The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria

BY

AGAJA, Toluwalope Mubo

MATRIC.NO: 02/66ME031

DEPARTMENT OF GEOGRAPHY AND ENVIRONMENTAL MANAGEMENT UNIVERSITY OF ILORIN, ILORIN.

MAY, 2018

UNIVERSITY RIN, ILORIN

The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria

Thesis Submitted to the Post Graduate School, University of Ilorin, Ilorin, Nigeria, in Fulfillment of the Requirement of the Award of Degree of Doctor of Philosophy (Ph.D.) in Geography.

Department of Geography and Environmental Management, Faculty of Social Sciences, University of Ilorin, Ilorin, Nigeria.

BY

AGAJA, Toluwalope Mubo B.Sc. (Hons) ILORIN, M.Sc. (IBADAN)

MAY, 2018

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

CERTIFICATION

This is to certify that the thesis titled: The Impact of Tillage Methods on Land Resources in the Guinea Savanna Ecological Zone, Kwara State, Nigeria by AGAJA, Toluwalope Mubo (Matriculation Number 02/66ME031) meets the regulations governing the Award of Degree of Doctors of Philosophy (Ph.D.) in Geography of the University of Ilorin and it is approved for its contribution to scientific knowledge and literary presentation.

Dr. U.A. Raheem .....
Head of Department Signature and Date

Prof. L.T. Ajibade …….
Supervisor Signature and Date

……..
Internal Examiner Signature and Date

……..
External Examiner Signature and Date

DEDICATION

This research is dedicated to the Author and Finisher of my faith, Jesus Christ, who loved me and died for me even while I was yet wallowing in sin. He brought me out, dusted me and chooses me to be His. I also dedicate this research to bone of my bone and flesh of my flesh, Engineer Oluwafemi Oluwatoyin Michael Agaja. He was there all the way encouraging and supporting me. God bless Him and I pray that we shall both live long to fulfill our destiny and the number of our days in joy, peace and happiness in Jesus name. Amen.

ABSTRACT

Man's relation with his natural environment is a complex one. Although, he is subject to natural controls and events, he acts as the dominant force creating major long term environmental challenges like soil degradation, water pollution among others. One of such activities of man is adopting different tillage methods in crop production. This study investigated the environmental impact of tillage methods on land resources in the guinea savanna ecological zone of Kwara State, Nigeria. The objectives were to: (i) examine the effects of tillage methods on soil quality; (ii) examine the effects of tillage methods on surface runoff; (iii) determine the impact of tillage methods on crop yield; and (iv) model the pattern and processes of pollution associated with tillage methods.

The study was carried out at Unilorin Teaching and Research Farm (UTRF) and National Center for Agricultural Mechanization (NCAM), Idofian during the 2015 and 2016 maize seasons. Traditional heap (T), Notill (NT), Plough/Harrow (PH) and Plough/Harrow/Ridge (PHR) tillage were applied to surface runoff plots. Treatments were replicated thrice making 12 plots at each location. Soil samples were taken from 0-15cm and 16-30cm depths. Samples of surface runoff were collected from experimental plots. Yield parameters were measured. Soil and water physico-chemical analysis were carried out using standard laboratory procedures. Data were subjected to Analysis of variance, Least Significant Difference, Tukey's test, Regression analysis at α=0.05% and Soil Water Assessment Tool (SWAT).

The findings of the study were that:

i. ten soil physico-chemical parameters (e.g nitrate for UTRF (0.019 and 0.012mg/kg) and NCAM (0.001 and 0.025mg/kg)) were significant for PH and PHR while six (e.g soil water for UTRF (0.001 and 0.043mg/kg) and NCAM (0.029 and 0.03)) were significant for T and NT in the topsoil and subsoil ($P < 0.05$) in the seasons;
ii. ten surface runoff physico-chemical parameters (e.g nitrate with 0.001 and 0.001 mg/l in the seasons) were significant for NT and T while seven (e.g magnesium (0.001 and 0.045 mg/l in 2015) (0.001 and 0.027mg/l in 2016) were significant on PH and PHR for UTRF and NCAM sites;
iii. crop yield (kg/ha) parameters showed that PH yield > NT yield ($P (0.015) < 0.05$) > T yield ($P (0.04) < 0.05$) and > PHR yield ($P (0.046) < 0.05$) for UTRF and NCAM sites in 2015 while in 2016, PH yield > T yield ($P (0.026) < 0.05$) > PHR yield ($P (0.046) < 0.05$) and no statistical difference between PH and NT at both locations; and
iv. SWAT model showed that four of nine biophysical factors examined (sediment yield-10.54 metric tons/ha, groundwater amount-174.45GWQmm, organic nitrogen- 62.62kg/ha, and nitrogen in surface runoff -5.15kg/ha) were higher for T, while three (surface runoff amount- 374.42SURQmm, evapotranspiration-752.78ETmm and soil loss-1.05USLE_LS) were higher for PH and PHR.

The study concluded that tillage methods have impact on land resources, however, PH had comparatively favorable effect on the soil environment, contribution to surface runoff and crop yield. It is therefore recommended that PH should be adopted for a sustainable environment.

Word Count: 497

ACKNOWLEDGEMENT

O GIVE thanks to the Lord, for He is good; for His mercy and loving-kindness endures forever! (Ps 118:1 AMP). All glory and majesty be to the King of kings, Lord of lords, Alpha and Omega, the beginning and the end, the One who speaks and watches His words to bring it to accomplishment, to Him alone be glory forever and ever in Jesus name. Amen.

I want to appreciate the tireless effort of my supervisor, Professor Ajibade Lanre Tajudeen. I am forever grateful to him for instilling in me hard work and confidence to forge ahead in this pursuit. May God bless him richly in Jesus name.

I am grateful to the authorities of University of Ilorin for the award of staff development to me, this had assisted in the easy completion of this research. I am especially grateful to Dr. I.P. Ifabiyi for his efforts geared towards making this pursuit a reality. Also, the encouragement from other members of academic staff in the Department of Geography and Environmental Management cannot be over emphasized. They include Professors, J.F. Olorunfemi, A.F. Adedayo, and R.A. Olawepo. I appreciate Dr. E.O. Oriola, Dr (Mrs.) R.M. Olanrewaju, Dr. U.A. Raheem, Dr. A.Y. Ahmed, Dr. K.A. Iroye, Dr. G.P. Afolayan, Dr. S.L. Tilakersiri, Dr. (Mrs.) A.M. Tunde, Dr. B.A. Usman, Dr. D.O.Ajewole, Dr. I. Orire, Dr. N.A. Malik, Dr. E.A. Adeleke, Mrs. E.E. Adeniyi. and Mr. R.A. Olatian. Also, acknowledged are the assistance rendered by the non-academic staff of the department.

I am blessed to have great shoulders to climb on in the persons of my parents, Prof. and Dr. (Mrs.) S.B. Agaja and Prof. and Mrs. J.O. Atteh. I thank them for their prayers and support towards the success of this programme. May God bless them richly, they will live long to fulfill the number of their days and see all their children and children's children becoming great in good health, joy and happiness in Jesus name. Amen.

I would like to say a big thank you to authorities of the University of Ilorin Teaching and Research Farm as well as National Centre for Agricultural Mechanization (NCAM),Idofian for providing the land, machineries and the personnel needed to make this research a success. I must mention the Farm Manager Dr. K.O. Azeez, Mr. W.R. Ifabiyi, Mr. A. Johnson, Mr. S. Adeniyi, Mr. P. Oladele, Mr. U. Dalumo, Mr. J.N.Mohammed, Mr. E. James, Mr. Ayo and all members of staff of the research farm. Mr. K. Adebayo, Mr. Akoko, Mr. S. Bamisaye and other members of staff of NCAM, Idofian that assisted in making my experiment a success. This project would have being impossible without the effort of the Laboratory Technician at the Department of Chemistry, University of Ilorin, Mr. Jemerin who assisted me with the laboratory analyses. He worked tirelessly to the extent of accompanying the digested samples to the Chemistry laboratory in University of Ibadan. God bless him richly in Jesus name.

I must also acknowledge the efforts of Prof. G. Olaoye, Dr. F. Takim and Dr. (Mrs.) Afenihin of Department of Agronomy for providing knowledge and insight to this research. I want to thank Mr. M. Maja for being there for me at every point of soil sample collection. I also recognize the efforts of Aro Joseph, Abiodun and Ashaolu Eniola (Postgraduate Students in the same Department) who helped in the organization and analysis of the data gathered. I thank them very much.

I am forever grateful to God for His servants who have always prayed and encouraged me all the way. Evangelist Dayo Olorunmola, Pastor David Abikoye , Pastor Bidemi Abraham, Rev. (Dr.).B. Olugbemi, Prophetess. M. Oshagbami and Pastor Gideon Adewoye. May God bless and keep them. To the family of God, the Couples Koinonia Fellowship, COR UMCA, Gaa-Akanbi, I love and thank them for their prayers and support.

I appreciate my wonderful children Michelle, Oluwarogbayimika and Oluwademilade Agaja for being enduring at periods of my absence at home. May God bless them, and keep them, make His face to shine upon them. They will be great and surpass their parents in Jesus name, Amen. I am most grateful to the love of my life, bone of my bone, flesh of my flesh, Engr. Oluwafemi Oluwatoyin Michael Agaja. I thank him for his support, prayers, encouragement, and efforts all the way. Words can't express how blessed I am to have him by my side. I love him so much and by the grace of God we would fulfill our purpose and destiny in life to the glory of God's name in Jesus name. Amen.

I am blessed to have great siblings who supported, prayed and encouraged me all the way. Mr. and Mrs. Rotimi Agaja, Pastor and Mrs. David Olaiya, Dr. and Dr. (Mrs.) Ayodeji Agaja, Mr. and Mrs. Bamidele Atteh, Engr. and Dr. (Mrs.) Abiola Ojo and Mr. Oluwafemi Atteh, I thank them so much and God bless you. To my brother and sister from another mother but the same Heavenly Father, Mr. and Mrs. Jonathan Joseph, I am most grateful for their love, support, prayers and encouragement all the way. May God bless them richly in Jesus name. Amen

TABLE OF CONTENTS

Contents		Pages
Title		i
Certification		iii
Dedication		x
Acknowledgement		xiii
Table of contents		xvi
List of tables		xx
List of figure		xxii
List of plates		xxiv
CHAPTER ONE: INTRODUCTION		1
1.1	Background to the study	1
1.2	Statement of the Problem	3
1.3	Aim and Objectives	6
1.4	Research Hypotheses	6
1.5	Relevance of Study	6
1.6	The Scope of Study	8
1.7	Study Area	9
1.7.1	Location	9
1.7.2	Climate	13
1.7.3	Vegetation	16
1.7.4	Geology	18
1.7.5	Soil	20
1.7.6	Drainage	22
1.7.7	Population and People	22

1.7.8 Socio Economic Activities 25

1.7.8 Land Use 25

1.8 Definition of Terms 27

CHAPTER TWO:CONCEPTUAL ISSUES, THEORETICAL FRAMEWORK, LITERATURE REVIEW AND EMPERICAL STUDIES 29

2.1 Introduction 29

2.2 Conceptual Issues 29

2.2.1 Ecosystem 29

2.3 Theoretical Framework 34

2.3.1 Man- environment relationship 34

2.3.2 Farming paradigm 39

2.4 Literature Review 40

2.4.1 Conservation agriculture 40

2.4.2 Tillage 42

2.4.3 Types of Tillage Systems 42

2.4.4 Effect of Tillage on Soil Quality 45

2.4.5 Effect of Tillage on Surface Runoff 48

2.4.6 Effect of Tillage on Crop Yield 53

2.4.7 Tillage Systems and Environmental Sustainability 55

CHAPTER THREE: RESEARCH METHODS 58

3.1 Introduction 58

3.2 Types of Data Required 58

3.3 Sources of Data 58

3.4 Method of Data Collection 59

3.4.1 Sampling Procedures 59

3.4.2 Sampling frame 62

3.4.3 Sampling unit 67
3.4.4 Sample population 67
3.4.5 Sampling Technique 67
3.5 Method of Data Analysis 75
3.5.1 Laboratory methods 75
3.5.2 Statistical methods 78
CHAPTER FOUR: IMPACT OF TILLAGE PRACTICES ON SOIL QUALITY 84
4.1 Introduction 84
4.2 Distribution of Soil Quality among the Tillage Methods at UTRF and NCAM Experimental Sites 84
4.3 Impact of Tillage Methods on Soil Quality on UTRF and NCAM Experimental Site 95
4.4 Comparism between the UTRF and NCAM Experimental Sites 108
CHAPTER FIVE: IMPACT OF TILLAGE METHODS ON SURFACE RUNOFF 111
5.1 Introduction 111
5.2 Distribution of the Surface Runoff Composition on the Different Tillage Methods at the UTRF and NCAM Experimental Plots 111
5.2 Pattern of the Impact of Tillage Methods on Surface Runoff Water Quality on the Experimental Plots 118
5.3 Comparism between the UTRF and NCAM Experimental Sites 127
CHAPTER SIX: IMPACT OF TILLAGE METHOD ON CROP (MAIZE) YIELD 130
6.1 Introduction 130
6.2 Agronomic Variables and Crop Yield in the University Teaching Research Farm (UTRF) and National Center for Agricultural Mechanization (NCAM) Experimental sites 130
6.3 Impact of Tillage Methods on Maize Yield Parameters 137
CHAPTER SEVEN: MODELLING THE PATTERN AND PROCESS OF POLLUTION FROM THE TILLAGE TYPES 144
7.1 Introduction 144
7.2 Distribution of the Hydrological Response Units (HRU) in UTRF and NCAM Sub Catchments 144
7.2.1 Soil Types and Soil loss 149

7.2.2 Sediment 151
7.2.3 Surface Runoff Amount Generated and Groundwater Flow 155
7.2.5 Crop Yield 157
7.2.6 Organic Nitrogen, Nitrogen in Surface Runoff and Phosphorus 158
7.3 Agricultural Land Use Predictions 163
CHAPTER EIGHT: SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS 170
8.1 Summary of Findings 170
8.2 Conclusion 171
8.3 Recommendations 172
8.4 Contribution to Knowledge 173
REFERENCES 174
APPENDIX I 186
APPENDIX II 206
APPENDIX III 219
APPENDIX IV 231

LIST OF TABLES

Table 1.1: Average Mean Temperature for the year 2015 and 2016 14
Table 3.1: Features modeled in SWAT 69
Table 3.2: Details of Soil Quality Parameters Determined 76
Table 3.3: Details of Water Quality Parameters Determined and Nigerian Drinking Water Standard 77
Table 3.3 Two Way Analysis of Variance Table 80
Table 3.4: Application of the Regression Equation into the ANOVA Table. 82
Table 4.1: Summaries of Soil Quality Parameter Values in UTRF Experimental Site for 2015 and 2016 planting season 86
Table 4.2: Summaries of Soil Quality Parameter Values in NCAM Experimental Site for 2015 and 2016 planting season 88
Table 4.3: Pattern of the Impact of Tillage Methods on Soil Quality at Different Depth in UTRF Site for 2015 and 2016 Planting Season 97
Table 4.4: Pattern of the Impact of Tillage Methods on Soil Quality at Different Depth in NCAM Site for 2015 and 2016 Planting Season 98
Table 4.5 Mean and LSD values for Soil Temperature, Soil Water, Ph, Bulk density and Organic Matter at UTRF site 99
Table 4.6 : Mean and LSD values for Soil Temperature, Soil Water, Ph, Bulk density and Organic Matter at NCAM site 99
Table 4.7: Mean and LSD values for Nitrate-nitrogen, Phosphorus, Potassium, Sodium and Calcium at UTRF site 99
Table 4.8 Mean and LSD values for Nitrate-nitrogen, Phosphorus, Potassium, Sodium and Calcium at NCAM site 100
Table 4.9 Mean and LSD values for Magnesium, Copper, Manganese, Lead, Iron and Zinc at UTRF site 100
Table 4.10: Mean and LSD values for Magnesium, Copper, Manganese, Lead, Iron and Zinc at NCAM site 100
Table 5.1: Summaries of Surface Runoff Quality Values on UTRF and NCAM Experimental Site for 2015 and 2016 Planting Season 114

Table 5.2: Tillage Impact on Surface Runoff Quality Parameters at UTRF and NCAM Experimental plots for 2015 and 2016 planting season using ANOVA 121
Table 5.3 Means and LSD values for Turbidity, Carbon. Sodium, Potassium, Zinc and Nitrate from the Experimental sites 122
Table 5.4: Mean and LSD values Total dissolved solids, Calcium, Magnesium, Dissolved oxygen, Lead and Iron parameters from the Experimental sites 122
Table 5.5: Mean and LSD values for Phosphorus, pH, Conductivity, Chlorine and Copper from the Experimental sites 122
Table 6.1: Summaries of Yield Parameters for 2015 and 2016 planting season (UTRF) 132
Table 6.2: Summaries of Yield Parameters on NCAM site for 2015 and 2016 planting season 133
Table 6.3: Tillage Impact on Maize Height 137
Table 6.4: Tillage Impact on Number of Maize Leaves 138
Table 6.5: Tillage Impact on Maize Leave Length 138
Table 6.6: Tillage Impact on Maize Leave Width 139
Table 6.7: Tillage Impact on Leave Area Index 140
Table 6.8: Impact of Tillage Methods on Crop Yield in UTRF Experimental Plot 141
Table 6.9: Impact of Tillage Methods on Crop Yield in NCAM Experimental Plot 142
Table 7.1: Distribution of the Hydrological Response Unit (HRU) in UTRF and NCAM sub catchments 147
Table 7.2: Soil loss from the experimental plots 149
Table 7.3: Average sediment yield from the experimental plot 152
Table 7.4: Sediment Yield for the entire study area 152
Table 7.5: Surface runoff and Groundwater contribution to stream flow in the main channel in the study area 156
Table 7.6: Evapotranspiration and Biomass in the study area 156
Table 7.7: Crop/harvest yield in the study area 157
Table 7.8: Organic nitrogen and Nitrogen in surface runoff in the study area 159
Table 7.9: Land Use Predictions on Features Modelled For the Study Area 165

LIST OF FIGURE

Figure 1.1: Map of Kwara State Showing the Study Area with Inset Map of Nigeria 10

Figure 1.2: Map of National Center for Agricultural Mechanization (NCAM) with inset of Ifelodun Local Government Area, Kwara State, Nigeria 11

Figure 1.3: Map of University of Ilorin showing the Teaching Research Farm with inset map of Ilorin South Local Government Area 12

Figure 1.4: Total Annual Rainfall for Ilorin South and Ifelodun Local Government Area 15

Figure 1.5: Vegetation Map of Ifelodun and Ilorin South Local Government Area 17

Figure 1.6: Geology Map of Ifelodun Local Government Area 19

Figure 1.7: Soil Map of Ilorin South and Ifelodun Local Government Area 21

Figure 1.8: Drainage pattern for the Study Area 24

Figure 1.9: Land Use Map of Ilorin South and Ifelodun Local Government Area 26

Figure 2.1: The Water cycle 31

Figure 2.2: Basic plant nutrient cycle 32

Figure 2.3: Energy and Mineral Movement Model in the Ecosystem 33

Figure 3.1: Experimental Layout at University of Ilorin Teaching and Research Farm and National Centre for Agricultural Mechanization (NCAM), Idofian 68

Figure 3.2: Flow chart of the steps in the SWAT model application for the study area. 72

Figure 3.3: Catalog of SWAT Running the Input Data 73

Figure 3.4: Catalog of SWAT Output 74

Figure 4.1: Pattern of Distribution of soil temperature, soil water, pH and iron for 2015 and 2016 on the experimental sites. 90

Figure 4.2.: Pattern of distribution of Soil Quality Indicators on the Experimental Sites 91

Figure 5.1: Pattern of Distribution of the Surface runoff Quality and the Tillage Methods for the experimental sites 117

Figure 6.1: Mean Maize Height on Different Tillage Type in UTRF and NCAM Experimental Plot for 2015 and 2016 planting season 134

Figure 6.2: Mean Leave Number on Different Tillage Type in UTRF and NCAM Experimental Plot for 2015 and 2016 planting season 134

Figure 6.3: Mean Leave Length on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season 135
Figure 6.4: Mean Leave Width on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season 135
Figure 6.5: Mean Crop Yield on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season 136
Figure 6.6: Mean Leave Area Index on Different Tillage Type in UTRF and NCAM Experimental Site 136
Figure 7.1: Schematic Representation of the Hydrologic Cycle of the study area. 146
Figure 7.2: SWAT model showing the study area watershed delineated into Hydrological Response Units 148
Figure 7.3: Soil type in the study area 150
Figure 7.4: Mean slope of the study area 153
Figure 7.5: SWAT modeled summary of sediment yield in the study area 154
Figure 7.6: SWAT modelled summary for crop yield in the study area 158
Figure 7.7: SWAT model for Nitrogen in the study area 161
Figure 7.8: SWAT modeling phosphorus in the study area 163
Figure 7.9: Dominant land use in the study area 166
Figure 7.10: Landuse Distribution classes across the Study Area 167

LIST OF PLATES

Plate 3.1: Constructed Experimental plots at Unilorin Teaching and Research Farm (UTRF) site. 60
Plate 3.2: Runoff outlet on each Experimental plots at the National Center for Agricultural Mechanization (NCAM) Idofian. 61
Plate 3.3: Runoff outlet covered to prevent entering of debris Unilorin Teaching and Research Farm (UTRF) site. 61
Plate 3.4: Soil Auger used to collect soil samples before planting from the experimental plots 62
Plate 3.5: Tractor tilling the experimental plot 63
Plate 3.6: Traditional Heap Tillage in Progress at Experimental plot. 64
Plate 3.7: Traditional Heap plots tilled and planted with flow path for runoff 64
Plate 3.8: Pre-emergence application of herbicide by Field Assitant on the tilled experimental plots 65
Plate 3.9: Experimental plots with maize at 4weeks 65
Plate 3.10: Measurement of plant height by the Researcher and field assistant at 8weeks. 66
Plate 3.11: Measurement of the leaf length by the Researcher and field assistant at 8weeks. 66

CHAPTER ONE

INTRODUCTION

1.1 Background to the study

Agriculture is an essential human activity that facilitates food production. For a long time, the increasing demand for food was met by extending the area under cultivation. One of the consequences of crop production is the clearing of vegetal cover which in turn exposes the cleared land to weathering processes and degradation. Such weathering activities include soil erosion, leaching of nutrient, pollution, change in nutrient profile of the soil which has increased the inability of the soil to sustain crop production. It is for such reasons that land is left fallow to regain some of its original attributes.

Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation involving activities such as ploughing, digging, overturning, shovelling, hoeing and raking (Aina, 2011). Ahn and Hintze (1990) defined tillage as any physical loosening of the soil as carried out in a range of cultivation operations, either by hand or through mechanization. According to Lal (1977; 1983), it is the physical, chemical or biological soil manipulation aimed at optimizing conditions for germination, seedling establishment and crop growth. One of the basic steps in most crop production activities is tillage. Tillage is also defined as the soil-related activities necessary for crop production (Boone, 1988). From the definitions above, one can summarize the definition of tillage as the process of loosening of the soil with a view to optimizing crop production.

According to Ohu (2011), an important effect of tillage on soil sustainability is its impact on the environment through soil degradation, poor water quality, emission of greenhouse gases from soil-related processes among others. As a subsystem of a crop production, tillage can be used

to achieve many agronomic objectives which will eventually lead to sustainability of the ecosystems. These include soil conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation, water infiltration, soil temperature control among others), weed/pest suppression (direct termination or disruption of weed/pest life cycles), residue management (movement, orientation or sizing of residues to minimize negative effects of crop yield/cover crop residues and promote beneficial effects), nutrient incorporation/mixing (placement or redistribution of substances such as fertilizers, manure, seeds, residues, sometimes from a less favorable location to a more favorable spatial distribution), segregation (consolidation of rocks, root crops, soil crumb sizes) and land forming (changing the shape of the soil surface such as ridging and roughening).

Land and Land Resources refer to a delineable area of the earth's terrestrial surface, encompassing all attributes of the biosphere immediately above or below this surface, including those of the near-surface climate, the soil and terrain forms, the surface hydrology (including shallow lakes, rivers, marshes and swamps), the near-surface sedimentary layers and associated groundwater and geohydrological reserve, the plant and animal populations, the human settlement pattern and physical results of past and present human activity (terracing, water storage or drainage structures, roads, buildings, agricultural farmland etc.(FAO/UNEP, 1997).

Conservative Agriculture (CA) are methods of managing agro-ecosystems for improved and sustained productivity, increased profits and food security while preserving and enhancing the resource base and the environment. The minimum mechanical soil disturbance, permanent organic soil cover and crop diversification are the three basic principles of CA. CA has emerged as an alternative to conventional agriculture as a result of losses in soil productivity due to soil degradation (FAO, 2011). CA was introduced to solve the problems associated with conventional

agriculture such as the problem of tillage which is responsible for natural resource and soil degradation. CA can also be defined as minimal soil disturbance (no-till) and permanent soil cover (mulch) combined with rotations, as a more sustainable cultivation system for the future.

1.2 Statement of the Problem

Land and water resources are central to agriculture and development, and are intrinsically linked to global challenges of food insecurity and poverty, climate change adaptation and mitigation, as well as degradation and depletion of natural resources that affect the livelihoods of millions of people across the world (FAO, 2011). As a result, land utilization is now confronted with serious need for the protection of soil fauna, landscape, climate and water quality.

Nigeria is an agrarian society with more than 70% of its population employed by agriculture and this agricultural sector provides over 40% of GDP of the country. It has high potential for agriculture in terms of land and biophysical conditions necessary for crop production. Nigeria has about 79 million hectares of arable land, of which 32 million hectares are cultivated. Over 90% of agricultural production is rain-fed. Smallholders, mostly subsistence producers account for 80% of all farm holdings (FAO,2002).

Despites these, production output are low and the agricultural practices are characterized by low returns. Although the average agricultural growth rate was 7% between 2006 and 2008, this growth lies below the 10% necessary for attaining food security and poverty reduction. The need for increased production has fostered ecologically unsustainable agricultural intensification in many places, leading in particular to soil degradation. Also, meeting the present and future needs of the population in terms of food, fibre, shelter, etc. without destroying the soil and water resource base and the environment, remains an important concern. To avert food crisis, it is expected that the rate of food production corresponds with the pace of population growth.

As population increases and economy grows, the competition for the limited supply of land and water will intensify and so will conflicts among users. Activities such as bulldozing and inappropriate mechanical tillage subject Nigerian soils to devastating processes like erosion and the formation of hardpans as reported by Ahaneku (2010). The major problem is that the land and land resources present are faced with issues such as erosion, improper land management problems such as degradation, pollution, overgrazing among others. Also, the agricultural practices carried out by the farmers are done with crude implement and are not favourable to the land such as bush burning.

Farming systems today have more obvious and detectable social, ecological, economic, and environmental implications because of the growing concern about agricultural sustainability and the environment (Shrestha and Clements, 2003). Agricultural sustainability is therefore needed as it increases the trend in per capita productivity to meet the present needs without jeopardizing the future potential. With continued population growth and increasing demand on water resources, conservation tillage will have an increasing role to play in farming during this millennium. The world population has been projected to be expected to be 8.5 and 9.0 billion by 2025 and 2050 respectively (Berry *et al.*, 2003). Therefore, the greatest threat to sustaining agricultural productivity in the Nigerian farming communities and the world at large is the declining productivity of soil caused by the loss of soil fertility through the erosion of the top-soil. This is due to the use of inappropriate land use practices and the loss of soil water content, soil structure and porosity. Thus, transformation of natural resources not only brings the affected land under nature's degradation regime but also accelerates the process (Aromolaran, 1998).

Abundance of land in Nigeria has prevented the adoption of conservative agriculture which according to Giller *et al.,* (2009), the potential of Conservative Agriculture (CA) in Africa are

based on widespread adoption in the America. CA is said to increase yields, reduce labor requirements, improve soil fertility, reduce erosion and sustain the land resources. Yet, empirical evidence is not clear nor consistent on many of these points neither is it clear which of the principles of CA contribute to the desired effects (Giller *et al.*, 2009). Though there is a lot of information on tillage studies, the aspects that characterize the complexity of tillage systems and their environmental impact is yet to be fully researched. Therefore, there is a need to adopt a study on conservative agriculture that will help to understand the appropriate land management techniques that can be used to sustain the land resources present. Also, estimates of the use of conservation tillage in Nigeria are quite low currently, projections indicate largely unexplored potential for conservation tillage in the country (Lal, 2001; Aina, 2011). In addition, the application of an experiment design to assess environmental issues are no more popular whereas the advantages of using experiment in a research are numerous such as drawing causal conclusions, regarding interventions or treatments and establishing whether or not one or more factors causes a change in an outcome, controlling extraneous variables, repeating, checking and verifying the result collected among others.

Even some of the studied tillage variations are not adequately described in terms of efficiency and effect. This is because most of the studies focused on the problem of nutrient loss in terms of economics of crop production (i.e how much Nitrogen (N) or Phosphorus (P) was available for crop intake) and not on soil degradation and water pollution or quality concerns (Aina, 2011). In Nigeria like many parts of the third world countries, solute transfer or pollution is an acute problem. Several studies on water pollution have focused on water channel pollution (EPA, 1999; Clark *et al.*, 1993; Abulude *et al.*, 2007; Ifabiyi, 2008) but few provided information on sources of pollutant. Consequently, the effort at reducing pollution has not been too successful

since a little understanding exists on sources and processes of pollution especially in watershed areas. Thus, from the foregoing, the following questions are put forward:

i. What are the effects of tillage methods on soil quality?

ii. What are the effects of tillage methods on surface runoff?

iii. What are the impacts of tillage methods on crop yield?

iv. What are the pattern and processes of non-point sources pollution in a tillage system?

1.3 Aim and Objectives

The aim of this research was to assess the impacts of soil tillage methods on land resources with emphasis on water and soil quality with a view to:

i. determine the effect of tillage methods on soil quality;

ii. determine the effect of tillage methods on surface runoff;

iii. examine and evaluate the impact of tillage methods on crop yield; and

iv. model the pattern and processes of pollution from the tillage types in the study area.

1.4 Research Hypotheses

In relation to the above objectives, the following hypotheses were tested

1. There is no significant impact of the types of tillage on soil quality.
2. There is no significant impact of the types of tillage on surface runoff.
3. There is no significant relationship between the types of tillage and crop yield.

1.5 Relevance of Study

Zero-tillage systems of cultivation with crop residue are the basis of conservation farming because the approach prevents erosion while maintaining organic matter content at high levels. Adequate amount of crop residue and the residue requirement varies with soil and the use of residue is one of the best methods of controlling erosion, conserving soil moisture, and decreasing

pollution due to water runoff (Lal, 1983; Unger, 1984). Yet, tillage (conventional) is still in vogue and widely used by farmers. Several indigenous local technologies in use with organic fertilizers have recorded huge successes especially among peasant farmers (Tekwa and Belel, 2008). In spite of all these, recent evidences have shown that farmers are not eager to adopt or invest in soil management practices which are known for their efficiency in combating land resource degradation issues and improving soil productivity. Junge *et al.,* (2007) observed that some of the farming system practices aimed at tackling soil and water quality decline and degradation have wide spread acknowledgement with low usage.

Desperch (2007) concluded that no-till as well as any other conservation tillage have many benefits in the agricultural system including decreasing surface runoff and erosion which are major environmental concerns almost exclusively to the agricultural community. Therefore, there is an urgent need to understand the soils and water systems due to the fact that sediment and dissolved organic matter from the soil for instance, eventually contaminate surface water through runoff thereby degrading the water supplied to the populace as well as the aquatic ecosystem. Conservation tillage will reduce water runoff and therefore increase infiltration of water into the soil.

It is worth noting that studies focused on increased crop productivity derived from the use and comparison of tillage methods through the consideration of soil properties and nutrient content without thought of the quality of water (Aina, 2011; Ohu, 2011; Giller *et al*., 2009; Reji *et al*., 2012; Agbede *et al* ., 2008; Olaoye, 2002 and Senjobi *et al*., 2013). However, agricultural practices and their impact with reference to the quality of soil and water are very relevant in the field of water resources and land evaluation. These anomalies therefore justify the assessment of

impacts of soil tillage methods on land resources with reference to soil and water quality. The study was useful in:

i. examining the environmental effects of conservation tillage and the benefits derivable from its application by farmers in the study area;
ii. broaden the knowledge on water quality, land management methods and sustainable resources;
iii. evaluation of the negative effects of soil and water reaction as a result of the tillage method ; and
iv. provide information to the citizens on the environmental conditions in their neighborhood.

1.6 The Scope of Study

The study considered different tillage methods and their impact on land resource in a typical guinea savanna ecological zone. The tillage methods used were limited to those used by farmers in the study area which are Traditional heap, No-tillage, Plough/Harrow and Plough/Harrow/Ridge. It examined the different variations and relationships that may occur between the tillage methods and surface runoff quality due to the fact that surface runoff from agricultural landuse flow into a receiving drainage basin. It also considered the impact of the different tillage methods on soil quality and crop yield. The study was carried out at the University of Ilorin Teaching Research Farm (UTRF), Ilorin and National Centre for Mechanized Agriculture (NCAM), Idofian both located in Ilorin South and Ifelodun Local Government Areas (LGA) of Kwara State, Nigeria and modelled the pattern and processes of pollution from the tillage methods from the study area using Soil Water Assessment Tool (SWAT).

1.7 Study Area

1.7.1 Location

The study was carried out at the University of Ilorin Teaching and Research Farm, Ilorin (UTRF) and National Centre for Agricultural Mechanization (NCAM), Idofian which are located in Ilorin South Local Government Area and Ifelodun Local Government Area, Kwara State respectively. University of Ilorin is located between latitude 8º28″N – 8º29′ 30″N and between longitude 4º 38′ 30″E – 4º40′ 30″E while NCAM is located between latitude 8º22″N- 8º23″N and between longitudes 4º40″E- 4º41″E (Figure 1.1, 1.2 and 1.3). The Ilorin-Lokoja trunk A road marks the northern limit from the Oyun river bridge (Ahaneku, 1990).

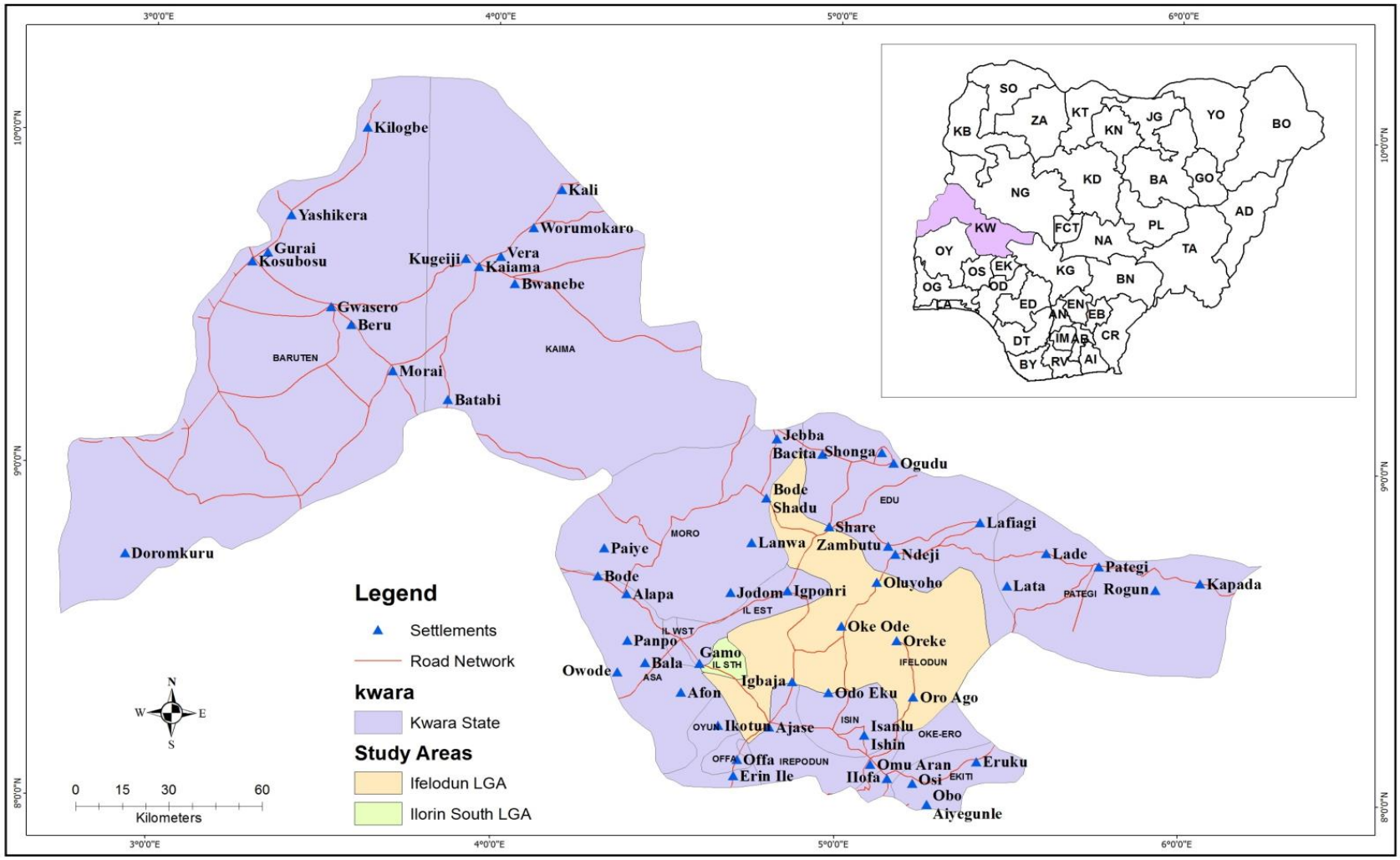


Figure 1.1: Map of Kwara State Showing the Study Area with Inset Map of Nigeria
Sources: Adapted from Kwara State Bureau of Lands and Survey (2002)

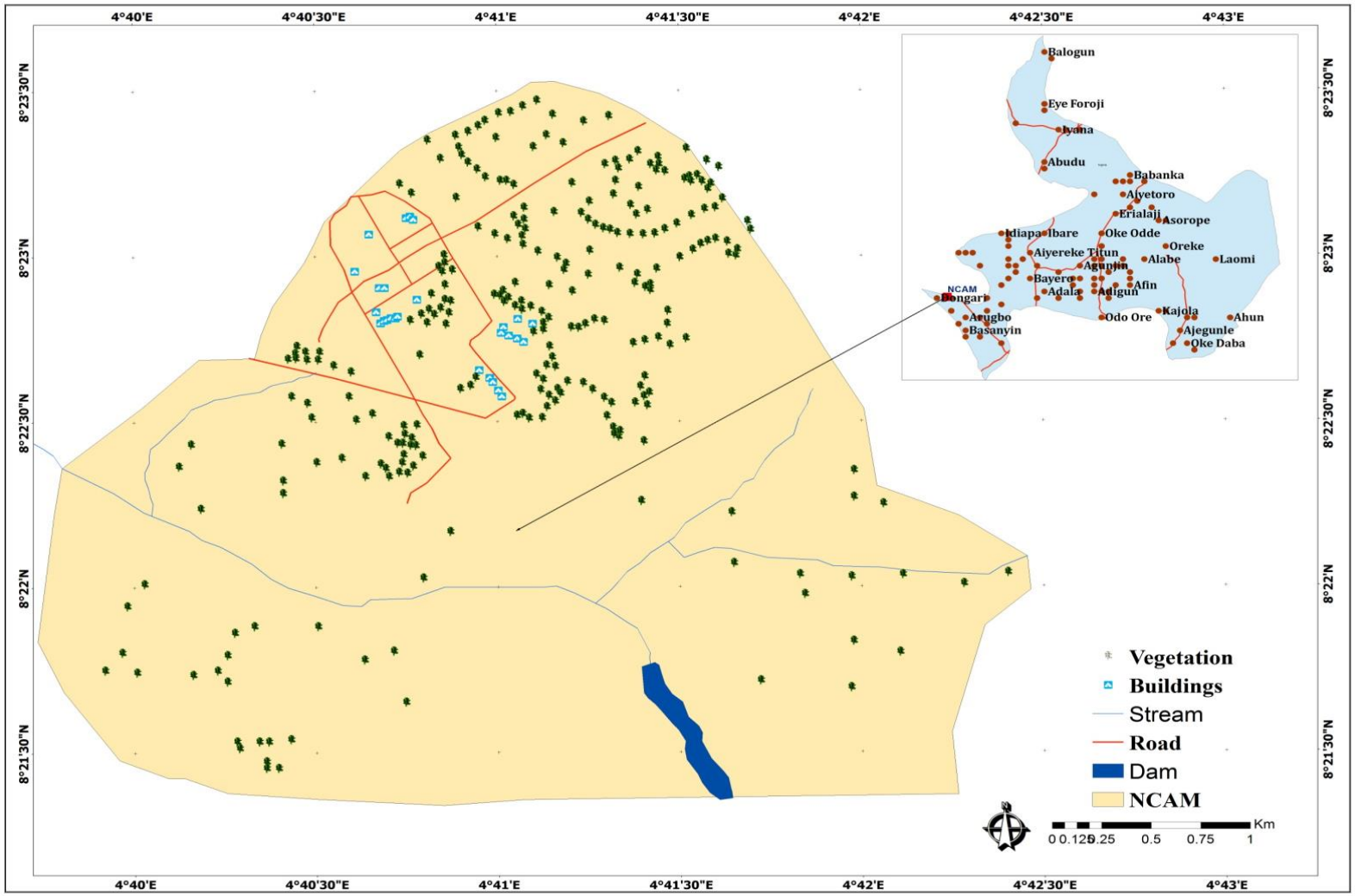


Figure 1.2: Map of National Center for Agricultural Mechanization (NCAM) with inset of Ifelodun Local Government Area, Kwara State, Nigeria

Source: National Space Research and Development Agency (2016)

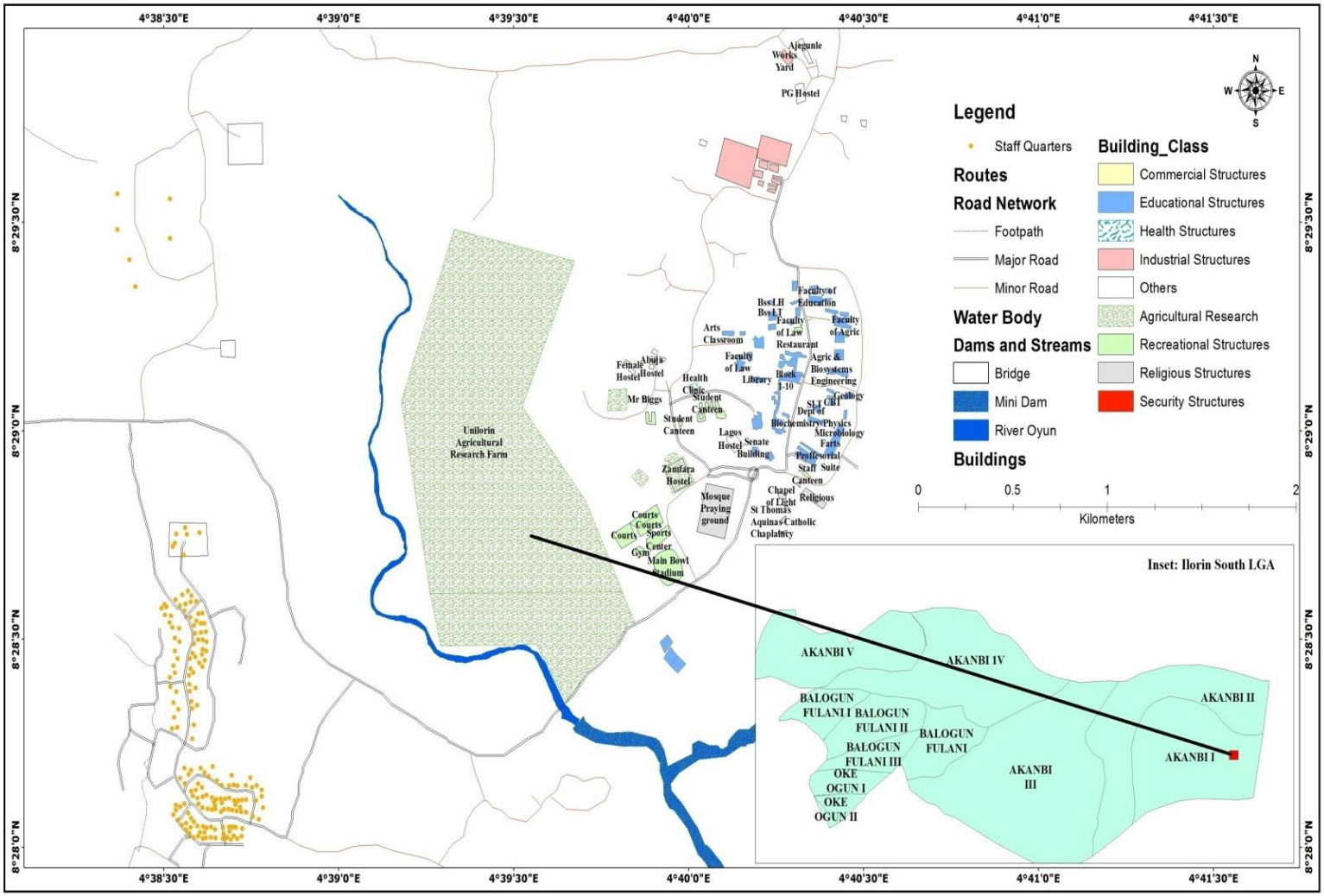


Figure 1.3: Map of University of Ilorin showing the Teaching Research Farm with inset map of Ilorin South Local Government Area
Source: GISCleric International (2016)

1.7.2 Climate

The climate of the University of Ilorin falls within the tropical hinterland climatic zone. It is tropical and seasonal having a dry season occurring between November to April while the rainy season between May and October. Occasionally, there could be early beginning of the rainy and the dry season may be extended (Mustapha, 2008).The dry season is characterized by absence of rainfall, high temperature and mean monthly rainfall total of about 360mm. The mean annual evaporation is in the range of 1000-1200mm (Figure 1.4). The humidity ranges between 30-80%. Relative humidity is high during the rainy season and low in dry season. The temperature ranges from 20^{o}C-30^{o}C (Adelana and Olasehinde, 2004).

National Centre for Agricultural Mechanization (NCAM) also falls within the climatic zone of the country generally referred to as the "Tropical Hinterland" zone of Nigeria and is defined as that area in Nigeria in which over a period of years, 50% or more of all the years have a dry season of 4 -5 months duration (Ahaneku, 1990). It is characterized by dry and wet season.The months of December and January are usually cold and dry months due to the influence of harmattan from the desert regions of the north. The type of rainfall experienced is convectional storms, sometimes very windy. The heaviest rainfall is often recorded between June and early August. There is a short spell of drought between August and early September (Olaniran, 2002; Oyegun, 1983). Relative humidity in the wet season is between 75 and 80% while in the dry season it is about 65% (Tinuoye, 1990). The daytime is always sunny with the sun brightly shinning for about 6.5 - 7.7 hours daily from November to May (Olaniran, 2002). The annual rainfall for the study area ranges between 1150mm-1250mm (Figure 1.4). The range of temperature for years 2015 and 2016 was between 18^{o}C -38^{o}C as shown in Table 1.1.

Table 1.1: Average Mean Temperature for the year 2015 and 2016

Minimum Temperature(°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	19.25	23.29	23.76	23.57	23.49	22.37	21.74	21.67	21.85	22.05	22.12	18.70
2016	19.64	21.85	24.66	24.33	23.64	22.41	21.66	21.42	21.69	21.66	22.33	19.88

Maximum Temperature(°C)

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
2015	35.84	35.28	35.28	35.34	33.40	29.54	29.81	28.45	28.54	29.93	34.16	35.29
2016	36.57	38.20	36.57	36.25	34.65	31.59	27.92	27.97	28.15	30.89	34.65	35.04

Source: National Space Research and Development Agency (2016)

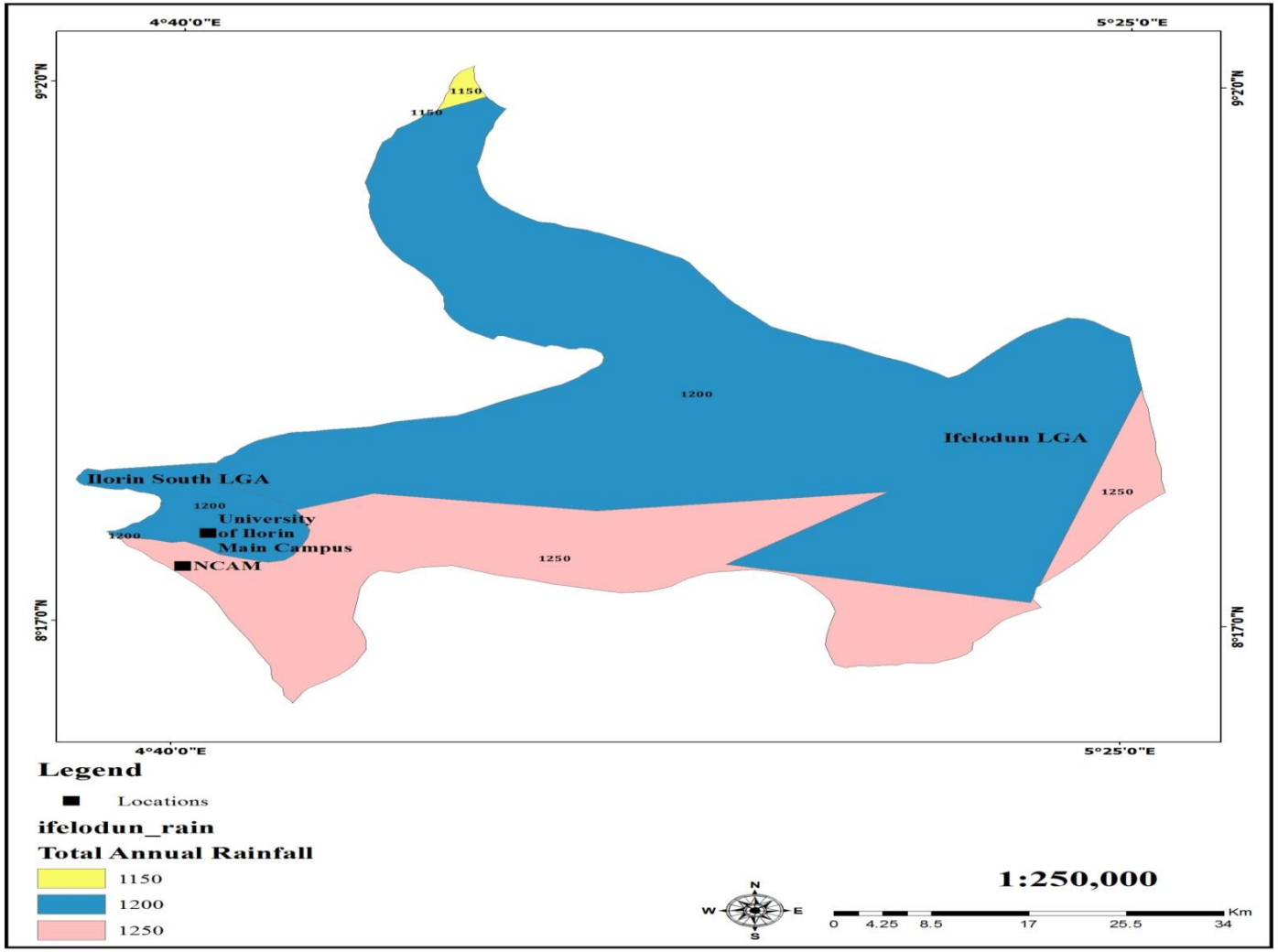


Figure 1.4: Total Annual Rainfall for Ilorin South and Ifelodun Local Government Area
Source: National Space Research and Development Agency (2016)

1.7.3 Vegetation

The experimental sites are located in the Guinea Savannah grassland and characterized by the presence of fire tolerant woody shrubs and trees which are biologically suited to withstand dry conditions (Figure 1.5). The plants are about 12 meters high with grass of about 1.5- 2.5 metres in height while some parts of the study area have some rainforest trees and bushes. The locust bean trees (*Parkiabiglobosa)*, shear butter trees (*Vitellariaparadoxa)*, acacia trees (*Acacia nilotica*), spear grasses (*Imperata cylindrical)*, goat weed (*Ageratum conyzoides)*, elephant grasses (*Pennisetumpurpureum)*, shrubs with more dense vegetation of taller trees(mostly palms) fringes the river bank and herbaceous plants are typical examples in the area (Jimoh and Ajao, 2009).

Soil water is an important source for vegetation development. Changes of soil water may greatly affect tree species diversity and forest canopy structure. It is one of the most important factors controlling hydrological processes. However, soil water is influenced by vegetation type and soil properties. Different vegetation and soil types have different water infiltration capacities, soil structure and texture which in turn determine the conditioning of the soil environment for crop production (Lavelle *et al.,* 2009).

