tube-wells was taken using global positioning system (GPS). Table 31 present detailed descriptions covering the location, height above sea level and the tube well orifice sizes. It was observed that all the tube wells were of two inches size.

Evaluation of the electrical conductivity (EC), total dissolved solids (TDS) and sodium adsorption ratio (SAR) of all the water samples from the tube-wells were low (Table 32), and therefore indicated no threat of salinity as their EC, TDS and SAR values fell below the critical levels of 0 to 4 dsm^{-1} , 0 to 2000 mg l^{-1} and <13 for irrigation water (Shahinasi and Kashuta, 2008). The pH of the tube well water ranges from 7.12 to 7.32, this all indicates slightly alkaline condition, this is safe pH ranges for irrigation water (Omar, 2012). Similarly, carbonates and bicarbonate levels in the tube well water did not exceed the limit proposed by Landon (1991), hence this makes the water suitable for irrigation.

Lower values of Mg, Ca and moderate value of Na were observed in all the tube wells (Table 32). Value of Na in irrigation water tends to be absorbed by clay particles, displacing Ca and Mg, there-by leading to reduced soil permeability and poor internal drainage (Belkhiri *et al.*, 2010).

Although nitrate, sulphate, chloride and boron are essential to plants in a very low concentration, they can be toxic to sensitive crops at high concentration (Bauder *et al.*, 2011). Nitrate concentration was in the range of 0.003 to 0.006, sulphate and chloride were in the ranges of 2.38 to 2.63 and 0.93 to 1.23, respectively. These values were not up to the

critical limits of 960 mg l^{-1} proposed by Landon (1991). Hence, this makes the three tube well water safe for irrigation purpose, thus caution must be taken after a long use for periodic evaluation of both the soil and irrigation water to ensure its safety.

Table 31: Description of each Tube-well Sample Point in the Field

S/No.	Sampled Point	Coordinate	Height above sea level (m)	Size (Inches)
1	A	N13 ⁰ 05.948` E005 ⁰ 12.635`	252	2
2	B	N13 ⁰ 05.959` E005 ⁰ 12.669`	243	2
3	C	N13 ⁰ 05.976` E005 ⁰ 12.644`	242	2

Source:From the tube well locations in the field.

Table 32: Irrigation Water Quality Indicators in Tube-wells of the Study Area, showing Mean and Ranges.

Point	pH	mgL ⁻¹										TDS	Ec (ds/m)
		CO ₃ ⁻	HCO ₃ ⁻	Na ⁺	Ca ²⁺	Mg ²⁺	SAR	Cl ⁻	NO ₃ ⁻	SO ₄ ²⁻	B		
A	7.32	0.00	3.07	28.0	10.0	2.60	11.15	1.23	0.006	2.38	0.30	192	0.30
B	7.22	0.00	2.93	20.0	9.0	2.43	8.37	0.93	0.005	2.42	0.32	205	0.32
C	7.12	0.00	2.73	26.0	6.0	1.62	12.58	1.13	0.003	2.63	0.30	198	0.31
Mean	7.10	0.00	2.91	24.67	8.33	2.22	10.70	1.10	0.005	2.48	0.31	198.33	0.31
Range	7.12- 7.32	0.00	2.73- 3.07	20.0- 28.0	6.0- 10.0	1.62- 2.60	8.37- 12.58	0.93- 1.23	0.003- 0.006	2.38- 2.63	0.30- 0.32	192- 205	0.30- 0.32

CO₃⁻=Carbonates, HCO₃⁻=Bicarbonates, Na⁺=Sodium, Ca²⁺=Calcium, Mg²⁺=Magnesium, SAR=Sodium adsorption ratio, Cl⁻=Chlorides, NO₃⁻=Nitrates, SO₄²⁻=Sulphates, B= Boron, TDS=Total dissolved solids and Ec= Electrical conductivity.

CHAPTER FIVE

5.0 SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Summary

Field trials were conducted to evaluate the effect of tillage practices and irrigation schedule on soil quality and performance of some rice (*Oryza sativa* L.) varieties grown in 2018 and 2019 dry season at Kwakwalawa, Sokoto state. The trials were conducted in a farmer's field near the Usmanu Danfodiyo University Teaching and Research Farm, Kwakwalawa Sokoto (N13°05.963"E005°12.650" and 252m asl). The treatments consisted of factorial combination of two tillage practice; (conventional tillage (CT); which involves cutting, inverting, puddling and leveling the field plots and reduced tillage (RT); which involves puddling and leveling of the plots all with local hoes, shovels and rakes), three irrigation schedules; (One day schedule, two days schedule and three days irrigation schedule, which were carried on one week after transplanting to hard dough stage) and three rice varieties; (FARO 44, 60 and 61). The treatments were laid in a split plot design replicated three times. Tillage practice and irrigation schedule were allocated to the main plots while variety were allocated to the sub-plots. Field observations and measurements were made for the two consecutive seasons using the same experimental design and field layout.