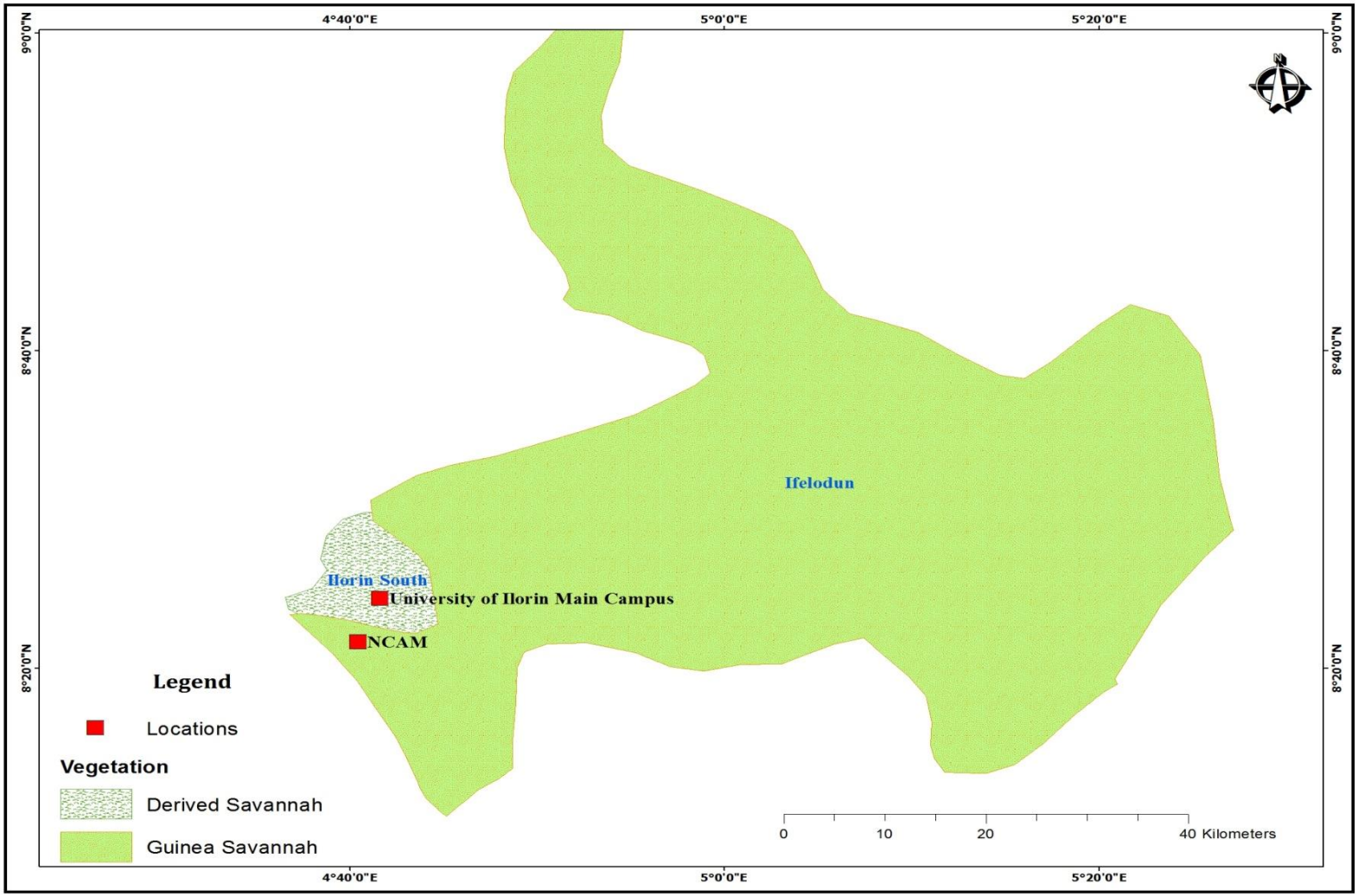


Figure 1.5: Vegetation Map of Ifelodun and Ilorin South Local Government Area
Source: National Space Research and Development Agency (2016)

1.7.4 Geology

The Geology of the University of Ilorin is underlain mainly by the precambian to lower palozoic crystalline basement of granitic and metamorphic rocks, mainly biotite gneiss with lensis and biotiteschots and pregmatite intrusions. NCAM, Idofian falls into undifferentiated basement complex comprising an admixiture of acid crystalline rock-gneisses schists (with biotite and mica) and quartizites. Basic amphibolites and olivine rich dykes are intruded within these formations while granites and grantic rocks occur (Figure 1.6). Apart from exposed iron pans in scattered areas, there are also localized outcrops of basement complex rocks. The percentage of the entire area occupied by the outcrop can be considered as localized impediments to mechanization. However, these outcrops can be effectively utilized in conservation planning as erosion barrier (Ahaneku, 1990).

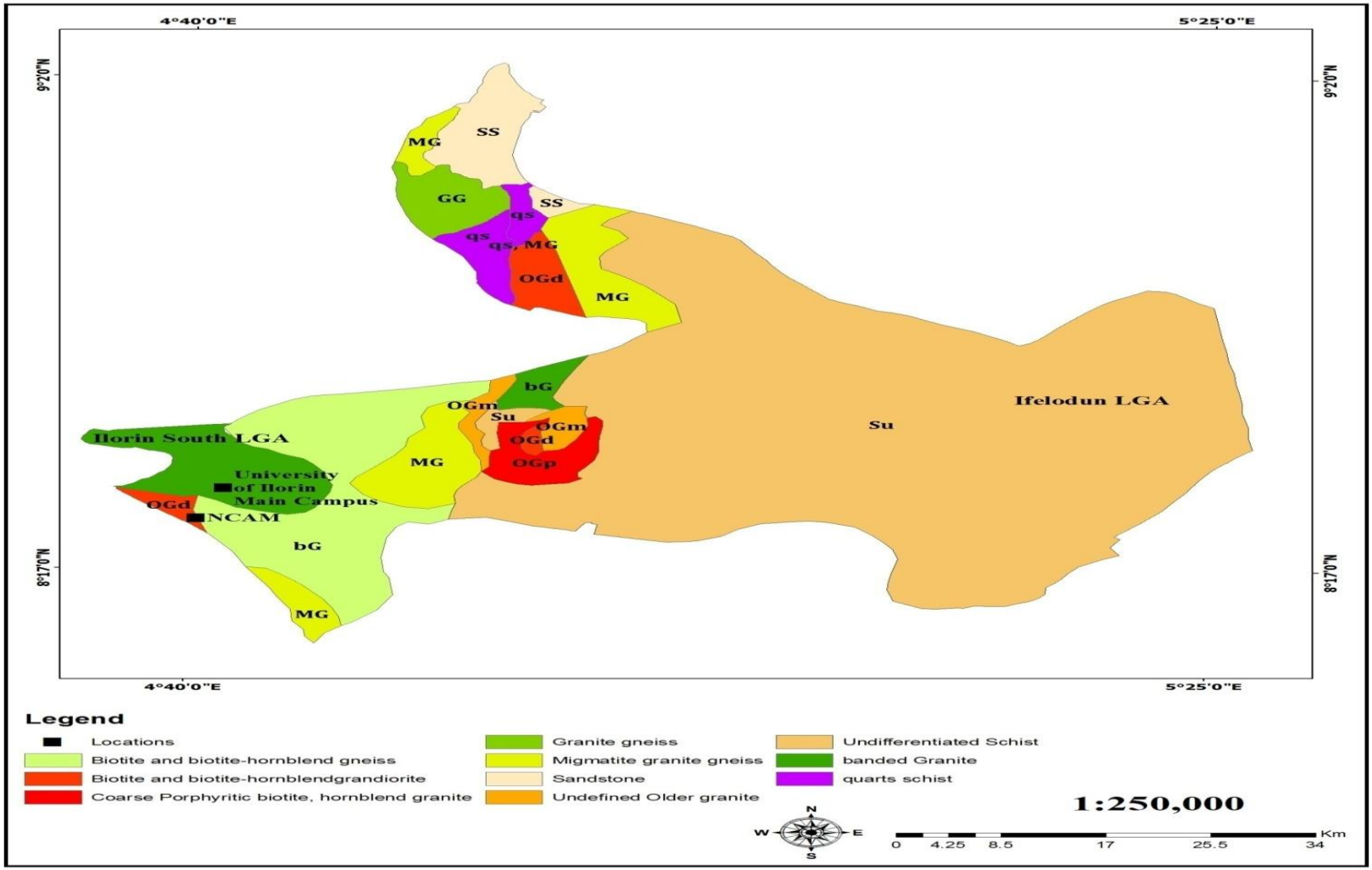


Figure 1.6: Geology Map of Ifelodun Local Government Area

Source: Nigerian Geological Agency, Kaduna State (2016)

1.7.5 Soil

The soil of the University of Ilorin is ferruginous tropical soil while NCAM, Idofian soil is classified as Topic Haplustalf of Eruwa, and Odo-owa series (Figure 1.7). The parent material consists of Micaceousschists and genesis of basement complex origin which are rich in ferro-magnesian minerals. The soil formation is characteristic of the geology of the study area exhibiting Jurassic, pan African and Precambrian tendencies (Ahaneku, 1990). The different properties of soil are texture, moisture, fertility (level of nitrogen, phosphorus, potassium) and pH level. The chemical properties of a soil are usually related to soil fertility such as available nitrogen (N) phosphorus (P) potassium (K), micronutrient uptake of Cu, Zn, Mn, among others, as well as organic matter content (OM) and pH. Soil structural characteristics such as aggregate formation and stability, tilth, and texture are physical properties. The biological properties of a soil unite the soil physical and chemical properties. For instance, fungi and bacteria recycle all the carbon, nitrogen, phosphorus, sulphur and other nutrients in soil OM, including animal residues, into the mineral forms that can be used by plants. (Clapperton and Ryan, 2002).

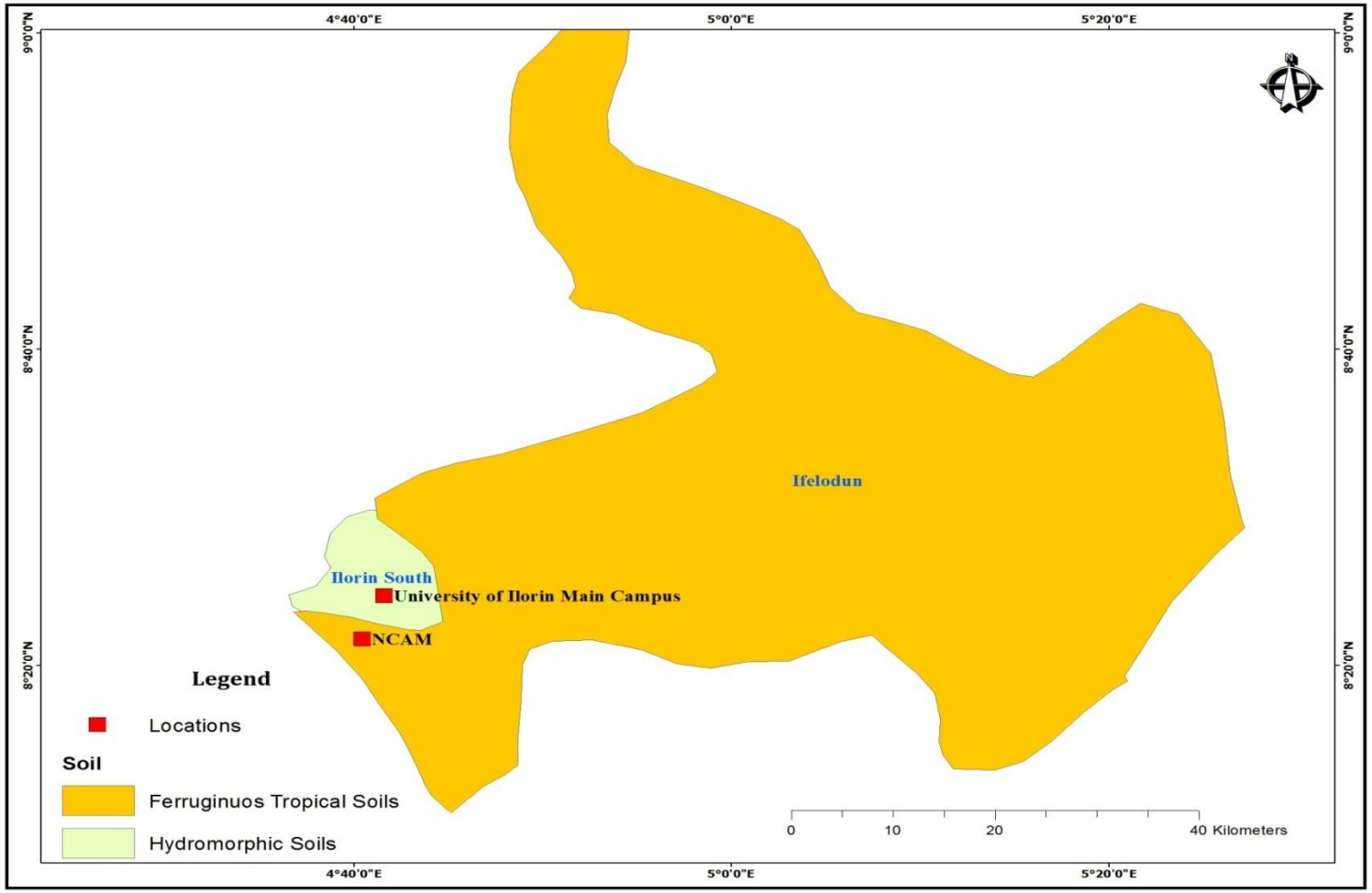


Figure 1.7: Soil Map of Ilorin South and Ifelodun Local Government Area

Source: Nigerian Geological Agency, Kaduna State (2016)

1.7.6 Drainage

The first experimental site located at University of Ilorin Teaching and Research Farm is drained mainly by Oyun River which takes her source cross-sect from Ita-Oregun in Osun State and flow through Otan-Aiyegbaju (also in Osun State) to Offa and finally to Ilorin where it is dammed at the University of Ilorin main campus.The second experimental site which is located in the center of NCAM which forms parts of the lower catchment area of River Oyun that bounds it to the West. The catchment of Oyun River is located between latitudes $9^0$50' and $8^0$24' North and Longitudes 4º38' and 4º03' East. Its total area is 800.0 km2 with a length of 71.4 km and it lies within Kwara State (Figure 1.8).

The drainage pattern of the University of Ilorin Teaching and Research Farm is dendritic pattern with the tributaries joining Oyun and Asa River obliquely. This defines the form of the topography of the study area. The Oyun and Asa Rivers' path mark the topographical lows, while the highest portions are to the east and south- east. Cross section from the east to the west will give a shallow V-shaped topography. The main River that drains the study area joins the Asa River which finally empties its water into the Niger River at Jebba in Niger state (Unilorin Master Plan, 1977).

1.7.7 Population and People

Ifelodun is the largest local government area in Kwara State with an estimated population of about 206,042, an estimated total land area of about 3,435 km2 and a population pressure of 60 persons/sq km (Federal Republic of Nigeria Official Gazette 2009, KWSMI, 2002). Due to the massive size of the Local Government Area and for the purpose of administrative convenience, the Local Government has nine districts and eighteen political wards, these districts are in turn grouped into four (4) development area offices i.e. Omupo, Oro-Ago, Oke-Ode and Igbaja. Ilorin

South Local Government Area, Kwara State has an area of 174 km² and a population of 208,691 with high population density of 1199 person/sq km at the 2006 census (Federal Republic of Nigeria Official Gazette 2009, KWSMI, 2002). The study area however consists of 24 communities

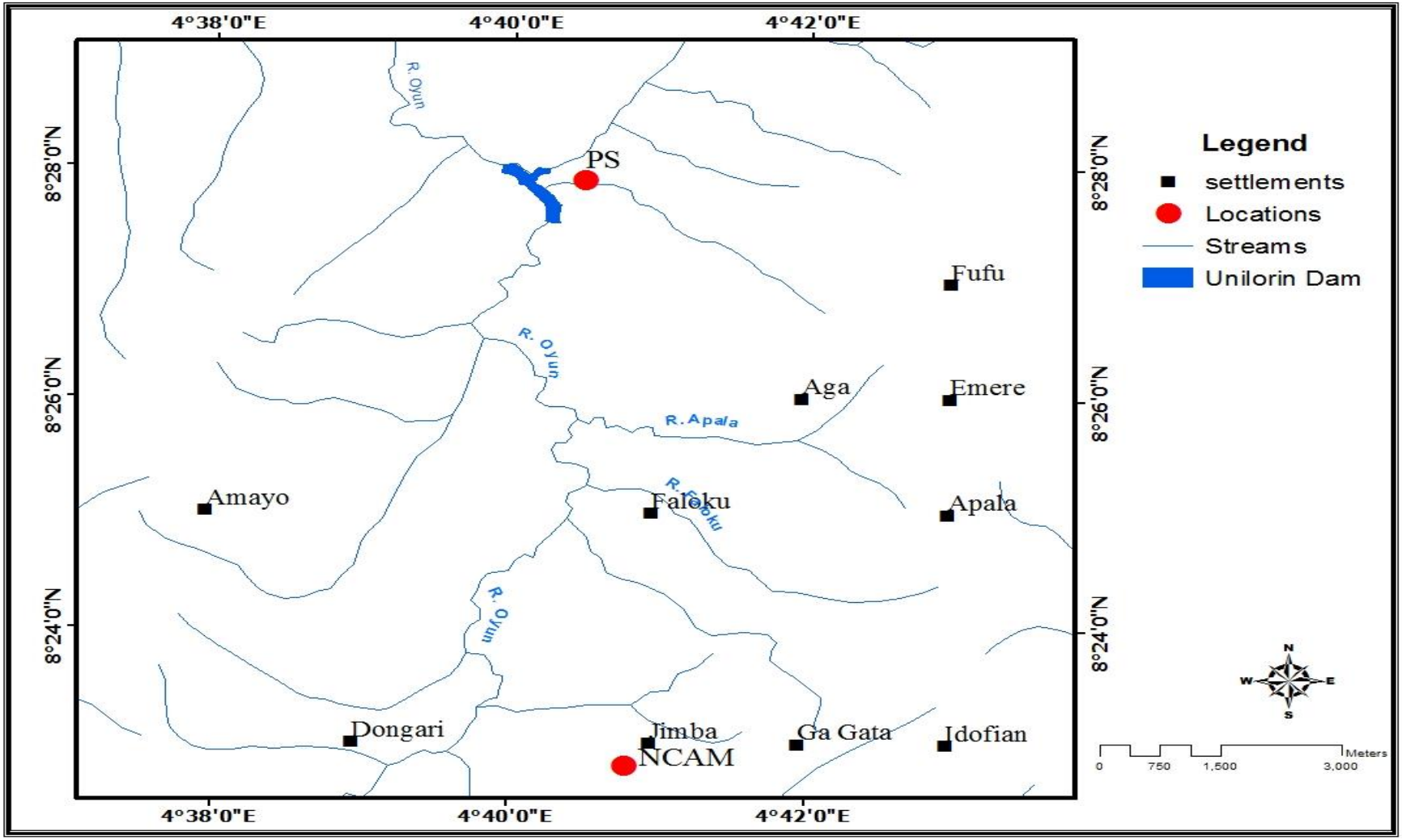


Figure 1.8: Drainage pattern for the Study Area
Source: National Space Research and Development Agency (2016)

1.7.8 Socio Economic Activities

Majority of the people in Ifelodun and Ilorin South Local Government Area practice subsistence farming and petty trading to earn their living. They are small holder farmers comprising of Yoruba, Fulani and Nupe origin and practice a combination of land tenure systems such as individual, rent, communal, lease hold among others. According to Ahmed (2009), food crops that are perennial and annual are produced abundantly. These include: Yam, Cassava, Maize, Rice, Soya beans, Locust-beans and Groundnut. Generally the people are very hospitable, peace-loving, accommodating and famous for their high level of self help development efforts. The popular local industries in the area include: Garri processing, minning, Shea butter processing, trading, commerce, administration, etc

1.7.8 Land Use

The major land use type characterizing both Ifelodun Local Government Area and Ilorin South Local Government Area is agricultural land use (Figure 1.9). The major source of livelihood and occupation of the people in Ifelodun Local Government Area is farming though some other people engage in activities like trading, commerce, administration among others. Farming is traditional in nature with emphasis on the cultivation of crops such as sorghum, cassava, yam, maize and melon (KWSMI, 2002; Ahmed, 2009). The crops commonly grown include cassava, yam, melon, groundnut, sorghum, millet, pepper, tomato, and tree crops such as cocoa, kola, oil palm, mango, guava, citrus among others.

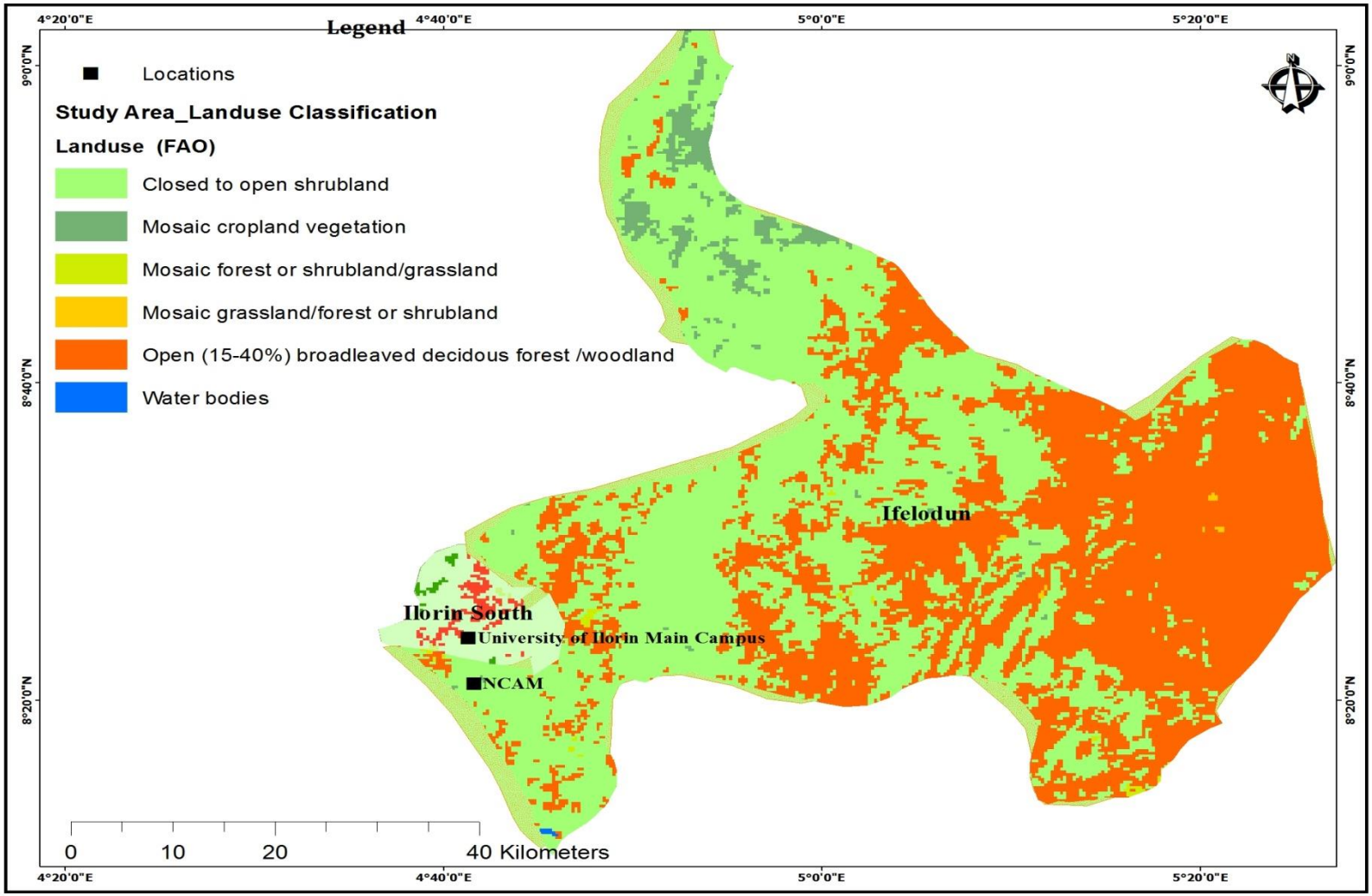


Figure 1.9: Land Use Map of Ilorin South and Ifelodun Local Government Area
Source: USGS Global Landcover Facility (2016)

1.8 Definition of Terms

a. **Tillage:** Tillage is any physical loosening of the soil as carried out in a range of cultivation operations, either by hand or through mechanization (Ahn and Hintze, 1990).

b. **Land resources:** Land resource can be defined or taken to be those components of land units that are of direct economic use for human population living in the area or expected to move to the area in terms of near climatic conditions, soil and terrain conditions, freshwater conditions and vegetation and animal conditions in so far as they provide produce (FAO, 2011).

c. **Water quality**: The quality of water is determined by a lot of attributes which define a good water quality. This attributes define that a good water quality must be tasteless, colorless, odorless and suitable for use (Ayoade, 1988).

d. **Soil quality**: Soil quality is defined as the capacity of a specific kind of soil to function in providing nutrient to the plants as well as the ability to absorb and drain water (Lavelle *et al.*, 2009).

e. **Crop yield**: Crop yield refers to both the measure of the yield of a crop per unit area of land cultivation, and the seed generation of the plant itself (FAO, 2008).

f. **Environmental impacts**: Environmental impact is the possible effect caused by a development, industrial or infrastructural project or by the release of a substance into the environment (MEA, 2005).

g. **Environmental sustainability**: Environmental sustainability is defined as the decision making and the action taking that are in the interests of protecting the natural world, with particular emphasis on preserving the capability of the environment to continuously support human life (MEA, 2005).

h. **Conservation Agriculture:** Conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment (FAO, 2007).

i. **Soil Water Assessment Tool (SWAT)**: SWAT is a basin-scale, continuous-time model that operates on a daily time step and is designed to predict the impact of land management on water, sediment, and agricultural chemical yields in ungauged watersheds (Gassman *et al*., 2007). SWAT is a hydrologic model that makes use of the following components: weather, soil, land use as well as other variables to generate data on surface runoff, return flow, percolation, evapotranspiration, transmission losses, pond and reservoir storage, crop growth and irrigation, groundwater flow, reach routing, nutrient and pesticide load, water transfer, sediment yield amongst a host of other variables.

CHAPTER TWO

CONCEPTUAL ISSUES, THEORETICAL FRAMEWORK, LITERATURE REVIEW AND EMPERICAL STUDIES

2.1 Introduction

Detailed explanation on soil tillage methods and their impacts on land resources cannot be explained and comprehended to the fullest without considering major conceptual issues. This chapter therefore discusses the various concepts, theories that are relevant to this study. It also presents a review of relevant literature.

2.2 Conceptual Issues

2.2.1 Ecosystem

An ecosystem is a dynamic complex of plant, animal, and microorganism communities as well as the non-living environment interacting as a functional unit. The ecosystem is the set of species in a given area that interact among themselves. They interact through processes such as predation, parasitism, competition and symbiosis as well as with their abiotic environment to disintegrate and become part of cycles of energy and nutrients. The species of the ecosystem, including bacteria, fungi, plants and animals are dependent on each other. The relationships between species and their environment facilitate the flow of matter and energy within the ecosystem (Willis, 1997).

According to Rusell *et al*.,(1993), the relevance of the ecosystem concept to geography cannot be overemphasized since it provides not only a means of describing, analyzing and understanding a wide variety of problems in physical geography, but also provides a theoretical framework and approach which can be validly used in human geography. The four fundamental ecological processes of ecosystems are the water cycle, biogeochemical (or nutrient) cycling, energy

flow and community dynamics, i.e. how the composition and structure of an ecosystem changes following a disturbance (succession).

a. Water cycle

The water cycle (Figure 2.1), also known as the hydrologic cycle, describes the continuous movement of water on, above, and below the surface of the earth. Since the water cycle is truly a "cycle," there is no beginning or end. Water can change states among liquid, vapour, and ice at various places in the water cycle (USGS, 1999).

UNEP (1998) reported that through adapted tillage techniques, moisture loss in the soil can be reduced and soil quality and agricultural production can be improved. Soil moisture loss (and also soil degradation) can be minimized through different techniques of soil moisture conservation: soil cover and reforestation, mulching, soil amendments and different tillage techniques. Adapting tillage techniques is a very helpful tool to lower soil moisture loss through evaporation. Conservation tillage and reduced tillage are suitable under most conditions, provided other factors, like slope and rainfall intensity are taken into account in the practices.

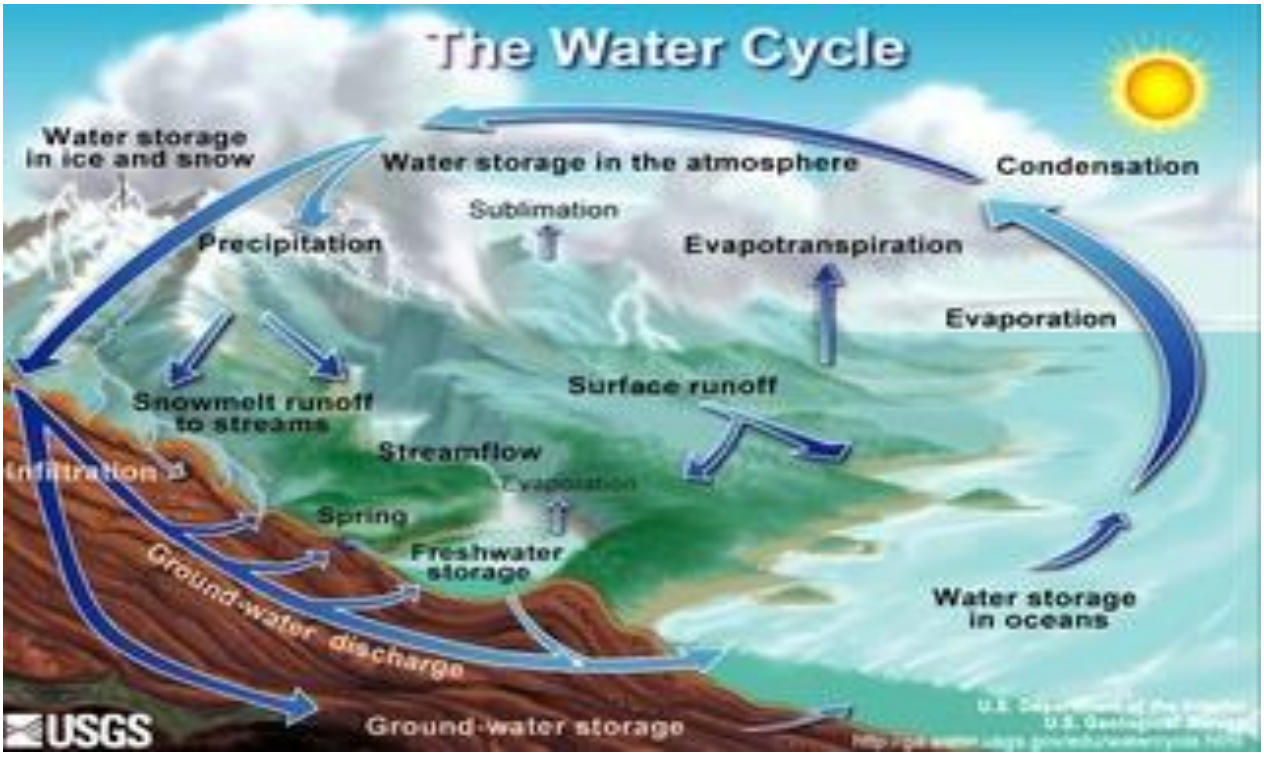


Figure 2.1: The Water cycle
Source: USGS (1999)

b. Nutrient cycle

According to Lavelle *et al.*, (2009), there are at least 16 essential chemical elements for plant growth. Carbon, hydrogen, and oxygen, obtained in large amounts from air and water, make up the bulk of plant dry matter in the products of photosynthesis, but usually are not included as "nutrient" elements. Nitrogen (N), Phosphorus (P), Potassium (K), Calcium (Ca), Magnesium (Mg), Sulfur (S), Iron (Fe), Manganese (Mn), Zinc (Zn), Copper (Cu), Boron (B), Molybdenum (Mo), and Chlorine (Cl) are obtained from the soil and required by all plants. Figure 2.2 shows a basic plant nutrient cycle.

A slightly expanded version of the basic equation for photosynthesis shows how plants use energy from the sun to turn nutrients and carbon into organic compounds:

$CO_2 + PO_4$ (phosphate) + NO_3 (nitrate) + $H_2O \rightarrow CH_2O$, P, N (organic tissue) + O_2

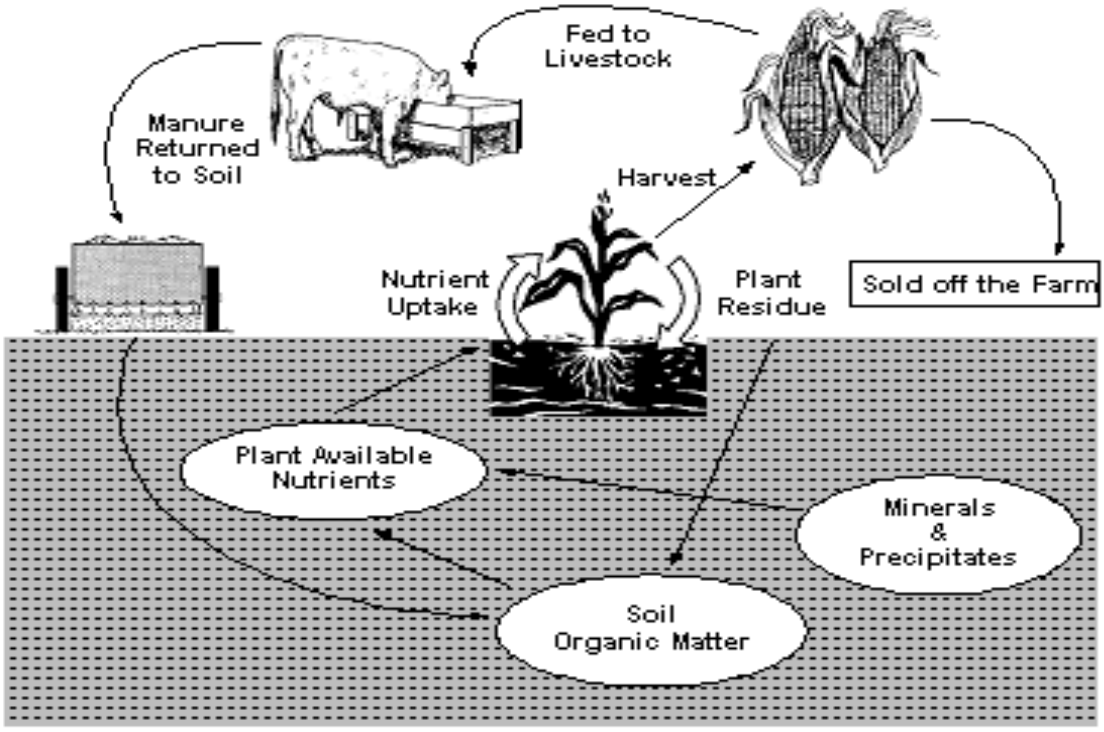


Figure 2.2: Basic plant nutrient cycle
Source: Adopted from Lavelle *et al.*,(2009)

Nitrogen and Phosphorus are two of the most essential mineral nutrients for all types of ecosystems and often limit growth if they are not available in sufficient quantities. This is why the basic ingredients in plant fertilizer are nitrogen, phosphorus, and potassium, commonly abbreviated as NPK.

c. Energy flow

Energy flow in our ecosystems is sometimes referred to as the carbon cycle because carbon is involved in all energy storage and transfer. Energy flow is closely related to the other ecosystem processes— water cycling, mineral cycling, and succession. It drives these activities and make them possible as observed by Wayne and Kauffman (1994.). Figure 2.3 shows how both energy and inorganic nutrients flow through the ecosystem. Energy "flows" through the ecosystem in the form

of carbon-carbon bonds. When respiration occurs, the carbon-carbon bonds are broken and the carbon is combined with oxygen to form carbon dioxide. This process releases the energy, which is either used by the organism or the energy may be lost as heat.

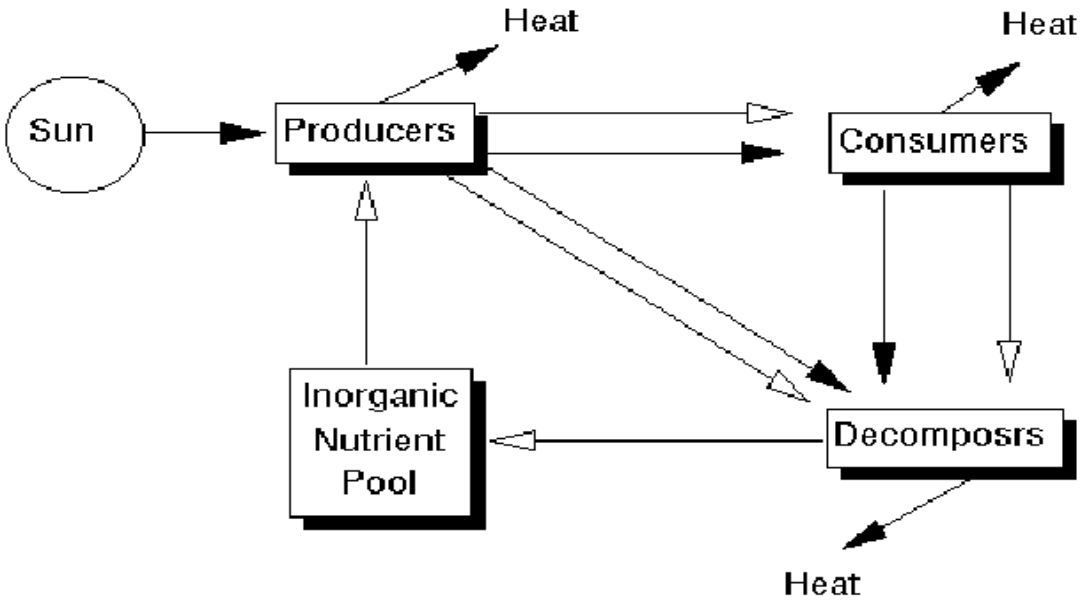


Figure 2.3: Energy and Mineral Movement Model in the Ecosystem
Source: United States Environmental Protection Agency (2012)

d. Community Dynamics

This is how the composition and structure of an ecosystem changes following a disturbance (succession).The process of change is the only constant in all ecosystems. Wayne and Kauffman (1994) described the four processes (water cycle, nutrient cycle, energy flow and community dynamics) of the ecosystem as four different windows through which a room can be viewed. Changes in soil and water qualities are results of human activities one of which is tillage for improved crop yield. In this sense, need for increased yields calls for appropriate tillage methods as well as maintaining optimized conditions for germination, seedling establishment and crop growth.

2.3 Theoretical Framework

2.3.1 Man- environment relationship

A body of theories, or perhaps better called *perceptions*, exists regarding the interactions between human beings and the physical environment. The debate amongst these ideas centers around the role of the environment, i.e whether it is *deterministic*, *irrelevant*, or a matter of *influence* that differs based on a host of mutable factors. Many authors have spent considerable time debating these ideas and defending particular positions. According to Hardesty (1977), there are three traditions of environmental explanation: Environmental determinism, possibilism, and probabilism or cultural ecology.

a. Environmental determinism

Environmental determinism is the idea that the physical surroundings and environments in which people live are responsible for shaping the lives of those that live there. It is based on the brutal idea that individual intelligence level, work ethic and personality depend strongly on geographic location and not on how the individual was raised and/or educated among others (Soeftestad,1989).

b. Environmental possibilism

After determinism came environmental possibilism, which is a way of looking at the relationship between people and their environments. The concept of possibilism is based on the idea that the environment has an effect on people (though not as much as determinists believe) but in turn people also affect the environment. Possibilism or "Cultural determinism" are two related notions. Cultural determinism is the stronger of the two, in essence, a rejection of the environment as a controlling influence. It claims that cultures are the result of human agency and action, and that the environment is largely a non-issue. Possibilism gives more credence to the environmental role,

seeing it more from the position of sizeable influencer. The most visible and common examples in this regard are, Industrial Revolution, Agricultural Advancement and Technological revolution.

1. **Industrial Revolution:**

Industrial revolution which began in the 18th century in Great Britain changed the way of living of the people. It was not a one night phenomenon but was a result of series of inventions. It originated in Great Britain in 1750 and from there, it spread in North America and Europe in 19th and the remaining world in 20th century. The invention of steam engine gave a boost to the iron and textile industries for instance. The industrial sectors now have a share of more than thirty percent in the world's GDP.

2. **Agricultural Advancement:**

The Green revolution, Invention of fertilizers and pesticides, mechanization, tillage, the modern irrigation methods and the organic farming methods have also contributed to the high output of crops and other products related to agriculture to meet the high food demands across the world. All these efforts were done by humans to meet their increased demands indicating the influence of Possibilism.

All people depend on the services supplied by ecosystems, either directly or indirectly. Services are delivered both by ''near-natural'' ecosystems, such as rangelands, oceans, and forests, and by highly managed ecosystems such as cultivated or urban landscapes (Amir and Theodor, 2012). Ecosystem services are "the benefits people obtain from ecosystems. These include provisioning services such as food and water; regulating services such as regulation of floods, drought, land degradation, and disease; supporting services such as soil formation and nutrient cycling; and cultural services such as recreational, spiritual, religious, and other nonmaterial

benefits. The Millennium Ecosystem Assessment (2005) submitted some of the factors leading to changes in our ecosystem as a result of man-environment interaction are:

- **Increasing Demand for Ecosystem Services**: Increasing consumption per person, multiplied by a growing human population, are the root causes of the increasing demand for ecosystem services. The human population increased from 3 billion to 6 billion between 1960 and 2000 and is likely to peak at 8.2–9.7 billion around the middle of the twenty-first century. Overall demand for food, fiber, and water continue to rise. Improvements in human well-being, enabled by economic growth, almost invariably lead to an increase in the per capita demand for provisioning ecosystem services such as food, fiber, and water and in the consumption of energy and minerals and the production of waste. (MEA 2005).
- **Increasing Pollution and Waste*:*** Ecosystem problems associated with contaminants and wastes are in general growing. Some wastes are produced in nearly direct proportion to population size (such as sewage). Others, such as domestic trash and home-use chemicals, reflect the affluence of society. The neglect of waste management leads to impairment of human health and wellbeing, economic losses, aesthetic value losses, and damages to biodiversity and ecosystem function.

  The oversupply of nutrients (eutrophication) is an increasingly widespread cause of undesirable ecosystem change, particularly in rivers, lakes, and coastal systems. Nutrient additions on the land, including synthetic fertilizers, animal manures, the enhancement of N-fixation by planted legumes, and the deposition of airborne pollutants, have resulted in approximately a doubling of the natural inputs for reactive nitrogen in terrestrial ecosystems and an almost fivefold increase in phosphorus accumulation. The reduction of biodiversity at the species and landscape levels has permitted nutrients to leak from the soil into rivers,

oceans, and the atmosphere. Emissions to the atmosphere are a significant driver of regional air pollution and the buildup of the greenhouse gas nitrous oxide.

- **Changing Climate:** The effects of climate change on ecosystems are becoming apparent, especially in polar regions, where the average temperatures are now warmer than at any time in the last 400 years and the Antarctic peninsula is one of the most rapidly warming regions on the planet. In the mountains, there has been widespread glacier retreat and loss of snowpack as well as in the coastal systems, where coral reefs in particular have been affected by sea temperature warming and increased carbon dioxide concentrations. Climate change over the next century is projected to affect, directly and indirectly, all aspects of ecosystem (IPCC, 2007).
- **Overexploitation of Natural Resources:** If a renewable natural resource is used at a faster rate than it is replenished, the result is a decline in the stock and eventually a decrease in the quantity of the resource that is available for human use. Overfishing, overgrazing, and over logging are widespread examples of overexploitation. Significant areas of forest, cultivated land, dryland rangelands, and coastal and marine systems are now degraded, and the degraded area continues to expand.
- **Changing Land Use and Land Cover:** Current rates of land cover change are greatest for tropical moist forests and for temperate, tropical, and flooded grasslands, with 14% of each of these lost between 1950 and 1990. Mediterranean forests and grasslands had already lost more than 70% of their original extent by 1950. The rates of loss in these forest types have now slowed, and in some cases the forest area has expanded. Deforestation and forest degradation are currently focused in the tropics. Habitat loss is the fastest-growing threat to species and populations on land and will continue to be the dominant factor for the next few

decades. Habitat fragmentation (the reduction of natural cover into smaller and more disconnected patches) compounds the effects of habitat loss. The disruptive effects of fragmentation extend hundreds of meters inwards from the edges of the patches, making small patches highly vulnerable to loss of species and functions.

3. **Technological Revolution:**

Technological Invention through fertilizer and pesticide, mechanization, tillage, modern irrigation methods and the organic farming methods have contributed to the high output of crops and other products related to agriculture to meet the high food demands across the world. All these efforts were carried out by humans to meet their increased demands indicating the influence of Possibilism. These revolutions have helped humans to make their lives easy, comfortable and have clearly show that human activities affect the natural environment.

c. Environmental probabilism

Probabilism or "cultural ecology" is rightly seen as a more open-ended treatment of the possibility. It is with the view that sometimes the environment is a key influence, while at other times human actions are more influential. Often tied to this discussion, is the notion of cost-benefit analysis of any human action with relationship to the environment (Willis, 1997).

The Millennium Ecosystem Assessment (MEA, 2005) reported that earlier attempts at intensification of agricultural production have allowed output to keep up with global demand. However, these have also created problems of sustainability such as decrease in soil health including excessive soil nutrient mining, increase in soil erosion, excessive water use, decline and degradation of biodiversity, the impact on the environment of the overuse and inefficient use of fertilizer especially pesticides, leading to pest resistance and pest outbreaks.

2.3.2 Farming paradigm

In 1962, Thomas Kuhn wrote “The Structure of Scientific Revolution”, defined and popularized the concept of "paradigm shift". Kuhn argued that scientific advancement is not evolutionary, but rather a "series of peaceful interludes punctuated by intellectually violent revolutions", and in those revolutions "one conceptual world view is replaced by another"(Kuhn, 1962).The situation has been exacerbated by the fact that the quality and direction of the dominant, tillage-based, agricultural production systems world-wide, and the agricultural supply chains that support them, have moved dangerously off course onto a path of declining productivity and increasing negative externalities (MEA, 2005).

Amir and Theodor (2012) proposed two farming paradigms operating and both of which are aspiring to sustainability.

(a) Interventionist paradigm: The tillage-based farming systems, including intensive tillage with inversion ploughing during the last century. It aims at modifying soil structure to create a clean seed bed for planting seeds and to bury weeds or incorporate residues. In this situation, most aspects of crop production are controlled by technological interventions such as soil tilling, use of improved varieties, protective or curative pest, pathogen and weed control approaches with agrochemicals, and the application of mineral fertilizers for plant nutrition.

(b) Agro-Ecological Paradigm: The no-tillage farming systems, since the forties or so, allow for a predominant ecosystem approach and can be productive as well as ecologically sustainable. This is characterized by minimal disturbance of the soil and the natural environment, use of traditional or improved adapted varieties, plant nutrition from a mix of organic and non-organic sources including biological nitrogen fixation, an integrated approach to pest management leaving curative pesticides as a last resort, and the use of both natural and managed biodiversity

to produce food, raw materials and other ecosystem services. Crop production based on an ecosystem or agro-ecological approach can sustain the health of farmland already in use, and can regenerate land left in poor condition by past misuse.

The new paradigms of "sustainable production intensification" recognize the need for a productive and remunerative agriculture which at the same time conserves and enhances the natural resource base and environment. Consequently, it contributes positively to harnessing the environmental services. (Derpsch *et al.,* (2010)**.** A set of soil crop- nutrient-water-landscape system management practices known as conservative agriculture (CA), delivers on all of these goals. Attention to soil health and good soil system management is critical and this message was highlighted in an international Technical Workshop held at Food Agriculture Organization (FAO) headquarters in July 2008 entitled: "Investing in Sustainable Crop Intensification: The Case for Improving Soil Health"(FAO, 2008). Conservation Agriculture represents a practical concept to achieve improved soil health and better soil-crop-nutrient-water management leading to ecologically and economically sustainable agriculture.

2.4 Literature Review

2.4.1 Conservation agriculture

Conservation agriculture is a concept for resource-saving agricultural crop production that strives to achieve acceptable profits together with high and sustained production levels while concurrently conserving the environment according to FAO (2007). Conservation agriculture (CA) was proposed as a panacea to agricultural problems in smallholder farming systems in the tropics (Derpsch, 2003). It is based on enhancing natural biological processes above and below the ground. Intervention such as mechanical soil tillage is reduced to an absolute minimum, and the use of

external inputs such as agrochemicals and nutrients of mineral or organic origin are applied at an optimum dose. It specifically aims to address the problems of soil degradation resulting from agricultural practices that deplete the organic matter and nutrient content of the soil. It is therefore a method that can prevent further destruction of precious soils while increasing rainwater use efficiency and labour productivity, thereby ensuring higher and more stable yields at low production cost as observed by the African Conservation Tillage Network (2008).

The three principles of conservation agriculture are:

i. No mechanical soil disturbance or no tillage
ii. Permanent soil cover, especially by crop residues and cover crops and
iii. Crop rotation.

Derpsch (2003) submitted that conservation agriculture

a) provides and maintain an optimum condition of the root-zone to maximum possible depth for crop roots to function most effectively and without hindrance, in capturing high amounts of desired plant nutrients and water,
b) ensure that water enters the soil so that plants never, or for the shortest time possible, suffer water stress that will limit the expression of their potential growth.
c) Ensure that residual water passes down to groundwater and stream flow, not over the surface as runoff.
d) favour beneficial biological activity in the soil in order to maintain and rebuild soil architecture; compete with potential in-soil pathogens; contribute to soil organic matter and various grades of humus; contribute to capture, retention, chelation and slow release of plant nutrients and avoid physical or chemical damage to roots that disrupts their effective functioning.

2.4.2 Tillage

Tillage is the agricultural preparation of the soil by mechanical, draught-animal or human-powered agitation, such as ploughing, digging, overturning, shovelling, hoeing and raking. The term tillage used broadly, embraces all operations of seedbed preparations that optimize soil and environmental conditions for seed germination, seedling establishment and crop growth. Tillage includes mechanical methods based on conventional technologies of ploughing and harrowing, weed control using herbicides and fallowing with cover crops controlled by direct seeding through its residue mulch according to Ohu (2011).

According to Unger (1984), the choice of a tillage practice will depend on one or more of the following factors for any given location:

i. Soil factors which includes relief (slope), erodibility, erosivity, rooting depth|, texture and structure, organic-matter content and mineralogy.
ii. Climatic factors such as rainfall amount and distribution, water balance, length of growing season, temperature (ambient and soil) and length of dry spell period.
iii. Crop factors which include growing duration, rooting characteristics, water requirements and seed.
iv. Socio-economic factors such as farm size, availability of a power source, family structure and composition, labour situation and access to cash and credit facilities.

2.4.3 Types of Tillage Systems

There are two main types of tillage systems: conventional tillage and conservation tillage.

a. Conventional tillage

Conventional tillage is a tillage system using cultivation as the major means of seedbed preparation and weed control. It is defined as any tillage and planting system that leaves less than 15

percent residue cover after planting or less than 560 kilograms per hectare of small grain residue equivalent throughout the critical wind erosion period as proposed by CTIC (2004). It includes systems such as:

- Mechanized tillage: This involves the mechanical soil manipulation of an entire field, by ploughing followed by one or more harrowing. The degree of soil disturbance depends on the type of implement used, soil and intended crop type.
- Traditional tillage: In the humid and sub-humid regions of West Africa, and in some parts of South America, traditional tillage is practiced mostly by manual labour. It uses native tools which are generally few and simple, the most important are the cutlass and hoe which come in many designs depending on function. To facilitate seedbed preparation and planting, forest undergrowth or grass is cleared with a cutlass and trees while shrubs are left, but pruned. The cut biomass and residues are disposed of by burning in situ. This type of clearing is non-exhaustive, leaving both appreciable cover on the soil, and the root system which gives the topsoil structural stability for one or two years as observed by Aina et al;(1993).

b. Conservation tillage

Conservation tillage (CT) is defined as any tillage and planting system that covers 30 percent or more of the soil surface with crop residue after planting, to reduce soil erosion by water (CTIC, 2004). There are many variations of conservation tillage systems covering abroad spectrum of farming methods primarily aimed at reducing soil disturbance, conserving and managing crop residue to reduce erosion. Ohu (2011) divided conservation tillage practices into the following categories:

i. No-tillage: No-tillage system refers to a method of planting crops in previously unprepared soil by opening a narrow slot, trench, or band only of sufficient width to obtain proper seed coverage. In this system, the soil is left undisturbed from harvest to planting except for nutrient injection.

ii. Ridge tillage: Ridge-tillage is a method of preparing the seedbed and planting on a preformed ridge. It is a form of conservation tillage that uses sweeps, disk openers, coulters or row cleaners to maintain permanent ridges on which row crops are grown. The ridges are usually 10 to 15 centimeters higher than the middle row. The soil for making the ridges is derived from the area between the rows. The practice is intended for the production of row crops like corn, soybeans, cotton, sorghum, and sunflower. After harvest, crop residue is left until planting time.

iii. Strip tillage: Strip tillage or zone tillage is a method of preparing a seedbed on a strip *2.5 to 30cms* wide and 2.5 to 20cms deep. It also refers to the practice of tilling a narrow strip of soil where the seed is sown into the strip of tilled soil. However, the soil between the sown rows remains undisturbed. Strip-tillage is a modified form of no-tillage and it incorporates subsoil shanks with fluted coulters and crumbling baskets and offers the combination of deep tillage. In this system, a uniform seedbed is produced and difficulties associated with transplanting into established sod, as in no-tillage, are minimized.

iv. Mulch tillage: Mulch is dead plant material such as dry grass, straw, maize stalks, corn stalks, dry leaves, banana leaves, sugar-cane trash and other crop residues that can be spread on a soil surface or placed around stems. Mulch tillage is a tillage system in which a significant amount of crop residue is left on the soil surface to reduce wind and water erosion. In this system, the soil surface is disturbed with tools such as chisels, field

cultivators, disks, and sweeps prior to planting. Weed control is in most cases accomplished with herbicides. Mulching creates a more favourable- environment for the macro fauna, which modify the soil by creating pores, thereby increasing their capacity and soil permeability.

2.4.4 Effect of Tillage on Soil Quality

Soil quality is simply defined as "the capacity of a specific kind of soil to function", i.e. mainly to provide nutrition to plants as well as absorb and drain water (USDA, 1996). It can be referred to as the attributes that characterize a particular soil. Important soil attributes are texture, structure, bulk density and rooting depth, permeability and water storage capacity, carbon content, organic matter and biological activity, pH, and electrical conductivity (National Research Council, 1993). Tilling has a long history and is beneficial because it disrupts compacted areas, aerates and loosens the soil. The mixing of nutrients and organic matter promotes micro-organisms and worms which in turn maintain soil fertility. Soil quality can be maintained or enhanced through the use of appropriate crop production technologies and related resource management systems. Inappropriate farming practices, on the other hand, can lead to soil degradation, loss of topsoil through erosion; loss of organic matter through oxidation; soil compaction; acidification; loss of nitrates, phosphorous, and pesticides; and accumulation of salts and trace elements. Inappropriate practices can also increase runoff of fertilizers and pesticides to surface and groundwater systems.

Most commonly, modern conventional tillage involves repeated tillage operations . A typical primary operation, using a mouldboard, turns the top soil over to a depth of 25 cm. This method cuts through and fragments the bulk soil, and buries crop residues and pest weeds. The organic matter content of the soil is briefly increased by the inversion of the soil but ultimately the decomposition of the organic matter is hastened due to an acute but relatively brief increase in microbiological

activity (Stockfisch *et al.*, 1999). The secondary operations involve disks and harrows and have the purpose of further fragmentation of the soil to obtain a desired aggregate size to create a good seed-to-soil contact for fast and uniform seed germination (Hadas, 2004).

Stratification of soil organic matter and differences in nutrient distribution has also been observed in long-term conservation tillage systems. Thus, altered soil physical and chemical conditions under conservation tillage create significantly different habitats for microorganisms and result in shifts of soil microbial community structure (Reji *et al.*, 2012). By modifying the soil structure, it changes water infiltration, the air and water dynamics that control microbial activity. Tillage affects the amount of residue on the surface which changes soil temperature and water content.

Deterioration of land resources or productivity occur when there is loss of organic matter and physical degradation of the soil, such as when forests are cleared and soil structure declines rapidly. Also, nutrient depletion and chemical degradation of the soil may occur due to misuse of land resources. Globally, only half of the nutrients that crops take from the soil are replaced, with nutrient depletion in many Asian countries equivalent to 50 kg/ha annually (Sheldrick *et al*., 2002). In some Eastern and Southern African countries, annual depletion of nitrogen, phosphorus and potassium is estimated at 47 kg/ha of nitrogen, 6 kg/ha of phosphorus, and 37 kg/ha of potassium. (Sheldrick *et al*., 2002). Rockwood and Lal (1974) observed that biological (for example, earthworm) activity was stimulated by more favourable water and temperature regimes in no-tillage plots than in conventionally tilled plots. As many as 2400 earthworm casts per square metre were counted in no-tillage plots, compared with fewer than 100 casts per square metre for the ploughed plots.

Gbadamosi (2013) considered the impact of different tillage practices on soil moisture content, soil bulk density and soil penetration resistance and the study revealed that there are significant differences between the tillage treatment and among soil moisture content (SMC), soil bulk density (SBD) and soil penetration resistance (SPR). SMC had highest value of 21.67% with the least value of 14.67% obtained for MDD (moldboard plow followed by two passes of disk harrow (MDD) as conventional tillage,) and NT(non- tillage area) respectively. However, SBD values were highest (1.82gcm-3) and lowest (1.67 gcm-3) for NT and MDD treatments. The SPR value was favoured at NT (1123kPa) with the least value of 490kPa for MDD. Lal (1985) reported that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanized farming and twelve crops of maize, while the decline in the soil properties was decidedly less in the no-tillage watershed. The lower maize yields of the ploughed watershed are related to erosion, compaction, fall in organic matter content and fall in pH.

According to Busari *et al.,* (2015), effects of conservation tillage on soil properties vary, and these variations depend on the particular system chosen. No-till (NT) systems, which maintain high surface soil coverage, have resulted in significant change in soil properties, especially in the upper few centimeters. Jacobs, Rauber, and Ludwig as citied in Busari *et al.,* (2015) found that minimum tillage (MT), compared with Conservative Tillage (CT), did not only improve aggregate stability but also increased the concentrations of Soil Organic Carbon(SOC) and Nitrogen(N) within the aggregates in the upper 5–8 cm soil depth after 37–40 years of tillage treatments. In terms of water conservation, No-Tillage has been found to be more effective in humid and sub-humid tropics. Kargas *et al.,* (2012) as citied in Busari *et al.,* (2015) observed that untilled plots retain more water than tilled plots. In comparison with conventional ploughing, minimum tillage improved the soil pore system by increasing the storage pores (0.5–50 mm) and the amount of the elongated

transmission pores (50–500 mm). They related the higher microporosity in minimum tillage soils to an increase of water content in soil and consequently, to an increase of available water for plants. Higher water holding capacity or moisture content has been found in the topsoil (0–10 cm) under NT than after ploughing. Therefore, to improve soil water storage and increase water use efficiency (WUE) most researchers have proposed replacement of traditional tillage with conservation tillage (Busari *et al.,* 2015)

Aina (2011) in his review of tillage systems applied in crop production concluded that conservation tillage in its many and varied forms, holds promise for the sustainability of agricultural productivity and the environment by reducing production costs, preserving soil quality, reducing herbicide and weeding labour input costs as well as greenhouse gas emissions. Although the adoption in Nigeria is currently low, projections indicate largely unexplored potential for conservation tillage production system in the country. Also, Aina (2011) reported that substantial work has been carried out to develop technologies that can reverse or prevent land degradation and sustain productivity by several authors. Some of the technologies which have been tested are Mulching, Cover cropping, Intercropping, Alley cropping, Ridging or Tied ridging, Conservation tillage, Planted fallows and Natural Fallows. Several studies as cited by Aina (2011) in Nigeria have shown that no-tillage system with crop residue mulch can maintain productivity of upland soils by reducing erosion, maintain a favourable soil temperature, improve water retention capacity, improve water use efficiency and; increase nutrient efficiency.

2.4.5 Effect of Tillage on Surface Runoff

The soil tillage systems can have considerable impact on the environment through its influences on soil structure which substantially affect water quality, nutrient availability, crop yield, sediments, pesticides, air quality and greenhouse effect. These effects of soil structure on

agricultural production can be felt at different scales ranging from local; soil productivity and sustainability, to regional; water quality and landscape to global; global water, energy balance and greenhouse effect (Hobbs, 2004 and Derpsch, 2007).

Non-point or diffused pollutants are applied to a river or lake through a number of points or locations whereas point source pollutant contamination can be traced to specific points of discharge from waste water treatment plants and factories or from sewers. Drainage water from agricultural land is a major example of non-point source pollutant. The major agricultural non point solution (NPS) pollutants that result from these activities are sediment, nutrients, pathogens, pesticides, and salts. The National Water Quality Inventory according to EPA (2012) reported that agricultural nonpoint source (NPS) pollution is the leading source of water quality impacts to surveyed rivers and lakes, the third largest source of impairments to surveyed estuaries, and also a major contributor to ground water contamination and wetlands degradation. Tillage systems influence physical, chemical, and biological properties of soil and have a major impact on soil productivity and water quality at large.

Agricultural practices cause more water pollution than any other single source (Gliessman, 1998). Runoff from farms can contain sediment, pesticides, and fertilizers as well as animal waste products. Agricultural nutrient pollution is the leading cause of decreased water quality in lakes and estuaries, and agricultural fertilizers are the dominant source of nutrient pollution in the Southeast (ERS, 1997). Most crops remove more nitrogen from the soil than any other nutrient so more nitrogen is applied as fertilizer. About 50% of the nitrogen fertilizer applied to crops is not taken up by the plant and remains as residue in the fields. These residues are carried by runoff and easily leach into groundwater especially when fields are irrigated (Hallberg, 1986).

Agricultural practices have been increasingly criticized for contributing to the deterioration of the nation's water resources. Nonpoint sources of nutrients, primarily in runoff from agricultural lands, are thought to be a major factor promoting accelerated eutrophication of lakes and streams. Nitrogen (N) and Phosphorus (P) concentrations of water leaving the land application sites are of great concern since high levels of these nutrients in surface and ground water are unacceptable for human consumption according to Mostaghimi *et al*., (1988). The Chesapeake Bay study indicated that agricultural nonpoint sources contribute nearly 67 percent of the N and 39 percent of the P entering the Bay each year (U.S. EPA 1983). Also, It has been estimated that agriculture is responsible for 75% of the sediment in watercourses, (Anthony and Collin, 2006) although a study on the river Sem suggests that only about 25% of silt comes from agricultural top soils, with some 18% from road verges and the majority coming from channel banks and subsurface sources (ECSFDI, 2008).

Typically, runoff water contains sediment, dissolved nutrients, and possibly some chemicals from conventional tillage methods. Conservation tillage reduces water runoff, thereby increasing infiltration of water into the soil. Improved surface water quality is one immediate and obvious result of conservation tillage. Agricultural runoff may result in stimulation and excessive growth of algae and other aquatic vegetation, causing severe water quality problems. Overgrowth of algae, in particular, causes taste and odor problems for drinking water supplies and oxygen depletion that may kill fish. Sediment from cropland erosion may also increase the turbidity (cloudiness) of water, impairing fisheries (Devlin and Barnes (2009).

According to Devlin and Barnes (2009), Contaminants leave fields in both the water and the sediment portion of runoff. Many pesticides, i.e. atrazine, herbicide, and soluble nutrients leave primarily with the water and not with the sediment. Overtime, conservation tillage systems change

the soil's physical properties, such as the development of macropores. Macrospores allow larger quantities of water to rapidly infiltrate the soil, increasing the possibility of leaching. Several studies have monitored the movement of nitrogen (nitrate form) through no-till and moldboard plowed fields. Data indicate that in some cases, nitrogen does move deeper into the soil in no-till fields; other studies show the reverse. Even if nitrogen moves deeper into the soil, it may not enter ground water. The fate of chemicals deep in the soil profile is poorly understood. (Derpsch, 2007).

Polluted water containing sediments and parasites is very expensive to be treated to the desired standard for any household or even industrial application. This can also be coupled with the financial implications of eradicating the associated diseases. In turn, children and new born babies are mostly affected by these severities, as can be seen from the high infant mortality rate in the country. The adults are also not an exception as they suffer from associated "killer-poverty", especially in the northern region. For full and effective malaria eradication up to N880 millions are required per year. This Figure represents about 12.0% of the Gross Domestic Product (GDP). Malaria burden alone is therefore enormous and devastating enough to cripple economic growth (Jimoh *et al*., 2007). Water related diseases are the most common causes of illness and death, affecting mainly poor inhabitants in the local communities. Several cases have been reported. In October 2010, 29,115 cases involving 1,191 deaths of cholera was reported in 15 of the 36 states including Federal Capital Territory, Abuja. It was observed that the outbreak is still in existence in new areas due to continuous water pollution (Galadima *et al.*, 2011).

Drainage water from conventional tillage watersheds are usually brown in colour and carry a lot of sediments. However, watersheds in areas of Brazil that have adopted no-tillage have been found to drain clear water even in times of heavy rainfall. Turbidity and siltation levels are increased in areas where conventional tillage practices still occur during various water quality sampling and

habitat assessment events. The implication is that adoption of conservation tillage practices is likely to reduce the loading of fine clay particulates and surface erosion materials that are delivered to adjacent waterways. Therefore, perhaps the biggest water quality benefit from conservation production systems is the resulting reduction sediment loss through soil erosion and runoff (Philps *et al*., 1980).

Angle *et al.,* (1984) contrasted surface water runoff sediment and nutrient losses from conventional and no till corn fields in the Maryland coastal plain hypsographic province. The results showed that no till corn field produced more runoff and nutrient in April than the conventional tilled field, but less suspended sediment, suggesting two mechanisms: enhanced infiltration of the plowed fields and increased nutrient availability of broad cast fertilized no till fields. Research on quantifying the effects of different tillage operations on runoff and erosion were also conducted by Lal (1984) and he recorded that soil loss was 42 times higher from the plowed watershed (5.5 t ha-1) than from the no-till watershed (0.1 t ha-1).

Romkens *et al.,* (1973) used a rainfall simulator to compare the N and P composition in runoff water and sediment 'from five tillage systems. They observed from the study that the coulter and chisel systems reduced soil losses, but the surface application of fertilizer on these plots resulted in high concentrations of soluble and sediment-bound N and P and the greatest soluble N and P yields. Disk and till systems were less effective in controlling soil erosion, but had lower concentrations of N and P in runoff. They concluded that Conventional tillage under which the fertilizers were plowed under, had the highest losses of soil, runoff, and sediment-bound nutrients but lower losses of soluble N and P.

Mostaghimi *et al.,* (1988) in his work "Tillage Effects on Runoff Water Quality from Sludge-Amended Soils" submitted that No-till reduced soil loss and runoff by 73 and 54 percent,

respectively, relative to conventional tillage. Surface application of sludge reduced runoff volume by 25 percent relative to the incorporated treatments. They concluded that no-till was effective in reducing sediment, runoff, and nutrient yields, thereby reducing potential nonpoint source pollution problems from cropland.

2.4.6 Effect of Tillage on Crop Yield

Many studies have investigated the effect of soil tillage on crop yields, however the results are often contradictory owing to different soils and crops and using different tillage intensities. Some authors reported sustained or increased crop productivity in conservation tillage, but usually a negative yield impact was observed depending on the duration and extent to which the conservation tillage is enacted, crop type, as well as on the climate region. The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice.

According to Cook and Trlica (2016), Corn-yield reductions during the first several years after conversion to Notill from conventional tillage have been noted particularly on poorly drained soils, in Continuous Corn rotations, on certain soil types (e.g., high Organic Matter, fine texture), and in colder, wetter, and more northernly climates . However, other Notill studies have shown no distinct effect of tillage on yield and even a yield advantage in certain years indicating that relative crop performance under Notill may depend on environmental and management interactions.

Agbede *et al.,* (2008) reported that compared with zero tillage methods, mechanized tillage methods caused reduction in plant height, leaf area, stalk girth, dry matter and grain yield and also gave lower N, P, k, Ca and Mg content of the plant. Growth and yield parameters reduced with increased implement pass. Hence, Grain yield was reduced by 11 to 25% as a result of mechanized tillage which was not favourable to performance of sorghum.

According to Opara-Nadi (1999), earlier studies on the effects of mechanized tillage systems on maize yield showed that maize grain yields for six consecutive years were higher on no-till than on ploughed plots . At the end of six years in 1999, no-till plots yielded 3 times the ploughed plots (3 t $ha^{-1}a^{-1}$ and 1 t $ha^{-1}a^{-1}$ respectively); however, maize yields declined from 1998 in both plots.

Odjugo (2008) concluded that soil moisture at 0 - 15 cm depth was significantly higher in zero tillage, followed by ridge and mound. The reverse was true with soil temperature. Ridge tillage (9.6 t ha-1) significantly produced more cassava tubers, followed by mound tillage (7.5 t ha-1) and zero tillage (5.2 t ha 1). The conventional ridge tillage method is recommended because it yielded more than the local practice of the zero tillage by 46%.

Obalum *et al.,* (2011) reported that the differences in sorghum yields among the tillage methods were less pronounced in the first compared to the second year when rainfall distribution was relatively erratic. The treatment-induced moisture explained over 60 and 72% of the variability in grain yield of the intercropped sorghum in the first and second year respectively. Osuji (1984) observed that water-use efficiency and maize grain yields during the early season of 1978-80 were significantly higher under zero tillage than under other tillage treatments

Senjobi *et al.,* (2013) concluded that the traditional tillage system resulted in the most favorable soil environment, for crop growth and best performance of crop followed by conventional and no-tillage system in the area studied respectively. The significant difference in yields adduced to lower bulk density, higher water holding capacity and porosity which increased plant root proliferation and optimal utilization of soil nutrients under tilled methods. Hence tillage methods have the capability to increase production while no-tillage is better under long term production for sustainable land use.

Akinbile and Yusoff (2011) investigated the response of *Amaranthuscurentus* in Nigeria to varying levels of fertilizers and different tillage practices for optimum vegetable production. Four treatments based on fertilizer applications viz; nitrogen, phosphorus and potassium, (N-P-K, 15-15-15), manure, peat and urea were administered on the vegetable in four different tillage methods namely: zero, bed, heap and ridge using standard procedures. The treatments were replicated four times using Randomized Complete Block Design (RCBD). From the study, responses of measured agronomic parameters showed that the ridge tillage method with N.P.K fertilizer application gave optimum yield among the treatments. The vegetables in this treatment had average leaf length, root depth, plant height and Leaf Area Index (LAI) values of 29.8, 9.9, 143 and 13.8, respectively all at 8 Weeks after Planting (WAP). These were highest when compared with results from other treatments. They concluded that ridge tillage and N.P.K application affected biomass yield and growth of *Amaranthus cruentus* considerably and is recommended for increased vegetable productivity in Nigeria.

Olaoye (2002) evaluated the effects of five different tillage treatments commonly used in Nigeria on crop residue cover, soil properties and some yield parameters of cowpea. The author found that disc harrowing and no tillage treatments had the highest grain yield and number of pods per plant among the treatments considered.

2.4.7 Tillage Systems and Environmental Sustainability

Farming systems today have more obvious and detectable social, ecological, economic, and environmental implications than ever before because of the growing concerns about agricultural sustainability and the environment (Shrestha and Clements, 2003). Agricultural sustainability implies an increasing trend in per capita productivity to meet the present needs without jeopardizing the future potential. Lynam and Herdt (1989) defined sustainability as the capacity of a system to

maintain output at a level approximately equal to or greater than its historical average, with the approximation determined by its historical level of variability. Hence a sustainable system is one with a positive trend in measured output and which technology can enhance if it increases the slope of this trend line. However, a problem with this definition is that it focuses on the productivity of an individual system at the expense of other systems, including the environment. Nevertheless, it provides a framework by which the sustainability of a system can be analysed. Adoption of new technology and farming practices is seen as the key to improving the sustainability of the system.

An important effect of soil tillage on sustainability is through its impact on the environment, for example, soil degradation, water quality, emission of greenhouse gases from soil-related processes, etc. As a subsystem of a crop production system, tillage can be used to achieve many agronomic objectives. Such objectives as suggested by Anderson (2009) include soil conditioning (modification of soil structure to favor agronomic processes such as soil seed contact, root proliferation, water infiltration, soil temperature control, etc.), weed/pest suppression (direct termination or disruption of weed/pest life cycles) and residue management , incorporation/mixing (placement or redistribution of substances such as fertilizers, manures, seeds, residues, sometimes from a less favorable location to a more favorable spatial distribution), segregation (consolidation of rocks, root crops, soil crumb sizes) and land forming (changing the shape of the soil surface e.g. ridging, roughening and furrowing). Among the disadvantages are land degradation, compaction of soil below the depth of tillage (i.e., formation of a tillage pan), increased susceptibility to water and wind erosion, accelerated decomposition of soil organic matter (negative from a long term perspective), high energy cost of tillage operations, labour and temporal obligations.

Policymakers and environmentalists believe that there is an urgent need for a change in the agricultural land management practices towards the adoption of “best management practices”

(Phillips *et al*., (1980), Derpsch and Friedrich (2010), Amir and Theodor (2012), IAASTD(2009), FAO (2008) and IPCC,2007). Some of such agricultural land management practices include crop rotation, alternate management practices on cultivated land, and conservation tillage practices. Besides, numerous Federal and State incentive-based programmes have been introduced in order to improve several environmental amenities. Some of the programmes are the Conservation Reserve Program (CRP), the Environmental Quality Incentive Program (EQIP), the Wetland Reserve Programs, Agricultural Development Programme (ADP) among others.

The information from the literature so far point to the fact that tillage practices have great impact on the soil physical, chemical and biological properties, runoff amount, sediment loss, nutrient cycling (input and output), velocity ,water quality and crop yield (Aina, 2011, Ohu, 2011, IAASTD; 2009, Giller *et al*; 2009, Mostaghimi *et al*;1988, Lal 1989; 1999). However, the type of soil, slope, precipitation amount, climatic condition, and the type of crop planted vary from place to place consequently influencing the level of impact of tillage on water quality, soil quality and crop yield. Aina(2011) therefore suggested that for the development and adoption of appropriate conservation tillage production systems, the future course for a tillage management zoning of the country, regionally coordinated systems approach research networking, evolution of adaptable conservation-tillage-planting systems model that is compatible with smallholder farm operations and crop and ecological diversity.

CHAPTER THREE

RESEARCH METHODS

3.1 Introduction

This section deals with the methods of experimentation and procedures of data collection and analysis. In scientific research, the methodology is central because the quality confers credibility on the entire research. Research methodology must include the types of data required, sources of data and method of data collection. It must also include the techniques of data analysis.

3.2 Types of Data Required

The types of data required for the assessment of the impact of tillage methods on land resources with emphasis on soil quality, surface runoff and crop yield using experimental method in the University of Ilorin Teaching and Research Farm (UTRF) and National Center for Agricultural Mechanization (NCAM), Idofian are:

i. soil samples from the experimental plots
ii. surface runoff samples from the experimental plots
iii. yield and yield components of maize
iv. satellite images of the study area
v. map showing the layout of the experimental plots

3.3 Sources of Data

The data for this research were obtained from both primary and secondary sources. Primary data were gathered by collecting water (surface runoff) and soil samples from constructed experimental plots taking cognizance of different tillage methods and subjecting samples to laboratory testing. The choices of parameters tested were those that are closely related to agricultural practices. The results obtained were used for subsequent analysis. Furthermore, Maize

yield data were generated by taken specific measurement of plants parameters. Secondary data required the use of maps showing spatially selected tillage practices across the study area. Maps and satellite images showing the landuse types, soil, climate, relief and drainage were sourced from National Space Research and Development Agency, Nigerian Geological Agency, Kaduna State and Kwara State Bureau of Lands and Survey. Data was complemented with information from relevant books, journals, internet sources, and literature such as International Soil and Water Conservation Research, Soil and Water Conservation Society, Journal of Sustainable Development among others.

3.4 Method of Data Collection

3.4.1 Sampling Procedures

The study employed purposive sampling technique to determine the tillage practices after a reconnaissance survey was conducted on the different tillage methods available in the study area and consultation was made with known Agronomist. The availability of mechanical equipments, personnel to operate them as well as expanse of land influenced the choice of the experimental sites. The construction of runoff plot was to enable the collection of runoff samples. The plot size was 5 x 5 m^2 with 2m inter replicate spacing with a total area of 300m^2 for each set of the experimental plot at each location (see Figure 3.1). This plot size is suitable for surface flow and soil erosion research projects conducted where space is limiting and may be used either for monitoring natural or simulated rainfall events (William and Buckhouse, 1991; William, 1988). Each plot was bounded to prevent runoff into it as well as preventing runoff from escaping into the encompassing field. A slot was created at the lower end of each plot to allow collection of runoff and covered to prevent debris from falling into the collection outlet (Plate 3.1, 3.2 and 3.3). The water (surface runoff) and soil samples were collected from selected runoff plots in plastic bottles and polythene bags respectively

and immediately taken for laboratory analysis at the Biochemistry and Agronomy laboratories of the University of Ilorin.



Plate 3.1: Constructed Experimental plots at Unilorin Teaching and Research Farm (UTRF) site.
Source: Author's Fieldwork (2015)



Plate 3.2: Runoff outlet on each Experimental plots at the National Center for Agricultural Mechanization (NCAM) Idofian.
Source: Author's Fieldwork (2015)



Plate 3.3: Runoff outlet covered to prevent entering of debris Unilorin Teaching and Research Farm (UTRF) site.
Source: Author's Fieldwork (2016)

The runoff and soil samples were collected during the cropping seasons of maize (*Zea mays L. Suwan I*) for two cropping seasons (i.e 2015 and 2016) using natural rainfall occurrence (runoff). Soil samples were taken from different depths viz topsoil (0-15cm) and subsoil (15-30cm). The two depths are deliberately chosen for two main reasons. Firstly, the 0–15cm represents the average plough layer in the area while the 15–30 cm depth is the layer where the clay particles leached from the topsoil accumulate. Secondly, samplings at these predetermined depths enhance comparability of soil properties with depth among the studied tillage types (Adugna and Abegaz, 2015 and Oladoye, 2015). The soil samples were taken for test at Agronomy laboratory, University of Ilorin for analysis as shown in Plate 3.4.



Plate 3.4: Soil Auger used to collect soil samples before planting from the experimental plots
Source: Author's Fieldwork (2016)

3.4.2 Sampling frame

Four treatments with three replicates were carried out using Randomized Complete Block Design (RCBD) approach. They were treatment A (zero or no-tillage) treatment B (plough and

harrow), treatment C (plough, harrow and ridge) and treatment D (traditional heap farming) as shown in Figure 3.1. Maize (*Zea Mays.L. SWAM 1* variety) was planted for two farming seasons i.e 2015 and 2016 farming year with two seeds per slot in plot size of 5m x 5m at spacing of 75cm between rows and 50cm within row. The application of NPK (15:15:15) fertilizer was applied at 4 weeks and 8 weeks of planting, pre-emergence and post emergence herbicide(Glyphosate and Atrazine) for weed control were administered on the sets of the experimental plot as a normal agronomic practice carried out by farmers in the study area. Plate 3.5,3.6,3.7 and 3.8 shows the process of tillage applications at the experimental plots. Agronomic parameters such as plant height, number of leaves, leaf length, leaf width and leaf area index were measured at eight weeks of maize growth while crop yield was measured after harvest (see Plate 3.9, 3.10 and 3.11)



Plate 3.5: Tractor tilling the experimental plot
Source: Author's Fieldwork (2015)



Plate 3.6: Traditional Heap Tillage in Progress at Experimental plot.
Source: Author's Fieldwork (2016)



Plate 3.7: Traditional Heap plots tilled and planted with flow path for runoff
Source: Author's Fieldwork (2016)



Plate 3.8: Pre-emergence application of herbicide by Field Assitant on the tilled experimental plots
Source: Author's Fieldwork (2016)



Plate 3.9: Experimental plots with maize at 4weeks
Source: Author's Fieldwork (2016)



Plate 3.10: Measurement of plant height by the Researcher and field assistant at 8weeks.
Source: Author's Fieldwork (2016)



Plate 3.11: Measurement of the leaf length by the Researcher and field assistant at 8weeks.
Source: Author's Fieldwork (2016)

Crop yield was estimated using 1,000 Kernel Weight for Calculating Seeding Rates and Harvest Losses as proposed by Alberta Agriculture Food and Rural Development (2002). The

harvested crop was then weighed per sample plot and the crop yield of the entire field was extrapolated from the sample. Yield (in kg/acre*) was estimated using the following formula:

Yield = maize cub/ft2 x seeds/cub x 1,000 kernel weight (grams) x 0.43560…….Equation 1

To avoid bias, Table of Random Number was used to select the location of the each tillage method/plot (replicates). The experimental layout at each location is shown in Figure. 3.1.

3.4.3 Sampling unit

Three replicates of each tillage methods were constructed giving a total of 12 experimental plots at each location for thorough comparative study i.e 12 experimental plots at University of Ilorin Teaching and Research Farm and 12 experimental plots at National Centre for Agricultural Mechanization (NCAM), Idofian. Therefore, a total of 24 water samples were collected from all the experimental plots after a rainfall event. Two soil samples were collected from each plot i.e top soil and subsoil using a soil auger which is commonly used for obtaining disturbed soil samples at or near the surface. This gave a total of 24 topsoil and 24 subsoil samples.

3.4.4 Sample population

A total of nine runoff samples were collected from the experimental plots across each farming season (i.e 2015 and 2016 planting seasons). This was dependent on the amount of rainfall and overland flow accumulated in the collection outlet after each rainfall event. Soil samples were collected before planting, after planting, and at harvest for each planting season as well. Crop yield measured after harvest of maize for each planting seasons.

3.4.5 Sampling Technique

Two sets of experimental plots with different tillage methods were constructed at University of Ilorin Teaching and Research Farm (UTRF) and NCAM, Idofian. The four tillage methods are No- tillage, Traditional heap tillage, mechanized tillage which are Plough/Harrow and

plough/harrow/ridge(see Figure 3.1) These covered for both conventional and conservative tillage methods commonly used in the study.

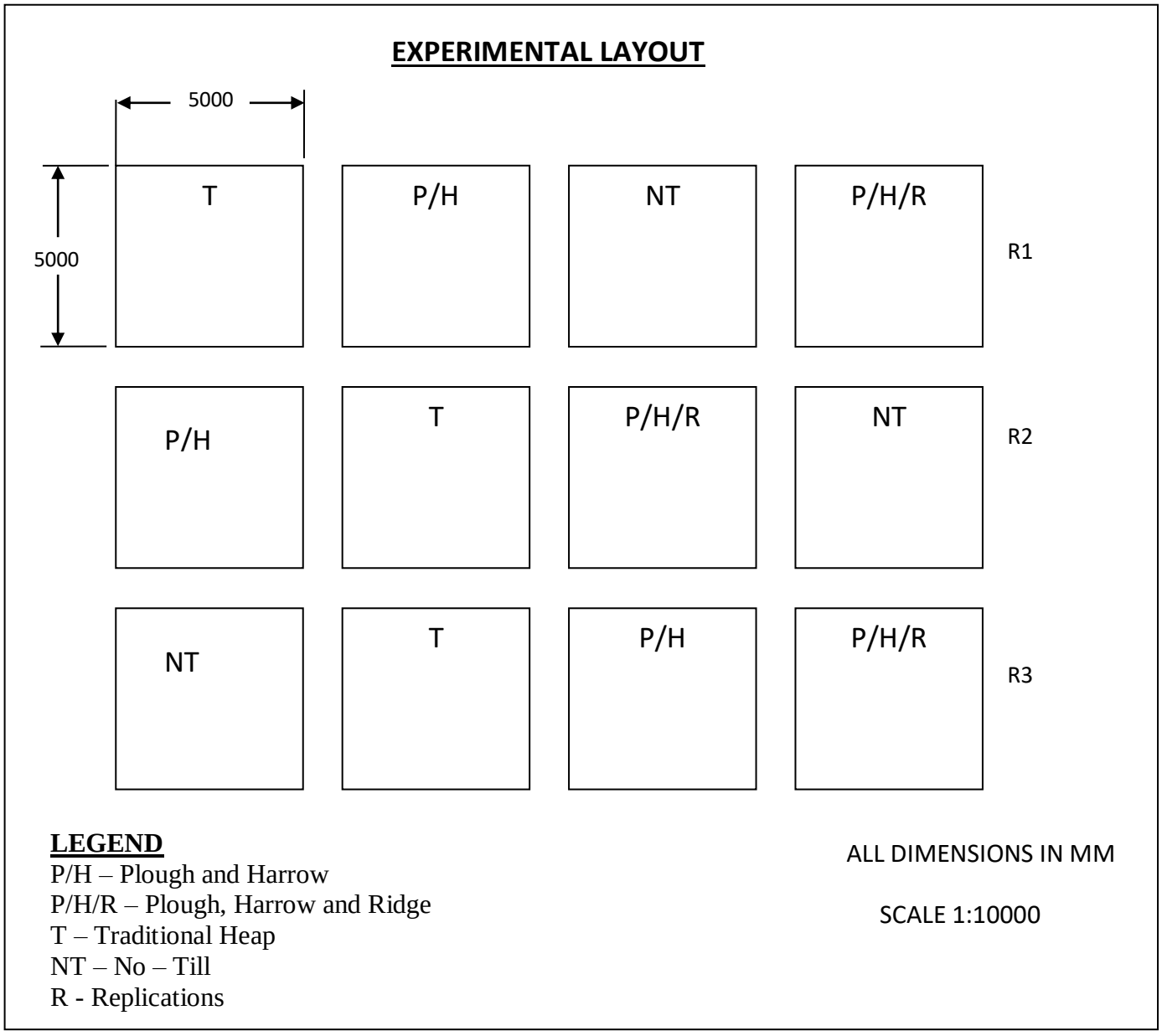


Figure 3.1: Experimental Layout at University of Ilorin Teaching and Research Farm and National Centre for Agricultural Mechanization (NCAM), Idofian

Source: Author's Fieldwork (2015)

Soil Water Assessment Tool (SWAT) was used to model the pattern and process of pollution from the tillage types through an ARCSWAT 2012.10.19 for ARCGIS software 10.2, 10.3 and 10.4. SWAT is a hydrologic model and it made use of the following components: weather, soil, land use as well as other variables to generate data on Hydrologic Response Unit (HRU). Some of the features modeled in the SWAT environment are stated in the Table 3.1 below.

Table 3.1: Features modeled in SWAT

UNITS	DESCRIPTION
HRU	Hydrologic Response Unit
SUB	Sub basin
PREC mm	Precipitation
SURQGEN mm	Surface runoff generated in HRU during time step (mm H2O)
SED th	Sediment yield (metric tons/ha)
SURQ mm	Surface runoff contribution to stream flow in the main channel
USLE_LS	Soil loss during the time step calculated with the USLE equation
GWQ mm	Groundwater contribution to stream flow (mm H2O)
ET mm	Actual evapotranspiration
NO3 kgh	NO3 in surface runoff (kg N/ha)
ORGN kgh	Organic N yield (kg N/ha)
BIOM th	Biomass
YLD th	Crop yield (metric tons/ha)

Source: Author's fieldwork (2016)

The SWAT was chosen because it can simulate the model with limited data. SWAT included many useful constituent and functions for simulating the water balance, sediment loss, climate change, crop growth, and land management practices. SWAT subdivided the basin into sub-basins closely joined by stream network and hereinafter delineates hydrological response units (HRU) using a unique combination of land cover, soils, and slope in each sub-basin. SWAT simulated

surface runoff volumes and peak runoff rates for each HRU using daily or sub-daily rainfall amounts using a modification of the soil conservation. SWAT can describe the relationship of land use on watershed hydrology.

SWAT model involved various kinds input data for simulation of the watershed. The materials required were Digital Elevation Model (DEM), Land use/Land cover, soil cover, and precipitation. All these data were collected, processed and converted into the SWAT input format. The software was runned by giving these data as inputs. The various steps involved in the software are watershed delineation, HRU (Hydrological response Unit) analysis, and write input tables, edit input data and SWAT simulation. Afterwards, the software executed the command and the output file was printed. This output file was used to plot the graphs and maps. These graphs and maps show the characteristics of watershed.

The watershed delineation was carried out with phases of activity such as data input Digital Elevation Model (add DEM grid), the determination of the network river, determination outlet, outlet selection and determination of the watershed, and calculations parameter sub-basins. The end result of this process was the formation of the watersheds, sub-basins and watersheds. HRU analysis was done by defining the input data using land use map, soil type map, and slope map that are overlaid to form the HRU. The third stage was the processing of climate data generalization. This step was performed using climate data input from each of the existing climate variables. Soil layer map was from Nigerian Geological Survey, land use layer was interpreted from Landsat Thematic Mapper by National Space Research and Development Agency(NASRDA) taken in 2016 with a resolution of 30 m. Land use is one of the dynamic parameters caused by human activities. The DEM was used to delineate watershed which is the very first step of the simulation. The DEM was extracted from the ASTER Global Digital Elevation Model (ASTER GDEM) which has a spatial

resolution of 30 m. Based on the elevation, the flow accumulation, stream network and the stream links was created. Figure 3.2, 3.3 and 3.4 show flow chart of the steps in the SWAT model application for the study area, SWAT Running the Input Data and SWAT Output.

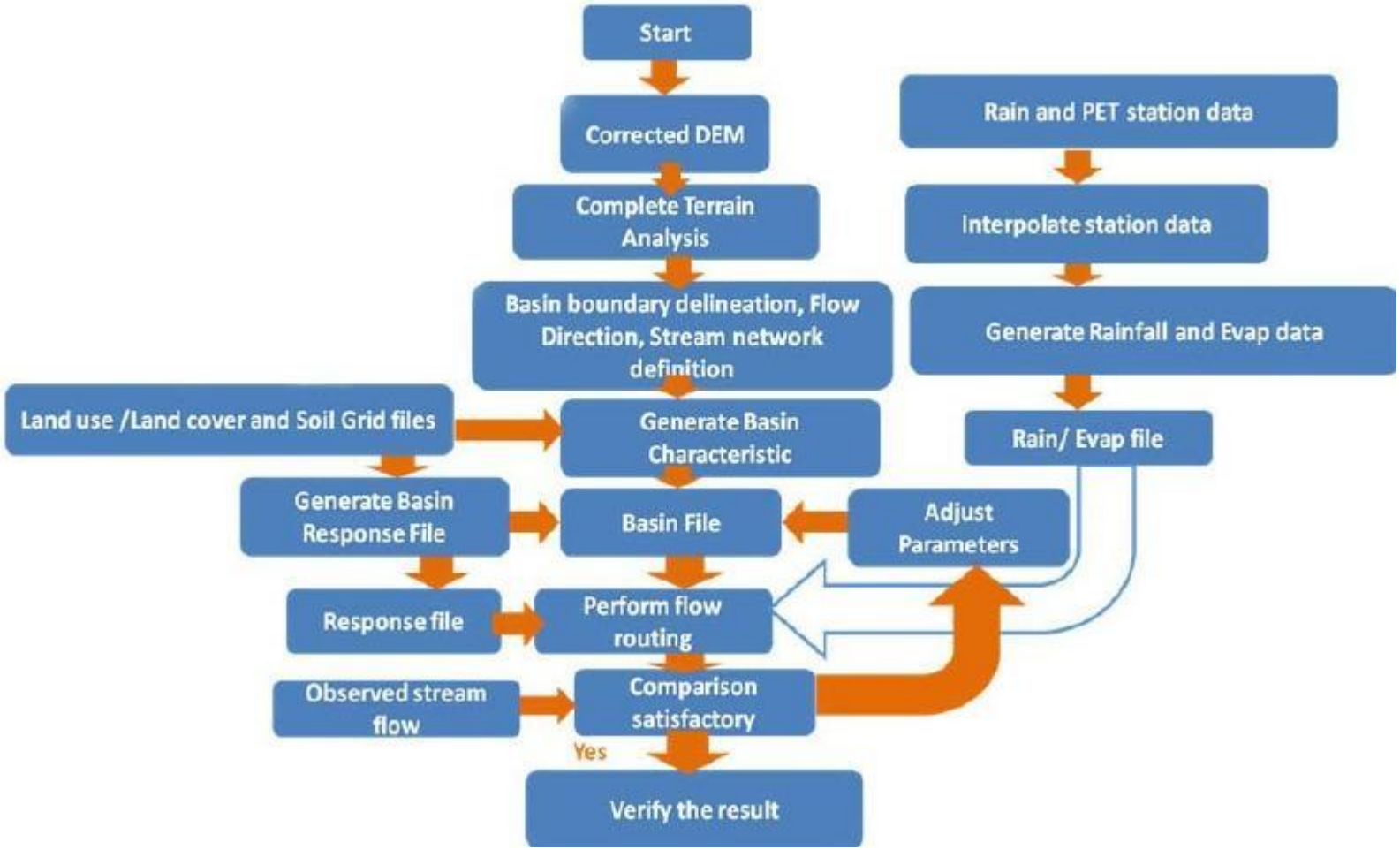


Figure 3.2: Flow chart of the steps in the SWAT model application for the study area.
Source: Adopted from Akpoti (2015) and modified by Author (2016)

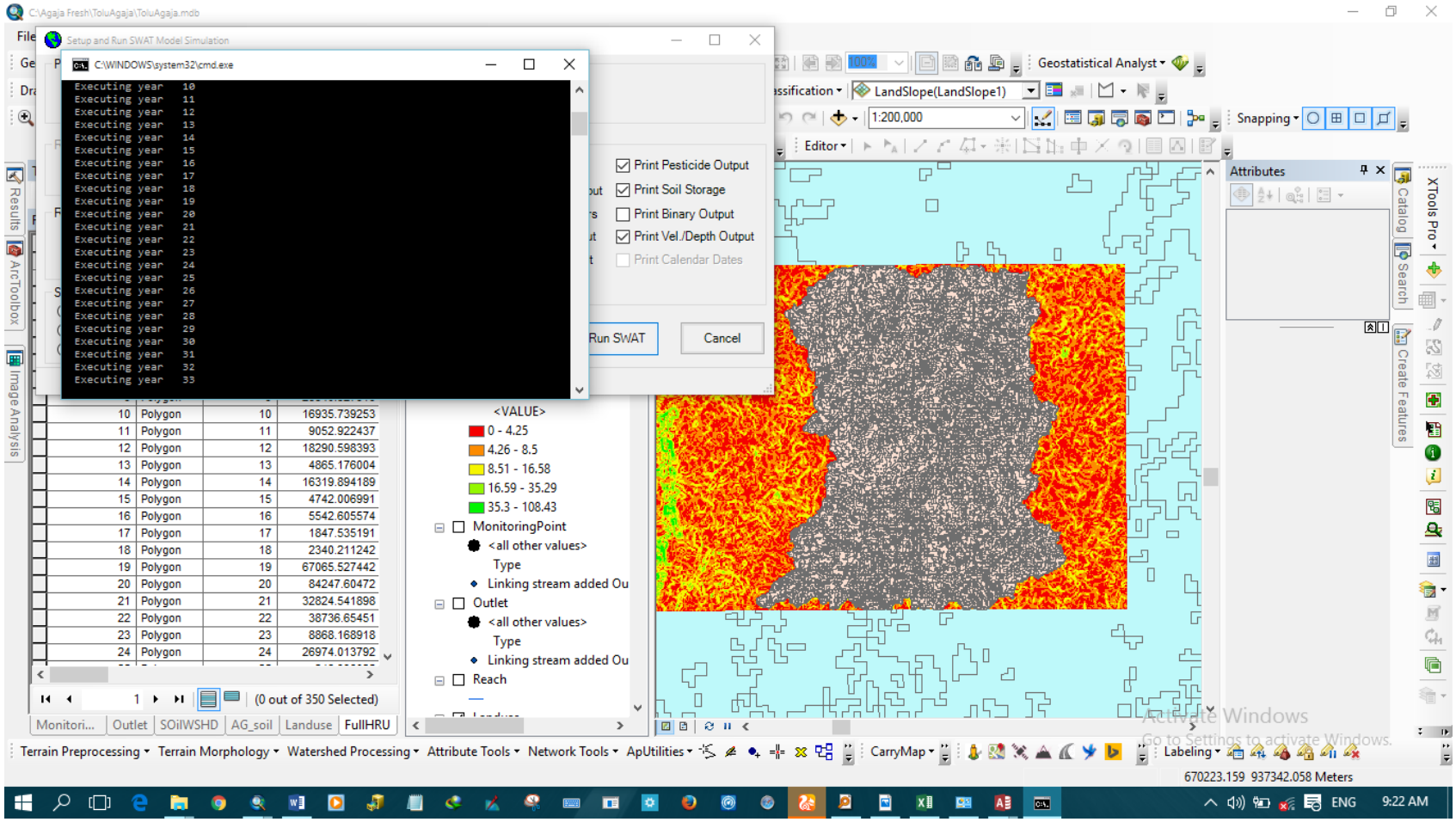


Figure 3.3: Catalog of SWAT Running the Input Data

Source: Author's fieldwork (2016)

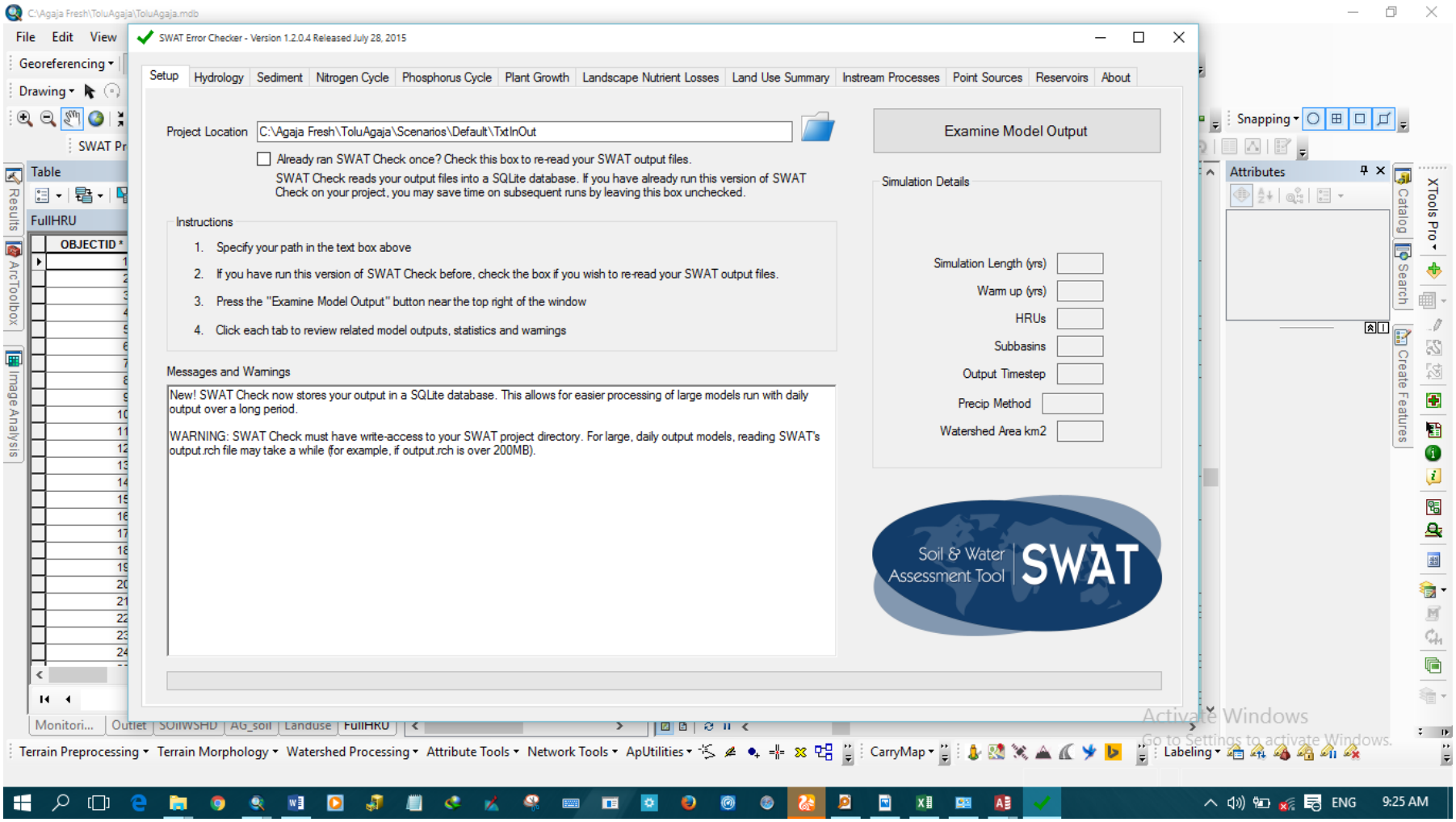


Figure 3.4: Catalog of SWAT Output
Source: Author's fieldwork (2016)

3.5 Method of Data Analysis

Data analysis in this study were of two categories including laboratory and statistical methods. The laboratory analytical methods were used to determine the physical, chemical and biological water composition and soil nutrient while the statistical method were used to organize, analyze, present, describe and interpret the data collected.

3.5.1 Laboratory methods

The samples (water and soil) collected from the field were analyzed at the Biochemistry and Agronomy laboratories of the University of Ilorin. In both the soil and water samples, sixteen parameters which are closely related to agricultural practices were examined (Table 3.2 and 3.3). This enabled determination of variation in concentration of soil and water parameters from one tillage method to the other. Standard laboratory analytical method from the Association of Official Analytical Chemists (AOAC, 1990) was used to analyze all the selected parameters.

Table 3.2: Details of Soil Quality Parameters Determined

S/N	Soil quality	Laboratory method	Source
1	Soil Temperature	Thermometer	AOAC (1990)
2	Soil water content	Oven dry method	AOAC (1990)
3	Ph	Electrometric method	AOAC (1990)
4	Bulk density	Soil Core Method	Carter (1990)
5	Organic matter	Wet Oxidation Method	Nelson and Summers (1996)
6	Nitrogen	Kjeldahi method	AOAC (1990)
7	Phosphorus	Bray P1 Method	Kno (1996)
8	Potassium	Neutral N Ammonium Acetate Entraction Method	Anderson and Ingram (1993)
9	Sodium	Flame photometric method	AOAC (1990)
10	Calcium	Titrimetric methods	AOAC (1990)
11	Magnesium	Gravimetric method	AOAC (1990)
12	Copper	Atomic absorption spectrometric method	AOAC (1990)
13	Manganese	Colorimetric method	AOAC (1990)
14	Lead	Atomic absorption spectrometric method	AOAC (1990)
15	Iron	1% EDTA Extraction method	Anderson and Ingram (1993)
16	Zinc	1% extraction method	Anderson and Ingram (1993)

Source: Author's Fieldwork (2015)

Table 3.3: Details of Water Quality Parameters Determined and Nigerian Drinking Water Standard

S/N	Water quality	Laboratory methods	NDWS Maximum permitted levels (2007)
1	Turbidity	Nephelometric Method	>5 TU
2	Carbon (C)	Titrimetric method	NIL
3	Sodium (Na)	Atomic absorption spectrophotometer	200 mg/l
4	Potassium (K)	Atomic absorption spectrophotometer	NIL
5	Zinc	Atomic absorption spectrophotometer	3 mg/l
6	Nitrate (NO_3)	Nitrate colourimetric method	50 mg/l
7	Phosphorus(P)	Standard curve and calibration of spectrophotometer	>0.1 mg/l
8	Ph	Glass electrode pH meter	6.5-8.5
9	Conductivity	Conductivity method	0.4-0.85millimoles per centimeter
10	Copper (Cu)	Atomic absorption spectrophotometer	2 mg/l
11	Total Dissolved Solids(TDS)	Conductivity method	500mg/l
12	Calcium	Titrimetric method	NIL
13	Magnesium	Titrimetric method	0.20 mg/l
14	Dissolved Oxygen (DO)	Titrimetric method	5-6 mg/l
15	Chloride (Cl)	Argentometric Method	250 mg/l
16	Lead(Pb)	Atomic absorption spectrophotometer	0.01 mg/l
17	Iron (Fe)	1% EDTA Entraction method	0.3 mg/l

Source: Association of Official Analytical Chemists -AOAC (1990)

3.5.2 Statistical methods

The study employed both descriptive and inferential statistics to analyze the field data and laboratory results of water and soil samples obtained. The descriptive analysis covered the use of minimum and maximum values of means, standard deviation and coefficient of variation (CV) alongside tables and bar graphs to organize and summarize the data.

a. **Arithmetic Mean**: arithmetic mean is the most frequently used measure of central tendency which is what most people commonly consider to be the average. The artimetic mean of a set of data was obtained by summing up all the items in the distribution (Σx) and dividing the result by the number of observations (Udofia, 2011). The formula is given as:

Mean = $\frac{\Sigma fx}{N}$ .....Equation 2

Where: Σfx is the sum of the observations or items

N is the number of scores

b. S**tandard deviation**: is a measure that is used to quantify the amount of variation or dispersion of a set of data values. A standard deviation close to 0 indicates that the data points tend to be very close to the mean (also called the expected value) of the set, while a high standard deviation indicates that the data points are spread out over a wider range of values. This was used to determine the deviation of each soil and water element from the original means. The formula for standard deviation is stated below:

$$s = \sqrt{\frac{1}{N-1}\sum_{i=1}^{N}(x_i - \overline{x})^2}$$

.....Equation 3

c. **Coefficient of variation**- Coefficient of Variation is the ratio of the standard deviation of a distribution to the distribution and was used to explain the homogeneity and heterogeneity of the samples. It is expressed as a percentage:

$\frac{\sigma}{x}$ *100% (Eno ,2001) **.....**Equation 4

The inferential statistics used were two way Analysis of Variance (ANOVA), multiple comparison using least square significant difference, regression analysis and soil water assessment tool (SWAT).

a. Analysis of variance (ANOVA): is a parametric test used to determine variations that exist between and within samples mean where more than two variables are involved (Santra, 2005). Variation in parameters within the four tillage methods under the study was examined through the application of ANOVA. Two way analysis of variance (ANOVA) was used to determine the variations among the examined parameters from different tillage methods. It was also used for comparison between and among the means of the results collected from the laboratory. This afforded the opportunity of knowing the level of disparities that occurred in the means of the water and soil composition results obtained. The formular is given below:

F= $\frac{MST}{MSE}$ ….....Equation 5

Where,

F= Anova Coefficient

MST=Mean Sum of Squares due to treatment

MSE= Mean Sum of Squares due to error.

Formula for MST is given below:

MST= $\frac{SST}{P-1}$ .....Equation 6

SST=Σ n(x-$\bar{x}$) ^{2} .....Equation 7

Where,

SST=Sum of Squares due to treatment

P= total populations

N= total number of samples in a population.