The results revealed that BD, SHC and TP were all significant ($P < 0.05$) across the two tillage and irrigation schedule after the second year of evaluation. The BD value of RT was significant ($P < 0.05$) greater compared to CT; SHC and TP values for CT gave a higher values compared to RT. A consistent trend in aggregate size fraction was observed between the two tillage systems in both years, were a significant decrease in values of aggregate

fractions of both the CT and RT in 2019 compared to in 2018. Aggregate size fraction of 5-2 mm had a significantly higher value of RT compared to CT, 2-0.25 mm fractions were at par (0.41) while a greater value of aggregate fractions for CT in both 0.25-0.005 and <0.005 mm were observed compared to RT. A significant difference in MWD and GMD between the two tillage practice, irrigation schedule and depth was noticed in both years of the trial, where RT and one day irrigation schedule had higher values of MWD and GMD, which increased with increasing depth.

Evaluation of the crop performance shows significant difference in plant height at harvest, with CT having significantly ($P < 0.05$) taller plant height compared to RT. One day irrigation schedule had taller plants while three days irrigation schedule had the least. Variation in numbers of tillers, days to 50 % heading and TDM were significantly higher, with CT having more values compared to RT. All the three varieties showed a significant decrease in days to 50 % heading in 2019 compared to in 2018 where FARO 60 took 96 days to reach 50 % heading while FARO 44 and 61 were the same (82) in number of days. Significant difference was observed between CT and RT in the value of 1000 grain weight, where CT had higher value compared to RT. The one day irrigation schedule was significantly higher than others and FARO 44 had significantly higher value of 1000 grain weight, followed by FARO 60 while FARO 61 was the least. Conventional tillage had significantly higher grain yield/ha compared to RT. There was increase in grain yield with a corresponding increase in water application, where one day irrigation schedule had significantly higher grain yield and FARO 44 out yielded both FARO 60 and 61.

Variation between the two tillage systems in water retention among the various matric potentials, with RT having significantly higher values compared to CT, while at -33, -100

and -500 KPa, both RT and CT were statistically similar in the second year. Soil water retention increases with increase in both days to irrigation schedule and depth, but from -5 to -1500 KPa, there was no significant difference between moisture contents among the various matric potentials for the two depths, excepts at -100 KPa in 2019. The RETC output for Van-Genutchen parameters shows significant difference between the two tillage system, irrigation schedule and depth on the value of n while θ_s and θ_r were significant only at irrigation schedules, where both one and two days irrigation schedule were similar in value for both θ_s and θ_r while the S-index value was greater in RT compared to CT. S-index increased with increase in soil depth, though it was not statistically different. From these findings, the value of S-index in the study area was in the range of 0.023 to 0.025, which by grouping was considered to be a moderately suitable condition for optimal root growth. Considering the measured and fitted water retention values compared to validate the suitability of RETC for hydraulic properties, both the measured and fitted values at all depths and irrigation schedule were not close to 1:1 solid line, except at 10-20 cm depth with one day irrigation schedule having a coefficient of determination value of 0.733, while other values were <0.60 all through, showing weak and positive values. From these predictions, it point to the fact that RETC cannot predict with accuracy the hydraulic behavior of the soil under both tillage practices.

Final evaluation of irrigation water quality from the three tube-wells in the study area revealed that all the tube-wells were two inch orifice sizes. The EC, TDS and SAR values of all the tube-wells were low, though the relatively high value of Na in one of the tube-well may pose a threat to the soil and crop production in future. The pH value of the tube-wells ranges between 7.12-7.32, which indicates slightly alkaline condition and

considered suitable for rice production. Carbonates, bicarbonates, Mg and Ca levels in the water were very low while Na content was moderate. Nitrates, sulphates, chlorides and boron concentrations were below the critical limits proposed by Landon (1991). Hence, this makes the three tube-wells safe for irrigation purpose, but caution must be taken to periodically evaluate both the soil and irrigations water to ensure its safety for use in irrigation.

5.2 Conclusion

Based on the result obtained from this study, it can be concluded that:

- ❖ FARO 44 performed better than the other varieties in terms of yield and yield attributes, with the highest yield of 5410.05, and 5835.85 Kg/ha in both 2018 and 2019 respectively with one day irrigation schedule.
- ❖ Conventional tillage practice and one day irrigation schedule gave higher paddy yield for the three varieties.
- ❖ The soil physical quality index (S) is measured between 0.023-0.025 which is moderately suitable.
- ❖ RETC cannot predict with accuracy the hydraulic behavior of the soil.
- ❖ The irrigation water was considered safe for irrigation.

5.3 Recommendations

- ❖ The use of good and improved rice variety such as FARO 44 in the study area should be encourage, with adequate irrigation management to increase farmers yield

- ❖ For optimum yield, conventional tillage practice with one day irrigation schedule should be adopted and proper crop rotation with the incorporation of forage legumes to improve soil health.
- ❖ HYDRUS model and other soil water application models should be evaluated to ascertain their suitability for hydraulic study in this area.
- ❖ Periodic evaluation of both the soil and irrigation water to ensure its safety for use in irrigation and to advice on appropriate management strategy to adopt.

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