Formula for MSE is given below:

MSE= $\frac{SSE}{N-P}$ .....Equation 8

SSE=Σ (n-1) S^2 .....Equation 9

Where,

SSE=sum of squares due to error

S=standard deviation of samples

N=total number of observations

Table 3.3 Two Way Analysis of Variance Table

Source	**SS**	**Df**	**MS**	**F**
Main Effect A	Given	A,a-1	SS/df	MS(A)/MS(W)
Main Effect B	Given	B, b-1	SS/df	MS(B)/MS(W)
Interaction Effect	Given	A*B(a-1)(b-1)	SS/df	MS(A*B)/MS(W)
Within	Given	N-ab, ab(n-1)		
Total	Sum of others	N1, abn-1		

b. Least significance difference test (LSD): The LSD was used to calculate the smallest significance between two means as if a test had been run on those two means (as opposed to all of the groups together). This enables one to make direct comparisons between two means from two individual groups. Any difference larger than the LSD

value is considered a significant result. When an ANOVA (Analysis of Variance) test is done and a significant result is achieved, it means that at least one of the groups tested differs from the other groups. This was used to further ascertain which of the tillage methods has a greater impact on the soil and water parameters analyzed. The formula for the least significant difference is:

$$LSD_{A,B} = t_{0.05/2,DFW}\sqrt{MSW(1/n_A + 1/n_B)}$$ .....Equation 10

Where:

t = critical value from the t-distribution table

MSw = mean square within, obtained from the results of your ANOVA test

n = number of scores used to calculate the means

c. **Regressions Analysis:** Regression from the point view of ANOVA was used to determine the magnitude of the effect of tillage on yield parameters. It was used to test the strength and significant relationship between the dependent (plant height, leaf width, leaf length, number of leaves, leaf area index (LAI) and maize yield) and independent (tillage method) variables. There are two sources of variation, that part that can be explained by the regression equation and the part that can't be explained by the regression equation. These variations goes into the SS column of the ANOVA table as shown in Table 3.4 Multiple regression formula is also be expressed as follows:

$$\boldsymbol{Y1 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}$$ ..... Equation 11

$$\boldsymbol{Y2 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}$$..... Equation 12

$$\boldsymbol{Y3 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}$$..... Equation 13

$$\boldsymbol{Y4 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}$$..... Equation 14

$$\boldsymbol{Y5 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}\ldots\ldots \text{Equation 15}$$

$$\boldsymbol{Y6 = a + b1x1 + b2x2 + b3x3 \ldots\ldots bnxn + e}\ldots\ldots \text{Equation 16}$$

Where

Y =dependent variable (Y1= plant height , Y2= leaf width , Y3= crop yield

a = constant

b_1, b_2 = regression co-efficient

x_1 and x_2 = independent variables (tillage practices, climatic seasons, type of soil, vegetation cover etc.)

e = error term

Table 3.4: Application of the Regression Equation into the ANOVA Table.

Source	SS	Df
Regression (Explained)	$\sum(\hat{y} - \bar{y})^2$ Sum the squares of the explained deviations	# of parameters - 1 always 1 for simple regression
Residual / Error (Unexplained)	$\sum(y - \hat{y})^2$ Sum the squares of the unexplained deviations	sample size - # of parameters n - 2 for simple regression
Total	$\sum(y - \bar{y})^2$ Sum the squares of the deviations from the mean	sample size - 1 n – 1

Source: ICTCM, 2004

The above was achieved using regression analysis from the point of view of analysis of variance (Gujarati, 2004; Daramola, 2013) affording the opportunity of knowing the level of disparities that occurred in the means of the agronomic parameters measured as well as crop yield.

To model the pattern and process of pollution from tillage types, Soil Water Assessment Tool (SWAT) was used. SWAT is a hydrologic model and it made use of the following components: weather, soil, land use as well as other variables to generate data on Hydrologic Response Unit (HRU), surface runoff, Sediment yield, Soil loss, Groundwater contribution to stream flow, return flow, percolation, evapotranspiration, nitrate (NO_3) in surface runoff transmission, crop growth and irrigation, groundwater flow, nutrient and pesticide load, water transfer, amongst a host of other variables.

CHAPTER FOUR

IMPACT OF TILLAGE PRACTICES ON SOIL QUALITY

4.1 Introduction

This section presents the results on soil quality analysis with respect to the stated objective under the study. It shows the results of descriptive and inferential statistics used from the laboratory analysis. The acronym for each tillage methods used includes Traditional heap (T), Plough/Harrow (PH), No-tillage (NT) and Plough/Harrow/Ridge (PHR). The analyses of soil quality parameters presented in this section are for University of Ilorin Teaching and Research Farm (UTRF) and National Center for Agricultural Mechanization (NCAM) Experimental Site for 2015 and 2016 Planting Season. The coefficients of variation for all the soil parameters in all the tillage methods present a homogenous pattern i.e. all the values were less than 33%. The soil quality standard used for comparism was adapted from the report for Alberta Environmentally Sustainable Agriculture (AESA) Soil Quality Program by Bremer and Ellert (2004) for aquatic ecosystems and the Environmental Management (Soil Quality Standards) Regulations, 2007 for Tanzania. The full details of the result from the ANOVA and Least Significance Difference (LSD) can be found in Appendix I.

4.2 Distribution of Soil Quality among the Tillage Methods at UTRF and NCAM Experimental Sites

The soil quality indicators that were within the AESA standard for UTRF site are soil temperature, iron, pH and organic matter. Sodium, calcium, and magnesium had no proposed permissible limit while bulk density, nitrate-nitrogen, phosphorus, potassium, copper, manganese, lead and zinc did not fall within the permissible limit of AESA (2004) as revealed in Table 4.1. On NCAM site, soil temperature, iron and pH were within the AESA (2004), while bulk density,

organic matter, nitrate-nitrogen, phosphorus, potassium, manganese, lead and zinc were not within the permissible standard. Soil water, sodium, calcium and magnesium did not have any proposed permissible limit as shown in Table 4.2.

Table 4.1: Summaries of Soil Quality Parameter Values in UTRF Experimental Site for 2015 and 2016 planting season

SN	Soil Parameters	Tillage Types	Minimum				Maximum				Mean				Std. Deviation				CV			
			0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
			2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1	Soil Temp (°C)	Traditional	30.00	28.00	30	28.00	31	30.00	32	31.00	30.33	29.16	30.5	29.83	0.49	.75	0.67	1.16	1.62	2.57	2.2	3.89
		PH	29.00	28.00	30	28.00	30	30.00	32	30.00	29.33	29.33	31	29.00	0.49	1.03	0.85	.63	1.67	3.51	2.74	2.17
		NT	29.00	29.00	28	28.00	32	31.00	32	30.00	30.33	29.83	30	29.50	1.30	.75	1.71	.83	4.29	2.51	5.7	2.81
		PHR	29.00	29.00	29	29.00	31	31.00	31	30.00	30	29.50	30	29.50	0.85	.83	0.85	.54	2.83	2.81	2.83	1.83
		Standard																				
2	Soil Water	Traditional	8.73	10.43	8.69	10.62	9.44	11.20	9.38	12.06	9.02	10.85	8.94	11.28	0.32	.34	0.32	.62	3.55	3.13	3.58	5.5
		PH	8.46	10.40	8.66	10.60	9.16	11.20	9.05	11.05	8.88	10.57	8.92	10.78	0.32	.30	0.19	.21	3.6	2.84	2.13	1.95
		NT	8.42	10.40	8.48	10.60	9.58	12.08	9.4	12.10	8.94	11.37	8.86	11.24	0.50	.80	0.41	.64	5.59	7.04	4.63	5.69
		PHR	9.16	10.40	9.08	10.60	9.69	11.08	9.36	11.13	9.46	10.58	9.18	10.87	0.23	.25	0.13	.26	2.43	2.36	1.42	2.39
		Standard																				
3	Ph	Traditional	4.40	4,80	4.7	4.80	4.5	5.80	5.4	5.60	4.47	5.15	5.07	5.01	0.05	.50	0.29	.29	1.12	9.71	5.72	5.79
		PH	4.50	4.70	4.5	4.30	5.2	4.90	5.5	5.00	4.8	4.83	4.93	4.71	0.31	.08	0.44	.24	6.46	1.66	8.92	5.1
		NT	4.30	4.80	4.6	4.70	4.6	5.30	5.00	5.80	4.43	5.06	4.80	5.21	0.13	.17	0.17	.44	2.93	3.36	3.54	8.45
		PHR	4.60	4.60	4.9	4.60	5.4	5.50	5.4	5.10	4.9	4.93	5.13	4.91	0.37	.31	0.21	.17	7.55	6.29	4.09	3.46
		Standard									**5.0-8.2**											
4	*Bulk Density (gcm-3)	Traditional	1.81	1.87	1.85	1.89	1.89	1.94	1.88	1.94	1.86	1.91	1.86	1.92	0.03	.02	0.01	.01	1.61	1.05	0.54	0.52
		PH	1.82	1.87	1.86	1.90	1.89	1.91	2.04	1.94	1.85	1.89	1.93	1.91	0.03	.01	0.08	.01	1.62	0.53	4.15	0.52
		NT	1.86	1.90	1.83	1.89	1.9	1.93	1.86	1.98	1.88	1.91	1.85	1.92	0.02	.01	0.01	.03	1.06	0.52	0.54	1.56
		PHR	1.87	1..86	1.84	1.91	2.02	1.93	1.88	1.94	1.92	1.89	1.86	1.92	0.07	.02	0.02	.01	3.65	1.06	1.08	0.52
		Standard									**1.25-1.65 (**gcm-3**)**											
5	Organic Matter(%)	Traditional	1.62	2.10	1.58	2.09	1.89	2.14	1.73	2.21	1.73	2.11	1.64	2.13	0.12	.01	0.07	.05	6.94	0.47	4.27	2.35
		PH	1.42	2.09	1.57	2.09	2.15	2.18	1.68	2.15	1.79	2.11	1.61	2.12	0.31	.03	0.05	.02	17.32	1.42	3.11	0.94
		NT	1.53	2.06	1.56	2.09	2.12	2.11	1.6	2.19	1.75	2.08	1.58	2.12	0.27	.01	0.02	.03	15.43	0.48	1.27	1.42
		PHR	1.48	2.06	1.53	2.10	1.83	2.12	1.62	2.20	1.62	2.09	1.59	2.14	0.16	.02	0.04	.04	9.88	0.96	2.52	1.87
		Standard									**≥1%**											
6	*Nitrate Nitrogen (mg/kg)	Traditional	0.314	.306	0.316	.284	0.325	.346	0.317	.41	0.33	.32	0.32	.34	0.005	.01	0.0004	.05	1.52	3.13	0.13	14.71
		PH	0.319	.306	0.319	.288	0.329	.380	0.411	.39	0.32	.34	0.35	.33	0.005	.03	0.04	.04	1.56	8.82	11.43	12.12
		NT	0.318	.319	0.316	.292	0.402	.400	0.324	.41	0.35	.35	0.32	.34	0.04	.04	0.003	.05	11.43	11.43	0.94	14.71
		PHR	0.32	.304	0.318	.296	0.412	.392	0.404	.37	0.35	.33	0.35	.34	0.04	.03	0.04	.03	11.43	9.09	11.43	8.82
		Standard									**>20mg/kg**											
7	*Phosphorous (mg/kg)	Traditional	2.8	2.08	2.42	2.08	2.82	2.31	2.66	2.98	2.81	2.17	2.55	2.42	0.01	.09	0.10	.36	0.36	4.15	3.92	14.88
		PH	2.66	2.09	2.57	2.06	2.75	2.52	2.81	2.94	2.69	2.20	2.67	2.39	0.04	.16	0.11	.37	1.49	7.27	4.12	15.48
		NT	2.62	2.09	2.51	2.10	2.79	2.30	2.85	2.92	2.71	2.17	2.64	2.39	0.07	.07	0.16	.38	2.58	3.23	6.06	15.9
		PHR	2.65	2.06	2.66	2.09	2.8	2.68	2.8	2.77	2.7	2.28	2.72	2.40	0.071	.25	0.06	.30	2.63	10.96	2.21	12.5
		Standard									**>15mg/kg**											
8	*Potassium (mg/kg)	Traditional	1.2	1.18	1.31	1.26	1.36	1.34	1.5	1.38	1.29	1.26	1.39	1.32	0.07	.07	0.09	.05	5.43	5.56	6.47	3.79
		PH	1.22	1.21	1.26	1.16	1.36	1.40	1.37	1.32	1.29	1.30	1.3	1.25	0.06	.07	0.05	.05	4.65	5.38	3.85	4
			1.26	1,19	1.3	1.20	1.34	1.36	1.39	1.49	1.29	1.25	1.35	1.35	0.04	.06	0.04	.11	3.1	4.8	2.96	8.15
		PHR	1.32	120	1.29	1.24	1.41	1.41	1.44	1.55	1.35	1.29	1.34	1.34	0.04	.08	0.07	.14	2.96	6.2	5.22	10.45
		Standard									**>150mg/kg**											
	Sodium (mg/kg)	Traditional	1.18	1.18	1.27	1.24	1.28	1.28	1.3	1.29	1.24	1.22	1.28	1.26	0.05	.03	0.01	.02	4.03	2.46	0.78	1.59
		PH	1.17	1.19	1.14	1.11	1.24	1.27	1.29	1.29	1.21	1.21	1.21	1.20	0.03	.03	0.06	.07	2.48	2.48	4.96	5.83-9

Table 4.1 (contd)

9		NT	1.22	1.18	1.18	1.18	1.32	1.30	1.28	1.27	1.27	1.24	1.22	1.21	0.04	.05	0.04	.03	3.15	4.03	3.28	2.48
		PHR	1.2	1.19	1.29	1.25	1.29	1.24	1.42	1.38	1.25	1.20	1.35	1.33	0.04	.02	0.06	.05	3.2	1.67	4.44	3.76
		Standard																				
		Traditional	1.49	1.48	1.49	1.49	1.55	1.71	1.58	1.68	1.52	1.63	1.52	1.60	0.03	.08	0.04	.06	1.97	4.91	2.63	3.75
		PH	1.52	1.49	1.53	1.56	1.61	1.68	1.58	1.72	1.56	1.59	1.56	1.63	0.04	.06	0.02	.07	2.56	3.77	1.28	4.29
10	Calcium (mg/kg)	NT	1.48	1.55	1.13	1.48	1.55	1.68	1.58	1.68	1.5	1.59	1.41	1.55	0.03	.04	0.21	.07	2	2.52	14.89	4.52
		PHR	1.38	1.50	1.49	1.56	1.56	1.70	1.54	1.72	1.48	1.57	1.51	1.65	0.08	.07	0.02	.06	5.41	4.46	1.32	3.64
		Standard																				
		Traditional	0.44	.36	0.52	.37	0.48	.62	0.56	.50	0.45	.45	0.54	.42	0.02	.08	0.02	.05	4.44	17.78	3.7	11.9
		PH	0.4	.38	0.46	.40	0.63	.45	0.58	.50	0.52	.41	0.51	.44	0.09	.02	0.05	.04	17.31	4.88	9.8	9.09
11	Magnesium (mg/kg)	NT	0.39	.36	0.47	.30	0.45	.43	0.59	.52	0.42	.40	0.53	.41	0.03	.02	0.05	.08	7.14	5	9.43	19.51
		PHR	0.38	.32	0.53	.33	0.48	.51	0.56	.48	0.44	.41	0.55	.41	0.05	.06	0.01	.07	11.36	14.63	1.82	17.07
		Standard																				
		Traditional	1.68	1.68	1.48	1.48	2.19	2.24	1.78	1.78	2.01	1.99	1.61	1.61	0.24	.25	0.13	.13	11.94	12.56	8.07	8.07
		PH	1.5	1.44	1.52	1.46	2.04	2.05	1.88	1.82	1.75	1.72	1.69	1.64	0.23	.25	0.15	.15	13.14	14.53	8.88	9.15
12	*Copper (mg/kg)	NT	1.65	1.49	1.63	1.61	1.91	1.92	2.14	2.18	1.8	1.74	1.84	1.85	0.11	.19	0.23	.23	6.11	10.92	12.5	12.43
		PHR	1.48	1.48	1.59	.156	1.86	1.86	1.76	1.76	1.62	1.64	1.65	1.62	0.18	.17	0.08	.08	11.11	10.37	4.85	4.94
		Standard										**2-100mg/kg**										
		Traditional	1.36	1.26	1.37	1.34	1.46	1.47	1.49	1.46	1.39	1.35	1.43	1.39	0.05	.08	0.05	.04	3.6	5.93	3.5	2.88
		PH	1.38	1.36	1.2	1.18	1.56	1.56	1.48	1.46	1.48	1.46	1.38	1.32	0.08	.07	0.14	.11	5.41	4.79	10.14	8.33
13	*Manganese (mg/kg)	NT	1.31	1.29	1.28	1.24	1.42	1.38	1.73	1.38	1.38	1.34	1.43	1.30	0.05	.04	0.22	.05	3.62	2.99	15.38	3.85
		PHR	1.22	1.16	1.24	1.24	1.49	1.49	1.38	1.46	1.32	1.35	1.29	1.30	0.12	.15	0.06	.08	9.09	11.11	4.65	6.15
		Standard										**20-3000mg/kg**										
		Traditional	1.49	1.42	1.38	1.38	1.65	1.68	1.71	1.76	1.59	1.55	1.51	1.55	0.07	.09	0.15	.16	4.4	5.81	9.93	10.32
		PH	1.21	1.20	1.39	1.48	1.57	1.58	1.68	1.58	1.45	1.45	1.53	1.53	0.17	.17	0.124	.04	11.72	11.72	8.1	2.61
14	*Lead (mg/kg)	NT	1.2	1.20	1.46	1.42	1.55	1.57	1.49	1.49	1.39	1.41	1.48	1.46	0.15	.14	0.01	.03	10.79	9.93	0.68	2.05
		PHR	1.52	1.20	1.46	1.36	1.58	1.64	1.55	1.68	1.54	1.56	1.5	1.50	0.03	.05	0.04	.13	1.95	3.21	2.67	8.67
		Standard										**2-200mg/kg**										
		Traditional	36.18	36.28	32.18	32.26	44.38	44.38	41.4	41.46	39	39.00	35.28	35.37	3.97	4.08	4.52	4.70	10.18	10.46	12.81	13.29
		PH	29.52	29.48	32.24	32.24	47.28	47.28	38.19	38.26	36.09	36.04	35.63	35.65	8.31	8.70	2.61	2.75	23.03	24.14	7.33	7.71
15	Iron (mg/kg)	NT	30.68	30.62	30.48	30.43	46.67	46.67	37.28	37.23	36.57	36.54	34.74	34.69	7.49	7.85	3.17	3.31	20.48	21.48	9.12	9.54
		PHR	31.11	31.41	34.6	34.67	40.33	40.45	35.18	35.18	35.53	35.69	34.95	34.99	3.94	4.04	0.26	25	11.09	11.32	0.74	71.45
		Standard										**>10mg/kg**										
		Traditional	1.3	1.10	1.24	1.29	1.63	1.67	1.68	1.58	1.43	1.42	1.47	1.46	0.15	.20	0.19	.12	10.49	14.08	12.93	8.22
		PH	1.43	1.49	1.26	1.16	2.16	2.19	1.53	2.06	1.74	1.74	1.44	1.65	0.32	.33	0.13	.33	18.39	18.97	9.03	20
16	*Zinc (mg/kg)	NT	1.33	1.36	1.14	1.19	1.65	1.68	1.48	1.56	1.5	1.49	1.25	1.43	0.14	.12	0.17	.15	9.33	8.05	13.6	10.49
		PHR	1.29	1.36	1.52	1.22	2.09	2.14	2.08	1.65	1.62	1.66	1.73	1.45	0.36	.36	0.26	.18	22.22	21.69	15.03	12.41
		Standard										**10-3000mg/kg**										

KEY- T-traditional, PH-plough/harrow, NT-No-till, PHR-Plough/harrow/ridge, CV- coefficient of variation, UTRF –Unilorin Teaching and Research Farm plots. NCAM- National Centre for Agricultural Mechanization experimental plot , NOTE- *=Not within permissible limits

Source: Authors Fieldwork (2016)

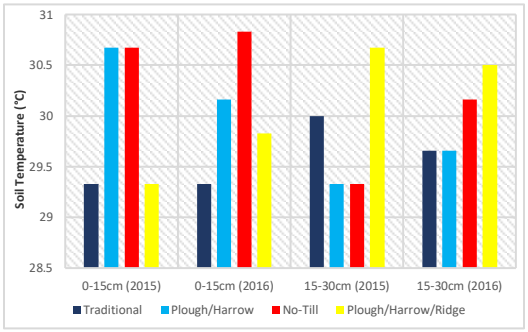
Table 4.2: Summaries of Soil Quality Parameter Values in NCAM Experimental Site for 2015 and 2016 planting season

SN	Soil Parameters	Tillage Type	Minimum				Maximum				Mean				Std. Deviation				CV			
			0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
			2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1	Soil Temp	Traditional	28	28.00	29	29.00	30	30.00	31	31/00	29.33	29.33	30	29.66	0.98	.81	0.85	.81	3.34	2.76	2.83	2.73
		PH	29	29.00	28	29.00	32	32.00	31	31.00	30.67	30.16	29.33	29.66	1.30	.98	1.30	.98	4.24	3.25	4.43	3.3
	°C	NT	30	30.00	28	30.00	31	32.00	30	31.00	30.67	30.83	29.33	30.16	0.49	.98	0.98	.98	1.6	3.18	3.34	3.25
		PHR	28	29.00	29	30.00	30	31.00	32	31.00	29.33	29.83	30.67	20.50	0.98	.75	1.30	.75	3.34	2.51	4.24	3.66
		Standard																				
2		Traditional	9.38	10.44	9.24	10.62	10.02	11.16	9.68	12.14	9.73	10.91	9.4	11.06	0.27	.35	0.20	.35	2.77	3.21	2.13	3.16
		PH	8.66	10.40	8.52	10.65	9.43	11.05	9.12	12.04	9.16	10.53	8.77	11.16	0.37	.25	0.26	.25	4.04	2.37	2.96	2.24
	Soil Water	NT	9.56	10.42	8.77	10.46	9.86	12.10	9.72	12.60	9.75	11.24	9.2	11.31	0.14	.88	0.41	.88	1.44	7.83	4.46	7.78
		PHR	8.56	10.46	9.06	10.48	10.01	11.15	9.2	11.40	9.07	10.74	9.11	10.87	0.69	.30	0.06	.30	7.61	2.79	0.66	2.76
		Standard																				
3		Traditional	4.6	4.50	4.6	4.70	10.02	5.00	5.7	5.60	6.51	4.78	4.97	5.20	2.59	.22	0.54	.22	39.78	4.6	10.87	4.23
		PH	4.7	4.60	4.5	4.80	4.7	4.80	5.6	5.60	4.7	4.68	4.9	5.18	0.00	.09	0.51	.09	0	1.92	10.41	1.74
	pH	NT	4.9	4.50	4.9	4.50	5.2	5.00	5.4	5.30	5.03	4.80	5.1	4.86	0.13	.18	0.22	.18	2.58	3.75	4.31	3.7
		PHR	4.7	4.70	4.6	4.50	5.6	5.20	5.1	5.30	5.07	4.85	4.83	4.90	0.40	.20	0.21	.20	7.89	4.12	4.35	4.08
		Standard									**5.0-8.2**											
4	*Bulk	Traditional	1.9	1.85	1.9	1.90	1.9	1.92	1.93	1.95	1.9	1.89	1.92	1.92	0.00	.02	0.01	.02	0	1.06	0.52	1.04
		PH	1.86	1.86	1.9	1.90	1.9	1.96	1.94	1.94	1.88	1.91	1.92	1.91	0.01	.03	0.01	.03	0.53	1.57	0.52	1.57
	Density	NT	1.91	1.88	1.9	1.90	1.95	1.93	1.93	1.96	1.92	1.90	1.91	1.92	0.01	.01	0.01	.01	0.52	0.53	0.52	0.52
	(gcm-3)	PHR	1.89	1.90	1.9	1.91	1.91	1.92	1.95	1.96	1.9	1.91	1.92	1.92	0.008	.008	0.02	.008	0.42	0.42	1.04	0.42
		Standard											**1.25-1-65 (**gcm-3**)**									
5		Traditional	3.06	2.11	3.05	2.06	3.11	2.12	3.06	2.12	3.09	2.11	3.06	2.07	0.02	.005	0.004	.005	0.65	0.24	0.13	0.24
		PH	3.04	2.08	3.08	2.06	3.1	2.13	3.09	2.11	3.07	2.10	3.09	2.09	0.02	.02	0.004	.02	0.65	0.95	0.13	0.96
	Organic	NT	3.01	2.08	3.04	2.08	3.06	2.14	3.09	2.12	3.04	1.20	3.06	2.10	0.02	.02	0.02	.02	0.66	1.67	0.65	0.95
	Matter(%)	PHR	3.08	2.08	3.05	2.08	3.1	1.10	3.13	2.15	3.09	2.09	3.09	2.10	0.009	.008	0.03	.008	0.29	0.38	0.97	0.38
		Standard									**≥1%**											
6	*Nitrate	Traditional	0.28	.300	0.31	.320	0.32	.364	0.322	.367	0.29	.317	0.32	.343	0.01	.02	0.002	.02	3.45	6.31	0.63	5.83
		PH	0.32	.320	0.32	.308	0.32	.366	0.322	.360	0.32	.335	0.32	.337	0.002	.01	0.0008	.01	0.63	2.99	0.25	2.97
	Nitrogen	NT	0.28	.310	0.31	.316	0.36	.391	0.341	.371	0.33	.350	0.33	.339	0.03	.03	0.012	.03	9.09	8.57	3.64	8.85
	(mg/kg)	PHR	0.28	.298	0.31	.321	0.32	.392	0.344	.381	0.3	.335	0.33	.341	0.015	.03	0.01	.03	5	8.96	3.03	8.8
		Standard									**>20 mg/kg**											
7		Traditional	2.18	2.14	2.5	2.32	2.24	2.68	2.71	2.69	2.21	2.26	2.61	2.55	0.02	.20	0.09	.20	0.9	8.85	3.45	7.84
	*Phosphorous	PH	2.17	2.18	2.52	2.55	2.49	2.56	2.71	2.70	2.29	2.33	2.61	2.60	0.15	.16	0.08	.16	6.55	6.87	3.07	6.15
		NT	2.18	2.18	2.2	2.19	2.2	2.28	2.72	2.78	2.19	2.22	2.54	2.56	0.009	.04	0.24	.04	0.41	1.8	9.45	1.56
	(mg/kg)	PHR	2.21	2.18	2.18	2.20	2.63	2.70	2.57	2.70	2.44	2.47	2.43	2.51	0.18	.19	0.18	.19	7.38	7.69	7.41	7.57
		Standard									**>15mg/kg**											
8		Traditional	1.19	1.16	1.32	1.30	1.39	1.34	1.55	1.55	1.31	1.25	1.4	1.40	0.08	.08	0.11	.08	6.11	6.4	7.86	5.71
	*Potassium	PH	1.29	1.34	1.34	1.31	1.39	1.40	1.52	1.48	1.34	1.36	1.45	1.41	0.04	.02	0.08	.02	2.99	1.47	5.52	1.42
		NT	1.30	1.24	1.28	1.31	1.35	1.32	1.59	1.56	1.32	1.28	1.41	1.42	0.02	.02	0.13	.02	1.52	1.56	9.22	1.41
	(mg/kg)	PHR	1.30	1.21	1.26	1.21	1.38	1.39	1.3	1.37	1.33	1.30	1.28	1.30	0.03	.06	0.01	.06	2.26	4.62	0.78	4.62
		Standard									**>150mg/kg**											
9		Traditional	1.29	1.21	1.26	1.16	1.38	1.38	1.28	1.28	1.32	1.29	1.27	1.24	0.04	.06	0.009	.06	3.03	4.65	0.71	4.84
	Sodium	PH	1.21	1.21	1.27	1.23	1.32	1.26	1.3	1.27	1.27	1.23	1.29	1.25	0.04	.01	0.01	.01	3.15	0.81	0.78	0.8
	(mg/kg)	NT	1.2	1.11	1.21	1.20	1.29	1.24	1.24	1.28	1.24	1.18	1.23	1.25	0.04	.05	0.01	.05	3.23	4.24	0.81	4
		PHR	1.21	1.18	1.26	1.20	1.27	1.25	1.28	1.27	1.24	1.20	1.27	1.24	0.02	.03	0.008	.03	1.61	2.5	0.63	2.42

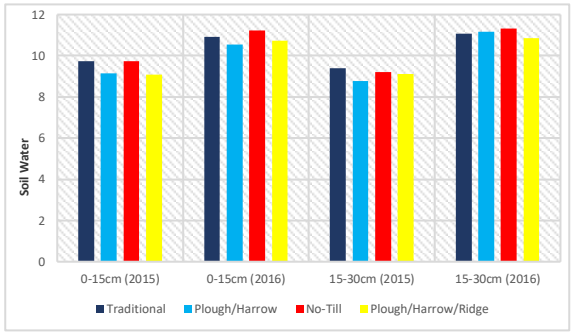
		Standard																				
10		Traditional	1.56	1.39	1.53	1.44	1.64	1.68	1.63	1.68	1.6	1.54	1.59	1.53	0.03	.12	0.04	.12	1.88	7.79	2.52	7.84
	Calcium	PH	1.52	1.52	1.53	1.50	1.62	1.68	1.55	1.63	1.58	1.61	1.54	1.54	0.04	.05	0.008	.05	2.53	3.11	0.52	3.25
	(mg/kg)	NT	1.51	1.54	1.52	1.29	1.56	1.58	1.62	1.64	1.54	1.56	1.57	1.54	0.02	.01	0.042	.02	1.3	0.64	2.68	1.3
		PHR	1.44	1.20	1.53	1.08	1.54	1.56	1.69	1.66	1.48	1.41	1.62	1.49	0.04	.13	0.06	.13	2.7	9.22	3.7	8.72
		Standard																				
11		Traditional	0.43	.30	0.43	.26	0.62	.62	0.52	.47	0.5	.406	0.48	.385	0.09	.11	0.03	.11	18	27.09	6.25	28.57
	Magnesium	PH	0.4	.32	0.44	.32	0.43	.42	0.45	.48	0.41	.391	0.45	.405	0.01	.03	0.004	.03	2.44	7.67	0.89	7.41
	(mg/kg)	NT	0.32	.30	0.43	.32	0.4	.45	0.48	.45	0.37	.386	0.46	.401	0.03	.05	0.02	.05	8.11	12.95	4.35	12.47
		PHR	0.37	.19	0.46	.40	0.45	.43	0.5	.46	0.42	.328	0.47	.431	0.03	.09	0.01	.09	7.14	27.44	2.13	20.88
		Standard																				
12		Traditional	1.48	1.69	1.42	1.42	1.81	2.44	2.17	2.18	1.65	2.04	1.7	1.69	0.14	.32	0.34	.32	8.48	15.69	20	18.93
	*Copper	PH	2.08	2.16	1.43	1.37	2.16	2.21	1.46	1.52	2.12	2.18	1.45	1.44	0.03	.02	0.01	.02	1.42	0.92	0.69	1.39
	(mg/kg)	NT	1.48	1.46	1.41	1.43	1.56	2.48	1.67	1.69	1.51	1.81	1.55	1.56	0.03	.51	0.11	.51	1.99	28.18	7.1	32.69
		PHR	1.47	1.42	1.39	1.38	1.61	2.28	2.1	2.08	1.52	1.72	1.72	1.69	0.06	.42	0.30	.42	3.95	24.42	17.44	24.85
		Standard										**10-100mg/kg**										
13		Traditional	1.16	1.16	1.23	1.29	1.56	1.58	1.49	1.48	1.42	1.41	1.33	1.36	0.19	.19	0.12	.19	13.38	13.48	9.02	13.97
	*Manganese	PH	1.25	1.21	1.26	1.26	1.42	1.41	1.4	1.44	1.35	1.33	1.32	1.32	0.07	.09	0.06	.09	5.19	6.77	4.55	6.82
	(mg/kg)	NT	1.15	1.10	1.22	1.26	1.36	1.36	1.46	1.44	1.24	1.21	1.35	1.35	0.09	.10	0.10	.10	7.26	8.26	7.41	7.41
		PHR	1.25	1.36	1.22	1.26	1.47	1.46	1.38	1.36	1.37	1.42	1.3	1.30	0.09	.04	0.06	.04	6.57	2.82	4.62	3.08
		Standard										**20-3000mg/kg**										
14		Traditional	1.44	1.41	1.46	1.38	1.48	1.48	1.58	1.57	1.46	1.45	1.51	1.46	0.01	.03	0.05	.03	0.68	2.07	3.31	2.05
	*Lead	PH	1.31	1.28	1.64	1.60	1.38	1.38	1.82	1.82	1.35	1.34	1.73	1.71	0.03	.03	0.07	.03	2.22	2.24	4.05	1.75
	(mg/kg)	NT	1.2	1.20	1.28	1.21	1.38	1.36	1.49	1.48	1.27	1.27	1.36	1.37	0.08	.07	0.09	.07	6.3	5.51	6.62	5.11
		PHR	1.41	1.40	1.49	1.46	1.5	1.48	1.6	1.59	1.47	1.46	1.56	1.54	0.04	.03	0.05	.03	2.72	2.05	3.21	1.95
		Standard										**2-200mg/kg**										
15		Traditional	34.64	34.62	30.68	30.62	42.16	42.26	48.42	48.24	37.81	37.77	37.16	37.02	3.32	3.53	8.34	3.53	8.78	9.35	22.44	9.54
	Iron	PH	38.49	38.42	29.76	29.72	42.4	42.38	36.22	36.38	40.72	40.66	32.49	32.50	1.71	1.81	2.85	1.81	4.2	4.45	8.77	5.57
	(mg/kg)	NT	32.38	32.38	33.1	32.41	37.48	37.47	46.76	46.76	35.05	35.09	38.35	38.16	2.18	2.28	6.27	2.28	6.22	6.5	16.35	5.97
		PHR	29.41	29.46	36.68	36.62	33.26	33.19	47.43	47.43	31.28	31.25	41.45	41.40	1.64	1.65	4.67	1.65	5.24	5.28	11.27	3.99
		Standard										**>10mg/kg**										
		Traditional	1.22	1.28	1.12	1.19	1.58	1.57	1.82	1.80	1.41	1.40	1.41	1.42	0.15	.11	0.31	.11	10.64	7.86	21.99	7.75
	*Zinc	PH	1.25	1.48	1.6	1.58	1.68	1.65	1.72	1.69	1.47	1.53	1.66	1.64	0.18	.07	0.05	.07	12.24	4.58	3.01	4.27
16	(mg/kg)	NT	1.52	1.48	1.18	1.16	2.15	2.15	1.46	1.45	1.78	1.74	1.37	1.34	0.28	.30	0.13	.30	15.73	17.24	9.49	22.39
		PHR	1.48	1.41	1.16	1.13	1.71	1.74	2.14	2.18	1.63	1.61	1.56	1.55	0.10	.13	0.44	.13	6.13	8.07	28.21	8.39
		Standard										**10-3000mg/kg**										

KEY- T-traditional, PH-plough/harrow, NT-No-till, PHR-Plough/harrow/ridge, CV- coefficient of variation, UTRF –Unilorin Teaching and Research Farm plots. NCAM- National Centre for Agricultural Mechanization experimental plot, NOTE- *=Not within permissible limits

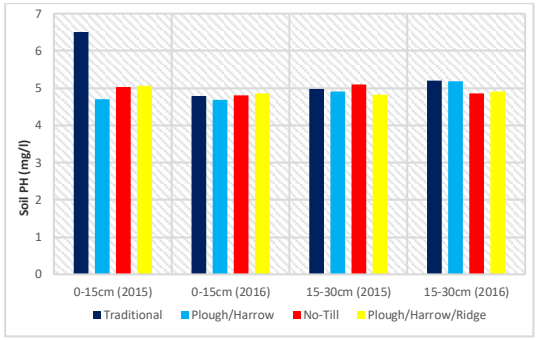
Source: Authors Fieldwork (2016)



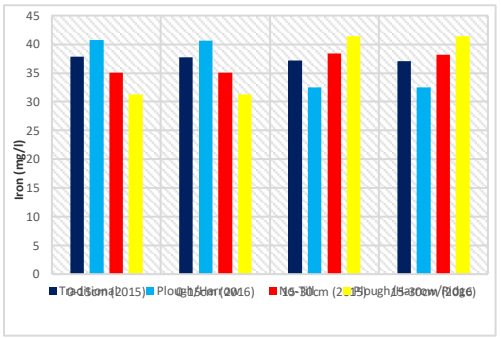
Soil temperature on NCAM Site



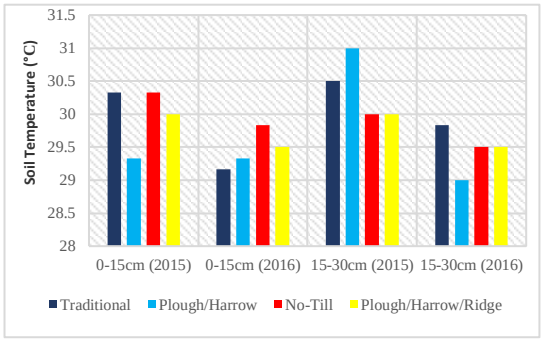
Soil Water on NCAM Site



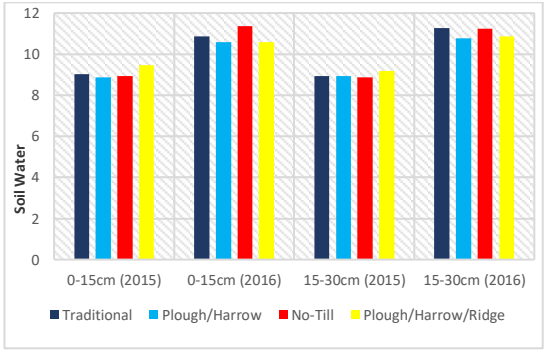
pH on NCAM Site



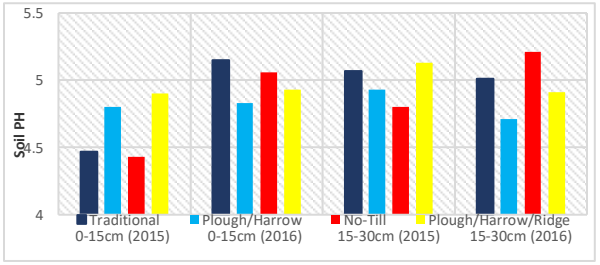
Iron on NCAM site



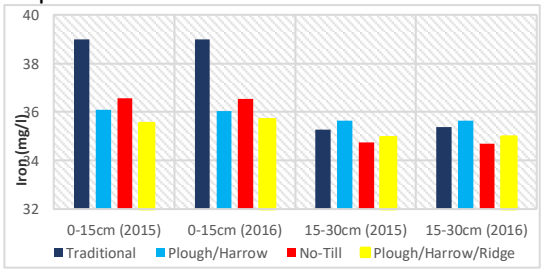
Soil temperature on UTRF Site



Soil water for UTRF Site

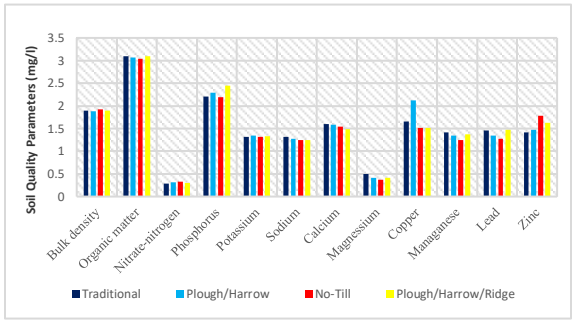


pH for UTRF Site

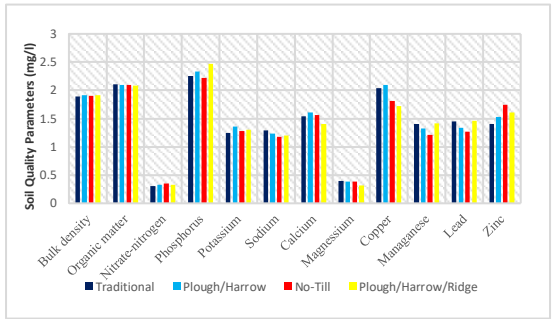


Iron on UTRF Site

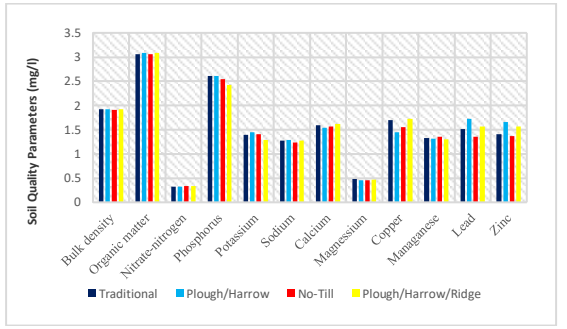
Figure 4.1: Pattern of Distribution of soil temperature, soil water, pH and iron for 2015 and 2016 on the experimental sites.
Source: Authors Fieldwork (2017)



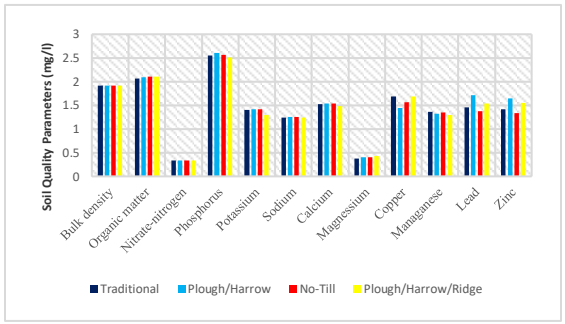
0-15cm 2015 NCAM



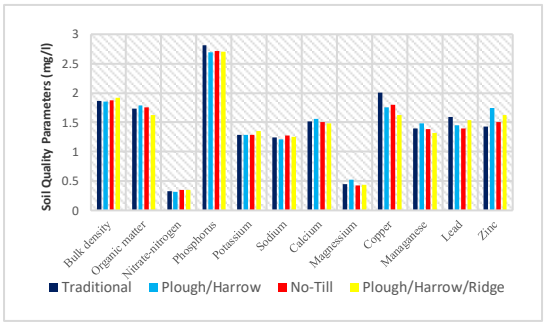
0-15cm 2016 NCAM



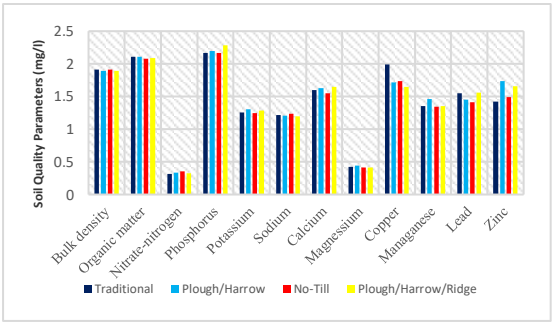
15-30cm 2015 NCAM



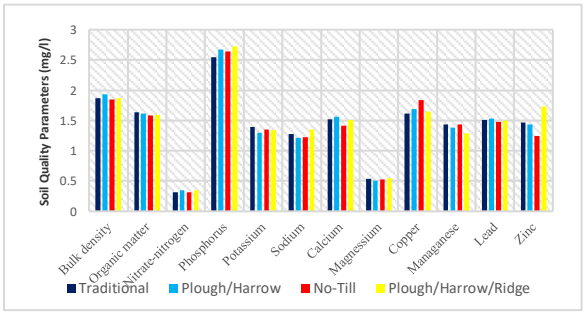
15-30cm 2016 NCAM



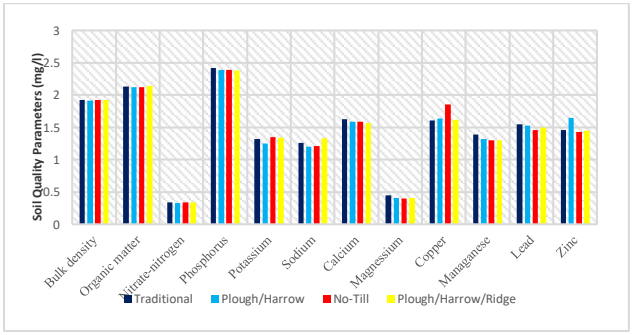
0-15cm 2015 UTRF



0-15cm 2016 UTRF



15-30cm 2015 UTRF



15-30cm 2016 UTRF

Figure 4.2: Pattern of distribution of Soil Quality Indicators on the Experimental Sites

Source: Authors Fieldwork (2017)

From the soil quality indicators that were not within the permissible limit for AESA (2004), Bulk density was highest on Plough/Harrow/Ridge with 1.92 gcm-3 at 0-15cm depth in 2015 while in 2016, it was recorded highest on both Traditional heap and Notill with value of 1.91 gcm-3 each. For 15-30cm, bulk density in 2015 was recorded on Plough/Harrow with 1.93 gcm-3, while in 2016, Traditional heap, Plough/Harrow/Ridge and Notill had the same highest mean value of 1.92 gcm-3 on UTRF site (see Table 4.1 and Figure 4.2). Also, the highest mean (1.92 and 1.91 gcm-3) for bulk density in the topsoil in 2015 and 2016 was recorded on Notill plot for 2015 and Plough/Harrow and Plough/Harrow/Ridge in 2016 whereas in the subsoil, it was recorded on Traditional heap, Plough/Harrow and Plough/Harrow/Ridge for 2015 and in Traditional heap, Notill and Plough/Harrow/Ridge for 2016 with 1.92 gcm-3 on NCAM site (see Table 4.2 and Figure 4.2). All the values did not fall within the permissible limit of AESA (2004) for bulk density with 1.25- 1.65 gcm-3. Research on no-till soils generally shows an increase in N-containing trace emissions upon conversion from conventional tillage practices. This increase has been attributed to an increase in soil bulk density under no-tillage (Oballum, 2011).

Table 4.1 and Figure 4.2 show nitrate-nitrogen in the topsoil was recorded highest on Plough/Harrow/Ridge and Notill with 0.35mg/kg each in 2015 and 2016 however in the subsoil, it was recorded on Plough/Harrow and Plough/Harrow/Ridge with 0.35mg/kg in 2015 and on Traditional heap, Notill and Plough/Harrow/Ridge with 0.34mg/kg in 2016 on the UTRF site. On NCAM site, the highest mean (0.33 and 0.35mg/kg) for nitrate-nitrogen in the topsoil in 2015 and 2016 was recorded on Notill whereas, the highest mean (0.33mg/kg) for nitrate-nitrogen in the subsoil was recorded on Notill and in 2015 and Traditional heap in 2016 with 0.343mg/kg. All the values did not fall within the permissible limit of AESA (2004) for nitrate-nitrogen with >20mg/kg.

Phosphorous had the highest mean value recorded on Traditional heap and Plough/Harrow/Ridge with 2.81 and 2.28 mg/kg at 0-15cm soil depth in 2015 and 2016 and 2.72 and 2.42mg/kg in 2015 and 2016 in the subsoil on UTRF site as revealed in Table 5.1 and Figure 5.1. The mean for phosphorous at NCAM site was highest on Plough/Harrow/Ridge with 2.44 and 2.47mg/kg at 0-15cm soil depth in 2015 and 2016 however at 15-30cm depth, it was recorded on Traditional heap and Plough/Harrow with 2.61mg/kg in 2015 and Plough/Harrow/Ridge in 2016 with 2.60mg/kg (see Table 4.2 and Figure 4.2). All the values did not fall within the permissible limit of AESA (2004) for phosphorus with >15mg/kg.

Plough/Harrow plot was highest with 1.48 and 1.46mg/kg manganese at 0-15cm depth in 2015 and 2016 while No till and Traditional heap had the highest in manganese with 1.43 and 1.39mg/kg at 15-30cm depth in 2015 and 2016 at UTRF site (see Table 4.1 and Figure 4.2). For NCAM site, Manganese was highest on Traditional heap and Plough/Harrow/Ridge with 1.42mg/kg in the topsoil in 2015 and 2016 respectively as well as Notill and Traditional heap with 1.35 and 1.36mg/kg in the subsoil in 2015 and 2016 respectively. All the values did not fall within the permissible limit of AESA (2004) for manganese with 20-3000 mg/kg (see Table 4.2 and Figure 4.2).

Lead was highest on Traditional heap and Plough/Harrow/Ridge (1.59 and 1.56mg/kg) at 0-15cm depth in 2015 and 2016 respectively while at 15-30cm depth, it was highest on Plough/Harrow and Tradition heap with mean value of 1.53 and 1.55mg/kg in 2015 and 2016 at UTRF site (see Table 4.1 and Figure 4.2). In addition, lead was highest on Plough/Harrow/Ridge with 1.47 and 1.46mg/kg in the topsoil for both years respectively as well as Plough/Harrow with 1.73 and 1.71mg/kg in the subsoil in 2015 and 2016 at NCAM site. All the values did not fall

within the permissible limit of AESA (2004) for lead with 2-200mg/kg (see Table 4.2 and Figure 4.2).

Zinc had the highest mean value on PH and PHR with 1.74mg/kg in the topsoil in 2015 and 2016 while in the subsoil, PHR and PH was highest with 1.73 and 1.65mg/kg in 2015 and 2016 at UTRF site (see Table 4.1 and Figure 4.2). Lastly on NCAM site, NT was highest with 1.78 and 1.74mg/kg at 0-15cm soil depth in 2015 and 2016 while at 15-30cm depth, PH with 1.66 and 1.64mg/kg was the highest mean value in 2015 and 2016. All the values did not fall within the permissible limit of AESA (2004) for zinc 10-3000mg/kg (see Table 4.2 and Figure 4.2).

4.3 Impact of Tillage Methods on Soil Quality on UTRF and NCAM Experimental Site

The sixteen variables examined in this study showed that the tillage methods had significant impact on the soil quality in the topsoil and subsoil in 2015 with exception of soil temperature, organic matter, magnesium, manganese, lead and iron on UTRF site. This is however not the case in 2016 as only two variables (soil water in the topsoil and sodium in the subsoil) out of all the sixteen examined were significant as shown in Table 4.3. On NCAM site, sixteen variables were significantly impacted on in both the topsoil and subsoil on for pH, bulk density and nitrate in the topsoil while potassium and manganese in the subsoil in 2015. On the other hand, seven variables (potassium, sodium, calcium, manganese, iron and zinc in the topsoil while lead at both depth) out of the sixteen studied were significantly impacted on by the tillage methods in 2016 as shown in Table 4.4.

To further buttress this, the least significant difference test which was used to test which tillage method differs in its significant impact using the significant values from the ANOVA showed that soil temperature was significantly different in Traditional heap and Notill compared to Plough/Harrow in the topsoil in 2015 however in the subsoil, soil temperature was not significantly different among the tillage types. In 2016, soil temperature was not significantly different in all the tillage types both in the topsoil and subsoils on UTRF site as revealed in Table 4.5.

NCAM site revealed that Soil temperature was significantly different in Plough/Harrow and Notill compared to Traditional heap and Plough/Harrow/Ridge in the topsoil for 2015 while in subsoil, soil temperature are significantly different in Plough/Harrow/Ridge compared to Plough/Harrow and Notill plots. In 2016, it was not significantly different in the topsoil and

subsoil among all the tillage types at NCAM site as shown in Table 4.6. According to Lal (1974), Soils under zero tillage management have been reported to exhibit lower daily maximum temperatures than tilled soil. Wall and Stobbe (1984) also affirmed in their work that Tillage tended to have a greater effect on the maximum soil temperatures than on the minimum soil temperatures. Differences in maximum soil temperature between tillage methods were evident to the 20.0-cm depth although the greatest differences tended to occur in the surface 5.0 cm.

Soil water was significantly different in Plough/Harrow/Ridge compared to Traditional heap, Plough/Harrow and Notill for 2015 and significantly different in Notill compared to Plough/Harrow and Plough/Harrow/Ridge for 2016 in the topsoil. For the subsoil, soil water was significantly different in Plough/Harrow/Ridge compared to Traditional heap , Plough/Harrow and Notill treatment for 2015 while soil water at 15-30cm depth across the four tillage type were not significantly different in 2016 at UTRF site as shown in Table 4.5. On NCAM site, Soil water was significantly different in NT and T compared to PH and PHR in the topsoil. In the subsoil, it was significantly different in T compared to PHR and PH and significantly different in NT and PHR compared to PH in 2015. There was no significant difference among all the tillage methods in the topsoil and subsoil in 2016 as shown in Table 4.6. This contradicts Odjugo (2008) reported that soil moisture at 0 - 15 cm depth was significantly higher in zero tillage, followed by ridge and mound. however, this is inline with Bhattacharyya *et al*., (2008) reporting that tillage affects the soil water status and the capacity of plants to utilize it, as well as increasing detention of surface water and its entry into the soil.

Table 4.3: Pattern of the Impact of Tillage Methods on Soil Quality at Different Depth in UTRF Site for 2015 and 2016 Planting Season

SN	Soil Parameters	Soil Depth	Sum of Squares		Df		Mean Square		F		Sig.	
			2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1.	Soil Temp	0-15cm	8	1.458	3	3	2.667	.486	3.667	.670	0.019*	.580
		15-30cm	8.25	2.125	3	3	2.75	.708	2.283	1.024	0.092	.403
2.	Soil Water	0-15cm	2.455	2.561	3	3	0.818	.854	6.476	3.674	0.001*	.029*
		15-30cm	0.725	1.172	3	3	0.242	.391	2.951	1.693	0.043*	.201
3.	PH	0-15cm	1.987	.355	3	3	0.662	.118	10.506	1.209	0.001*	.332
		15-30cm	0.787	.780	3	3	0.262	.260	2.943	2.746	0.043*	.070
4.	Bulk Density	0-15cm	0.038	.002	3	3	0.013	.001	6.552	1.840	0.001*	.172
		15-30cm	0.043	.001	3	3	0.014	.000	7.328	.261	0.001*	.852
5.	Organic Matter	0-15cm	0.196	.004	3	3	0.065	.001	1.237	2.359	0.308	.102
		15-30cm	0.024	.002	3	3	0.008	.001	3.305	.300	0.029*	.852
6.	Nitrate Nitrogen	0-15cm	0.01	.003	3	3	0.003	.001	3.663	1.146	0.019*	.355
		15-30cm	0.012	.001	3	3	0.004	.000	4.113	.044	0.012*	.987
7.	Phosphorous	0-15cm	0.105	.047	3	3	0.035	.016	11.615	.590	0.001*	.629
		15-30cm	0.182	.004	3	3	0.061	.001	4.784	.010	0.006*	.999
8.	Potassium	0-15cm	0.03	.008	3	3	0.01	.003	3.438	.462	0.025*	.712
		15-30cm	0.042	.037	3	3	0.014	.012	3.419	1.279	0.025*	.309
9.	Sodium	0-15cm	0.025	.004	3	3	0.008	.001	5.206	.946	0.004*	.437
		15-30cm	0.146	.066	3	3	0.049	.022	20.767	8.527	0.001*	.001*
10.	Calcium	0-15cm	0.04	.011	3	3	0.013	.004	5.693	.758	0.002*	.531
		15-30cm	0.143	.034	3	3	0.048	.011	4.144	2.369	0.011*	.101
11.	Magnesium	0-15cm	0.065	.007	3	3	0.022	.002	6.745	.706	0.001*	.560
		15-30cm	0.01	.004	3	3	0.003	.001	2.269	.286	0.094	.835
12.	Copper	0-15cm	0.943	.406	3	3	0.314	.135	7.957	2.722	0.001*	.072
		15-30cm	0.385	.225	3	3	0.128	.075	5.176	2.886	0.004*	.061
13.	Manganese	0-15cm	0.152	.053	3	3	0.051	.018	7.669	1.918	0.001*	.159
		15-30cm	0.149	.029	3	3	0.05	.010	2.684	1.504	0.058	.244
14.	Lead	0-15cm	0.281	.100	3	3	0.094	.033	6.279	2.025	0.001*	.143
		15-30cm	0.02	.027	3	3	0.007	.009	0.671	.698	0.574	.564
15.	Iron	0-15cm	84.074	40.306	3	3	28.025	13.435	0.716	.315	0.548	.814
		15-30cm	5.465	3.204	3	3	1.822	1.068	0.195	.105	0.899	.956
16	Zinc	0-15cm	0.692	.390	3	3	0.231	.130	3.383	1.716	0.026*	.196
		15-30cm	1.385	.191	3	3	0.462	.064	12.407	1.389	0.001*	.275

Note: *Significant at 0.05 between the soil quality across the tillage type

KEY- UTRF –Unilorin Teaching and Research Farm experimental plot

Source: Author's Fieldwork (2016)

Table 4.4: Pattern of the Impact of Tillage Methods on Soil Quality at Different Depth in NCAM Site for 2015 and 2016 Planting Season

SN	Soil Parameters		Sum of Squares		Df		Mean Square		F		Sig.	
		Soil Depth	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1	Soil Temp	0-15cm	21.333	7.125	3	3	7.111	2.375	7.333	3.00	0.001*	.055
		15-30cm	14.667	3.00	3	3	4.889	1.000	3.841	2.222	0.016*	.117
2	Soil Water	0-15cm	4.719	1.633	3	3	1.573	.544	8.764	2.063	0.001*	.137
		15-30cm	2.462	.610	3	3	0.821	.203	11.456	.578	0.001*	.636
3	PH	0-15cm	23.265	.088	3	3	7.755	.029	4.477	.847	0.008*	.484
		15-30cm	0.467	.575	3	3	0.156	.192	0.944	1.544	0.428	.234
4	Bulk Density	0-15cm	0.013	.002	3	3	0.004	.001	22.458	1.028	0.001*	.401
		15-30cm	0.001	.001	3	3	0	.000	0.815	.644	0.493	.595
5	Organic Matter	0-15cm	0.023	.001	3	3	0.008	.000	16.669	1.678	0.001*	.204
		15-30cm	0.011	.003	3	3	0.004	.001	7.816	2.245	0.001*	.114
6	Nitrate Nitrogen	0-15cm	0.01	.003	3	3	0.003	.001	7.538	1.366	0.001*	.282
		15-30cm	0.001	.000	3	3	0	.000	2.577	.081	0.066	.969
7	Phosphorous	0-15cm	0.463	.231	3	3	0.154	.077	10.885	2.770	0.001*	.068
		15-30cm	0.257	.026	3	3	0.086	.009	3.06	.288	0.038*	.834
8	Potassium	0-15cm	0.007	.046	3	3	0.002	.015	0.817	4.848	0.492	.011*
		15-30cm	0.172	.055	3	3	0.057	.018	6.027	2.303	0.002*	.108
9	Sodium	0-15cm	0.058	.041	3	3	0.019	.014	12.262	6.085	0.001*	.004*
		15-30cm	0.021	.001	3	3	0.007	.000	51.333	.133	0.001*	.939
10	Calcium	0-15cm	0.103	.127	3	3	0.034	.042	23.381	4.648	0.001*	.013*
		15-30cm	0.036	.013	3	3	0.012	.004	5.65	.222	0.002*	.880
11	Magnesium	0-15cm	0.101	.021	3	3	0.034	.007	11.909	1.030	0.001*	.400
		15-30cm	0.008	.007	3	3	0.003	.002	4.648	.726	0.007*	.548
12	Copper	0-15cm	2.925	.793	3	3	0.975	.264	146.926	1.924	0.001*	.158
		15-30cm	0.586	.275	3	3	0.195	.092	3.443	1.528	0.025*	.238
13	Manganese	0-15cm	0.205	.174	3	3	0.068	.058	4.494	3.808	0.008*	.026*
		15-30cm	0.014	.014	3	3	0.005	.005	0.539	.902	0.658	.458
14	Lead	0-15cm	0.312	.144	3	3	0.104	.048	43.715	21.855	0.001*	.001*
		15-30cm	0.84	.374	3	3	0.28	.125	53.417	15.253	0.001*	.001*
15	Iron	0-15cm	581.944	288.856	3	3	193.981	96.285	36.188	16.231	0.001*	.001*
		15-30cm	498.05	244.280	3	3	166.017	81.427	4.778	2.103	0.006*	.132
16	Zinc	0-15cm	0.983	.366	3	3	0.328	.122	8.809	3.768	0.001*	.027*
		15-30cm	0.662	.326	3	3	0.221	.109	2.835	1.357	0.049*	.284

Note: *Significant at 0.05 between the soil quality across the tillage type

KEY- NCAM- National Centre for Agricultural Mechanization experimental

Source: Author's Fieldwork (2016)

Table 4.5 Mean and LSD values for Soil Temperature, Soil Water, Ph, Bulk density and Organic Matter at UTRF site

	Soil temp				Soil water				pH				Bulk density				Organic matter			
Tillage types	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	30.33	29.16	30.5	29.83	9.02	10.85	8.94	11.28	4.47	5.15	5.07	5.01	1.86	1.91	1.86	1.92	1.73	2.11	1.64	2.13
PH	29.33	29.33	31	29.00	8.88	10.57	8.92	10.78	4.8	4.83	4.93	4.71	1.85	1.89	1.93	1.91	1.79	2.11	1.61	2.12
NT	30.33	29.83	30	29.50	8.94	11.37	8.86	11.24	4.43	5.06	4.80	5.21	1.88	1.91	1.85	1.92	1.75	2.08	1.58	2.12
PHR	30	29.50	30	29.50	9.46	10.58	9.18	10.87	4.9	4.93	5.13	4.91	1.92	1.89	1.86	1.92	1.62	2.09	1.59	2.14
LSD (0.05)	0.96	1.24	1.44	1.41	0.40	0.32	0.81	0.81	0.28	0.34	0.53	0.52	0.05	0.05	0.00	0.05	0.26	0.05	0.05	0.08

Table 4.6 : Mean and LSD values for Soil Temperature, Soil Water, Ph, Bulk density and Organic Matter at NCAM site

	Soil temp				Soil water				pH				Bulk density				Organic matter			
Tillage types	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	29.33	29.33	30	29.66	9.73	10.91	9.4	11.06	6.51	4.78	4.97	5.20	1.9	1.89	1.92	1.92	3.09	2.11	3.06	2.07
PH	30.67	30.16	29.33	29.66	9.16	10.53	8.77	11.16	4.7	4.68	4.9	5.18	1.88	1.91	1.92	1.91	3.07	2.10	3.09	2.09
NT	30.67	30.83	29.33	30.16	9.75	11.24	9.2	11.31	5.03	4.80	5.1	4.86	1.92	1.90	1.91	1.92	3.04	1.20	3.06	2.10
PHR	29.33	29.83	30.67	20.50	9.07	10.74	9.11	10.87	5.07	4.85	4.83	4.90	1.9	1.91	1.92	1.92	3.09	2.09	3.09	2.10
LSD (0.05)	1.11	1.27	1,50	1,13	0.48	0.30	0.87	1.00	1.48	0.46	0.32	0.60	0.04	0.04	0.05	0.00	0.04	0.04	0.00	0.00

Table 4.7: Mean and LSD values for Nitrate-nitrogen, Phosphorus, Potassium, Sodium and Calcium at UTRF site

	Nitrate-nitrogen				Phosphorus				Potassium				Sodium				Calcium			
Tillage Types	Mean				Mean				Mean								CV			
	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.33	.32	0.32	.34	2.81	2.17	2.55	2.42	1.29	1.26	1.39	1.32	1.24	1.22	1.28	1.26	1.52	1.63	1.52	1.60
PH	0.32	.34	0.35	.33	2.69	2.20	2.67	2.39	1.29	1.30	1.3	1.25	1.21	1.21	1.21	1.20	1.56	1.59	1.56	1.63
NT	0.35	.35	0.32	.34	2.71	2.17	2.64	2.39	1.29	1.25	1.35	1.35	1.27	1.24	1.22	1.21	1.5	1.59	1.41	1.55
PHR	0.35	.33	0.35	.34	2.7	2.28	2.72	2.40	1.35	1.29	1.34	1.34	1.25	1.20	1.35	1.33	1.48	1.57	1.51	1.65
LSD (0.05)	0.04	0.04	0.05	0.08	0.06	0.13	0.28	0.61	0.06	0.07	0.13	0.17	0.05	0.05	0.05	0.09	0.05	0.12	0.12	0.12

Table 4.8 Mean and LSD values for Nitrate-nitrogen, Phosphorus, Potassium, Sodium and Calcium at NCAM site

Tillage types	Nitrate-Nitrogen				Phosphorus				Potassium				Sodium				Calcium			
	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.29	.317	0.32	.343	2.21	2.26	2.61	2.55	1.31	1.25	1.4	1.40	1.32	1.29	1.27	1.24	1.6	1.54	1.59	1.53
PH	0.32	.335	0.32	.337	2.29	2.33	2.61	2.60	1.34	1.36	1.45	1.41	1.27	1.23	1.29	1.25	1.58	1.61	1.54	1.54
NT	0.33	.350	0.33	.339	2.19	2.22	2.54	2.56	1.32	1.28	1.41	1.42	1.24	1.18	1.23	1.25	1.54	1.56	1.57	1.54
PHR	0.3	.335	0.33	.341	2.44	2.47	2.43	2.51	1.33	1.30	1.28	1.30	1.24	1.20	1.27	1.24	1.48	1.41	1.62	1.49
LSD (0.05)	0.04	0.04	0.05	0.00	0.13	0.19	0.28	0.29	0.06	0.11	0.09	0.15	0.05	0.04	0.08	0.08	0.04	0.05	0.16	0.04

Table 4.9 Mean and LSD values for Magnesium, Copper, Manganese, Lead, Iron and Zinc at UTRF site

Tillage Types	Magnesium				Copper				Manganese				Lead				Iron				Zinc			
	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm						0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**201**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.45	.45	0.54	.42	39	39.00	35.28	35.37	2.01	1.99	1.61	1.61	1.39	1.35	1.43	1.39	39	39.00	35.28	35.37	1.43	1.42	1.47	1.46
PH	0.52	.41	0.51	.44	36.09	36.04	35.63	35.65	1.75	1.72	1.69	1.64	1.48	1.46	1.38	1.32	36.09	36.04	35.63	35.65	1.74	1.74	1.44	1.65
NT	0.42	.40	0.53	.41	36.57	36.54	34.74	34.69	1.8	1.74	1.84	1.85	1.38	1.34	1.43	1.30	36.57	36.54	34.74	34.69	1.5	1.49	1.25	1.43
PHR	0.44	.41	0.55	.41	35.53	35.69	34.95	34.99	1.62	1.64	1.65	1.62	1.32	1.35	1.29	1.30	35.53	35.69	34.95	34.99	1.62	1.66	1.73	1.45
LSD (0.05)	0.06	0.05	0.09	0.12	0.23	0.18	0.38	0.27	0.09	0.16	0.16	0.13	0.14	0.11	0.21	0.19	7.06	3.45	11.04	5.39	0.29	0.22	0.47	0.36

Table 4.10: Mean and LSD values for Magnesium, Copper, Manganese, Lead, Iron and Zinc at NCAM site

Tillage Types	Magnesium				Copper				Manganese				Lead				Iron				Zinc			
	0-15cm		15-30cm		0-15cm		15-30cm		0-15cm		15-30cm						0-15cm		15-30cm		0-15cm		15-30cm	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**201**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.5	.406	0.48	.385	1.65	2.04	1.7	1.69	1.42	1.41	1.33	1.36	1.46	1.45	1.51	1.46	37.81	37.77	37.16	37.0	1.41	1.40	1.41	1.42
PH	0.41	.391	0.45	.405	2.12	2.18	1.45	1.44	1.35	1.33	1.32	1.32	1.35	1.34	1.73	1.71	40.72	40.66	32.49	32.5	1.47	1.53	1.66	1.64
NT	0.37	.386	0.46	.401	1.51	1.81	1.55	1.56	1.24	1.21	1.35	1.35	1.27	1.27	1.36	1.37	35.05	35.09	38.35	38.1	1.78	1.74	1.37	1.34
PHR	0.42	.328	0.47	.431	1.52	1.72	1.72	1.69	1.37	1.42	1.3	1.30	1.47	1.46	1.56	1.54	31.28	31.25	41.45	41.4	1.63	1.61	1.56	1.55
LSD (0.05)	0.06	0.04	0.14	0.09	0.09	0.27	0.63	0.41	0.14	0.10	0.21	0.12	0.05	0.08	0.08	0.15	2.61	6.65	4,12	10.5	0.22	0.32	0.30	0.48

The level of pH was significantly different in Plough/Harrow/Ridge and Plough/Harrow compared to Traditional heap and Notill at 0-15cm depth in 2015. At 15-30cm depth, pH was significantly different in Plough/Harrow/Ridge and Traditional heap compared to Notill in 2015 at UTRF site. In 2016, pH at both 0-15cm and 15-30cm depth across the four tillage type was not significantly different at UTRF site. On NCAM site, tillage methods affected pH at 0-15cm depth and was significantly different in Traditional heap compared to Plough/Harrow, Notill and Plough/Harrow/Ridge but in the subsoil, pH was not significantly different in all the tillage types in 2015. In 2016, pH was not significantly different in all the tillage types in the topsoil and subsoil at NCAM site as shown in Table 4.6. Okubo *et al.*,(2008) noted that tillage technique has often shown to have no effect on soil pH though soil pH has been reported to be lower in no-till systems compared to Conventional Tillage. Also, Lal (1997) observed that soil chemical properties of the surface layer such as pH, CEC, exchangeable cations and soil total nitrogen are generally more favourable under the no-till method than under the tilled soil.

Bulk density was significantly different in PHR compared to T , PH and NT for top soil in 2015 while the subsoil, bulk density was significantly different in PH compared to T, PHR and NT in 2015. In 2016, bulk density was not significantly different among all the tillage types in the topsoil and subsoil at UTRF site (see Table 4.5). In addition, Bulk density was significantly different in NT compared to T, PH and PHR in the topsoil in 2015 and also significantly higher in T and PHR compared to PH while for the subsoil, it was not significantly different in all the tillage types. There was no significant difference in the bulk density in the topsoil and subsoil in 2016 at NCAM site (see Table 4.6). According to Akinbile *et al.*,(2016), Bulk density varied with depth of 10-20 cm having the highest and depth of 0-10 cm having the lowest. Increased activity of micro-organisms resulting in increased OM enable the increase in bulk density.

Organic matter was not significantly different in all the tillage types in the topsoil however in the subsoil, organic matter was significantly different in Traditional heap compared to Notill and Plough/Harrow/Ridge in 2015. In 2016, there was no significant different among the types of tillage for organic matter at 0-15cm and 15-30cm depth at UTRF site (see Table 4.5). Furthermore on NCAM site, organic matter was significantly different in Traditional heap compared to Plough/Harrow, Plough/Harrow/Ridge and Notill plots in the topsoil for 2015 while in the subsoil, organic matter was significantly different in Plough/Harrow and Plough/Harrow/Ridge compared to Traditional heap and Notill. In 2016, Organic matter was significantly different in Traditional heap plot compared to Plough/Harrow/Ridge in the topsoil but there was no significant difference in the subsoil in 2016 on NCAM site as revealed in Table 4.6. This is in line with Işildar *et al.*,(2006) findings that reduced tillage method usually increased organic matter and N, and other nutrient contents in the top soil (0 – 5 cm) in relation to traditional tillage methods. While the reduced tillage method usually increased OM and nutrient contents in the top soil (0 – 5 cm) in relation to traditional tillage. Also, Richard *et al.,* (2003) reported that no-till has a greater potential than other tillage methods to store more organic matter in the soil among several tillage practices. Organic matter helps to hold soil nutrients in place so that such nutrient would not be lost to runoff, erosion and leaching. If left undisturbed over the period, soil organic matter can eventually be transformed into long-lasting humus. Also, Akinbile *et al.*,(2010) reported that Organic Carbon is often associated with the Organic Matter which showed that increase in Organic Matter would result in increase in Organic Carbon. The actual amount of soil carbon that could be stored is dependent on the farming system, soil types and climatic condition, as well as the initial soil carbon level of the site.

Nitrate-nitrogen was significantly different in PHR and NT compared to T and PH in topsoil for 2015 whereas for the subsoil, nitrate-nitrogen was significantly different in PH and PHR compared to T and NT plot in 2015. In 2016, it was not significantly different in all the tillage type in the topsoil and subsoil at UTRF site (see Table 4.7) In addition, Nitrate-nitrogen was significantly different in PH and NT compared to PHR and T in the topsoil while in the subsoil, the LSD test shows that nitrate-nitrogen was significantly different in NT and PHR compared to T in 2015. There was no significantly difference in all the tillage types in the topsoil and subsoil in 2016 on NCAM site (see Table 4.8). This is inline with Işildar *et al.*,(2006) that reduced tillage method usually increases organic matter and Nitrate, and other nutrient contents in the top soil (0 – 5 cm) in relation to traditional tillage methods.

Phosphorous was significantly different in Traditional heap compared to Plough/Harrow, Notill and Plough/Harrow/Ridge in the topsoil for 2015 whereas in the subsoil, phosphorous was significantly different in Plough/Harrow and Plough/Harrow/Ridge compared to Traditional heap plot in 2015. However, phosphorus was not significantly different in all the tillage types in both the topsoil and subsoil in 2016 on the UTRF site (see Table 4.7). On NCAM site, Plough/Harrow/Ridge had significant difference on phosphorous compared to Traditional heap, Plough/Harrow and Notill at 0-15cm soil depth in 2015 while at 15-30cm depth, Traditional heap and Plough/Harrow was significantly different as compared to Plough/Harrow/Ridge. There was no significant different on phosphorus in the topsoil and subsoil in 2016 (see Table 4.8). This is in line with Işildar *et al.*,*(*2006) reporting that soil organic Carbon and Nitrate, extractable Phosphorus, exchangeable Calcium, Magnesium, and potassium, and pH were significantly higher with no-tillage than conventional mouldboard plough tillage in the 0 to 5 cm depth.

On UTRF site, potassium was significantly different in PHR compared to T, PH and NT in the topsoil and significantly different in T compared to PH in the subsoil in 2015. In 2016, there was no significant difference in the concentration of potassium among the tillage methods in both the topsoil and subsoil (see Table 4.7). There was no significant difference in the concentration of potassium among all the tillage types in the topsoil in 2015 however it was significantly different in T, PH and NT compared to PHR in the subsoil in 2015. In 2016, potassium was significantly different in PH compared to T and NT plots in 2016 in the topsoil although potassium in 15-30cm depth was not significantly impacted by tillage types at NCAM site (see Table 4.8). Işildar *et al.,(*2006) reported that while Nitrate and potassium were found to show no differences between zero and conventional tillage treatments in both cereals (wheat and maize),soybean showed some differences according to the tillage treatment.

Sodium was significantly different in Notill compared to Plough/Harrow/Ridge, Traditional heap and Plough/Harrow in the topsoil for 2015 even as in the subsoil, sodium was significantly different in Plough/Harrow/Ridge compared to Traditional heap, Plough/Harrow and Notill for 2015. In 2016, there was no significant difference in all the tillage types in the topsoil however in the subsoil, sodium was significantly different in PHR plots compared to Traditional heap, Plough/Harrow and Notill. Also, sodium was significantly different in Traditional heap treatment compared to Plough/Harrow at the UTRF site (see Table 4.7). For NCAM site, sodium was significantly different in Traditional heap compared to Plough/Harrow, Notill and Plough/Harrow/Ridge and also significantly higher in Plough/Harrow compared to Notill at 0-15cm soil depth while at 15-30cm depth, it was significantly different in Plough/Harrow compared to Traditional heap, Notill and Plough/Harrow/Ridge in 2015. In 2016, sodium are significantly different in Traditional heap compared to Plough/Harrow, Notill and Plough/Harrow/Ridge while

for the subsoil, sodium was not significantly different in all the tillage type at NCAM site as shown in Table 4.8.

Calcium was significantly different in PH compared to T, NT and PHR in the topsoil for 2015 whereas in the subsoil, it was significantly different in T, PH and PHR compared to NT for 2015. In addition, calcium was not significantly different in all the tillage types in the topsoil and subsoil in 2016 at UTRF site (see Table 4.7). On NCAM site, calcium was significantly different in PH compared to T, NT and PHR in the topsoil for 2015 while in the subsoil, it was significantly different in T and PHR compared to PH and NT. In 2016, there was significant difference in calcium at the topsoil across the four tillage types. Calcium was significantly different in T, PH and NT compared to PHR for the topsoil while in the subsoil, calcium was not significantly different in all the tillage type (see Table 4.8). Ismail *et al.*, (1994) also reported that soil organic C and N, extractable P, exchangeable Ca, Mg, and K, and pH were significantly higher with no-tillage than conventional mouldboard plough tillage in the 0 to 5 cm depth.

Magnesium was significantly different in Plough/Harrow compared to the other tillage types in the topsoil whereas in the subsoil, there was no significant differences among the tillage types in 2015 at UTRF site. There was no significant difference in magnesium among the tillage types in both topsoil and subsoil in 2016 (see Table 4.9). On NCAM site, Magnesium was significantly different in Traditional heap compared to the other tillage types in the topsoil for 2015 while the subsoil, magnesium was significantly different in Traditional heap compared to others. Magnesium was not significantly different in the topsoil and subsoil among all the tillage type in 2016 (see Table 4.10). This is contradicts the findings of Ismail *et al.*,(1994) reporting that soil organic Carbon, Nitrate, extractable Phosphorus, exchangeable Calcium, Magnesium, potassium, and pH

were significantly higher with no-tillage than conventional mouldboard plough tillage in the 0 to 5 cm depth.

Copper was significantly different in T compared, PH, NT and PHR at 0-15cm depth in 2015 while at 15-30cm depth, copper was significantly different in NT compared to T, PH and PHR at 15-30cm depth in 2015. Copper at 0-15cm and 15-30cm depth across the four tillage type was not significantly different in 2016 at UTRF site (see Table 4.9). In the topsoil at NCAM site, copper was significantly different in PH, compared to T, PHR and NT in 2015 but in the subsoil, it was significantly different in T and PHR compared to PH in 2015. In 2016, there was no significant difference between the tillage methods on copper in 0-15cm depth and 15-30cm at NCAM site (see Table 4.10). This is contrary to the findings of Lavado *et al.,* (2000) reporting that Fe, Cu, Mn and Ni concentrations were higher under conventional tillage as compared to conservation tillage while Pb, Zn, and Co showed higher concentration under zero tillage on topsoil than in conventional tillage.

Manganese was significantly different in Plough/Harrow compared to the other tillage types in the topsoil whereas it was not significantly different in the subsoil in 2015 on UTRF site. In 2016, manganese was not significantly different in all the tillage type in both the topsoil and subsoil (see Table 4.9). For NCAM site, the LSD significant test shows that manganese was significantly different in Traditional heap and Plough/Harrow/Ridge compared to Notill and Plough/Harrow on the topsoil while for the subsoil, manganese was not significantly different in all the tillage types. In 2016, manganese was significantly different in Traditional heap and Plough/Harrow/Ridge compared to NT plot in the topsoil while for the subsoil, manganese was not significantly different in all the tillage type (see Table 4.10). This is agreement with Lavado *et al.,* (2000) reporting that

Cu, Fe, Mn and Ni concentrations were higher under conventional tillage, but Zn, Co and Pb showed higher concentration under zero tillage on topsoil.

In the topsoil, lead was significantly different in T compared to PH and NT and also in PHR compared to NT while lead in the subsoil was not significantly different among tillage types in 2015. There was no significant difference in the topsoil and subsoil among the tillage types at UTRF site in 2016(see Table 4.9). Lead was significantly different in T compared to PHR, PH and NT in the topsoil for 2015 but for the subsoil, lead was significantly different in PH compared to PHR and T. The LSD significant test for topsoil in 2016 shows that lead was significantly different in T and PHR compared to PH and NT. In addition, lead was significantly different in PH compared to NT . For the subsoil, lead was significantly different in PH compared to the other tillage types at NCAM site (see Table 4.10). This is contrary to Lavado *et al.*,(2000) reporting that Pb, Zn, and Co showed higher concentration under zero tillage on topsoil than in conventional tillage while Cu, Fe, Mn and Ni concentrations were higher under conventional tillage.

Zinc was significantly different in PHR compared to T and NT in the topsoil for 2015 as well as there was significant differences in PHR compared to the others in zinc concentration in the subsoil in 2015. In 2016, zinc was not significantly different in all the tillage type in both the topsoil and subsoil at UTRF site (see Table 4.9). On NCAM site, zinc was significantly different in NT compared to the others in the topsoil in 2015 while in the subsoil, zinc was significantly different in PH compared to T and NT. In 2016, Zinc was significantly different in NT compared to T while for the subsoil, zinc was not significantly different in all the tillage type (see Table 4.10). This result contradicts the findings of Lavado *et al.,* (2000) observing that Zn, Co and Pb showed higher concentration under zero tillage on topsoil than in conventional tillage while Cu, Fe, Mn and Ni concentrations were higher under conventional tillage.

Iron was not significantly different among the tillage type at both depths. The LSD significant test also shows that iron was not significantly different in all the tillage type in 2015 and 2016 on UTRF site (see Table 4.9). Iron was significantly different in PH compared to others at 0-15cm depth however for 15-30cm, iron was significantly different in NT and PHR compared to PH in 2015. In 2016, iron was significantly different in T and PH compared to PHR and NT in the topsoil while in the subsoil, iron was not significantly impacted on by the tillage types at NCAM site (see Table 4.10). According to Lavado *et al.,* (2000), Cu, Fe, Mn and Ni concentrations were higher under conventional tillage, but Zn, Co and Pb showed higher concentration under zero tillage on topsoil.

4.4 Comparism between the UTRF and NCAM Experimental Sites

There was significant impact of the tillage methods on the soil water, phosphorus, sodium, calcium, copper and zinc in both the topsoil and subsoil at both locations in 2015 while in 2016, there was no parameter that the tillage methods had significant impact on in the topsoil and subsoil at both locations. The LSD significance test revealed that Plough/Harrow/Ridge and Plough/Harrow were significantly different in soil water, pH, bulk density, nitrate-nitrogen, calcium and zinc in both the topsoil and subsoil on UTRF site in 2015 while in Traditional heap and Notill, phosphorus, sodium and copper were significantly different in the topsoil only in 2015. In 2016, soil water and copper only was significantly different in T and NT in the topsoil and pH and copper in the subsoil in 2016 while sodium and calcium were significantly different in PHR in the topsoil but not in the subsoil on UTRF site in 2016. The LSD test for the other parameters (iron, soil temperature, magnesium, manganese, and lead) revealed that there was no significant difference in the contribution by either of the tillage methods to these parameters on UTRF site in 2015 in the topsoil and subsoil. In 2016, these parameters (pH, bulk density, organic matter, nitrate-nitrogen,

phosphorus, potassium, sodium, calcium, zinc, iron, soil temperature, magnesium, manganese, and lead) revealed that there was no significant difference in the contribution of the tillage methods to their concentration in topsoil and subsoil expect for sodium.

Soil temperature, phosphorus, calcium, magnesium and zinc were significantly different in Plough/Harrow and Plough/Harrow/Ridge in the topsoil and subsoil on NCAM site while organic matter was significantly different in the subsoil only 2015. Traditional heap and Notill tillage methods had organic matter, sodium, copper, lead, pH and bulk density significantly different in both topsoil and subsoil. The other parameters (iron, soil water, manganese, potassium and nitrate-nitrogen) revealed that there was no significant difference in the contribution of either of the tillage methods to these parameters in the topsoil in 2015. In the subsoil, soil temperature, organic matter, sodium, calcium, magnesium and zinc were significantly different on Plough/Harrow and Plough/Harrow/Ridge in 2015 on NCAM site while Traditional heap and Notill had phosphorus and copper significantly different from the other tillage methods.

In 2016, potassium and iron were significantly different on Plough/Harrow and Plough/Harrow/Ridge in the topsoil and subsoil at NCAM site while manganese, calcium, iron and lead were significantly different on Plough/Harrow and Plough/Harrow/Ridge tillage. Sodium and zinc were significantly different on Traditional heap and Notill in the topsoil and in the subsoil, only potassium and iron were significantly different on PH and PHR. The other parameters were not significantly different among the tillage types.

All these observations revealed that there were significant differences as to how these different parameters were affected by the different tillage methods spatially and temporally. It also shows that mechanized (Plough/Harrow and Plough/Harrow/Ridge) tillage had a greater contribution to the concentration of the parameters both in the topsoil and subsoil than Notill and

Traditional heap tillage. Also, there were some soil parameters that were significant in the topsoil but not significant in the subsoil and vice versa. Some of these findings were in line with related research such as Wolkowski (2009) and Kargas *et al.,* (2012) that showed that No-till soils tend to have lower porosity and higher water content, considerable variability by soil type continuous channels in no-till can increase infiltration rate and also observed that untilled plots retain more water than tilled plots respectively.

Some of the result findings in this work were contrary to past references. For instance, the results of Plough/Harrow and Plough/Harrow/Ridge having significant impact on organic matter, sodium, calcium, magnesium and zinc in 2015 at NCAM site are in contrast to the report of Richard *et al.,* (2003) showing that no-till has a greater potential than other tillage methods to store more organic matter in the soil among several tillage practices. Organic matter helps hold soil nutrients in place so they are not lost to runoff, erosion and leaching. If left undisturbed over the period, soil organic matter can eventually be transformed into long-lasting humus. In addition, Ismail *et al.*, (1994) reported that soil organic C and N, extractable P, exchangeable Ca, Mg, and K, and pH were significantly higher with no-tillage than conventional mouldboard plough tillage in the 0 to 5 cm depth and Işildar *et al., (*2006) reported that zero and conventional tillage treatments had no significant impact on N, K, and S in both cereals (wheat and maize), but soybean showed some differences according to the tillage treatment. There is evidence from this study that several factors are involved in the variations of the soil parameters such as the innate soil properties present in terms of texture, structure, type of soil, weather variability among others.

CHAPTER FIVE

IMPACT OF TILLAGE METHODS ON SURFACE RUNOFF

5.1 Introduction

This section presents the results on water analysis with respect to the stated objective under the study. It shows the results of descriptive and inferential statistics used from the laboratory analysis. The acronym for each tillage methods used include Traditional heap (T), Plough/Harrow (PH), No-till (NT) and Plough/Harrow/Ridge (PHR). The analysis of water quality parameters presented in this section are for Unilorin Teaching and Research Farm (UTRF) and National Center for Agricultural Mechanization, Idofian (NCAM) experimental site for 2015 and 2016 planting season. The Nigerian Drinking Water Standard (NDWS) and Aquatic and Habitat Standard adapted from Environmental Protection Agency (EPA) 2001 were used. The full details of the result from the ANOVA and the least significance difference (LSD) for multiple comparisons analysis can be found in Appendix II.

5.2 Distribution of the Surface Runoff Composition on the Different Tillage Methods at the UTRF and NCAM Experimental Plots

The water parameters that were within the permissible limit of the Nigerian Drinking Water Standard (NDWS) 2007 and Aquatic and Habitat Standard adapted from Environmental Protection Agency (EPA) 2001 are turbidity, sodium, potassium, zinc, phosphorus, calcium, magnesium, nitrate, pH and chlorine as revealed in Table 5.1 and Figure 5.1. Carbon and conductivity had no permissible limit proposed by the standards. The coefficients of variation (CV) for all the water parameters in all the tillage methods present a homogenous pattern i.e. all the values were less than 33% except for turbidity, conductivity, chlorine, magnesium, copper and lead displaying a heterogeous pattern (see Table 5.1 and Figure 5.1). The implication is that these parameters vary in

the nature of occurrence in the runoff pointing to the fact that the water chemistry properties are highly variable and according to Ifabiyi (2008), this suggests that there is a need for close monitoring of chemical parameters for the purpose of water resource management in the study area.

The mean for copper did not fall within the permissible limit of the NDWS (2007) which is 2mg/l but it was within the range of 0.2-50mg/l for EPA (2001) standard. This implies that the concentration of copper is not fit for human consumption but acceptable for an agro-ecological habitat. According to Gaffield *et al.,* (2003), Copper is an essential nutrient for all living things. Copper is a component of more than 30 enzymes in the human body, including some involved in collagen synthesis. In humans, copper is necessary for the healthy development of connective tissue, nerve coverings, and bone. It is also involved in both iron and energy metabolism. Copper deficiency, although rare, can cause anemia and connective tissue, bone, and nervous system abnormalities. Adverse effects of copper in an aquatic system include interferences with fish sensory system and behaviors related to predator avoidance, juvenile growth and migratory success.

Total dissolved solids did not fall within the NDWS (2007) and AES standards permissible limit of 500mg/l and 450-2000mg/l respectively. Changes in the amounts of dissolved solids can be harmful because the density of total dissolved solids determines the flow of water in and out of an organism's cells. Concentration of total dissolved solids that are too high or too low may limit the growth and may lead to the death of many aquatic organisms (see Table 5.1 and Figure 5.1). According to EPA (2001), agricultural runoff, and point/non-point wastewater discharges are among source of total dissolved solids in streams and rivers polluting the water and making it unsuitable for human use.

The mean for lead in all the tillage types were above the permissible limit of 0.01mg/l for the NDWS (2007) (see Table 5.1 and Figure 5.1). Lead can cause serious injury to the brain, nervous

system, red blood cells, and kidneys. Exposure to lead can result in a wide range of biological effects depending on the level and duration of exposure according to EPA (2001). Various effects occur over a broad range of doses, with the developing young and infants being more sensitive than adults. Lead is one out of four metals that have the most damaging effects on human health. It can enter the human body through uptake of food (65%), water (20%) and air (15%) as reported by Gaffield *et al.*,(2003).. Even at low levels according to StormwaterRx (2015), lead may cause a range of human health effects such as learning disability, kidney problems and high blood pressure when ingested. Children under 7years are most at risk because their brain is developing. Adverse effects of lead in water on aquatic species occur at concentrations of 1.0-5.1mg/l and include reduced survival, impaired reproduction and reduced growth.

Iron also had mean values in all the tillage methods that were above the permissible limit of 0.03mg/l giving by NDWS (2007) as well as dissolved oxygen with mean values above the permissible limit of 5-6mg/l for NDWS and 13-14mg/l for EPA (2001) (see Table 5.1 and Figure 5.1). StormwaterRx (2015) reported that Iron is an essential dietary mineral for aquatic animals and has been known to encourage algae blooms which create biological oxygen demand, fishes, smother aquatic plants and produce potent neuro-toxins.

Table 5.1: Summaries of Surface Runoff Quality Values on UTRF and NCAM Experimental Site for 2015 and 2016 Planting Season

SN	Parameters/ Units of Measurement	Tillage Type	Minimum				Maximum				Mean				Std. Dev.				CV			
			UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
1	Turbidity*	Traditional	0.28	.291	0.30	.29	0.56	.684	0.58	.88	0.40	.44	0.42	.48	0.10	.14	0.11	.12	25.00	31.82	26.19	25.00
		Plough/Harrow	0.24	.228	0.30	.30	0.51	.726	0.59	.58	0.41	.44	0.46	.43	0.08	.15	0.09	.08	19.51	34.09	19.57	18.60
		No-Till	0.30	.276	0.30	.29	0.75	.658	0.50	.88	0.45	.39	0.42	.45	0.16	.12	0.06	.12	35.56	30.77	14.29	26.67
		Plough/Harrow/Ridge	0.31	.291	0.31	.29	0.48	.722	0.56	.58	0.40	.48	0.40	.42	0.03	.15	0.06	.08	7.5	31.25	15.00	19.05
		Standard NDWS Aquatic Habitat Standard									**5**	**5**	**5**	**5**								
2	Carbon	Traditional	3.00	3.00	3.00	3.10	3.40	3.40	3.60	3.50	3.14	3.25	3.14	3.30	0.13	.13	0.16	.10	4.14	4.00	5.10	3.03
		Plough/Harrow	3.00	3.00	3.00	3.00	3.50	3.50	3.40	3.40	3.18	3.22	3.14	3.20	0.14	.11	0.13	.10	4.40	3.42	4.14	3.13
	(Mg/l)	No-Till	3.00	3.10	3.00	3.00	3.40	3.50	3.40	3.40	3.22	3.27	3.14	3.25	0.12	.11	0.12	.09	3.73	3.36	3.82	2.77
		Plough/Harrow/Ridge	3.00	3.10	0.79	3.00	3.40	3.40	3.40	3.40	3.14	3.20	2.88	3.16	0.10	.07	0.71	.11	3.18	2.19	24.65	3.48
		Standard NDWS Aquatic Habitat Standard																				
3	Sodium*	Traditional	0.20	.28	0.28	.29	0.47	.47	0.48	.48	0.36	.38	0.35	.37	0.07	.05	0.05	.05	19.44	13.16	14.29	13.51
		Plough/Harrow	0.19	.24	0.29	.30	0.47	.47	0.46	.49	0.32	.34	0.35	.37	0.08	.07	0.04	.04	25.0	20.59	11.43	10.81
	(Mg/l)	No-Till	0.27	.29	0.3	.32	0.48	.48	0.49	.49	0.35	.38	0.38	.40	0.06	.05	0.06	.05	17.14	13.16	15.79	12.5
		Plough/Harrow/Ridge	0.24	.28	0.3	.32	0.48	.48	0.5	.49	0.36	.38	0.38	.40	0.07	.06	0.05	.04	19.44	15.79	13.16	10.00
		Standard NDWS									**200**	**200**	**200**	**200**								
		Aquatic Habitat Standard									**0-40**	**0-40**	**0-40**	**0-40**								
4	Potassium*	Traditional	0.48	.34	0.3	.32	0.69	.70	0.4	.43	0.6	.59	0.34	.36	0.07	.10	0.02	.02	11.67	16.95	5.88	5.56
		Plough/Harrow	0.47	.30	0.25	.28	0.62	.69	0.45	.47	0.52	.53	0.358	.37	0.05	.09	0.05	.04	9.62	16.98	13.97	10.81
	(Mg/l)	No-Till	0.56	.32	0.29	.32	0.65	.67	0.43	.48	0.58	.56	0.34	.38	0.02	.09	0.04	.04	3.45	16.07	11.76	10.53
		Plough/Harrow/Ridge	0.52	.30	0.27	.29	0.66	.69	0.46	.48	0.58	.58	0.35	.36	0.04	.09	0.04	.04	6.9	15.52	11.43	11.11
		Standard NDWS Aquatic Habitat Standard									**0-2**	**0-2**	**0-2**	**0-2**								
5	Zinc*	Traditional	0.18	.26	0.18	.28	0.34	.36	0.32	.42	0.27	.31	0.26	.32	0.04	.02	0.04	.03	14.81	6.45	15.38	9.38
		Plough/Harrow	0.19	.22	0.19	.29	0.36	.38	0.33	.40	0.25	.29	0.271	.33	0.04	.04	0.04	.03	16.00	13.79	14.76	9.09
	(Mg/l)	No-Till	0.19	.23	0.19	.28	0.33	.37	0.31	.40	0.25	.29	0.26	.33	0.03	.03	0.03	.03	12.00	10.34	11.54	9.09
		Plough/Harrow/Ridge	0.2	.25	0.19	.28	0.38	.38	0.32	.40	0.26	.29	0.26	.32	0.04	.03	0.04	.03	15.38	10.34	15.38	9.38
		Standard NDWS									**3**	**3**	**3**	**3**								
		Aquatic Habitat Standard																				
6	Nitrate*	Traditional	37.08	31.29	37.08	37.26	41.22	41.82	41.2	41.81	38.79	38.89	38.17	38.31	1.6	1.72	0.93	1.01	4.12	4.42	2.44	2.64
		Plough/Harrow	34.09	37.09	34.09	37.05	40.2	39.36	40.2	39.36	37.98	38.33	38.04	38.19	1.21	.90	1.16	.86	3.19	2.35	3.05	2.25
		No-Till	34.09	33.30	33.01	33.14	38.41	38.20	38.42	38.22	34.6	35.06	34.44	34.51	1	1.23	1.36	1.13	2.89	3.51	3.95	3.27
	(Mg/l)	Plough/Harrow/Ridge	34.12	37.38	0.81	37.35	38.26	38.31	38.3	38.30	37.38	39.95	36.41	37.93	1.15	.38	6.76	.400	3.08	0.95	18.57	1.05
		Standard NDWS									**50**	**50**	**50**	**50**								
		Aquatic Habitat Standard									**0-10**	**0-10**	**0-10**	**0-10**								

*- Parameters within Acceptable Permissible Limit

Table 5.1 (Contd)

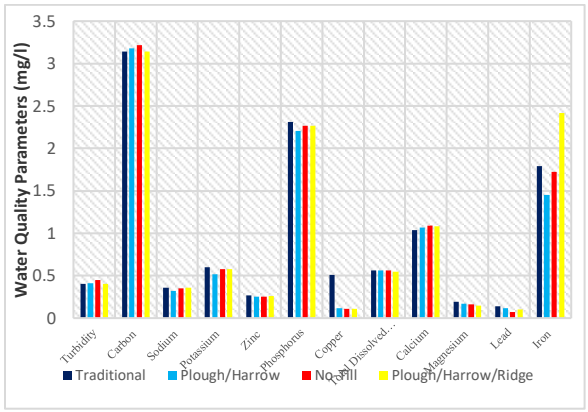
SN		Tillage Type	Minimum				Maximum				Mean				Std. Dev.				CV			
			UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
7	Phosphorous*	Traditional	2	2.00	2	2.10	2.6	2.60	2.6	2.60	2.31	2.25	2.19	2.30	0.16	.19	0.15	.12	6.93	8.44	6.85	5.22
		Plough/Harrow	2	2.00	2	2.20	2.5	2.60	2.4	2.60	2.21	2.32	2.21	2.33	0.13	.13	0.13	.08	5.88	5.60	5.88	3.43
		No-Till	2.1	2.20	2	2.10	2.5	2.50	2.5	2.40	2.27	2.31	2.26	2.31	0.1	.07	0.13	.08	4.41	3.03	5.75	3.46
	(Mg/l)	Plough/Harrow/Ridge	2.1	2.20	2	2.20	2.5	2.50	2.4	2.40	2.27	2.30	2.21	2.32	0.11	.08	0.11	.06	4.85	3.48	4.98	2.59
		Standard NDWS									**>0.1**	**>0.1**	**>0.1**	**>0.1**								
		Aquatic Habitat Standard									**0-2**	**0-2**	**0-2**	**0-2**								
8	pH*	Traditional	6.3	6.60	6.5	6.50	6.8	6.90	6.8	6.90	6.67	6.70	6.65	6.68	0.1	.07	0.11	.09	1.50	1.04	1.65	1.35
		Plough/Harrow	6.4	6.50	6.5	6.50	6.8	6.80	6.9	6.80	6.65	6.70	6.7	6.70	0.11	.08	0.1	.07	1.65	1.19	1.49	1.04
		No-Till	6.5	6.60	6.6	6.60	6.9	6.80	6.9	6.80	6.76	6.69	6.74	6.70	0.11	.07	0.07	.07	1.63	1.05	1.04	1.04
		Plough/Harrow/Ridge	6.5	6.60	6.5	6.60	6.9	6.80	6.9	6.80	6.74	6.72	6.69	6.72	0.12	.07	0.1	.06	1.78	1.04	1.49	0.89
		Standard NDWS									**6.5-8.5**	**6.5-8.5**	**6.5-8.5**	**6.5-8.5**								
		Aquatic Habitat Standard									**6.5-8.5**	**6.5-8.5**	**6.5-8.5**	**6.5-8.5**								
9	Conductivity	Traditional	0.65	79.00	0.75	78.00	0.86	87.00	0.84	84.00	0.8	81.62	0.799	80.40	0.04	1.92	0.01	1.33	5.00	2.35	1.25	1.65
		Plough/Harrow	0.78	79.00	0.68	79.00	0.86	86.00	6.6	83.00	0.8	81.62	0.987	80.88	0.01	1.64	1.06	1.25	1.25	2.01	107.40	1.55
		No-Till	0.79	79.00	0.77	78.00	0.84	84.00	6.8	84.00	0.8	81.70	1.39	80.77	0.01	1.46	1.81	1.25	1.25	1.79	130.22	1.55
		Plough/Harrow/Ridge	0.69	68.00	0.72	79.00	0.86	84.00	6.8	84.00	0.8	80.55	1.38	80.44	0.04	3.80	1.81	1.31	5.00	4.72	131.16	1.63
		Standard NDWS																				
		Aquatic Habitat Standard																				
10	Chlorine*	Traditional	47.68	48.09	0.75	47.82	49.23	49.08	49.15	49.15	48.53	48.28	43.52	48.26	0.53	.24	14.49	.29	1.09	0.50	33.30	0.60
		Plough/Harrow	47.52	48.10	0.68	48.04	49.2	49.29	49.1	49.10	48.33	48.48	43.64	48.54	0.45	.39	14.54	.36	0.93	0.80	33.32	0.74
		No-Till	47.23	48.04	0.78	48.06	48.12	48.31	48.12	48.32	48.01	48.16	43.3	48.19	0.17	.08	14.41	.07	0.35	0.17	33.28	0.15
	(Mg/l)	Plough/Harrow/Ridge	47.92	48.08	0.72	48.04	49.92	49.11	48.63	49.03	48.37	48.57	43.38	48.43	0.53	.39	14.45	.33	1.10	0.80	33.31	0.68
		Standard NDWS									**250**	**250**	**250**	**250**								
		Aquatic Habitat Standard									**0-30**	**0-30**	**0-30**	**0-30**								
11		Traditional	0.11	.078	0.1	.082	1.24	.146	0.12	.128	0.51	.119	0.11	.101	0.54	.029	0.01	.018	105.88	24.37	9.09	17.82
		Plough/Harrow	0.07	.085	0.098	.068	0.79	.126	0.11	.220	0.12	.116	0.11	.138	0.12	.011	0.003	.062	100.00	9.48	2.71	44.93
	Copper	No-Till	0.09	.082	0.086	.054	0.12	.146	0.121	.105	0.11	.106	0.10	.082	0.01	.026	0.01	.019	9.09	24.53	10.00	23.17
	(Mg/l)	Plough/Harrow/Ridge	0.096	.081	0.085	.112	0.12	.144	0.121	.245	0.11	.108	0.10	.162	0.01	.024	0.01	.057	9.09	22.22	10.00	35.19
		Standard NDWS									**2**	**2**	**2**	**2**								
		Aquatic Habitat Standard									**0.2-50**	**0.2-50**	**0.2-50**	**0.2-50**								

*- Parameters within Acceptable Permissible Limit

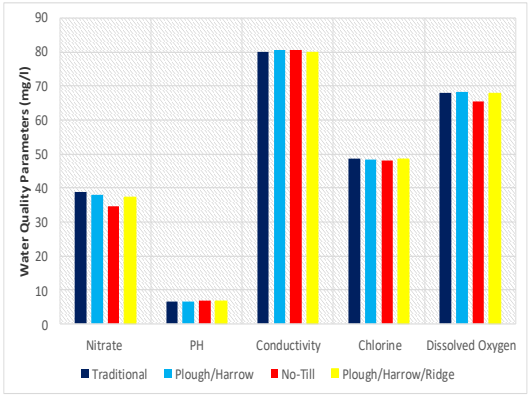
Table 5.1 (Contd)

SN		Tillage Type	Minimum				Maximum				Mean				Std. Dev.				CV			
			UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
12	Total Dissolved Solid (Mg/l)	Traditional	0.52	.54	0.51	.53	0.63	.82	0.68	.70	0.56	.60	0.57	.61	0.02	.06	0.05	.04	3.57	10.00	8.77	6.56
		Plough/Harrow	0.52	.53	0.5	.55	0.61	.63	0.61	.63	0.56	.58	0.55	.59	0.03	.031	0.03	.01	5.36	5.34	5.45	1.69
		No-Till	0.5	.54	0.5	.54	0.61	.62	0.61	.62	0.56	.57	0.55	.59	0.03	.022	0.03	.02	5.36	3.86	5.45	3.39
		Plough/Harrow/Ridge	0.5	.53	0.5	.54	0.6	.61	0.6	.61	0.55	.57	0.55	.58	0.02	.025	0.03	.01	3.64	4.39	5.45	1.72
		Standard NDWS									**500**	**500**	**500**	**500**								
		Aquatic Habitat Standard									**450-2000**	**450-2000**	**450-2000**	**450-2000**								
13	Calcium*	Traditional	0.109	1.13	1.01	1.38	1.12	1.92	1.14	1.91	1.04	1.63	1.094	1.68	0.17	.31	0.03	.21	16.35	19.02	2.74	12.50
		Plough/Harrow	1	1.06	1.02	1.43	1.11	2.04	1.16	2.05	1.07	1.34	1.11	1.73	0.02	.28	0.03	.23	1.87	20.90	2.70	13.29
		No-Till	1.06	1.34	1.04	1.68	1.13	2.09	1.14	2.00	1.09	1.79	1.09	1.81	0.01	.28	0.02	.11	0.92	15.64	1.83	6.08
	(Mg/l)	Plough/Harrow/Ridge	1.04	1.50	1.03	1.58	1.14	2.02	1.18	.32	1.08	1.70	1.1	1.80	0.02	.15	0.04	.17	1.85	8.82	3.64	9.44
		Standard NDWS																				
		Aquatic Habitat Standard									**0-20**	**0-20**	**0-20**	**0-20**								
14	Magnesium*	Traditional	0.13	.14	0.09	.24	0.23	.41	0.23	.36	0.191	.25	0.178	.29	0.03	.09	0.04	.02	15.71	36.00	22.47	6.90
		Plough/Harrow	0.12	.12	0.08	.26	0.23	.34	0.22	.34	0.17	.17	0.18	.30	0.03	.05	0.04	.02	17.65	29.41	22.22	6.67
		No-Till	0.09	.26	0.19	.27	0.24	.36	0.23	.32	0.16	.30	0.2	.29	0.04	.02	0.01	.01	25.00	6.67	5.00	3.45
	(Mg/l)	Plough/Harrow/Ridge	0.08	.16	0.1	.28	0.23	.31	0.24	.36	0.15	.21	0.19	.30	0.05	.03	0.03	.01	33.33	14.29	15.79	3.33
		Standard NDWS									**0.20**	**0.20**	**0.20**	**0.20**								
		Aquatic Habitat Standard									**0-5**	**0-5**	**0-5**	**0-5**								
15	Dissolved Oxygen	Traditional	65	67.00	59	60.00	71	110.00	69	110	68	89.48	62.9	81.96	1.74	15.08	2.68	16.22	2.56	16.85	4.26	19.79
		Plough/Harrow	60	66.00	58	59.00	73	102.00	70	101	68.23	84.70	62.7	81.40	2.59	12.02	2.94	14.07	3.8	14.19	4.70	17.29
		No-Till	57	58.00	58	59.00	71	108.00	69	109	65.4	86.66	63.4	83.59	3.95	14.95	3.36	15.68	6.04	17.25	5.30	18.76
	(Mg/l)	Plough/Harrow/Ridge	62	64.00	59	61.00	71	98.00	68	105	67.96	80.59	63.53	82.88	2.14	10.05	2.19	14.29	3.15	12.47	3.45	17.24
		Standard NDWS									**5-6**	**5-6**	**5-6**	**5-6**								
		Aquatic Habitat Standard									**13-14**	**13-14**	**13-14**	**13-14**								
16	Lead	Traditional	0.06	.06	0.09	.09	0.25	.90	0.2	.20	0.14	.17	0.14	.14	0.05	.15	0.03	.03	35.71	88.24	21.43	21.43
		Plough/Harrow	0.09	.09	0.08	.08	0.2	.21	0.19	.18	0.12	.13	0.11	.11	0.04	.04	0.02	.02	33.33	30.77	18.18	18.18
	(Mg/l)	No-Till	0.05	.05	0.09	.09	0.11	.20	0.2	.22	0.07	.09	0.13	.14	0.02	.03	0.04	.04	28.57	33.33	30.77	28.57
		Plough/Harrow/Ridge	0.01	.07	0.1	.10	0.19	.24	0.36	.35	0.10	.13	0.16	.17	0.04	.04	0.05	.05	40.00	30.77	31.25	29.41
		Standard NDWS									**0.01**	**0.01**	**0.01**	**0.01**								
		Aquatic Habitat Standard																				
17	Iron (Mg/l)	Traditional	1.4	1.43	1.38	1.39	2.44	2.48	2.4	2.42	1.79	1.83	1.75	1.75	0.45	.46	0.39	.39	25.14	25.14	22.29	22.29
		Plough/Harrow	1.4	1.42	1.38	1.40	1.52	2.46	2.36	2.29	1.45	1.54	1.7	1.71	0.03	.22	0.37	.36	2.07	14.29	21.76	21.05
		No-Till	1.2	1.26	1.41	1.38	2.5	2.53	2.54	2.57	1.72	1.74	1.81	1.82	0.55	.54	0.48	.47	31.98	31.03	26.52	25.82
		Plough/Harrow/Ridge	1.49	1.42	1.37	1.37	2.56	2.56	2.31	2.26	2.42	2.25	1.68	1.70	0.25	.43	0.36	.34	10.33	19.11	21.43	20.00
		Standard NDWS									**0.3**	**0.3**	**0.3**	**0.3**								
		Aquatic Habitat Standard									**1**	**1**	**1**	**1**								

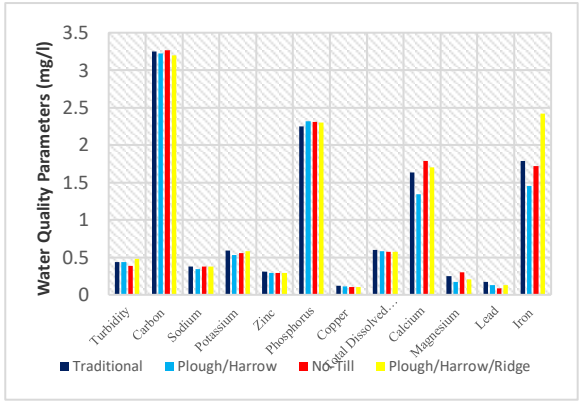
KEY- T-traditional, PH-plough/harrow, NT-No-till, PHR-Plough/harrow/ridge, CV- coefficient of variation, Red- value above 33%, UTRF-Unilorin Teaching and Research Farm experimental plots. NCAM- National Centre for Agricultural Mechanization experimental plot. **Source**: Authors Fieldwork (2016)



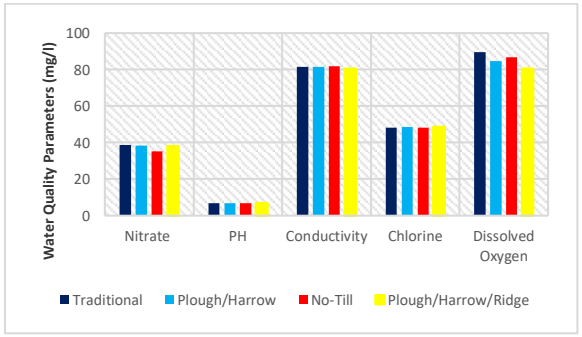
UTRF 2015



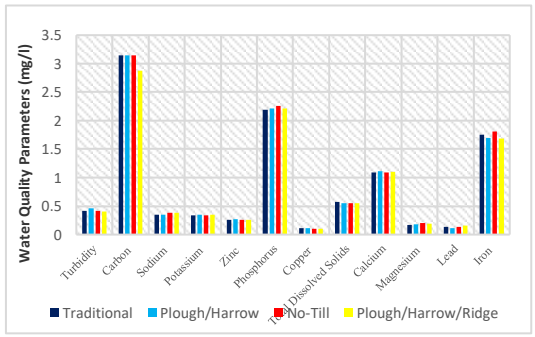
UTRF 2015



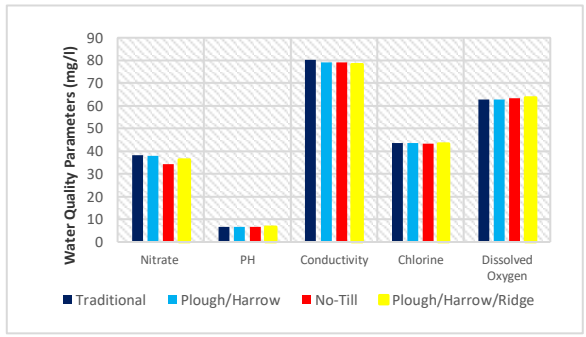
UTRF 2016



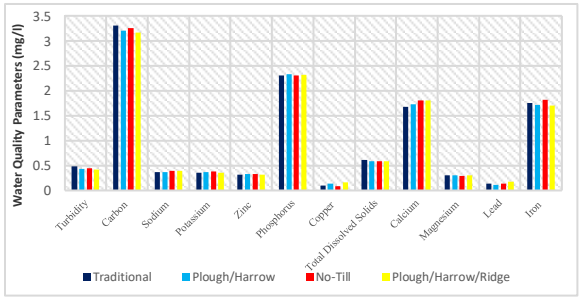
UTRF 2016



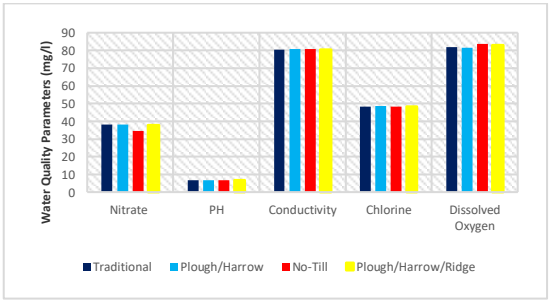
NCAM 2015



NCAM 2015



NCAM 2016



NCAM 2016

Figure 5.1: Pattern of Distribution of the Surface runoff Quality and the Tillage Methods for the experimental sites

Source: Authors Fieldwork (2017)

5.2 Pattern of the Impact of Tillage Methods on Surface Runoff Water Quality on the Experimental Plots

The seventeen variables examined in the study showed that the tillage methods had significant impact on the surface runoff in 2015 with exception of turbidity, sodium, zinc, phosphorus , conductivity , total dissolved solids and calcium on UTRF site. This is however not the case in 2016 as only six (nitrate, chlorine, calcium, magnesium, lead and iron) out of the seventeen examined were significant as shown Table 5.2. On NCAM site, seventeen variables were significantly different in concentration except for turbidity, potassium, zinc, phosphorus, conductivity, chlorine, total dissolved solids, calcium, dissolved oxygen and Iron in 2015. On the other hand, seven variables (carbon, nitrate, chlorine, copper, total dissolved solids, calcium and lead) out of the seventeen studied were significantly impacted on by the tillage methods in 2016 as shown 5.2.

To further buttress this, the least significant difference test which was used to test which tillage method differs in its significant impact using the significant values from the ANOVA showed that Carbon in the runoff samples was significantly different in Notill compared to the Traditional heap and Plough/Harrow/Ridge at UTRF experimental site in 2015. Furthermore, NCAM experimental site revealed that carbon was significantly different in Traditional heap, Plough/Harrow and Notill compared to Plough/Harrow/Ridge. In 2016, carbon was significantly different in Notill compared to Plough/Harrow/Ridge at UTRF site. NCAM experimental site revealed that carbon was significantly different in Traditional heap compared to Plough/Harrow and Plough/Harrow/Ridge. Also, carbon in Notill was significantly different compared to Plough/Harrow/Ridge as shown in Table 5.3. This is in line with Minase *et al.,* (2016) who found out that carbon could be increased in both soil and water by using minimum tillage. `

Sodium in water samples across the four tillage types was not significantly different at UTRF experimental site however, sodium was significantly different in Notill compared to Plough/Harrow and also significantly different in Plough/Harrow/Ridge compared to Traditional heap and Plough/Harrow in 2015 on NCAM site. Sodium was significantly different in Traditional heap and Plough/Harrow/Ridge compared to Plough/Harrow plot on UTRF site and significantly different in Plough/Harrow/Ridge compared to Plough/Harrow at NCAM site in 2016 (see Table 5.3).

Potassium was significantly different in T, NT, PHR compared to PH at URTF site in 2015 and also significantly different in T compared to PH in 2016. On NCAM site, potassium was not significantly different in all the tillage types in 2015 and 2016 (see Table 5.3). According to Bertol *et al.*, (2003), treatments that received fertilization in their study had mean potassium concentrations fourfold greater in the runoff water of the first rainfall compared to the other applied rainfalls, thus demonstrating the importance of a correct surface runoff management, especially for the first rain that falls after the application of fertilizers to the soil, or after surface plant residue management operations have been carried out, as it is the case with soil conservation tillage. This behaviour is explained by the high solubility of potassium, which can be easily lost through water erosion.

In addition, zinc was not significantly different in all the tillage types at both locations and both years (see Table 5.3). This is different from the findings of Giller *et al.*, (2009) reporting that Zn, Co and Pb showed higher concentration under zero tillage on topsoil and runoff while Cu, Fe, Mn and Ni concentrations were higher under conventional tillage.

Also, nitrate was significantly different in T compared to PH, NT, PHR, significantly different in PH, PHR compared to NT on UTRF sites and also in T, compared to NT plot on

NCAM site in 2015. In 2016, nitrate was significantly different in T compared to PH, NT, PHR on UTRF sites while on NCAM site, nitrate was significantly different greater in T, PH and PHR compared to NT (see Table 5.3). Romkens *et al.*, (1973) using a rainfall simulator to compare the N and P composition in runoff water and sediment from five tillage systems observed that conventional tillage systems were less effective in controlling soil erosion, but had lower concentrations of N and P in runoff. They concluded that conventional tillage under which the fertilizers were plowed under, had the highest losses of soil, runoff, and sediment-bound nutrients but lower losses of soluble N and P.

Table 5.2: Tillage Impact on Surface Runoff Quality Parameters at UTRF and NCAM Experimental plots for 2015 and 2016 planting season using ANOVA

SN		Experimental Sites	Sum of Squares		Df		Mean Square		F		Sig.	
			2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
1.	Turbidity	UTRF	0.056	.106	3	3	0.019	.035	1.609	1.665	0.191	.179
		NCAM	0.051	.049	3	3	0.017	.016	2.236	1.446	0.088	.234
2.	Carbon (C)	UTRF	0.132	.076	3	3	0.044	.025	2.711	1.910	0.048*	.132
		NCAM	1.487	.282	3	3	0.496	.094	3.46	8.541	0.019*	.001*
3.	Sodium (Na^{2+})	UTRF	0.036	.027	3	3	0.012	.009	2.062	2.326	0.109	.079
		NCAM	0.03	.018	3	3	0.01	.006	3.105	2.223	0.029*	.090
4.	Potassium (K)	UTRF	0.117	.056	3	3	0.039	.019	14.142	1.871	0.001*	.139
		NCAM	0.005	.004	3	3	0.002	.001	0.838	.779	0.476	.508
5.	Zinc (Zn^{2+})	UTRF	0.005	.005	3	3	0.002	.002	0.912	1.482	0.438	.224
		NCAM	0.003	.001	3	3	0.001	.000	0.521	.241	0.669	.868
6.	Nitrate (N^{2+})	UTRF	298.265	232.907	3	3	99.422	77.636	62.152	56.922	0.001*	.001*
		NCAM	274.927	268.532	3	3	91.642	89.511	7.351	110.951	0.001*	.001*
7.	Phosphorous (P)	UTRF	0.134	.079	3	3	0.045	.026	2.616	1.508	0.054	.217
		NCAM	0.071	.014	3	3	0.024	.005	1.347	.516	0.262	.672
8.	pH	UTRF	0.245	.013	3	3	0.082	.004	6.237	.757	0.001*	.521
		NCAM	0.122	.019	3	3	0.041	.006	4.27	1.004	0.007*	.394
9.	Conductivity	UTRF	14.205	24.546	3	3	4.735	8.182	.425	1.421	.735	.241
		NCAM	54.242	4.667	3	3	18.081	1.556	1.363	.938	.257	.425
10	Chlorine (Cl^{2+})	UTRF	4.233	2.817	3	3	1.411	.939	6.97	10.049	0.001*	.001*
		NCAM	2.019	2.088	3	3	0.673	.696	0.003	8.241	1.00	.001*
11.	Copper (Cu^{2+})	UTRF	3.558	.003	3	3	1.186	.001	15.23	1.871	0.001*	.139
		NCAM	0.002	.107	3	3	0.001	.036	9.004	18.028	0.001*	.001*
12	Total Dissolved Solid	UTRF	0.003	.010	3	3	0.001	.003	1.245	2.023	0.297	.115
		NCAM	0.008	.010	3	3	0.003	.003	1.526	4.470	0.211	.005*
13.	Calcium (Ca^{2+})	UTRF	0.049	3.089	3	3	0.016	1.030	1.941	14.200	0.127	.001*
		NCAM	0.007	.307	3	3	0.002	.102	1.894	2.783	0.134	.045*
14.	Magnesium (Mg^{2+})	UTRF	0.027	.272	3	3	0.009	.091	5.622	25.855	0.001*	.001*
		NCAM	0.013	.001	3	3	0.004	.000	3.172	1.302	0.027*	.278
15.	Dissolved Oxygen (Do)	UTRF	161.267	1130.028	3	3	53.756	376.676	7.171	2.162	0.001*	.097
		NCAM	14.20	76.185	3	3	4.733	25.395	0.591	.111	0.622	.953
16.	Lead(Pb^{2+})	UTRF	0.08	.083	3	3	0.027	.028	15.481	3.893	0.001*	.011*
		NCAM	0.033	.041	3	3	0.011	.014	6.81	9.206	0.001*	.001*
17.	Iron (Fe^{2+})	UTRF	15.079	7.276	3	3	5.026	2.425	34.773	12.871	0.001*	.001*
		NCAM	0.283	.275	3	3	0.094	.092	0.565	.572	0.639	.634

Note: * Significant at 0.05 between the water quality across the tillage type

Source: Authors Fieldwork (2016)

Table 5.3 Means and LSD values for Turbidity, Carbon. Sodium, Potassium, Zinc and Nitrate from the Experimental sites

Tillage type	Turbidity				Carbon				Sodium				Potassium				Zinc				Nitrate			
	UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
	2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.4	0.44	0.42	0.48	3.14	3.25	3.14	3.3	0.36	0.38	0.35	0.37	0.6	0.59	0.34	0.36	0.27	0.31	0.26	0.32	38.79	38.89	38.17	38.31
Plough/Harrow	0.41	0.44	0.46	0.43	3.18	3.22	3.14	3.2	0.32	0.34	0.35	0.37	0.52	0.53	0.35	0.37	0.25	0.29	0.271	0.33	37.98	38.33	38.04	38.19
No-Till	0.45	0.39	0.42	0.45	3.22	3.27	3.14	3.25	0.35	0.38	0.38	0.4	0.58	0.56	0.34	0.38	0.25	0.29	0.26	0.33	34.6	35.06	34.44	34.51
Plough/Harrow/Ridge	0.4	0.48	0.4	0.42	3.14	3.2	2.88	3.16	0.36	0.38	0.38	0.4	0.58	0.58	0.35	0.36	0.26	0.29	0.26	0.32	37.38	39.95	36.41	37.93
LSD (0.05)	0.08	0.11	0.06	0.08	0.09	0.08	0.26	0.08	0.05	0.05	0.04	0.04	0.04	0.07	0.03	0.03	0.03	0.02	0.03	0.02	0.88	0.85	2.45	0.66

Table 5.4: Mean and LSD values Total dissolved solids, Calcium, Magnesium, Dissolved oxygen, Lead and Iron parameters from the Experimental sites

	Total Dissolved Solid				Calcium				Magnesium				Dissolved Oxygen				Lead				Iron			
	UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
Tillage Type	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	0.56	0.6	0.57	0.61	1.04	1.63	1.094	1.68	0.191	0.25	0.178	0.29	68	89.48	62.9	81.96	0.14	0.17	0.14	0.14	1.79	1.83	1.75	1.75
Plough/Harrow	0.56	0.58	0.55	0.59	1.07	1.34	1.11	1.73	0.17	0.17	0.18	0.3	68.23	84.7	62.7	81.4	0.12	0.13	0.11	0.11	1.45	1.54	1.7	1.71
No-Till	0.56	0.57	0.55	0.59	1.09	1.79	1.09	1.81	0.16	0.3	0.2	0.29	65.4	86.66	63.4	83.59	0.07	0.09	0.13	0.14	1.72	1.74	1.81	1.82
Plough/Harrow/Ridge	0.55	0.57	0.55	0.58	1.08	1.7	1.1	1.8	0.15	0.21	0.19	0.3	67.96	80.59	63.53	82.88	0.1	0.13	0.16	0.17	2.42	2.25	1.68	1.7
LSD (0.05)	0.02	0.03	0.03	0.02	0.06	0.20	0.02	0.14	0.03	0.05	0.02	0.00	1.90	9.66	1.96	11.05	0.03	0.06	0.03	0.02	0.26	0.32	0.28	0.29

Table 5.5: Mean and LSD values for Phosphorus, pH, Conductivity, Chlorine and Copper from the Experimental sites

	Phosphorous				pH				Conductivity				Chlorine				Copper			
	UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM		UTRF		NCAM	
Tillage type	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
Traditional	2.31	2.25	2.19	2.3	6.67	6.7	6.65	6.68	0.8	81.62	0.799	80.4	48.53	48.28	43.52	48.26	0.51	0.119	0.11	0.101
Plough/Harrow	2.21	2.32	2.21	2.33	2.33	6.65	6.7	6.7	0.8	81.62	0.987	80.88	48.33	48.48	43.64	48.54	0.12	0.116	0.11	0.138
No-Till	2.27	2.31	2.26	2.31	6.76	6.69	6.74	6.7	0.8	81.7	1.39	80.77	48.01	48.16	43.3	48.19	0.11	0.106	0.1	0.082
Plough/Harrow/Ridge	2.27	2.3	2.21	2.32	6.74	6.72	6.69	6.72	0.8	80.55	1.38	80.44	48.37	48.57	43.38	48.43	0.11	0.108	0.1	0.162
LSD (0.05)	0.09	0.10	0.09	0.07	0.08	0.06	0.07	0.06	0.02	1.76	0.96	0.94	0.31	0.22	10.03	0.21	0.19	0.02	0.02	0.03

The tillage types showed no significant differences in total dissolved solids(TDS) at both sites in 2015, however, total dissolved solid was significantly different in T compared to NT and PHR at UTRF site in 2016 while on NCAM site, it was significantly different in T compared to PH, NT and PHR in 2016 (see Table 5.4). Muoghalu and Omocho (2000) reported that high TDS values have the tendency to absorb heat from the sun thereby raising the temperature and increasing the turbidity of water.

Calcium was significantly different in Notill compared to Traditional heap at UTRF site but on NCAM site was significantly different in Plough/Harrow compared to Notill in 2015. In 2016, calcium was significantly different in Notill compared to Traditional heap and Plough/Harrow on UTRF site. Also, calcium was significantly different in Traditional heap and Plough/Harrow/Ridge compared to Plough/Harrow but significantly different in Notill and Plough/Harrow/Ridge compared Traditional heap on NCAM site (see Table 5.4). These results do not match those reported by Bertol *et al.*,(2005) that an important factor that may have influenced the low calcium and magnesium concentrations in surface runoff under no-tillage was the fact that these elements, especially calcium, can complex with organic matter, which has neutral charge and is soluble, be leached with water down in the soil profile, and thus be reduced in the surface runoff in that soil tillage system. This phenomenon is favored under no-tillage because of greater accumulation of organic matter, and consequently, organic carbon in this soil, in comparison to conventional soil tillage.

Magnesium was significantly different in T compared to NT and PHR. Also, magnesium was significantly different in PH compared to PHR at UTRF site while Magnesium was significantly different in NT compared to T and PH at NCAM site in 2015. In 2016, Magnesium was significantly different in NT compared to T , PH and PHR at UTRF site. This implies that

tillage type has significant impact on magnesium concentration in the water samples from the tillage methods. On NCAM site, there was no significant difference in the level of magnesium among all the tillage types (see Table 5.4). This is inline with Hernanz *et al.*, (2009) that there was a greater calcium and magnesium concentration in run-off water from no-tillage than from conventional tillage. Moreover, calcium and magnesium can be easily transported adsorbed to sediments suspended in surface runoff.

In addition, dissolved oxygen was significantly different in Traditional heap, Plough/Harrow and Plough/Harrow/Ridge compared to No till on UTRF site while on NCAM site, there was no significant difference in the level of dissolved oxygen among all the tillage types. There was no significant difference the concentration of dissolved oxygen among all the tillage types on both UTRF and NCAM site in 2016 (see Table 5.4). This can influence the survival of aquatic life because the contribution of element such as phosphorus and nitrogen will encourage algae growth. The decomposition of algae consumes dissolved oxygen resulting in insufficient amounts available for fish and other aquatic life.

Furthermore, Lead was significantly different in T compared to NT, PH and PHR at UTRF site while on NCAM site, it was significantly different in PHR compared to PH and NT and also in T compared to PH in 2015. In 2016, lead was significantly different in T compared to NT and PHR on UTRF site while on NCAM site, Lead was significantly different in PHR compared T, PH and NT. Also, lead was significantly different in T and NT compared to PH (see Table 5.4). This is inline with Bertol *et al.*, (2005) reporting in their study that Zn, Co and Pb showed higher concentration under zero tillage on topsoil and runoff. Also, Giller *et al.*, (2009) reported that Zn, Co and Pb showed higher concentration under zero tillage on topsoil while Cu, Fe, Mn and Ni concentrations were higher under conventional tillage.

In addition, iron was significantly different in Traditional heap, No till and Plough/Harrow/Ridge compared to Plough/Harrow and was also significantly different in Plough/Harrow/Ridge compared to Traditional heap and No till on UTRF site however, there was no significant difference in all the tillage types on NCAM site in 2015. Iron across the four tillage types was significantly different in 2016. It implies that tillage type has significant impact on iron at experimental site. Iron was significantly different in Plough/Harrow/Ridge compared to Traditional heap, Notill and Plough/Harrow. Also, iron was significantly different in Traditional heap compared to Plough/Harrow on UTRF site but there was no significant difference in the concentration of iron among all the tillage types on NCAM site in 2016 (see Table 5.4). This is inline with Giller *et al.*, (2009) and Bertol *et al.*, (2005) reporting that Zn, Co and Pb showed higher concentration under zero tillage on topsoil and runoff while Cu, Fe, Mn and Ni concentrations were higher under conventional tillage and runoff.

Phosphorous was significantly different in Traditional heap compared to Plough/Harrow on UTRF site but there was no significant difference in all the tillage types on NCAM site in 2015. Furthermore, there was no significant difference in all the tillage types at both sites in 2016. The LSD test performed further on at UTRF and NCAM experimental site on conductivity showed that water conductivity was not significantly different in all the tillage types in 2015 and 2016 (see Table 5.5). This is contrary to Delvin and Barnes (2009) reporting that No-till/conservative till systems reduces total phosphorus losses by approximately 40 percent as compared to other tillage practices and also that phosphorus can move into surface waters associated either with soil particles during erosion or as soluble phosphorus with runoff water.

Furthermore, the runoff samples from Notill had a significantly different pH level compared to Traditional heap and Plough/Harrow and also in Plough/Harrow/Ridge compare to

Traditional heap and Plough/Harrow on UTRF site while on NCAM site, pH level was significantly different in Notill compared to Traditional heap and Plough/Harrow/Ridge in 2015. There was no significant difference in the level of pH in all the tillage types on UTRF and NCAM site in 2016 (see Table 5.5). This finding is inline with Lal (1989) reporting that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanized farming and twelve crops of maize, while the decline in the soil and water properties was decidedly less in the no-tillage watershed. The lower maize yields of the ploughed watershed are related to erosion, compaction, fall in organic matter content and fall in Ph.

Chlorine was significantly different in T, PH and PHR compared to NT at UTRF site while on NCAM site, there was no significant difference in chlorine among all the tillage types in 2015. In addition, chlorine was significantly different in PH and PHR compared to T and NT plots at UTRF and NCAM site in 2016 (see Table 5.5)

Copper was significantly different in T compared to PH, NT, PHR at UTRF site while Copper was significantly different in NT, T and PH compared to PHR plot at NCAM site in 2015. In 2016, copper was significantly different in T compared to NT also in PH compared to NT and T. Also, copper was significantly different in PHR compared to NT and T at NCAM site (see Table 5.5). This is contradicts the findings of Bertol *et al.,* (2005) reporting that Cu, Fe, Mn and Ni concentrations were higher under conventional tillage than under zero tillage on topsoil and runoff. Therefore, the application of tillage method can be used to achieve production, environmental and sustainable objective due to the fact that it can determine how much nutrient is available in the soil for plant growth as well as how these nutrients disintegrate into runoff and contaminate surface water.

5.3 Comparism between the UTRF and NCAM Experimental Sites

There are similarities and differences as to how the different parameters were spatio-temporally impacted on by the different tillage methods. The tillage methods had significant impact on nitrate and lead at both location (UTRF and NCAM site) and across both planting seasons (2015 and 2016) while there was no significant impact of the tillage methods on turbidity, sodium, zinc, phosphorus and conductivity at both locations and across the planting seasons. In 2015, carbon, pH, copper, and magnesium were significantly impacted on by the tillage methods at both UTRF and NCAM site while in 2016, chlorine and calcium were significantly impacted on by the tillage methods at both locations. The tillage methods had no significant impact on total dissolved solids and calcium at the sites in 2015 while in 2016, sodium, potassium, dissolved oxygen and pH were not significantly impacted on by the tillage methods at both locations. The tillage methods had no significant impact on turbidity, zinc, phosphorus, conductivity, dissolved oxygen and iron in both 2015 and 2016. From the foregoing, this indicate that location and time has a major role in determining the concentration of these parameters due to weather variability, topography of the area, type of soil among others.

Surface runoff is one of the diffused sources of the export of elements and chemical substances in water bodies. According to Klimaszyk and Rzymski (2011), significant loads of nitrogen, phosphorus, organic matter among others can be transported in overland flow from the catchment area to freshwater. They also reported that the quality and quantity of surface runoff depends on many factors but one most important factor is the morphology of the catchment area. The most significant loads of nutrients are exported from agriculturally used catchment. As a result, surface runoff from agricultural lands is a major contributor to the eutrophication in lakes and rivers. Therefore, the concentration of these parameters in overland flow can eventually

contaminate fresh water sources around the catchment area. As a result, there is a need for appropriate tillage method that will contribute less to the concentration of the parameters to surface runoff.

Climatic variations have caused unusual weather conditions. In recent times, an increase in average air temperature, sunshine hours and a decrease in precipitation have being observed. Particularly, during the period of experiment, the raining season for 2015 was longer than that of 2016. This has caused variability in the amount of water available for runoff, infiltration and percolation of nutrient into the soil. Consequently, this has affected the water and soil properties and amount of sediment carried along in the overland flow to the receiving river.

Also, the LSD significance test revealed that No till and Traditional heap tillage were significantly different in carbon, potassium, nitrate, pH, chlorine, copper, magnesium, lead, phosphorus, total dissolved solids, sodium and calcium in the water than the mechanized tillage (Plough/Harrow and Plough/Harrow/Ridge) while mechanized tillage were significantly different in dissolved oxygen, iron, turbidity, sodium and conductivity on UTRF site in 2015. In 2016, Traditional heap and Notill were significantly different in nitrate, calcium, magnesium and lead while Plough/Harrow and Plough/Harrow/Ridge tillage were significantly different in chlorine and iron. There was no significant difference in the impact of all the tillage methods on the remaining water parameters (turbidity, carbon, sodium, potassium, zinc, phosphorus, pH, conductivity, copper, total dissolved solids and dissolved oxygen). In addition, Traditional heap and Notill were significantly different in carbon, sodium, nitrate, pH, copper and magnesium while Plough/Harrow/Ridge were significantly different in lead only on NCAM site in 2015. There was no significant difference in the impact of all the tillage methods on the remaining water parameters (turbidity, potassium, zinc, phosphorus, conductivity, chlorine, total dissolved solids, calcium, iron

and dissolved oxygen). In 2016, Traditional heap and Notill were significantly different in carbon, nitrate, total dissolved solids and calcium while Plough/Harrow/Ridge and Plough/Harrow were significantly different in chlorine, copper, lead and sodium while the LSD test performed further on the other parameters (turbidity, potassium, zinc, phosphorus, pH, conductivity, magnesium, dissolved oxygen and iron) at NCAM experimental site in 2016 also revealed that there was no difference in the impact of the tillage types.

Observations in this study showed that Conservative tillage had a greater contribution to the concentration of some of the water parameters than mechanized tillage across the locations and season. There was some of the parameter that was not impacted on by either of the tillage methods irrespective of the locations. These are turbidity, potassium, zinc, phosphorus, pH, conductivity, magnesium, dissolved oxygen and iron. This is not farfetched from the findings of several authors among which is Hernanz *et al.,* (2009) showing that there was a greater calcium and magnesium concentration in run-off water from no-tillage than from conventional tillage. Moreover, calcium and magnesium can be easily transported adsorbed to sediments suspended in surface runoff. Also, Lal (1989) reported that soil physical properties and chemical fertility were substantially worse in ploughed watersheds after six years of continuous mechanized farming and twelve crops of maize, while the decline in the soil and water properties was decidedly less in the no-tillage watershed. The lower maize yields of the ploughed watershed are related to erosion, compaction, fall in organic matter content and fall in pH.

CHAPTER SIX

IMPACT OF TILLAGE METHOD ON CROP (MAIZE) YIELD

6.1 Introduction

This section shows the data presentation and result discussion for the agronomic parameters and how the various tillage types influenced the crop yield in the study area. The acronym of each tillage are Traditional heap (T), Plough/Harrow (PH), No-till (NT) and Plough/Harrow/Ridge (PHR). The Analysis of Agronomic Parameters for 2015 and 2016 planting season is for both UTRF and NCAM experimental site. The coefficient of variation presented a homogenous pattern with all the values less than 33%. The full details of the result from the regression analysis and Tukey's test can be found in Appendix III.

6.2 Agronomic Variables and Crop Yield in the University Teaching Research Farm (UTRF) and National Center for Agricultural Mechanization (NCAM) Experimental sites

Traditional heap had the highest maize height with 1.81m and 2.32m for 2015 and 2016 at UTRF site while Plough/Harrow had the highest maize height with 1.82m and 2.19m in 2015 and 2016 at the NCAM site (see Table 6.1, 6.2 and Figure 6.1). Number of leaves was highest on the T and PH for 2015 with 12.33 while NT recorded the highest number of leaves for 2016 with 13.66 (see Table 6.1, 6.2 and Figure 6.2). The leave length at UTRF experimental site was recorded on the T for 2015 and 2016 with 0.85m and 1.02m while on NCAM experimental site, it was recorded on the PHR for 2015 and 2016 with 0.89m each respectively (see Table 6.1, 6.2 and Figure 6.3). T had the highest Maize leave width in 2015 with 4.38 inch and on PHR with 4.66 inch for 2016 in UTRF site while for NCAM site, PHR was recorded highest with 3.76 inch and 4.23inch for both 2015 and 2016 (see Table 6.1, 6.2 and Figure 6.4). Crop yield was recorded

highest on the PH for 2015 (2333.33 kg/ha) and on Traditional heap (1253.33kg/ha) for 2016 on UTRF experimental site. On NCAM site, crop yield was recorded highest on the Plough/Harrow for 2015 and on Plough/Harrow/Ridge (733.33 kg/ha) for 2016(see Table 6.1, 6.2 and Figure 6.5). Leaf Area Index (LAI) was recorded on NT with 2.48 and 2.84 for 2015 and 2016 at UTRF experimental site however, while on NCAM site, it was recorded on T with 2.80 and 3.34 for 2015 and 2016(see Table 6.1, 6.2 and Figure 6.6).

Table 6.1: Summaries of Yield Parameters for 2015 and 2016 planting season (UTRF)

SN	Agronomy Parameters		Minimum		Maximum		Mean		Std. Dev.		CV	
		Tillage Type	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
	Maize	Traditional heap	1.65	1.98	1.95	2.93	1.81	2.32	0.15	0.52	8.29	22.41
1.	Height	Plough/Harrow	1.72	1.56	1.86	2.46	1.78	1.89	0.07	0.49	3.93	25.93
		Plough/Harrow/Ridging	1.33	1.89	2.11	2.2	1.60	2.02	0.44	0.15	27.5	7.43
		No-Till	1.42	2.09	1.78	2.35	1.65	2.18	0.19	0.14	11.52	6.42
	Number of	Traditional heap	12	10	13	13	12.33	11.33	0.58	1.52	4.7	13.42
2.	Leaves	Plough/Harrow	12	11	13	13	12.33	11.66	0.58	1.15	4.7	9.86
		Plough/Harrow/Ridging	12	11	12	12	12.00	11.66	0.00	0.57	0	4.89
		No-Till	10	12	12	15	11.00	13.66	1.00	1.52	9.09	11.13
	Leave	Traditional heap	0.76	0.97	0.9	1.1	0.85	1.02	0.08	0.06	9.41	5.88
3.	Length	Plough/Harrow	0.71	0.75	0.81	1.05	0.78	0.93	0.05	0.16	6.41	17.2
		Plough/Harrow/Ridging	0.76	0.9	0.87	0.94	0.83	0.91	0.06	0.02	7.23	2.2
		No-Till	0.62	0.86	0.83	1	0.75	0.95	0.11	0.07	14.67	7.37
4.	Leaf width	Traditional heap	4.13	4	4.88	5	4.38	4.33	0.43	0.57	9.82	13.16
		Plough/Harrow	4.05	3.5	4.41	4.3	4.21	3.93	0.18	0.40	4.28	10.18
		Plough/Harrow/Ridging	4.23	4	4.59	5	4.37	4.66	0.19	0.57	4.35	12.23
		No-Till	4.13	3.3	4.75	4	4.42	3.6	0.31	0.36	7.01	10.00
5.		Traditional heap	1000	1040	1800	1600	1400	1253.33	400	302.87	28.57	24.17
	Crop Yield	Plough/Harrow	2000	640	2600	1280	2333.33	880	305.51	348.71	13.09	39.63
	(kg/ha)	Plough/Harrow/Ridging	1200	760	2000	920	1533.33	826.66	416.33	83.26	27.15	10.07
		No-Till	1000	440	1400	720	1200	586.66	200	140.47	16.67	23.94
		Traditional heap	1.91	2.52	2.21	2.85	2.01	2.67	.169	.166	8.40	6.21
	Leave	Plough/Harrow	1.80	1.81	2.46	2.52	2.19	2.19	.348	.358	15.89	16.34
	Area	Plough/Harrow/Ridging	1.72	1.11	2.12	1.85	1.92	1.35	.201	.422	10.46	31.25
6.	Index(LAI)	No-Till	2.11	2.46	2.69	3.10	2.48	2.84	.327	.336	13.18	11.83

KEY- T-traditional heap, PH-plough/harrow, NT-No-till, PHR-Plough/harrow/ridge, CV- coefficient of variation, UTRF –Unilorin Teaching and Research Farm plots.

Source: Author's fieldwork (2016)

Table 6.2: Summaries of Yield Parameters on NCAM site for 2015 and 2016 planting season

SN	Agronomy Parameters	Tillage Type	Minimum		Maximum		Mean		Std. Dev.		CV	
			2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1.	Maize Height	Traditional heap	1.59	2.04	1.76	2.2	1.69	2.10	0.09	0.08	5.33	3.81
		Plough/Harrow	1.6	1.98	2.01	2.41	1.82	2.19	0.21	0.21	11.54	9.59
		Plough/Harrow/Ridging	1.57	1.9	1.85	2.28	1.67	2.11	0.16	0.19	9.58	9
2.	Number of Leaves	No-Till	1.53	1.06	1.68	1.29	1.58	1.15	0.08	0.11	5.06	9.57
		Traditional heap	10	12	12	13	11.33	12.33	1.15	0.57	10.15	4.62
		Plough/Harrow	11	11	12	13	11.33	12	0.58	1	5.12	8.33
		Plough/Harrow/Ridging	12	12	12	13	12	12.33	0.05	0.57	0.42	4.62
3.	Leave Length	No-Till	10	8	11	9	10.33	8.33	0.05	0.57	0.48	6.84
		Traditional heap	0.72	0.8	0.81	0.95	0.75	0.86	0.13	0.07	17.33	8.14
		Plough/Harrow	0.75	0.69	0.84	0.82	0.81	0.77	0.04	0.07	4.94	9.09
		Plough/Harrow/Ridging	0.79	0.82	1.03	0.96	0.89	0.89	0.13	0.07	14.61	7.87
4.	Leaf width	No-Till	0.71	0.59	0.78	0.82	0.75	0.68	0.04	0.11	5.33	16.18
		Traditional heap	3.48	4	3.63	4.2	3.55	4.13	0.08	0.11	2.25	2.66
		Plough/Harrow	3.2	3.5	3.9	4.1	3.60	3.76	0.36	0.30	10	7.98
		Plough/Harrow/Ridging	3.48	4	4.23	4.4	3.76	4.23	0.41	0.20	10.9	4.73
5.	Crop Yield (kg/ha)	No-Till	3.23	2.3	3.63	3	3.40	2.6	0.21	0.36	6.18	13.85
		Traditional heap	400	440	600	800	466.67	586.66	115.47	189.03	24.74	32.22
		Plough/Harrow	1200	600	1800	640	1400	613.33	346.41	23.09	24.74	3.76
		Plough/Harrow/Ridging	400	680	800	800	566.67	733.33	208.17	61.10	36.74	8.33
		No-Till	200	360	1000	800	733.33	520	461.88	243.31	62.98	46.79
6.	Leave Area Index(LAI)	Traditional heap	2.35	2.91	3.29	4.13	2.80	3.34	.471	.677	16.82	20.26
		Plough/Harrow	2.16	1.97	2.68	3.39	2.45	2.78	.270	.732	11.02	26.33
		Plough/Harrow/Ridging	1.92	2.13	2.81	2.97	2.48	2.57	.492	.423	19.83	16.45
		No-Till	2.41	2.70	2.96	3.53	2.72	3.200	.283	.439	10.40	13.71

KEY- T-traditional heap, PH-plough/harrow, NT-No-till, PHR-Plough/harrow/ridge, CV- coefficient of variation, NCAM- National Centre for Agricultural Mechanization experimental plot Source: Author's fieldwork (2016)

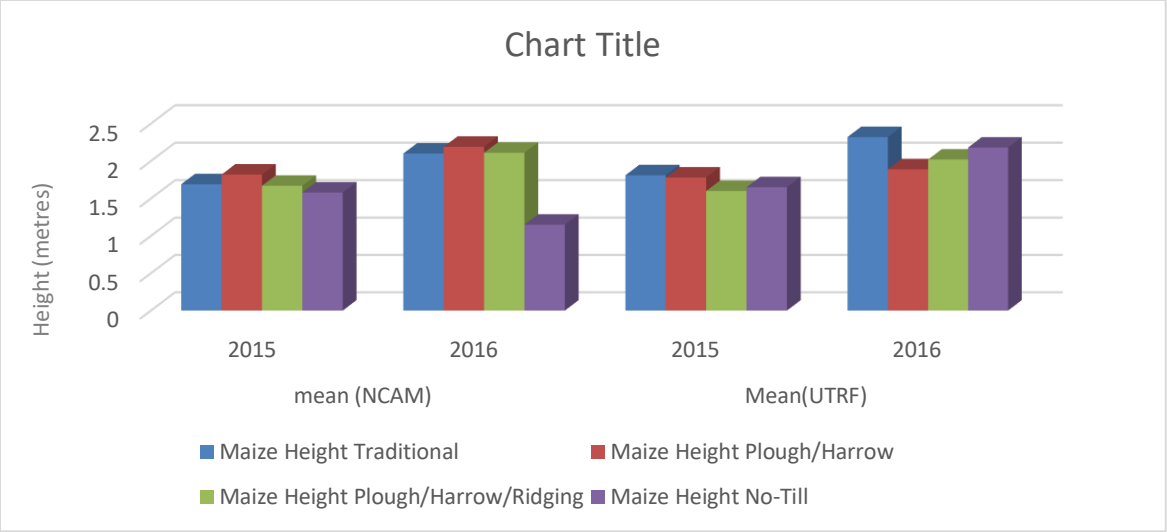


Figure 6.1: Mean Maize Height on Different Tillage Type in UTRF and NCAM Experimental Plot for 2015 and 2016 planting season

Source: Author's fieldwork (2016)

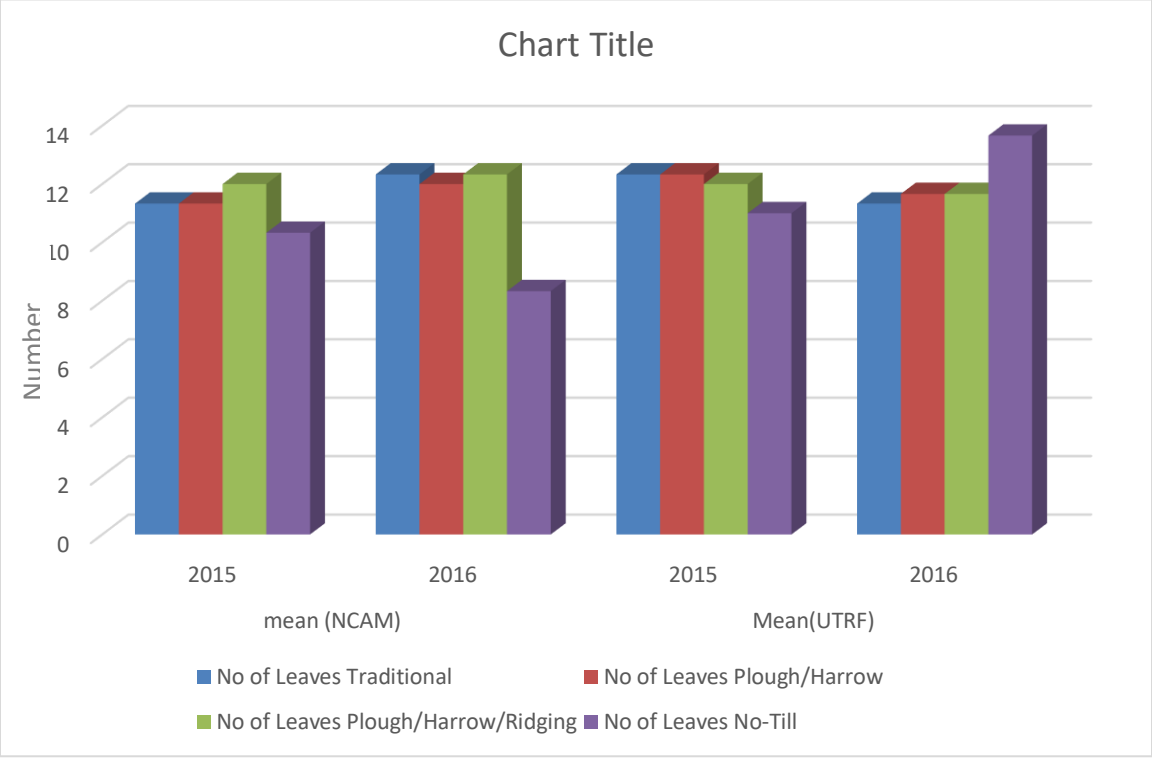


Figure 6.2: Mean Leave Number on Different Tillage Type in UTRF and NCAM Experimental Plot for 2015 and 2016 planting season

Source: Author's fieldwork (2016)

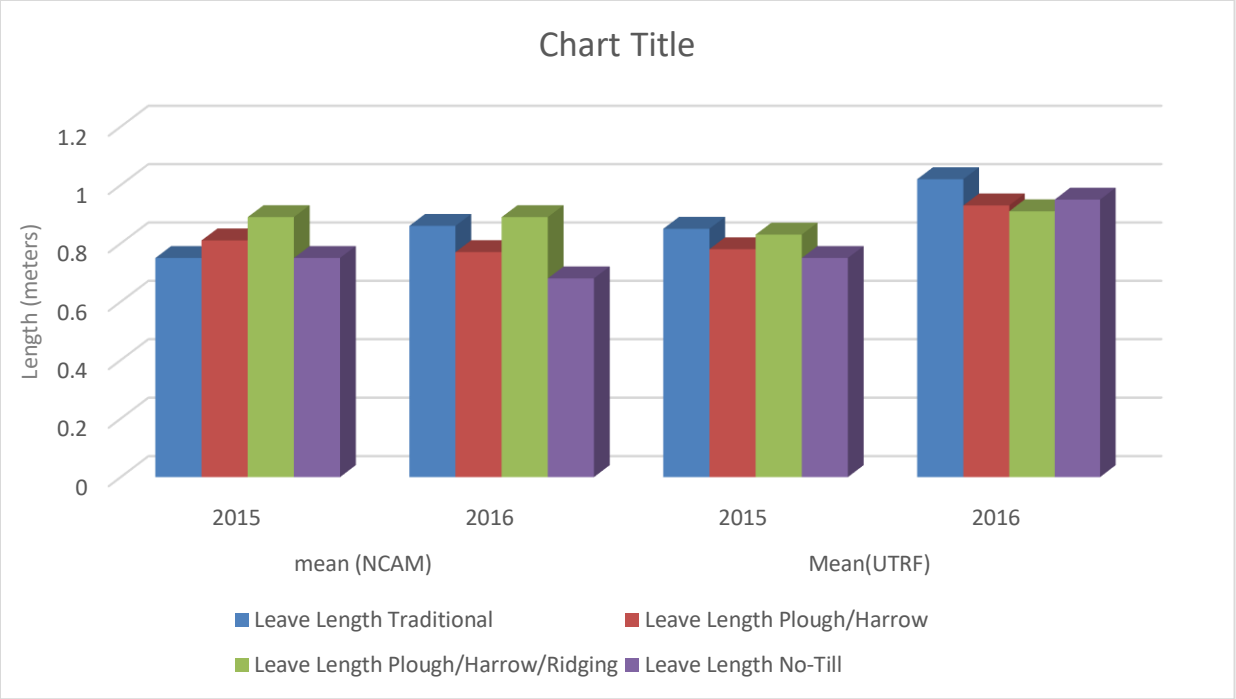


Figure 6.3: Mean Leave Length on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season

Source: Author's fieldwork (2016)

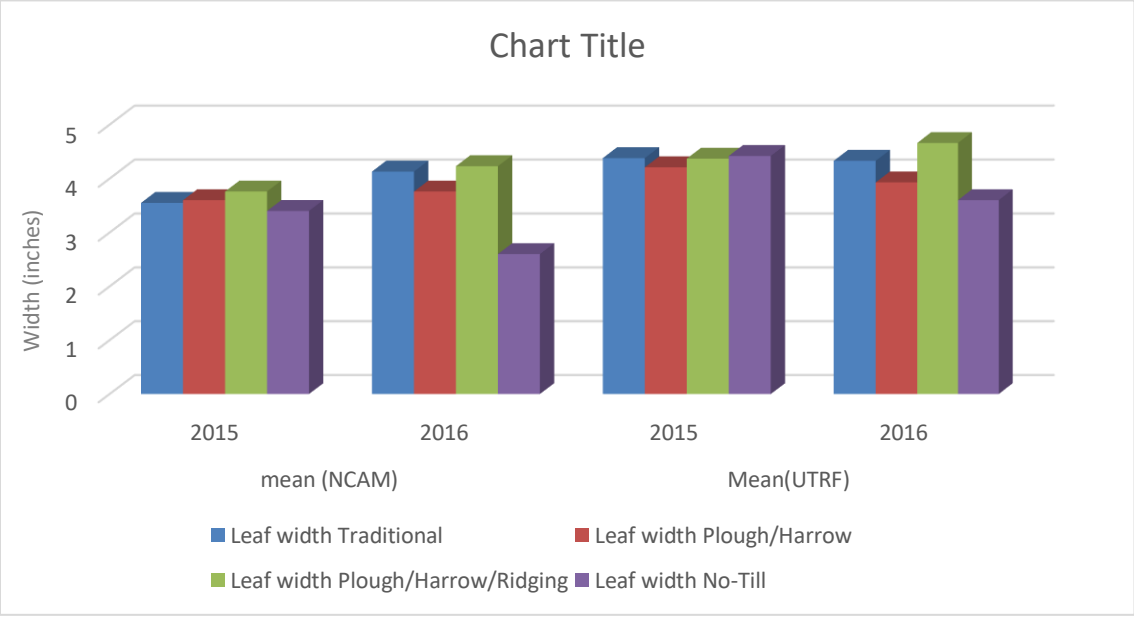


Figure 6.4: Mean Leave Width on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season

Source: Author's fieldwork (2016)

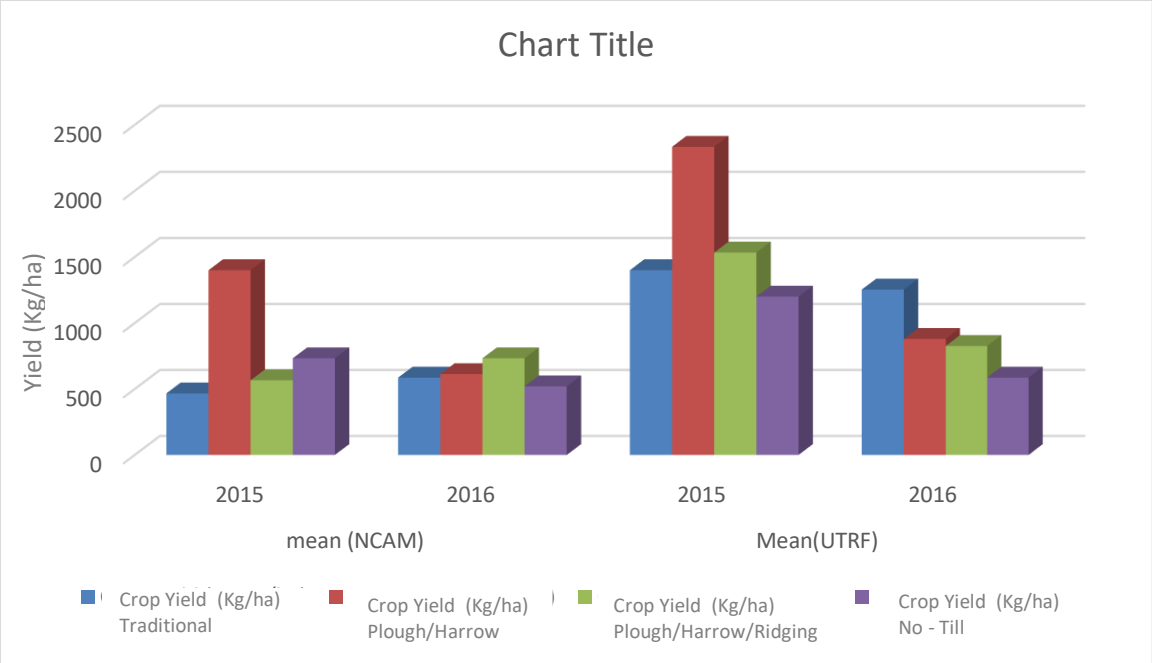


Figure 6.5: Mean Crop Yield on Different Tillage Type in UTRF and NCAM Experimental Site for 2015 and 2016 planting season

Source: Author's fieldwork (2016)

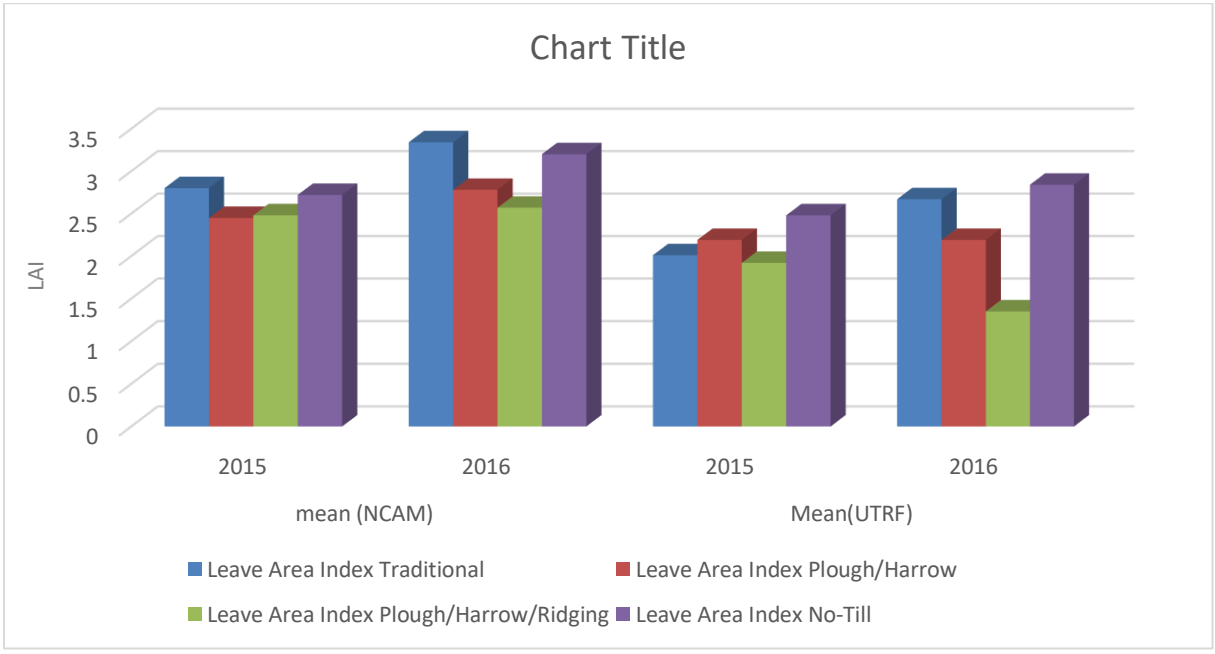


Figure 6.6: Mean Leave Area Index on Different Tillage Type in UTRF and NCAM Experimental Site

Source: Author's fieldwork (2016)

Most of the yield parameters measured was recorded highest on the Plough/Harrow and Plough/Harrow/Ridge except for the leaf area index which was recorded highest on Traditional heap and Notill. For instance, at highest mean value of leave width, leave length and maize height, an improved maize yield was recorded on PHR at the NCAM experimental site in both years while only 2015 recorded high yield on PH. The reverse is the case for UTRF experimental site where majority of the yield parameters were recorded highest on the Traditional heap and Notill. Also, leave length, number of leave area and plant height recorded an improved maize yield on Traditional heap in 2016 but 2015 was recorded high yield on Plough/Harrow. In addition, Plough/Harrow recorded the highest yield value for both site in 2015 although this was not the case in 2016. This implies that there is an improved maize yield in the application of mechanized tillage compared with the other tillage types.

6.3 Impact of Tillage Methods on Maize Yield Parameters

Table 6.3 shows that there was no significant impact of the tillage methods on maize height on the UTRF experimental site in 2015 and 2016 (p value (0.705) > 0.05 and p value (0.562) > 0.05 respectively). For the NCAM site, there was no significant impact of the tillage methods on maize height in 2015 (p value (0.317) < 0.05) however, there is a significant impact of the tillage methods on maize height in 2016 (p value (0.01) < 0.05). Hence, tillage methods do affect the maize height although a remarkable effect was not marked between 2015 and 2016.

Table 6.3: Tillage Impact on Maize Height

SN	Sites	Sum of Squares		Df		Mean Square		F		Sig.	
		2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1	UTRF	.094	.310	3	3	.031	.103	.481	.731	.705	.562
2	NCAM	.087	2.186	3	3	.029	.729	1.381	27.721	.317	.001

Source: Author's fieldwork (2016)

For the number of leaves, there was no significant impact of the tillage methods on the number of maize leaves on UTRF experimental plot in 2015 and 2016 with p value (0.104)>0.05 and p value (0.171) > 0.05 respectively as shown in Table 6.4. On NCAM experimental site, there was no significant impact of the tillage methods on the number of maize leaves in 2015 (p value (0.106) > 0.05) but there was significant impact in 2016 (p value (0.001) < 0.05). This implies that the tillage methods do affect the number of leaves although a remarkable effect was not marked between 2015 and 2016.

Table 6.4: Tillage Impact on Number of Maize Leaves

SN	Sites	Sum of Squares		Df		Mean Square		F		Sig.	
		2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1	UTRF	3.583	10.25	3	3	1.194	3.417	2.867	2.158	.104	.171
2	NCAM	4.250	34.25	3	3	1.417	11.417	2.833	22.83	.106	.001

Source: Author's fieldwork (2016)

Furthermore, Table 6.5 shows that there was no significant impact of the tillage methods on the maize leaf length at the UTRF experimental site in 2015 and 2016 (p values (0.418) > 0.05 and p value (0.555) < 0.05 respectively). On NCAM experimental site, there was no significant impact of the tillage methods on the maize leaf length in 2015 and 2016 (p value (0.176)> 0.05 and p value (0.072) < 0.05). Hence, tillage methods do not affect the maize leaf length between 2015 and 2016 and at both locations.

Table 6.5: Tillage Impact on Maize Leave Length

SN	Sites	Sum of Squares		Df		Mean Square		F		Sig.	
		2015	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**	**2015**	**2016**
1.	UTRF	.020	.021	3	3	.007	.007	1.602	.744	.418	.555
2.	NCAM	.036	.079	3	3	.012	.026	2.118	.3445	.176	.072

Source: Author's fieldwork (2016)

Table 6.6 reveals that there was no significant impact of the tillage methods on the maize leave width on the UTRF experimental site in 2015 and 2016 (p values (0.837) > 0.05 and p value (0.116) > 0.05). On NCAM experimental site, there was no significant impact of the tillage methods on maize leaf width in 2015 (p value (0.562) > 0.05) while in 2016, there was significant impact of the tillage methods on Maize leaf width (p value (0.001) < 0.05). The implication of this result is that tillage methods do affect the maize leave width although a remarkable effect was not marked between 2015 and 2016.

Table 6.6: Tillage Impact on Maize Leave Width

SN	Sites	Sum of Squares		Df		Mean Square		F		Sig.	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
1.	UTRF	.075	1.947	3	3	.025	.649	.282	2.704	.837	.116
2.	NCAM	.191	5.057	3	3	.064	1.686	.731	24.079	.562	*.001*

Source: Author's fieldwork (2016)

In addition, Table 6.7 reveals that leave area index across the four-tillage type (T, PH, PHR and NT) are not significantly different in 2015, but they are significantly different in 2016 with p value (0.134) >0.05 and (0.003)< 0.05 respectively. The result indicated that leave area index were independent of tillage types at UTRF experimental site in 2015, but are influenced by tillage type in 2016. Also, the leave area index across the four tillage types (T, PH, PHR and NT) were not significantly different at NCAM experimental site in both 2015 and 2016 with p value (0.651 and 0.396) > 0.05. It implies that tillage type has no significant impact on leave area index in 2015 and 2016 at NCAM experimental site. Maize leaf area is of importance to photosynthesis and yield. The photosynthetic capacity of crops is a function of leaf area. Leaf area is important for crop light interception and therefore has a large influence on crop yield. The findings in 2016 is in agreement with Sullivan (2003) as cited in Karuma *et al.*,(2016) who reported higher LAI values in maize

cultivated under conventional tillage and attributed this to improved access to soil moisture as compared to no-till. Thus, higher LAI results in better ground cover for lesser soil water evaporation and increased weed suppression. Therefore, the differences in maize LAI under the different tillage practices can also be attributed to the differences in exploration of the maize roots for soil moisture in the soil profile.

Table 6.7: Tillage Impact on Leave Area Index

SN	Sites	Sum of Squares		Df		Mean Square		F		Sig.	
		2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
1	UTRF	.558	3.982	3	3	.186	1.327	2.490	11.857	.134	.003*
2	NCAM	.264	1.152	3	3	.088	.384	.569	1.123	.651	.396

For crop yield, Table 6.8 shows that the regression model for the tillage methods significantly impacted on crop yield in 2015 but not in 2016 on the UTRF experimental site with a coefficient of determination of 59.3% for 2015 which is relatively high and 43.3% for 2016 respectively. This further shows that there is a strong relationship and it is statistically positive with $r^2 = 0.593$. This implies that an improvement on the tillage methods will bring about increase to the maize yield in 2015 on UTRF site only. There is a relatively weak relationship and statistically positive with $r^2 = 0.433$ between maize yield and tillage methods. This also implies that the tillage methods improves maize yield in 2016 as shown by the research findings in the experimental farm. The Turkey test for 2015 further shows that on UTRF experimental plots, PH yield > NT yield (p value (0.015) < 0.05), PH yield > T yield (p value (0.04) < 0.05) while PH and PHR are not statistically different in crop yield. The Turkey test for 2016 shows that on UTRF experimental plot, T yield >NT yield (p value (0.042) < 0.05) while there is no significant difference between the other treatment plots (see Appendix III).

Table 6.8: Impact of Tillage Methods on Crop Yield in UTRF Experimental Plot

Source	Type III Sum of Squares		Df		Mean Square		F		Sig.	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Corrected Model	2223333.333[a]	684266.667[b]	3	3	741111.111	228088.889	6.352	3.801	*.016*	.058
Intercept	31363333.333	9434133.333	1	1	31363333.333	9434133.333	268.829	157.236	.000	.001
Tillage Type	2223333.333	684266.667	3	3	741111.111	228088.889	6.352	3.801	.016	.058
Error	933333.333	480000.000	8	8	116666.667	60000.000				
Total	34520000.000	10598400.000	12	12						
Corrected Total	3156666.667	1164266.667	11	11						

a. Dependent Variable: Crop Yield, R Squared = .704 (Adjusted R Squared = .593)

b. R Squared = .588 (Adjusted R Squared = .433)

Source: Author's fieldwork (2016)

On NCAM experimental plot, the tillage methods significantly impact on crop yield in 2015 but not in 2016 with a coefficient of determination of 54.7% which is relatively high and 1.1% respectively as shown in Table 6.9. This shows that there is a strong relationship and direct that is statistically positive with $r^2 = 0.547$ between tillage methods and maize yield at NCAM Plot. This implies that the tillage methods improve maize yield only in 2015 on NCAM site. There is a very weak direct relationship and but statistically positive with $r^2 = 0.011$ between the tillage methods and maize yield because there are other environmental factors which contributed largely to the maize yield at the expense of the tillage methods in the area. This also implies that the tillage methods improves maize yield in 2016 as shown by the research findings in the experimental farm. The Turkey test for 2015 on NCAM shows that PH yield > T yield (p value (0.026) < 0.05). Also, PH yield > PHR yield (p value (0.046) < 0.05) which is statistically significant (see Appendix III). There is no statistical difference in maize yield between PH and NT. The Turkey test for 2016 experimental treatment revealed that there is no significant difference between all the treatment plots (see Appendix III).

Table 6.9: Impact of Tillage Methods on Crop Yield in NCAM Experimental Plot

Source	Type III Sum of Squares		Df		Mean Square		F		Sig.	
	2015	2016	2015	2016	2015	2016	2015	2016	2015	2016
Corrected Model	1589166.667[a]	71466.667[b]	3	3	529722.222	23822.222	5.433	.961	*.025*	.457
Intercept	7520833.333	4514133.333	1	1	7520833.333	4514133.333	77.137	182.02	*.000*	.000
Tillage Type	1589166.667	71466.667	3	3	529722.222	23822.222	5.433	.961	*.025*	.457
Error	780000.000	198400.000	8	8	97500.000	24800.000				
Total	9890000.000	4784000.000	12	12						
Corrected Total	2369166.667	269866.667	11	11						

a. Dependent Variable: Crop Yield, R Squared = .671 (Adjusted R Squared = .547)
b. R Squared = .265 (Adjusted R Squared = .011)
Source: Author's fieldwork (2016)

The observations reveal that plough and harrow tillage method is the most suitable for optimum crop yield in maize production in this ecological zone. Therefore, the application of this tillage type by farmers in the study area is expected to give increased maize yield as well as conserve water and soil quality. Many studies have investigated the effect of soil tillage on crop yields, however the results are often contradictory owing to different soils and crops and using different tillage intensities. Some authors reported sustained or increased crop productivity in conservation tillage, but usually a negative yield impact was observed depending on the duration and extent to which the conservation tillage is enacted, crop type, as well as on the climate region. The effect of tillage systems on crop yield is not uniform with all crop species, in the same manner as various soils may react differently to the same tillage practice. The variations experienced between the two planting seasons in the crop yield on UTRF and NCAM experimental sites are probably due to the rainfall pattern and other ecological factors. Rainfall started earlier and the amount was higher in 2015 than in 2016. The rainfall in 2015 also lasted longer (till October ending) as opposed to end of September and early October in 2016. This affected the grain yield on the site because of cessation of rains at the period the crops needed optimum moisture. This contradicts Lal (1997) who observed increased maize grain yields on plots with no-till treatment (2.5 t ha-1) compared with the plow-till treatment (2.0 t ha-1) in southwest Nigeria. Also, Agbede *et al*., (2008), Obalum *et al.*, (2011), and Senjobi *et al.*, (2013)

had different conclusion in their studies that traditional tillage system resulted in the most favorable soil environment, for crop growth and best performance of crop followed by conventional and no-tillage system and concluded that tillage methods have the capability to increase production while no-tillage is better under long term production for sustainable land use.

CHAPTER SEVEN

MODELLING THE PATTERN AND PROCESS OF POLLUTION FROM THE TILLAGE TYPES

7.1 Introduction

This section deals with modeling the pattern and processes of non-point source pollution from the different tillage methods as well as to quantify the impact of land management practices on water, soil and crop yield using a Soil Water Assessment Tool (SWAT). The model was calibrated for the period of 2014- 2016 which was within the period of the experiment. The acronym for each tillage are Traditional (T), Plough/Harrow (PH), No-tillage (NT) and Plough/Harrow/Ridge (PHR). The full details of the results from the SWAT can be found in Appendix IV.

7.2 Distribution of the Hydrological Response Units (HRU) in UTRF and NCAM Sub Catchments

The SWAT is a semi-distributed physical based model. It was developed by USDA (U.S. Department of Agriculture) Agricultural research Service (ARS) to predict the impact of land use practices on water, sediment and agricultural chemical yields in large and complex watersheds with varying soils, land use and management conditions over long period (Neitsch *et al.,* 2011). The model simulation is daily time step based. The values given in the Figure 7.1 are real figures for the study area according to the input data used in the SWAT model. All the values are in millimetres (mm). The spatial complexity of the watershed is taken into account in the model by combining the information from Digital Elevation Model (DEM), soil and land use. The SWAT model divides the watershed into sub-basins. Water balance is the driving force behind everything that happens in the watershed. According to Neitsch *et al.,* (2005), the hydrology of the watershed can be separated into two major divisions: the first division is the land phase of the hydrologic

cycle and the second division is the water or routing of the hydrologic cycle. The land phase of the hydrologic cycle is shown in Figure 7.1 which is the schematic representation of the hydrologic cycle in the study area. It controls the amount of water, sediments, nutrients and pesticides loading to the main channel in each sub-basin.

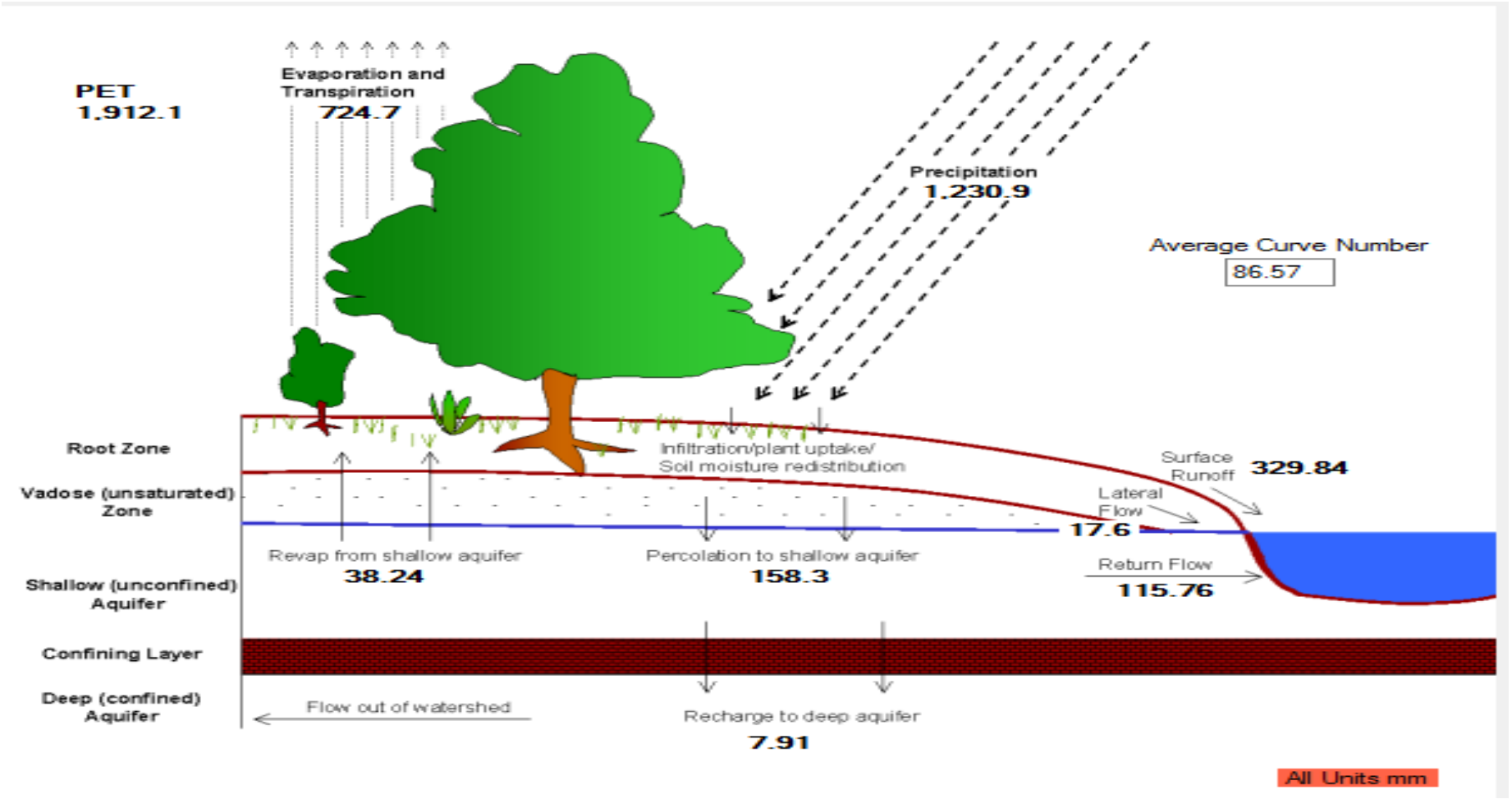


Figure 7.1: Schematic Representation of the Hydrologic Cycle of the study area.
Source: Author's fieldwork (2016)

The SWAT analysis generated three (3) hydrological response units (HRU) each for the two study areas (UTRF and NCAM). The HRU is the smallest spatial unit of the SWAT model. It is used to simulate processes such as rainfall, infiltration, plant dynamics, erosion, nutrient cycling, leaching of pesticides and it lumps all similar land use, soil, elevation profile, and slope within a sub basin based on user defined threshold (Neitsch *et al.,* 2005). The table displayed in this section was extracted from a general table in the Appendix IV.

Table 7.1: Distribution of the Hydrological Response Unit (HRU) in UTRF and NCAM sub catchments

Name	Sub basin	Hydrologic Response Unit	Land Area Covered (m^2)	Tillage method
UTRF	18	44	0.463	PH
UTRF	18	45	0.201	NT, T
UTRF	18	46	0.209	PHR
NCAM	42	103	0.872	NT ,T
NCAM	42	104	2.19	PH
NCAM	42	105	2.56	PHR

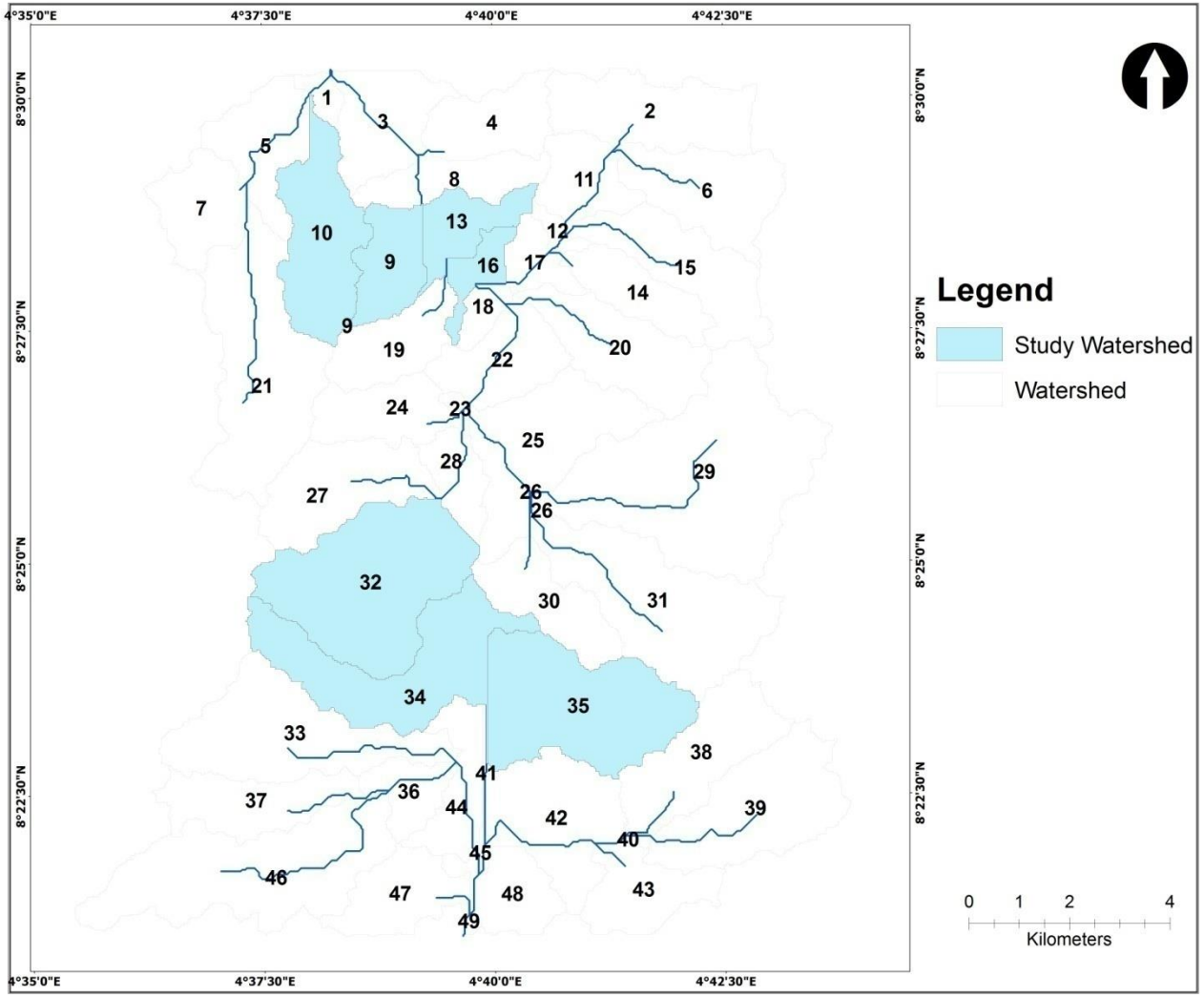


Figure 7.2: SWAT model showing the study area watershed delineated into Hydrological Response Units
Source: Author's fieldwork (2016)

7.2.1 Soil Types and Soil loss

From the SWAT, the soil types in both areas are same: Ferric Luvisols albeit with variants. UTRF sub- basin has a variant of the ferric luvisols Lf-26a while NCAM sub-basin has an Lf-12 soil variant as shown in Figure 7.3. The grand total of soil loss from UTRF and NCAM sub-basins are 1.661 and 6 metric tons/ha respectively as shown in Table 7.2. This shows that NCAM had a greater soil loss compared to UTRF although NCAM has a gentler slope (2.74) as compared to UTRF (6.39) (see Figure 7.4). In addition, PH had the highest soil loss with 1.05 metric tons/ha while NT, T and PHR had 0.201, 0.201 and 0.209 metric ton/ha respectively on UTRF sub-basin. NT and T had the highest soil loss with 2.31 metric tons /ha each, followed by PHR with 1 while PH had the least values of 0.38 metric tons /ha on NCAM sub-basin (see Table 7.3). This implies that the topography of area is a major determinant in the amount of soil lost. This is inline with Kaur *et al.,*(2003) submission that water and soil losses from a catchment area are a function of its topography(slope), physiography (land use, soil type, soil depth) climatic and management conditions

Table 7.2: Soil loss from the experimental plots

Tillage types	UTRF (USLE_LS)	NCAM (USLE_LS)
PH	1.05	0.38
NT	0.201	2.31
T	0.201	2.31
PHR	0.209	1
Grand total(metric tons/ha)	1.661	6

Source: Author's fieldwork (2016)



Figure 7.3: Soil type in the study area
Source: Author's fieldwork (2016)

7.2.2 Sediment

SWAT also modified sediments to account for in-stream deposition and erosion of stream banks and channels. Often, there is little or no measured data to differentiate between upland sediment and in-stream sediment changes. Streams may be either a net source of sediment, or a sink. In-stream sediment modification is impacted by physical channel characteristic's (slope, width, depth, channel cover, and substrate characteristics) and the quantity of sediment and flow from upstream. The grand total of sediment yield from UTRF and NCAM sub-basins are 28.2 and 27.28 metric tons/ha as shown in Table 7.4. This is as a result of the mean slope of UTRF sub-basin being higher (6.39) than that of NCAM (2.74) as shown in Figure 7.4.

From the tillage types on UTRF experimental plots, Notill and Traditional heap had the greatest sediment yield with 10.54 metric tons/ha each followed by Plough/Harrow with 5.31 metric tons/ha and the least is Plough/Harrow/Ridge with 1.81 metric tons/ha. Also at the NCAM site, Notill and Traditional heap had the highest sediment yield with 10.46metric tons/ha each followed by Plough/Harrow/Ridge with 4.79 metric tons/ha and lastly Plough/Harrow with 1.57 metric tons/ha as shown in Table 7.4. Due to high runoff, sediment yield in the basin is quite high with about 3.67 metric tons/ha lost from the streams annually with a sediment yield upland of 4.16 metric tons/ha. This is in agreement with Johannsen and Armita (2010) reporting that sediment yields were up to ten times greater from agricultural catchments than forested catchments. Kirsch et al., (2002) also reported that SWAT results gotten in their study indicated that implementation of improved tillage practices can reduce sediment yields by almost 20% in the Rock River in Wisconsin. However, the findings from the individual tillage methods contradicts the norm that the use of conservative tillage should reduce sediment yield as proposed by several authors such as

Philps *et al*., (1980), Aina *et al.,* (1993), Lewandowski *et al*., (1999), Anthony and Collin (2006), Derpsch, (2007),FAO (2007), Aina (2010), Reji *et al.,*(2012) among others.

The annual sediment yield for the study area (covering all the sub-basins) for the years 2013, 2014, 2015 and 2016 are 297.2, 103.7, 108.54 and 195.43 metric tons/ha respectively as shown in Table 7.4. The Average water holding capacity of the soil in the study area thus is same (175.77). The modeled summary for sediment yield is shown in Figure 7.5.

Table 7.3: Average sediment yield from the experimental plot

Tillage types	UTRF (SED th)	NCAM (SED th)
PH	5.31	1.57
NT	10.54	10.46
T	10.54	10.46
PHR	1.81	4.79
Grand total(metric tons/ha)	28.2	27.28

Source: Author's fieldwork (2016)

Table 7.4: Sediment Yield for the entire study area

Year	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Grand Total Metric tons/ha
2013	0.23	0.16	0.13	0.63	15.94	24.89	23.05	138.58	50.21	31.31	10.95	1.12	297.2
2014	0.36	0.25	0.32	1.01	6.84	0.35	1.61	45.8	45.5	1.58	0.06	0.02	103.7
2015	0.02	0.01	0.01	3.2	10.43	33.71	1.08	0.03	0.08	15.41	6.58	37.98	108.54
2016	38.7	16.98	41.94	58.71	17.89	4.21	3.57	13.43	7.56	10.78	5.34	0.59	219.7
Grand Total metric tons/ha	39.31	17.4	42.4	63.55	51.1	63.16	29.31	197.84	103.35	59.08	22.93	39.71	729.14

Source: Author's fieldwork (2016)

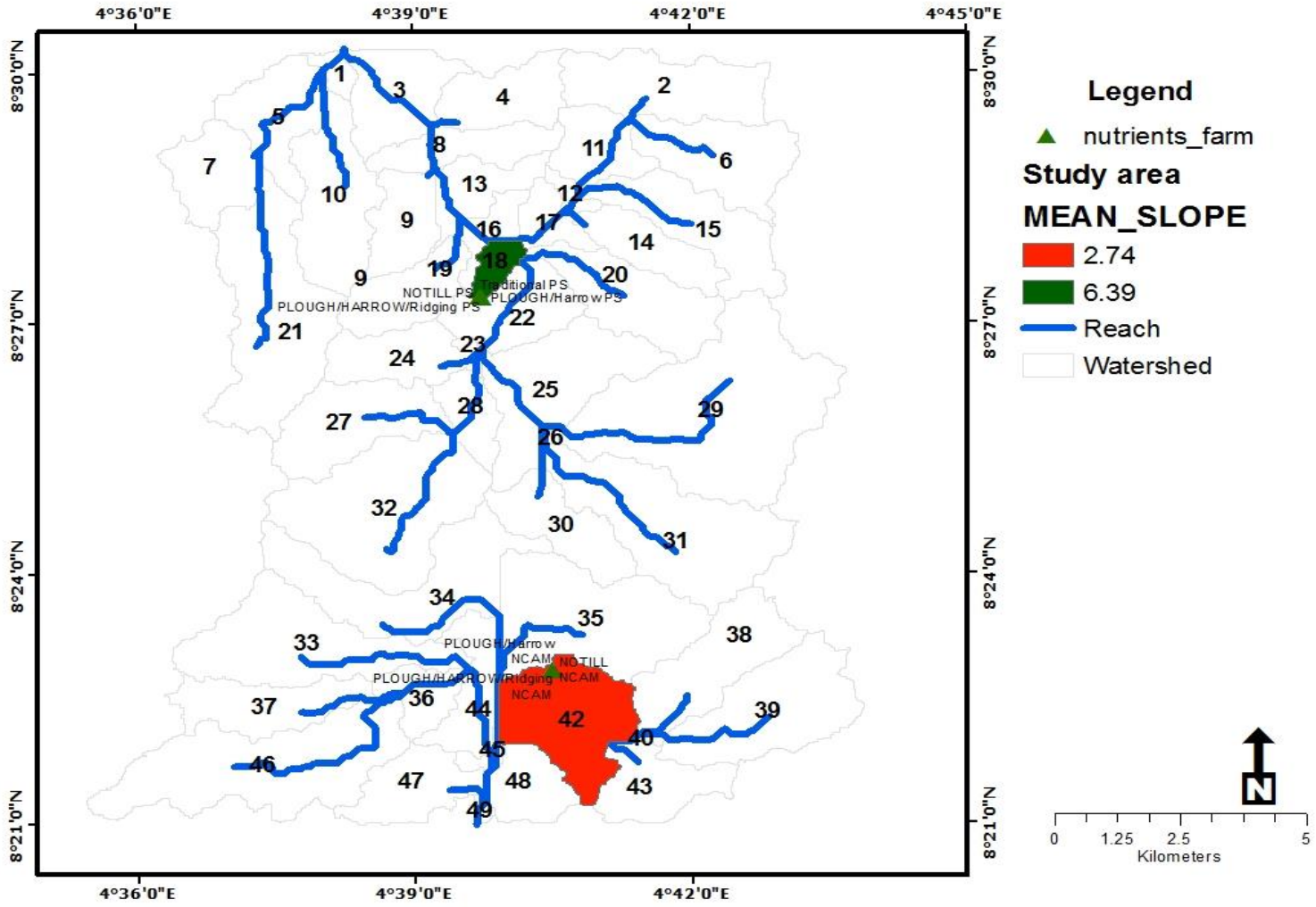


Figure 7.4: Mean slope of the study area
Source: Author's fieldwork (2016)

Sediment Yield

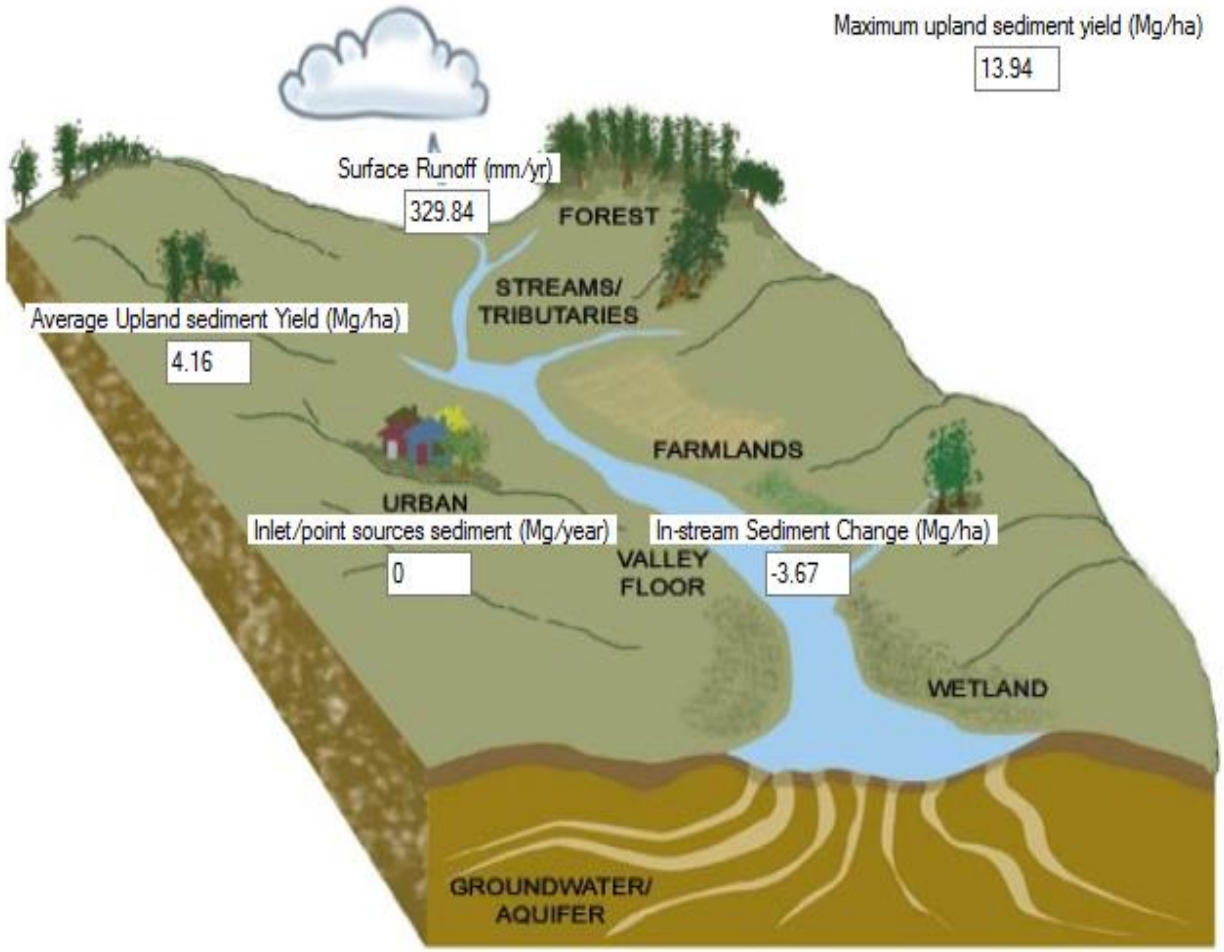


Figure 7.5: SWAT modeled summary of sediment yield in the study area
Source: Authors fieldwork (2016)

7.2.3 Surface Runoff Amount Generated and Groundwater Flow

The grand total surface runoff (SURQmm) generated in contribution to stream flow in the main channel for both UTRF and NCAM sub-basin are 1490.39mm and 1132.13mm respectively as shown in Table 7.5. This values shows that the amount of surface runoff generated in UTRF is higher than NCAM. For the tillage types at UTRF site, the Plough/Harrow/Ridge had the highest values for surface runoff generated with 374.42mm followed by Plough/Harrow with 372.91mm and the lowest was recorded on Notill and Traditional heap with 371.53mm each. For the tillage types at NCAM site, Plough/Harrow had the highest surface runoff contribution with 284.86mm followed by Plough/Harrow/Ridge with 283.39mm while Notill and Traditional heap had the lowest with 281.94mm each. This can be attributed both to the elevation of the areas which will increase the movement of surface runoff down slope (see Figure 7.5) where UTRF has a mean slope of 6.39 and NCAM has a mean slope of 2.74 and also the mean annual rainfall which was higher on UTRF than on NCAM with 1314.21mm and 1113.86m respectively as indicated in Appendix IV. According to Salsabilla and Kusratmoko (2017), runoff and sediment are positively related to the land cover in a watershed. More forest cover produces generally less runoff and soil loss. Land with cultivation has more erosion than land with agriculture.

The grand total for groundwater (GWQMM) contribution to stream flow for both UTRF and NCAM experimental Site are 687.95mm and 376.34mm respectively. This indicates that UTRF has a high volume contributing into the main channel as compared to NCAM. Among the tillage types on UTRF site, Notill and Traditional heap had the highest contribution with 174.45mm each followed by Plough/Harrow with 171.19mm while the lowest is Plough/Harrow/Ridge with 167.86mm. Also for NCAM, Notill and Traditional heap had the

highest value with 96.32mm each followed by Plough/Harrow/Ridge with 93.29mm and the lowest is Plough/Harrow plot with 90.41mm as shown in Table 7.5.

Table 7.5: Surface runoff and Groundwater contribution to stream flow in the main channel in the study area

Tillage types	UTRF (SURQmm)	NCAM (SURQmm)	UTRF (GWQmm)	NCAM (GWQ mm)
PH	372.91	284.86	171.19	90.41
NT	371.53	281.94	174.45	96.32
T	371.53	281.94	174.45	96.32
PHR	374.42	283.39	167.86	93.29
Grand total	1490.39	1132.13	687.95	376.34

Source: Author's fieldwork (2016)

7.2.4 Evapotranspiration and Biomass

The grand totals of evapotranspiration for both UTRF and NCAM from the SWAT model are 2897.77mm and 2788.77mm respectively. PHR had the highest value on UTRF site with 725.78mm followed by PH with 724.79mm while NT and T had the lowest values with 723.6mm each. On NCAM, PH had the highest values with 698.1mm followed by PHR with 697.47mm while NT and T had the lowest value with 696.6mm each as shown in Table 8.6. The grand total for biomass at both UTRF and NCAM were 54.24mm and 51.24mm respectively. NT and T had the highest values with 13.57 each followed by PHR with 13.56mm while PH had 13.54mm. For NCAM, all the tillage types had 12.82 BIOM th as shown in Table 7.6.

Table 7.6: Evapotranspiration and Biomass in the study area

Tillage types	UTRF (ETmm)	NCAM (ETmm)	UTRF (BIOMth)	NCAM (BIOMth)
PH	724.79	698.1	13.54	12.82
NT	723.6	696.6	13.57	12.83
T	723.6	696.6	13.57	12.82
PHR	725.78	697.47	13.56	12.82
Grand total	2897.77	2788.77	54.24	51.24

Source: Author's fieldwork (2016)

7.2.5 Crop Yield

The grand total of crop yield in SWAT model for both UTRF and NCAM experimental plots are 17.27 and 16.09 metric tons/ha. On UTRF site, NT, T and PHR had the same value of 4.32metric tons/ha while PH had 4.31 metric tons/ha. On NCAM experimental plot, all the tillage types had the same value of 4.03 metric tons/ha as shown in Table 7.7. The modeled summary for crop yield is shown in Figure 7.6. According to Aina (2011),No-tillage has proven to be an attractive alternative for maize *(Zea mays* L.) and other row crops on coarse-textured soils in the humid' and subhumid tropics while in the semi-arid region with fine textured soils, some type of conventional tillage system of mechanical seedbed preparation (plowing and harrowing) is necessary. The frequency and type of mechanical operation desired depends on soil characteristics and the crops to be grown.

Table 7.7: Crop/harvest yield in the study area

Tillage types	UTRF	NCAM
PH	4.31	4.03
NT	4.32	4.03
T	4.32	4.03
PHR	4.32	4.03
Grand total(metric tons/ha)	17.27	16.09

Source: Author's fieldwork (2016)

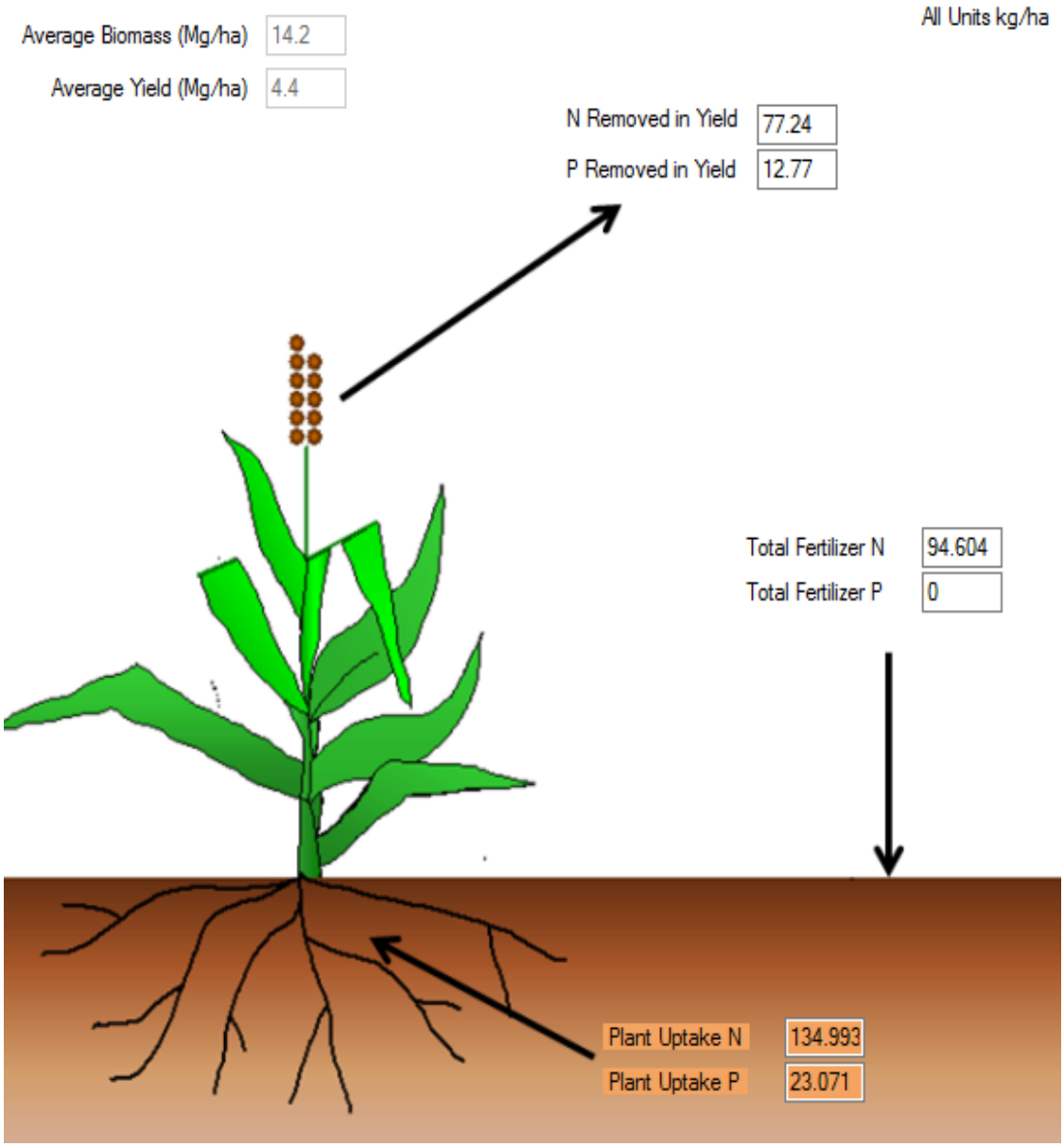


Figure 7.6: SWAT modelled summary for crop yield in the study area
Source: Author's fieldwork (2016)

7.2.6 Organic Nitrogen, Nitrogen in Surface Runoff and Phosphorus

Proper plant growth is key to accurate runoff and sediment predictions. Problems in plant growth are often related to excessive stress due to temperature or the lack of water/nutrients. The data presented here are basin averages, and may not reflect problems with individual land uses.

The grand total of organic nitrogen for both UTRF and NCAM sub-basin from the SWAT model are 206.01kg N/ha and 197.37 kg N/ha respectively. Notill and Traditional had the highest value of 62.62 kg N/ha at UTRF site followed by Plough/Harrow with 50.94 kg N/ha while Plough/Harrow/Ridge had 29.83 kg N/ha. For NCAM site, Notill and Traditional heap also had the highest value of 60.79 kg N/ha followed by Plough/Harrow/Ridge with 48.38kg N/ha while Plough/Harrow had the lowest value of 27.41 kg N/ha as shown in Table 7.8. The grand total for nitrogen in surface runoff for both UTRF and NCAM site are 18.39kg N/ha and 15.77 kg N/ha respectively. On UTRF sub-basin, Notill and Traditional heap had the highest contribution with 5.15 kg N/ha each, followed by Plough/Harrow with 4.41 kg N/ha while Plough/Harrow/Ridge had the lowest value of 3.68 kg N/ha. On NCAM site, Notill and Traditional heap also had the highest contribution of Nitrogen in surface runoff with 4.42 kg N/ha each, followed by Plough/Harrow/Ridge with 3,89 kg N/ha while Plough/Harrow had 3.04 kg N/ha as displayed in Table 7.8.

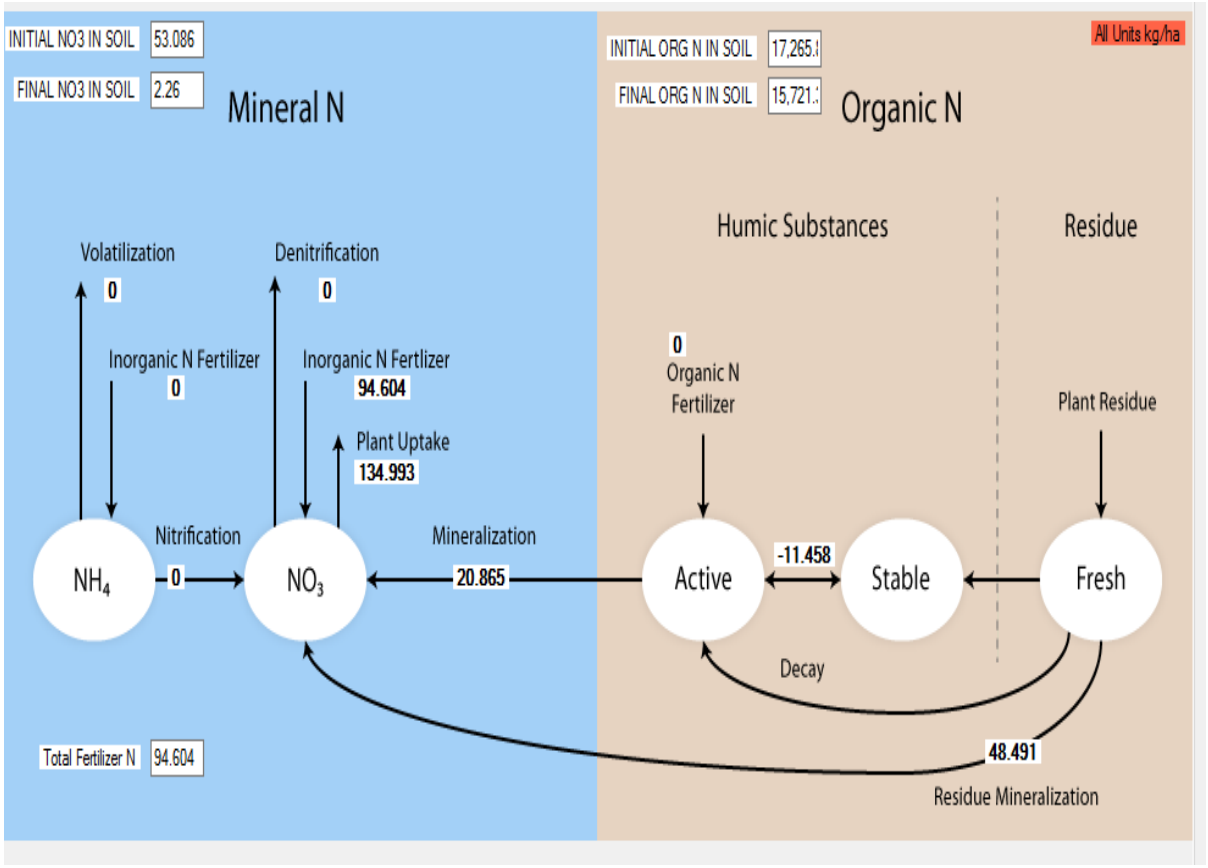
Table 7.8: Organic nitrogen and Nitrogen in surface runoff in the study area

Tillage types	UTRF (kg N/ha)	NCAM(kg N/ha)	UTRF (kg N/ha)	NCAM (kg N/ha)
PH	50.94	27.41	4.41	3.04
NT	62.62	60.79	5.15	4.42
T	62.62	60.79	5.15	4.42
PHR	29.83	48.38	3.68	3.89
Grand total(kg N/ha)	206.01	197.37	18.39	15.77

Source: Author's fieldwork (2016)

The nitrogen cycle is a key to biomass production, which in turn impacts on evapotranspiration, sediment yield and crop yield. It is generally not possible to validate these

routines outside a research setting. Of particular importance are the total applied nitrogen fertilizer and losses due to plant uptake, volatilization and denitrification. Soils contain a large amount of organic nitrogen in the form of organic matter. Large changes in initial and final nitrogen contents (in particular organic n) may indicate under or over fertilization during the simulation. All this is indicated in SWAT modeled summary in Figure 7.7. This is in line with Gassman *et al.*, (2007) reporting that adoption of no tillage, changes in nitrogen application rates, and land use changes could greatly impact nitrogen losses in the Walnut Creek Watershed in central Iowa.



Total nitrogen losses are greater than 40% of applied N

Organic/Particulate nitrogen losses in surface runoff may be high

Solubility ratio for nitrogen in runoff is low

Solubility ratio for phosphorus in runoff is low, may indicate a problem

Nitrate leaching is less than 21% of the applied fertilizer.

Nitrogen Losses (kg/ha)	
Total N Loss	59.064
Organic N	39.441
Nitrate Surface Runoff	2.824
Nitrate Leached	15.941
Nitrate Lateral Flow	0.73
Nitrate Groundwater Yield	0.128
Solubility Ratio in Runoff	0.067

Figure 7.7: SWAT model for Nitrogen in the study area
Source: Author's fieldwork (2016)

The phosphorus cycle is of particular interest in watersheds with significant agricultural activities. Soils contain a large reservoir of both mineral and organic phosphorus. Large increases in mineral phosphorus content during the simulation often result from over fertilization with either commercial or manure phosphorus sources. This also means that phosphorus concentrations in runoff also increase during the simulation period. Plant uptake is the dominant loss pathway for phosphorus under most conditions. Phosphorus decreased in the soil with both mineral P and Organic P recording losses between initial and final P. This implies that quite an amount of phosphorus is being lost to runoff while the plant uptake is also responsible without any major input of phosphorus to the soil. All this is indicated in the SWAT modeled summary in Figure 7.8.

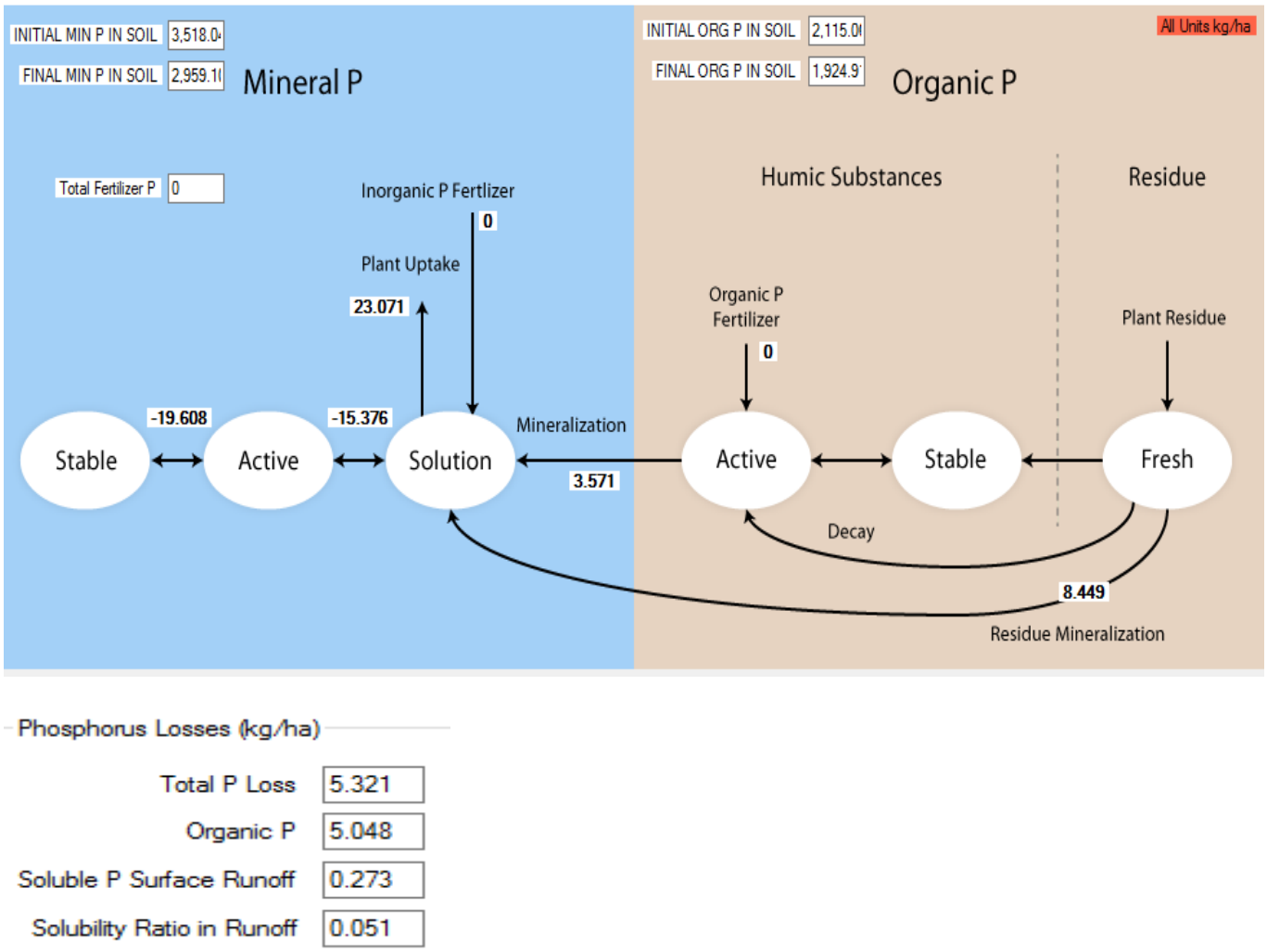


Figure 7.8: SWAT modeling phosphorus in the study area
Source: Author's fieldwork (2016)

7.3 Agricultural Land Use Predictions

The SWAT demarcated the subasins into three landuse types. They are agricultural cropland, area of thick vegetation and bare surfaces as shown in Figure 7.9 and 7.10. Each of these landuses has particular impact on the variables modeled. A few important predictions summarized by land use on each of these variables are shown in Table 7.9. The areas highlighted indicate highest contribution of land use to the variables modeled. From the Table 7.9, agricultural cropland had a greater contribution to the grand total of groundwater quality, sediment yield and

organic nitrogen than the other land use (i.e. bare surfaces and forested area) in the study area with values of 139.56mm, 4.72 kg/ha and 44.72 kg N/ha respectively.

Also, Bare surface contributed more to the grand total of surface runoff, precipitation, nitrogen and crop yield in the study area than the agricultural and forested area in the study area with values of 447.08mm, 1,314.21mm, 4.94 kg N/ha and 9.40 respectively. Furthermore, the forested areas contributed more to soil loss, evapotranspiration and biomass than the agricultural and barren surfaces with values of 1.00, 800.80mm and 22.62bioth respectively. This is in line with Arnold and Fohrer (2005), Coutu and Vega (2007) and Gassman *et al.*, (2007) who reported that bare surfaces contribute more to surface runoff and that there is a significant relationship between forested surfaces and the amount of runoff generated through the application of SWAT.

Table 7.9: Land Use Predictions on Features Modelled For the Study Area

Land Use	Area	Curve No (CN)	Average Water Capacity (AWC)	USLE (Soil Loss)	Precipitation	Surface Runoff (SURQ)	Groundwater Quality (GWQ)	Evapotranspiration (ET)	Sediment Yield (SED)	N03	Organic Nitrogen	Biomass	Yield
Agricultural cropland	166.07	87.00	175.77	0.92	1,235.15	338.02	139.56	714.23	4.72	3.90	44.72	13.27	4.21
Grasslands/ Shrubs/Bare surface	6.75	86.22	175.77	0.69	1,314.21	447.08	64.50	766.85	2.29	4.94	20.45	13.40	6.40
Thick cluster of trees (Dense Vegetation)	19.15	83.00	175.77	1.00	1,165.00	217.66	103.87	800.80	0.02	0.08	0.34	22.62	4.24

Source: Author's fieldwork (2016)

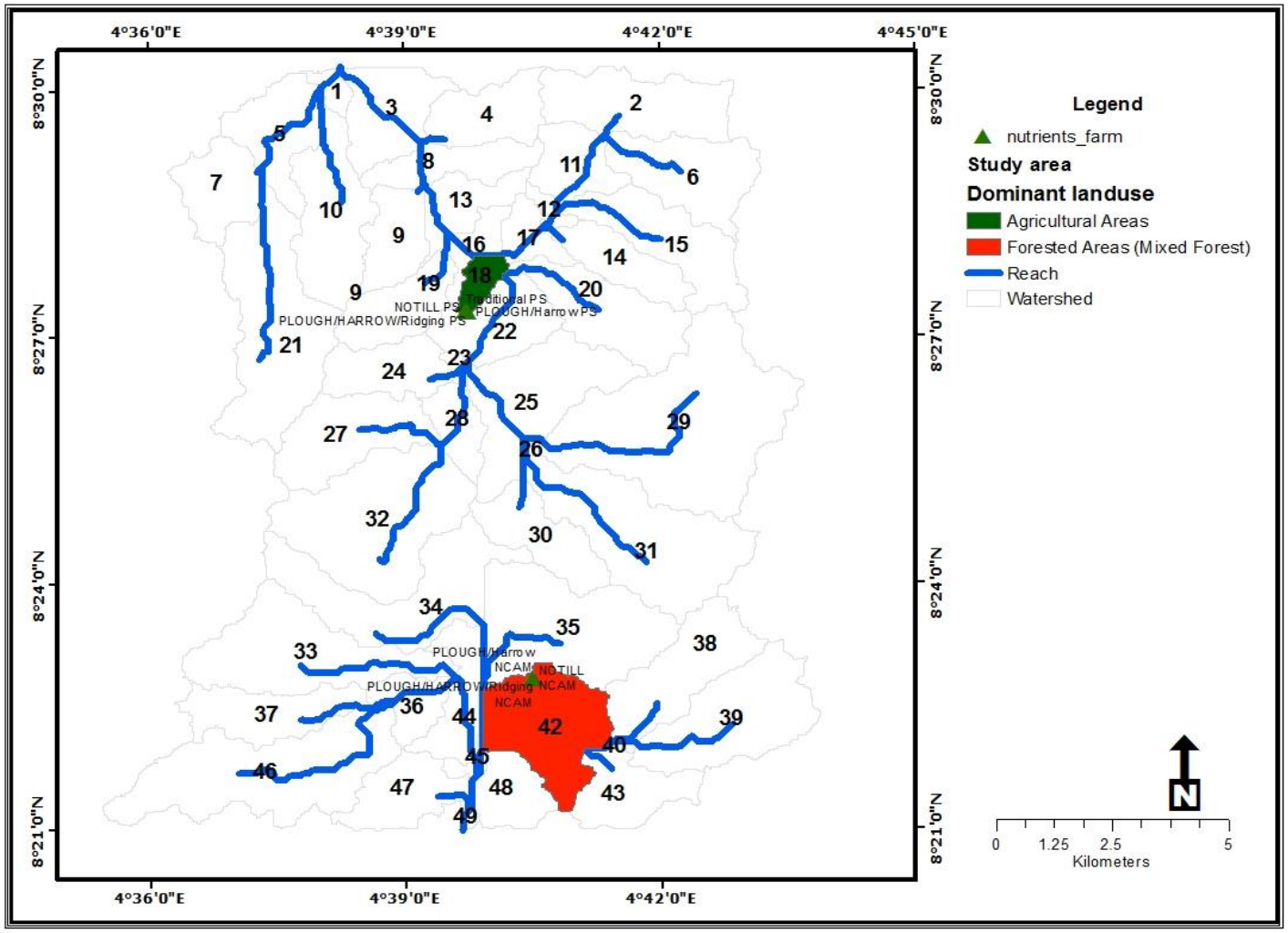


Figure 7.9: Dominant land use in the study area
Source: Author's fieldwork (2016)

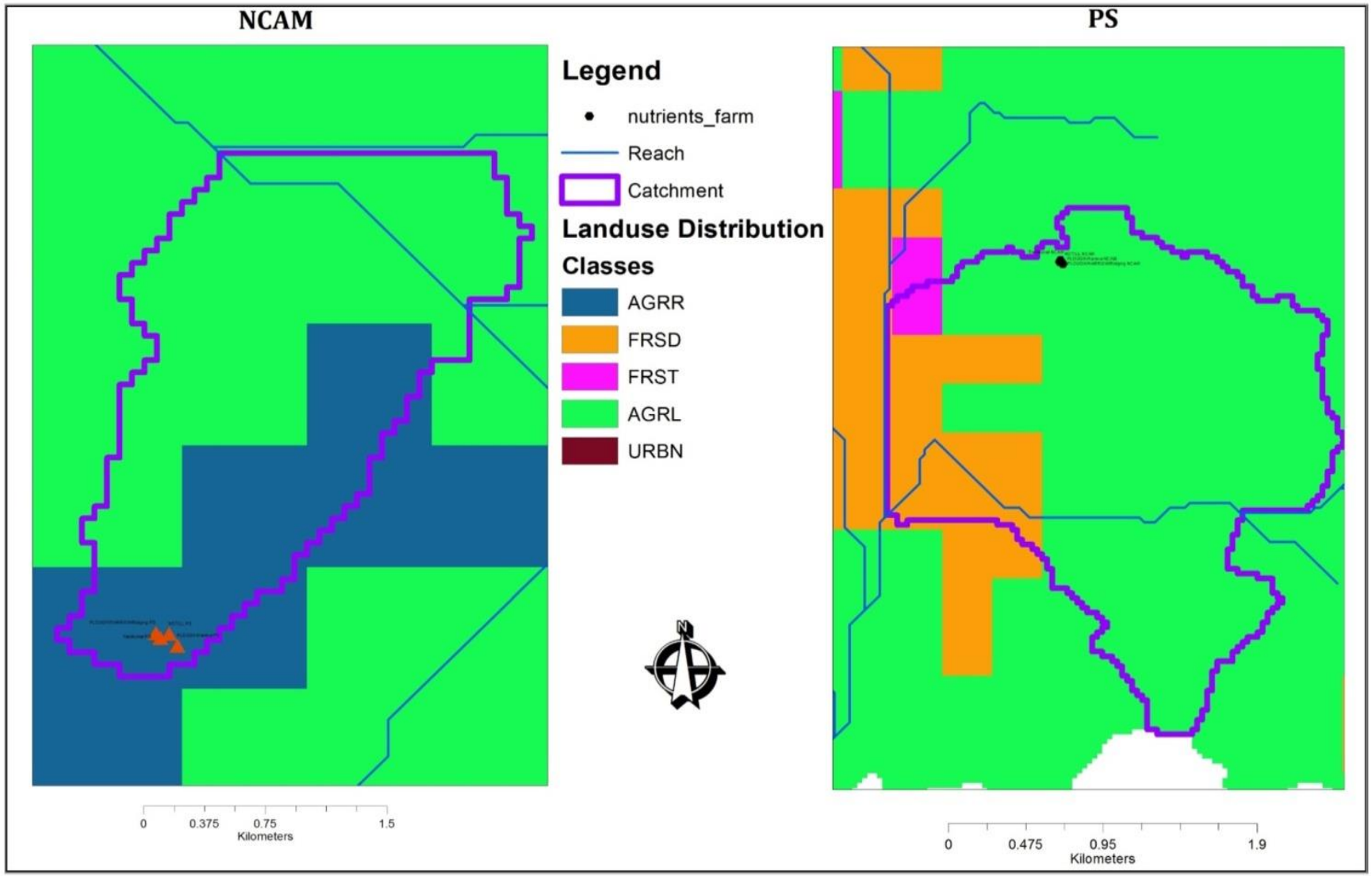


Figure 7.10: Landuse Distribution classes across the Study Area
Source: Author's fieldwork (2016)

The observations from the SWAT model revealed that UTRF sub-basin contributed more to all the features modeled than NCAM sub-basin expect for soil loss where NCAM site generated more soil loss than UTRF site with 6 and 1.661 USLE_LS respectively. Notill and Traditional heap contributed more to sediment yield, groundwater amount, organic nitrogen, and nitrogen in surface runoff water than the other tillage types at both locations as shown in Tables 7.3, 7.5 and 7.8 while Plough/Harrow and Plough/Harrow/Ridge contributed more to surface runoff amount and evapotranspiration at both locations has shown in Tables 7.5 and 7.6. Plough/Harrow contributed more to soil loss on UTRF subbasins than the other tillage types while Notill and Traditonal heap contributed more in NCAM subbasins as shown in Table 7.2. NT, T and PHR had the same values for crop yield in UTRF subbasins while all the tillage types had the same values in NCAM subbasins as shown in Table 7.7. For the biomass, NT and T contributed more in the UTRF subbasins than the other tillage types while NT contributed more in NCAM subbasins as shown in Table 7.6. Thus, conservative tillage contributed more to the features as against the opinion of it been the most suitable tillage type for attaining the best environmental conditions for growing maize giving rise to a sustained land resources as highlighted by several reference (Junge et al., 2008, Lewandowski *et al*., (1999), Anthony and Collin (2006), Derpsch, (2007), FAO (2007),Aina (2011),Reji *et al.,(*2012) among others.). Therefore, farmers must be conscious of the agricultural land management activities such that the best tillage method that is suitable for such an environment is applied to have optimum crop yield yet conserving the water and soil quality.

The Soil and Water Assessment Tool (SWAT) model has proven to be an effective tool for assessing water resource and nonpoint pollution problems for a wide range of scales and environmental conditions across the globe and has enabled in this study the quantification of the impact of land management practices, predict the impact of man-made changes and management

practices as well as natural changes. It has also allowed assessment of various physical phenomena such as water, sediment, nutrient and crop yields in complex watersheds with varying soils, land use and management conditions over a period of time with accuracy and also generate alternate scenarios

CHAPTER EIGHT

SUMMARY OF FINDINGS, CONCLUSION AND RECOMMENDATIONS

8.1 Summary of Findings

The study reveals that:

i. ten soil physico-chemical parameters (soil temperature, ph, bulk density, nitrogen, phosphorus, sodium, calcium, copper and zinc e.g nitrate (0.019 and 0.012mg/kg for UTRF) (0.001 and 0.025mg/kg for NCAM) were significant for PH and PHR while six (soil water, potassium, organic matter, manganese, lead, and iron e.g soil water (0.001 and 0.043mg/kg for UTRF) (0.029 and 0.03 for NCAM) were significant for T and NT in the topsoil and subsoil ($P < 0.05$) in 2015 and 2016;

ii. ten surface runoff physico-chemical parameters (carbon, potassium, nitrate, pH, chlorine, copper, magnesium, dissolved oxygen, lead and iron e.g nitrate (0.001 and 0.001 mg/l in 2015 and 2016)) were significant for NT and T while seven (turbidity, sodium, zinc, phosphorus, conductivity, total dissolved solids, and calcium e.g magnesium (0.001 and 0.045 mg/l in 2015) (0.001 and 0.027mg/l in 2016)) were significant on PH and PHR for UTRF and NCAM sites;

iii. crop yield (kg/ha) parameters showed that PH yield > NT yield ($P (0.015) < 0.05$) > T yield ($P (0.04) < 0.05$) and > PHR yield ($P (0.046) < 0.05$) for UTRF and NCAM sites in 2015 while in 2016, PH yield > T yield ($P (0.026) < 0.05$) > PHR yield ($P (0.046) < 0.05$) and no statistical difference between PH and NT at both locations. Also, in the UTRF site, plant height, number of leaves, leave length and leave width explained 59.3% and 43.3% in 2015 and 2016 of the variance in the yield of maize respectively,

while in NCAM site, these variables explained 54.7% and 1.1% in 2015 and 2016 respectively

iv. SWAT model showed that four of nine biophysical factors examined (sediment yield-10.54 metric tons/ha, groundwater amount-174.45GWQmm, organic nitrogen-62.62kg/ha, and nitrogen in surface runoff -5.15kg/ha) were higher for Traditional heap, while three (surface runoff amount- 374.42SURQmm, evapotranspiration-752.78ETmm and soil loss-1.05USLE_LS) were higher for Plough/Harrow and Plough/Harrow/Ridge.

8.2 Conclusion

The major research findings of the study draw some conclusion as follows:

i. The tillage methods which are traditional heap, Plough/Harrow, No-till and Plough/Harrow/Ridge greatly impact on soil quality, surface runoff and crop yield.

ii. Traditional Heap and Notill contributes more to the surface runoff parameters than Plough/Harrow and Plough/Harrow/Ridge except for turbidity and lead. Using the least significance difference comparison, most of the water samples from the T and NT had higher concentration of the parameters in the surface runoff as against the concentration gotten in the samples from the PH and PHR.

iii. Plough/Harrow and Plough/Harrow/Ridge had a higher concentration in the soil quality parameters needed for optimum growth as compared to Traditional Heap and Notill.

iv. For crop yield , Plough/Harrow had comparatively favorable effect on the soil environment, contribution to surface runoff and crop yield in this ecological zone

v. From the Soil Water Assessment Tool (SWAT) analysis, Plough/Harrow and Plough/Harrow/Ridge contributes more to soil loss and surface runoff amount flowing to the nearest river/drainage than Traditional Heap and Notill. Although, Traditional Heap and Notill contributes the highest sediment yield in the sub-basin compared to Plough/Harrow and Plough/Harrow/Ridge.

8.3 Recommendations

This research recommends the following:

i. Plough/Harrow should be adopted for a sustainable environment due to its comparatively favorable effect on the soil environment, contribution to surface runoff and crop yield in this ecological zone

ii. There is a need for appropriate technology for monitoring over time how farm management practices affect soil and water quality and also a call for cooperation in research and in the establishment of data banks operating on a unified information system, the eminence of education, training, and extension to farmers in Nigeria

iii. There is the need to further study on the assessment of the impact of different tillage methods on land resources in different ecological zones across the country and over a longer time frame will further authenticate the findings made in this study.

iv. The efforts of a multi-disciplinary team (comprising soil scientists, agricultural engineers, biogeographers, agronomists, economists, social scientists and the farmers) will help develop site-specific tillage methods to achieve both short and long-term goals of environmental/agricultural sustainability in Nigeria.

8.4 Contribution to Knowledge

This research has extended knowledge on the impact of tillage methods on soil degradation, water pollution, land resources and provide incentives for the creation of policies that value, restore and protect ecosystem services and also encouraged increased adoption of sustainable ecological agriculture and food systems. It has helped to fill the gap of lack of information and data needed for policy making and aid a holistic approach to understanding tillage and land management practices across the country. It has also granted a wider understanding for the best soil tillage methods that will conserve our environmental resources (soil and water), reduce deterioration of these resources and give room for a sustainable environment. It provided better understanding of the impact of tillage methods on water quality/pollution especially since this has been lacking over time in Nigeria where as it relates to the use of agricultural management activities. It further broaden the knowledge on water quality, land management methods and sustainable resources and help to determine the environmental effects of conventional and conservative tillage and the benefits derivable from its application by farmer in the study area. Also, the application of plough and harrow for maize production can be adopted by farmers in the study area due to the fact that it encourages utilization of the agricultural ecosystem resources in a sustainable way.

REFERENCES

Abulude, F.O. Obidiran. G.O. and Orungbemi, S. (2007). Determination of Physico-Chemical Parameter and Trace Metal Conducts of Drinking Water Samples in Akure, Nigeria, *Electronic Journal of Environmental Agricultural and Food Chemistry* 6(8), 2297-2303.

Adelana, S. M. A. and Olasehinde, P. I. (2004). Assessment of Aquifer System in Parts of South-Western Nigeria Using Isotope Techniques. *Proc. International Workshop on the Application of Isotope Techniques in Hydrological and Environmental Studies, Paris,* September 6 – 8.

Adugna. A. and Abegaz, A. (2015). Effects of Soil Depth on the Dynamics of Selected Soil Properties among the Highlands Resources of Northeast Wollega, Ethiopia: Are These Sign of Degradation? *Solid Earth Discuss.*, 7, 2011–2035. www.solid-earth-discuss.net/7/2011/2015/doi:10.5194/sed-7-2011-2015

African Conservation Tillage Network, 2008. 2009-06-26 www.act-africa.org/

Agbede, T.M., Ojeniyi, S.O., Adeyemo, A.J. (2008). Effect of Poultry Manure on Soil Physical and Chemical Properties, Growth and Grain Yield of Sorghum in Southwest Nigeria. *Ame-Eurasian J. Sustainable Agric.* 2(1), 72-77.

Ahaneku, I.E. (1997). Soil Degradation and Water Balance Studies under Different Tillage Systems, Unpublished Ph.D Thesis, University of Ibadan, Ibadan, Nigeria.

Ahaneku, I.E. (2010). Conservation of Soil and Water Resources for Combating Food Crisis, *Scientific Research and* Essays 5(6), 501-513.

Ahmed,Y.A. (2009). Settlements Pattern and Functional Distribution in Emerging Communities: A Case of A Local Government Area of Kwara State, Nigeria, *The Social Sciences*.4 (3):256-263.

Ahn, P.M. and Hintze, B. (1990). No Tillage, Minimum Tillage, and Their Influence on Soil Properties. In: Latham .M. (ed.) *Organic-matter Management and Tillage in Humid and Sub-humid Africa*. IBSRAM Proceedings 10, 341-349.

Aina, P.O (2011). Conservation Tillage for Sustainable Agricultural Productivity, 'Tillage for Agricultural Productivity and Environmental Sustainability' Lead Paper – *International*

Soil Tillage Research Organization (ISTRO)-Nigerian Symposium Conference, held in Ilorin, Nigeria, February 21-23 2011.

Aina, P.O. (1993). Rainfall Runoff Management Techniques for Erosion Control and Soil Moisture Conservation. In: FAO Information Division(ed.) *Soil Tillage in Africa: Needs and Challenges. FAO Soils Bulletin, 69*. Food and Agricultural Organization of the United Nations, Rome, Italy.

Akinbile .C.O and Yusoff, M.S (2011). Effect of Tillage Methods and Fertilizer Applications on *Amaranthuscurentus* in Nigeria. *International Journal of Agricultural Research,* 6, 280-*289.*

Akinbile, C.O., Famuyiwa, O.A., Ajibade, F.O. and Babalola,T.O. (2016). Impacts of Varying Tillage Operations on Infiltration Capacity of Agricultural Soils. *International Journal of Soil Science,* 11, 29-35.

Amir, K. and Theodor, F. (2012). An Ecologically Sustainable Approach to Agricultural Production Intensification: Global Perspectives and Developments, Field Actions *Science Reports* [Online], Special Issue 6 http://factsreports.revues.org/1382

Anderson. G. (2009). The Impact of Tillage Practices and Crop Residue (Stubble) Retention in the Cropping System of Western Australia, Bulletin Number 4786, ISSN 1833-7236

Angle, J.S, McCling, G., McIntosh, M.S, Thomas, P.M and Wolf, D.C (1984). Nutrient Loss in Runoff from Conventional and No-Till Watersheds. *Journal of Environment, Qual.* 13, 130-136.

Anthony, S. and Collins, A. (2006). Sediment Gap Analysis to Support Water Framework Directive, *Interim Report Project WQ0106 (Part 3)*

AOAC (1990). *Official Methods Of Analysis*, Kenneth Helrich (ed.), 15th edition , Published by the Association of Official Analytical Chemists, Inc, Virginia,USA.

Arnold, J. G., R. Srinivasan, R. S. Muttiah, and J. R. Williams. (1998). Large-Area Hydrologic Modeling and Assessment: Part I. Model Development. *J. American Water Resour. Assoc.*34 (1), 73-89

Arnold, J.G. and Fohrer, N. (2005). SWAT 2000: Current Capabilities and Research Opportunities in Applied Watershed Modelling. *Hydrol.Proc* .19(3), 563-572.

Aromolaran, A.B. (1998). Economics Analysis of Soil Conservation Practices in South Western Nigeria, *Eleventh Series of Issues in African Rural Development Monograph,* 1-28.

Ayoade, J.O. (1988). *Tropical Hydrology and Water Resources.* Macmillan Publishers, Ibadan.

Berry, J.K, Delgado, J.A, Khosla, R. and Pierce, F. (2003). Precision Conservation for Environmental Sustainability. *Final Draft for Publication in the J. of Soil Water Conservation.*

Bertol, I., Barbosa. F.T., Mafra,A.L. and Flores, M.C (2014). Soil Water Erosion under Different Cultivation Systems and Different Fertilization Rates and Forms over 10 years. *Rev. Bras. Ciênc. Solo* 38(6), 1918-1928. http://dx.doi.org/10.1590/S0100-06832014000600026

Bertol, I., Guadagnin, J.C., González, A.P., Amaral, A.J., and Brignoni, L.F. (2005). Soil Tillage, Water Erosion, Calcium, Magnesium and Organic Carbon Losses. *Sci. Agric. (Piracicaba, Braz.),* 62(6), 578-584.

Bhattacharyya, R. S., Kundu, S.C., Pandey, K.P. and Gupta, H.S. (2008). Tillage and Irrigation Effects on Crop Yields and Soil Properties under the Rice-Wheat System in the Indian Himalayas. *Agric. Water Manage.,* 95, 993-1002.

Boone, F.R. (1988). Weather and Other Environmental Factors Influencing Crop Responses to Tillage and Traffic. *Soil and Tillage Research* 11, 283-324.

Bremer, E. and Ellert, K, (2004). Soil Quality Indicators: A Review with Implications for Agricultural Ecosystems in Alberta, Report Prepared for: Alberta Environmentally Sustainable Agriculture Soil Quality Program, Alberta Agriculture, Food and Rural Development.

Busari, M.A, SinghKukal, S., Kaur, A., Bhatt, R. and AllyDulazi, A. (2015). Conservation Tillage Impacts on Soil, Crop and the Environment, *International Soil and Water Conservation Research*, 3(2), 119-129.

Clark, R.M, Goodrich, J.A, and Wymer, L.J.(1993).Effect of the Distribution System on Drinking- Water Quality. *Journal of Water Supply Research and Technology – Aqua.*42(1), 30-38.

Cook, R. L., and Trlica. A. (2016). Tillage and Fertilizer Effects on Crop Yield and Soil Properties over 45 Years in Southern Illinois. *Agron. J*. 108, 415-426. doi:10.2134/agronj2015.0397

Coutu, G.W. and Vega, C. (2007). Impacts Of Land Use Changes On Runoff Generation In the East Branch Of The Brandywine Creek Watershed Using A GIS-Based Hydrologic Model, *Middle States Geographer*, 40, 142-149

CTIC (2004). National Crop Residue Management Survey: Conservation Tillage Data. Conservation Technology Information Center. Available online at http://www.ctic.purdue.edu/CTIC/CRM.html

Daramola, J. (2013). Spatio-temporal Variation in Hydrochemistry of Landzun Stream in Bida, Niger State of Nigeria. *MSc. Dissertation*, Department of Geography and Environmental Management, University of Ilorin, Ilorin, Nigeria. Pp. 147.

Derpsch, R. (2007). No-Tillage and Conservation Agriculture, World Association of Soil and Water Conservation, *Special Publication* 3,7-11.

Derpsch, R., (2003). Conservation Tillage, No-tillage and Related Technologies.*Conserv.Agric. Environ. Farm. Exp. Innov. Socio-Econ. Policy* 181–190.

Derpsch, R., Friedrich, T., Kassam, A. and Li, H.W. (2010). Current Status of Adoption of No-till Farming in the World and Some of its Main Benefits. *Int. J. Agric. & Biol. Eng. 3(1).*

Devlin, D. and Barnes, P. (2009). Impacts of No-till on Water Quality, *No Till Series,* Kansas State University, *www.ksre.ksu.edu*

ECSFDI (2008). Effects on Runoff Water Quality from Sludge-Amended Soils. The First Phase: A Compendium of Advice Activity Examples by England Catchment Sensitive Farming Delivery Initiative *Bulletin 162*, URL: www.defra.gov.uk/.

EPA (2001). Parameters of Water Quality Interpretation and Standards. *Environmental Protection Agency, Ireland*. 24-112,

EPA (2012). Managing Nonpoint Source Pollution from Agriculture *Pointer No. 6EPA841-F-96-004F* http://water.epa.gov/polwaste/nps/outreach/point6.cfm

FAO (2007). Agriculture and Consumer Protection Department. Food and Agriculture Organization Rome, Italy Available from http://www.fao.org/ag/ca/

FAO (2008). Towards Alleviation of Poverty in the Tropics: An International Technical Workshop on Investing in Sustainable Crop Intensification: The Case for Improving Soil Health. *Proceedings FAO, Rome*, 22-24.

FAO (2011). The State of the World's Land and Water Resources for Food and Agriculture; Management Systems at Risks. Published by the Food and Agriculture Organization of the United Nations and Earth Scan, New York

FAO. (1993). Soil Tillage in Africa: Needs and Challenges. *FAO Soils Bulletin 69*, Soil Res. Manag. and Cons. Service, Land and Water Development Division, FAO, Rome.

FAO/UNEP (1997). *Negotiating a Sustainable Future for Land.* Structural and Institutional Guidelines for Land Resources Management in the 21st Century. FAO/UNEP, Rome.

Federal Republic of Nigeria Official Gazette (2009). Legal Notice on Publication of 2006 Census Final Results.

Gaffield, S.J. (2003). Public Health Effects of Inadequately Managed Stormwater Runoff. *American Journal of Public Health*. 93(9), 1527-1533.

Galadima, A., Garba, Z. N., Leke, L., Almustapha, M. N. and Adam, I. K. (2011). Domestic Water Pollution among Local Communities in Nigeria : Causes and Consequences. *European Journal of Scientific Research*. 52(4), 592-603 http://www.eurojournals.com/ejsr.htm

Gassman, P.W., Reyes, M.R., Green, C.H., and Arnold, J.G.(2007). The Soil and Water Assessment Tool: Historical Development, Applications, and Future Research Directions, *American Society of Agricultural and Biological Engineers* ISSN 0001-2351. 50 (4), 1211-1250.

Gbadamosi, J. (2013). Impact of Different Tillage Practices on Soil Moisture Content, Soil Bulk Density and Soil Penetration Resistance in Oyo Metropolis, Oyo State, Nigeria.*Transnational Journal of Science and Technology* 3(9), 50-57

Giller, K. E., Witter E., Corbeels, M. and Tittonell, P. (2009). Conservation Agriculture and Smallholder Farming in Africa: The Heretics' View, *Field Crops Research* 114, 23–34.

Gliessman, S.R. (1998). *Agroecology*: Ecological processes in sustainable agriculture. Ann Arbor Press, Chelsea, MI.

Gujarati, D.N. (2004). *Basic Econometrics*. Fourth Edition, The McGraw−Hill, New York.

Hadas, A., Kautsky, L., Goek, M. and Kara, E.E. (2004) Rates of Decomposition of Plant Residues and Available Nitrogen in Soil, Related to Residue Composition through Simulation of Carbon and Nitrogen Turnover. *Soil Biology and Biochemistry*, 36, 255-266.

Hallberg,G.R. (1987). The Impacts of Agricultural Chemicals on Groundwater Quality. *Geojournal* 15(3), 283-295.

Hardesty, D. L. (1977).*Ecological Anthropology*.New York: John Wiley & Sons.

Hem, J.D. (1989). Study and Interpretation of Chemical Characteristics of Natural Water, *U.S. Geological Survey Water-Supply Paper 2254*, Third Edition, Published by the United States Government Printing Office.

Hernanz, J.L, Sanchez-Giron, V. and Navarrete, L. (2009). Soil Carbon Sequestration and Stratification in a Cereal/Leguminous Crop Rotation with Three Tillage Systems in Semiarid Condition, *Agric.Ecosyst.Environ*. 133 (1-2), 114-122

Hobbs, P. R. (2007). Conservation agriculture: what is it and why is it important for future sustainable food production? *J. Agric. Sci*. 145, 127-137.

IAASTD (2009). International Assessment of Agricultural Knowledge, Science and Technology for Development, Global Report; pp.606, Washington DC.

ICTCM(2004). Regression Analysis. Capstone Project for 2004 ICTCM Short Course on Real-World Application and Assessment. Retrived 02/05/2018 https://people.richland.edu/james/ictcm/2004/weight.html

Ifabiyi, I.P. (2008). Self Purification of a Freshwater Stream in Ile-Ife: Lessons for Water Management, *J. Hum. Ecol.* 24(2), 131-137.

Ilorin Atlas (1982). Geography Department University Press, Ilorin, Nigeria.

IPCC, (2007). Climate Change 2007; Fourth Assessment report of the Intergovernmental Panel on Climate Change, Cambridge University Press .

Işildar , A.A., Bayhan ,A.K., Erdal, I. and Kaya, M. (2006). Tillage Impacts on Organic Matter and Plant Nutrients in a Loam Soil of Dryland in Turkey. *Archives of Agronomy and Soil Science*, 50(6), 623-629, DOI: 10.1080/03650340400005598

Ismail, I., Blevins, R.L. and Frye,W.W. (1994). Long-term No-tillage Effects on Soil Properties and Continuous Corn Yields. *Soil Sci. Soc. Am. J.* 58, 193-198.

Jimoh.H.I and Ajao.L.I. (2009). Problems of Suspended Sediments Loads in Asa River Catchment ,Ilorin, Nigeria , *Pakistan Journal Of Social Science*. 6, 19-25.

Johannsen, S. and Armitage,P. (2010). Agricultural Practice and the Effects of Agricultural Land-Use on Water Quality. *Freshwater Forum* 28, 45-60.

Junge, B., Abaidoo, R., Chickoye, D., Stahr, K. and Lal, R. (2008). Research Report on Soil Conservation in Nigeria: Past and Present On-Station and On-Farm Initiatives. *Soil and Water Conservation Society*, Ankeny, Iowa, USA.

Kargas, G., Kerkides, P., Poulovassilis, A. (2012). Infiltration of rain water in semi-arid areas under three land surface treatments, *Soil and Tillage Research,* 120, 15–24.

Karuma,A.N., Gachene, C.K.K, Gicheru,P.T., Mtankwa,P.W. and Amuri, N. (2016). Effect of Tillage and Cropping Systems on Miaze and Beans Yield and Selected Components in a Semi-Arid Area of Kenya. *Tropical and Subtropical Agroecosystems*, 19, 167-179

Kaur,R., Scinivansan, R., Mishra, K., Dutta, D., Prasad, D. and Bansal,G. (2003). Assessment of SWAT model for Soil and Water Management in India. *Land use and water Resources Research* 3, 1-7. http://www.luwrr.com

Killebrew, K. and Wolff, H. (2010). Environmental Impacts of Agricultural Technologies, EPAR Brief No. 65, *Prepared for the Agricultural Policy and Statistics Team of the Bill & Melinda Gates Foundation*

King, B. (1969), Comment on "Factor Analysis and Regression", *Econometrica 37, 538-540.*

Kirsch, K., Kirsch, A., and Arnold, J.G. (2002). Predicting sediment and phosphorus loads in the Rock River Basin using SWAT. *Trans. ASAE* 45 (6), 1757–1769.

Klimaszyk, P. and Rzymski, P. (2011), Surface Runoff as a Factor Determining Trophic State of Midforest Lake. *P1ol.J.Environ.Stud*.20 (5) 1203-1210

Klimaszyk, P. and Rzymski, P. (2011). Surface Runoff as a Factor Determining Trophic State of Midforest Lake" *Polish Journal of Environmental Studies*, 20(5), 1203-1210

Kuhn, T. S. (1962). *The Structure of Scientific Revolutions*, Second Edition, Enlarged, The University of Chicago Press, Chicago.

Kwara State Ministry of Information, (2002). Kwara State Diary, 1-10

Lal R., (1977). Importance of Tillage Systems in Soil Management in the Tropics. In: R. Lal (ed.) *Soil Tillage and Crop Production*. IITA, Ibadan, Nigeria.

Lal, R, (1991). Mechanized Tillage System, Effects on Properties of a Tropical Alfisoil in the Watershed Cropped to Maize, *Soil Tillage Research*, 6, 149-162.

Lal, R. (1983). No-Till Farming Soil and Water Conservation and Management in Humid and Subhumid Tropics. *IITA Monograph 2, (64)*.

Lal, R. (1989). Cropping Systems Effects on Runoff, Erosion, Water Quality, and Properties of a Savanna Soil at Ilorin, Nigeria, *Sediment and the Environment* (Proceedings of the Baltimore Symposium, May 1989) IAHS Publ. no. 184.

Lal, R. (1997). Long-Term Tillage and Maize Monoculture Effects on a Tropical Alfisol in Western Nigeria. II. Soil Chemical Properties, *Soil and Tillage Research*, 42. 161–174

Lal, R.(1974). No- Tillage Effects on Soil Conditions and Maize Production in Western Nigeria, *Plant and Soil 40, 321- 331.*

Lavado, R.S, Porcelli, C.A and Alvarez, R. (2000). Concentration and Distribution of Extractable Elements in a Soil as Affected by Tillage Systems and Fertilization. *The Science of the Total Environment* 232, 185–191

Lavelle, P., Dugdale, R., Scholes, R., Berhe, A.A, Carpenter, E., Codispoti, L., Izac, A.M., Lemoalle, J., Luizao, F., Scholes, M., Tre´guer, P., and Ward, B.(2009). Nutrient Cycling, *Ecosystems And Human Well-Being, Vol. 1: Current State And Trends*. Washington, DC: Island Press.

Lewandowski, A., Zumwinkle, M. and Fish, A. (1999): Assessing the Soil System: A Review of Soil Quality *Literature.*30 - 45.

Lynam ,J.K., and Herdt, R.W. (1989). Sense and Sustainability: Sustainability as an Objective in International Agricultural Research, *Agricultural Economics* 3, 381–98.´

MEA (2005). *Ecosystems and Human Well-Being: Synthesis.* Millennium Ecosystem Assessment. Washington, DC: Island Press.

Minase, N.A., Masafu, M.M., Geda, A.E., and Wolde, A.T. (2016). Impact of Tillage Type and Soil Texture to Soil Organic Carbon Storage: The Case of Ethiopian Smallholder Farms. *African Journal of Agricultural Research,* 11(13), 1126-1133.

Mostaghimi, S., Oeizman, M.M, Oillaha, T.A, Heatwole, C.O. and Perumpral, J.V (1988). Tillage Effects on Runoff Water Quality from Sludge-Amended Soils, *Bulletin 162*

Virginia Water Resources Research Center, Virginia Polytechnic Institute and State University, Blacksburg.

Muoghalu, L.N. and Omocho, V. (2000). Environmental Health Hazards Resulting from Awka Abattoir. *Afr. J. Environ. Stud.* 2, 72-73

Mustapha, K. M., (2008). Assessment of Water Quality of Oyun Reservoir, Offa, Nigeria, using Selected Physic-Chemical Parameters. *Turkish Journal of Fisheries and Aquatic Sciences* 8, 309-319.

National Research Council (1993). Nutrient Requirements of Fish. National Academies Press. 124pp. ISBN:0-309-59629-7. http://www.nap.edu/catalog/2115.html

Neitsch, J.R., Arnold, J.G., Kiniry, J.R. and Williams, J.R. (2005) Input/Output File Documentation Version 2005. User Manual Grassland, Soil and Water Research Laboratory, Agricultural Research Service, Blackland Research Center, Texas Agricultural Experiment Station, Temple, Texas

Nigerian Standards for Drinking Water Quality (NSDWQ), *Industrial standards. Standard Organisation of Nigeria (SON)*, 554, 1-14, 2007.

Obalum, S.E., Amana, S.M., Obi, M.E. and Akatsuki, T. (2011). Agronomic Responses to Four Tillage Variants on a Sandy-loam Ultisol Cropped to Sorghum and Soybean in the Derived Savanna of Southeastern Nigeria, *Exp.Agric*, 404-418.

Odjugo Peter A. O. (2008). The Impact of Tillage Systems on Soil Microclimate, Growth and Yield of Cassava (*Manihot utilisima*) in Midwestern Nigeria. *African Journal of Agricultural Research* 3(3), 225-233. Available online at http://www.academicjournals.org/AJARISSN 1991- 637X

Ohu, J.O. (2011).'Tillage for Agricultural Productivity and Environmental Sustainability' - Conference, *Keynote address held in Ilorin, Nigeria, from February 21-23 2011*.

Oladoye.A.O. (2015).Physicochemical Properties Of Soil Under Two Different Depths In A Tropical Forest Of International Institute Of Tropical Agriculture, Abeokuta, Ibadan , Nigeria**,** *Journal of Research in Forestry, Wildlife and Environmental* 7(1), 40-54.

Olaniran, J.O. (2002). "Rainfall Anomalies in Nigeria: The Contemporary Understanding" 55th Inaugural Lecture, University Press, Ilorin. 66pp

Olaoye, J.O. (2002). Influence of Tillage on Crop Residue Cover, Soil Properties and Yield Components of Cowpea in Derived Savannah Ectones of Nigeria, *Soil and Tillage Research*, 64(3-4), 179-187.

Opara-Nadi, O.A. (2000). Soil Resources and Agricultural Productivity in Nigeria. In: L.C. Nwaigbo, U.H. Ukpabi and A. Anene (eds). *Food and Fibre production in Nigeria in the 21st century*. Proc. of the First Annual Conference of the College of Agriculture and Veterinary Medicine Abia State University, Uturu. 195 - 210.

Osuji, G.E. (1984). Water storage, water use and maize yield for tillage systems on a tropical alfisol in Nigeria. *Soil Tillage Res.* 4, 339-348.

Oyegun, R. (1983) *Water Resources in Kwara State Nigeria*, Matanmi and Sons Printing and Publishers, Ilorin.

Phillips, R.E., Blevins, R.L., Thomas, G.W., Frye, W.W., and Phillips, S.H. (1980). No-tillage Agriculture, *Science* 208, 1108-1113.

Reicosky, D.C. (1997). Tillage-induced CO2 Emission from Soil. *Nutrient Cycling in Agroecosystems*.49:273-285.

Reji, P.M., Yucheng, F., Leonard, G., Ramble, A., and Kipling, S. B, (2012). Impact of No-Tillage and Conventional Tillage Systems on Soil Microbial Communities, *Applied and Environmental Soil Science*, 2012, Article ID 548620,doi:10.1155/2012/548620

Richard.L, Undersander.D, Peterson.P, Min.D, Harringer.T. and Grigar, J. (2003): Steps to Successful No-till Establishment of Forages, *E x t e n s i o n B u l l e t i n E - 2 8 8 0*, University of Minnesota.

Romkens, M.J.M., Nelson, D.W. and Mannering. J.V. (1973). "Nitrogen and Phosphorus Composition of Surface Runoff as Effected by Tillage Method." *J. Environ. Qual* 2(2), 292-295.

Russell, D.E., Martell, A.M. and Nixon, W.A.C. (1993). Range ecology of the PorcupineCaribou Herd in Canada. *Rangifer Special Issue* 8,167p

Salsabilla,A and Kusratimoko,E. (2017). Assessment of Soil Erosion Risk in Komering Watershed, South Sumatera, using SWAT Model. *AIP conference Proceedings.* 1862(1), 030192

Savabi, M.R., Golabi, M.H, Abou-Arab, A.A, and Kladivko, E.J. (2008). Effect Of No-Till Farming On Soil Water Intake, *Journal Of Environmental Hydrology,*16, 1-10

Senjobi, B. A., Ande, O.T., and Okulaja.A.E. (2013). Effects of Tillage Practices on Soil Properties under Maize Cultivation on OxicPaleustalf in South Western Nigeria, *Open Journal of Soil Science*, 3,163-168. (http://www.scirp.org/journal/ojss)

Sheldrick, W.F., Syers J.K., and Lingard.J. (2002). A Conceptual Model for Conducting Nutrient Audits at National, Regional, and Global Scales. *Nutrient Cycling in Agroecosystems* 62, 61-72.

Shrestha, A. and Clements, D. R. (2003). Emerging trends in cropping systems research. *J. Crop Prod*. 8, 1-32.

Soeftestad.L, T. (1989).Man-Environment Relations in Anthropology: On the formulation of the cultural Ecological approach, *ADH-serien, No. 12*,ISBN 82-7117-218-2. ISSN: 0802 – 202X

Stockfisch, N., Forstreuter, T. and Ehlers, W. (1999). Ploughing Effects on soil Organic Matter after Twenty Years of Conservation Tillage in Lower Saxony Germany. *Soil and Tillage Research*, 52(11), 91-101

Tekwa, I.J. and Belel, M.D. (2008) "Effectiveness of some Localized Soil and Water Conservation Techniques on Sustainable Crop Production in Mubi, Adamawa State".A Paper Presented at the 32ndNational Conference of the Soil Science Society of Nigeria (SSSN).Yola, Nigeria: 138-146.

Teshager, A.D., Gassman, P.W., and Secchi, S. (2016). *Environmental Management* 57: 894. doi:10.1007/s00267-015-0636-4

Tinuoye A. (1990). "Climatic Condition in Dry and Wet Years at Ilorin" *Unpublished B.Sc. Project Work*, University of Ilorin, Ilorin, Nigeria.

UNEP (1998). Environmental Effects of Ozone Depletion: 1998 Assesement, United Nations Environmental Programme, 205p ISBN 92-807-1724-3

Unger, P.W. (1984). Tillage Systems for Soil and Water Conservation. *Soils Bulletin 54*. FAO, Rome.

USDA (1996). Effect of Residue Management and No-Till on Soil Quality, *Soil Quality-Agronomy Technical Note, Auburn, No 3*

USEPA (1983). Methods for Chemical Analysis of Water and Waste, *EPA NO 600479020*

USGS (1999). The Hydrological Cycle, U.S Geological Survey. http://nd.water.usgs.gov/ukraine/english/pictures/watercycle/html

Wall, D.A. and Stobbe, E.H. (1984). The Effect of Tillage on Soil Temperature and Corn (*Zea mays* L.) Growth in Manitoba. *Can. J. Plant Sci.*, 64, 59-67.

WatManSup.(2007). Integrated Water Management Support Methodologies for Turkey and Kenya. Authors: Peter,D. and Loon,A.V . http://www.futurewater.nl/watmansup/

Wayne, E. and Kauffman,B.(1994). Riparian and Watershed Systems: Degradation and Restoration: In: Vavra, M., Laycock, W.A. and Pieper, R.D. (eds.), Ecological Implications of Livestock Herbivory in the West. *Society for Range Management,* 212–231. https://www.for.gov.bc.ca/hfd/pubs/docs/bro/bro66.pdf

Williams, J.D. (1988). Overland Flow and Sediment Production Potentials in Logged and Nonlogged Sites of a Ponderosa Pine Forest in Northeastern Oregon. *M.S. Thesis,* Oregon State Univ., Corvallis. 108 p.

Williams, J.D. And Buckhouse, J.C.(1991), Surface Runoff Plot Design for use in Watershed Research, *Journal Of Range Management* 44(4)

Willis, A.S. (1997). The Ecosystem: An Evolving Concept Viewed Historically. *Functional Ecology*, 11(2), 268-271. http://www.jstor.org/stable/2390328.

Wolkowski,D and Lauer,J. (2009). Tillage and Crop Residue Management Considerations for the Fall of 2009. University of Wisconsin Extension. www.uwex.edu Retrieved 7/28/14

APPENDIX I

ANOVA FOR 0-15cm SOIL DEPTH AT UTRF EXPERIMENTAL PLOT

		Sum of Squares	Df	Mean Square	F	Sig.
SoilTemp	Between Groups	1.458	3	.486	.670	.580
	Within Groups	14.500	20	.725		
	Total	15.958	23			
SoilWater	Between Groups	2.561	3	.854	3.674	.029
	Within Groups	4.646	20	.232		
	Total	7.207	23			
PH	Between Groups	.355	3	.118	1.209	.332
	Within Groups	1.955	20	.098		
	Total	2.310	23			
BulkDensity	Between Groups	.002	3	.001	1.840	.172
	Within Groups	.007	20	.000		
	Total	.009	23			
OrganicMatter	Between Groups	.004	3	.001	2.359	.102
	Within Groups	.011	20	.001		
	Total	.015	23			
NitrateNitrogen	Between Groups	.003	3	.001	1.146	.355
	Within Groups	.019	20	.001		
	Total	.023	23			
Phosphorous	Between Groups	.047	3	.016	.590	.629
	Within Groups	.535	20	.027		
	Total	.583	23			
Potassium	Between Groups	.008	3	.003	.462	.712
	Within Groups	.122	20	.006		
	Total	.130	23			
Sodium	Between Groups	.004	3	.001	.946	.437
	Within Groups	.027	20	.001		
	Total	.031	23			
Calcium	Between Groups	.011	3	.004	.758	.531
	Within Groups	.094	20	.005		
	Total	.105	23			
Magnessium	Between Groups	.007	3	.002	.706	.560
	Within Groups	.069	20	.003		
	Total	.077	23			
Copper	Between Groups	.406	3	.135	2.722	.072
	Within Groups	.995	20	.050		
	Total	1.401	23			
Manganese	Between Groups	.053	3	.018	1.918	.159
	Within Groups	.185	20	.009		
	Total	.238	23			
Lead	Between Groups	.100	3	.033	2.025	.143
	Within Groups	.330	20	.016		
	Total	.430	23			
Iron	Between Groups	40.306	3	13.435	.315	.814
	Within Groups	853.020	20	42.651		
	Total	893.326	23			
Zinc	Between Groups	.390	3	.130	1.716	.196
	Within Groups	1.514	20	.076		
	Total	1.903	23			

POST HOC TESTS FOR MULTIPLE COMPARISONS USING LEAST SIGNIFICANCE DIFFERENCE (LSD) FOR 0-15CM SOIL DEPTH ON UTRF EXPERIMENTAL SITE

Dependent Variable	(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SoilTemp	Traditional	PH	-.16667	.49160	.738	-1.1921	.8588
		NT	-.66667	.49160	.190	-1.6921	.3588
		PHR	-.33333	.49160	.506	-1.3588	.6921
	PH	Traditional	.16667	.49160	.738	-.8588	1.1921
		NT	-.50000	.49160	.321	-1.5255	.5255
		PHR	-.16667	.49160	.738	-1.1921	.8588
	NT	Traditional	.66667	.49160	.190	-.3588	1.6921
		PH	.50000	.49160	.321	-.5255	1.5255
		PHR	.33333	.49160	.506	-.6921	1.3588
	PHR	Traditional	.33333	.49160	.506	-.6921	1.3588
		PH	.16667	.49160	.738	-.8588	1.1921
		NT	-.33333	.49160	.506	-1.3588	.6921
SoilWater	Traditional	PH	.28333	.27828	.321	-.2972	.8638
		NT	-.52333	.27828	.075	-1.1038	.0572
		PHR	.27000	.27828	.344	-.3105	.8505
	PH	Traditional	-.28333	.27828	.321	-.8638	.2972
		NT	-.80667*	.27828	.009	-1.3872	-.2262
		PHR	-.01333	.27828	.962	-.5938	.5672
	NT	Traditional	.52333	.27828	.075	-.0572	1.1038
		PH	.80667*	.27828	.009	.2262	1.3872
		PHR	.79333*	.27828	.010	.2128	1.3738
	PHR	Traditional	-.27000	.27828	.344	-.8505	.3105
		PH	.01333	.27828	.962	-.5672	.5938
		NT	-.79333*	.27828	.010	-1.3738	-.2128
PH	Traditional	PH	.31667	.18051	.095	-.0599	.6932
		NT	.08333	.18051	.649	-.2932	.4599
		PHR	.21667	.18051	.244	-.1599	.5932
	PH	Traditional	-.31667	.18051	.095	-.6932	.0599
		NT	-.23333	.18051	.211	-.6099	.1432
		PHR	-.10000	.18051	.586	-.4765	.2765
	NT	Traditional	-.08333	.18051	.649	-.4599	.2932
		PH	.23333	.18051	.211	-.1432	.6099
		PHR	.13333	.18051	.469	-.2432	.5099
	PHR	Traditional	-.21667	.18051	.244	-.5932	.1599
		PH	.10000	.18051	.586	-.2765	.4765
		NT	-.13333	.18051	.469	-.5099	.2432
BulkDensity	Traditional	PH	.01833	.01084	.106	-.0043	.0409
		NT	-.00333	.01084	.762	-.0259	.0193
		PHR	.01333	.01084	.233	-.0093	.0359
	PH	Traditional	-.01833	.01084	.106	-.0409	.0043
		NT	-.02167	.01084	.059	-.0443	.0009
		PHR	-.00500	.01084	.650	-.0276	.0176
	NT	Traditional	.00333	.01084	.762	-.0193	.0259
		PH	.02167	.01084	.059	-.0009	.0443
		PHR	.01667	.01084	.140	-.0059	.0393
	PHR	Traditional	-.01333	.01084	.233	-.0359	.0093
		PH	.00500	.01084	.650	-.0176	.0276
		NT	-.01667	.01084	.140	-.0393	.0059
OrganicMatter	Traditional	PH	.00333	.01358	.809	-.0250	.0317

		NT	.03000*	.01358	.039	.0017	.0583
		PHR	.02333	.01358	.101	-.0050	.0517
	PH	Traditional	-.00333	.01358	.809	-.0317	.0250
		NT	.02667	.01358	.064	-.0017	.0550
		PHR	.02000	.01358	.156	-.0083	.0483
	NT	Traditional	-.03000*	.01358	.039	-.0583	-.0017
		PH	-.02667	.01358	.064	-.0550	.0017
		PHR	-.00667	.01358	.629	-.0350	.0217
	PHR	Traditional	-.02333	.01358	.101	-.0517	.0050
		PH	-.02000	.01358	.156	-.0483	.0083
		NT	.00667	.01358	.629	-.0217	.0350
NitrateNitrogen	Traditional	PH	-.018667	.017996	.312	-.05621	.01887
		NT	-.032500	.017996	.086	-.07004	.00504
		PHR	-.011333	.017996	.536	-.04887	.02621
	PH	Traditional	.018667	.017996	.312	-.01887	.05621
		NT	-.013833	.017996	.451	-.05137	.02371
		PHR	.007333	.017996	.688	-.03021	.04487
	NT	Traditional	.032500	.017996	.086	-.00504	.07004
		PH	.013833	.017996	.451	-.02371	.05137
		PHR	.021167	.017996	.253	-.01637	.05871
	PHR	Traditional	.011333	.017996	.536	-.02621	.04887
		PH	-.007333	.017996	.688	-.04487	.03021
		NT	-.021167	.017996	.253	-.05871	.01637
Phosphorous	Traditional	PH	-.02500	.09445	.794	-.2220	.1720
		NT	.00667	.09445	.944	-.1904	.2037
		PHR	-.10500	.09445	.279	-.3020	.0920
	PH	Traditional	.02500	.09445	.794	-.1720	.2220
		NT	.03167	.09445	.741	-.1654	.2287
		PHR	-.08000	.09445	.407	-.2770	.1170
	NT	Traditional	-.00667	.09445	.944	-.2037	.1904
		PH	-.03167	.09445	.741	-.2287	.1654
		PHR	-.11167	.09445	.251	-.3087	.0854
	PHR	Traditional	.10500	.09445	.279	-.0920	.3020
		PH	.08000	.09445	.407	-.1170	.2770
		NT	.11167	.09445	.251	-.0854	.3087
Potassium	Traditional	PH	-.03333	.04506	.468	-.1273	.0607
		NT	.01333	.04506	.770	-.0807	.1073
		PHR	-.02500	.04506	.585	-.1190	.0690
	PH	Traditional	.03333	.04506	.468	-.0607	.1273
		NT	.04667	.04506	.313	-.0473	.1407
		PHR	.00833	.04506	.855	-.0857	.1023
	NT	Traditional	-.01333	.04506	.770	-.1073	.0807
		PH	-.04667	.04506	.313	-.1407	.0473
		PHR	-.03833	.04506	.405	-.1323	.0557
	PHR	Traditional	.02500	.04506	.585	-.0690	.1190
		PH	-.00833	.04506	.855	-.1023	.0857
		NT	.03833	.04506	.405	-.0557	.1323
Sodium	Traditional	PH	.00833	.02136	.701	-.0362	.0529
		NT	-.01333	.02136	.539	-.0579	.0312
		PHR	.02167	.02136	.322	-.0229	.0662
	PH	Traditional	-.00833	.02136	.701	-.0529	.0362
		NT	-.02167	.02136	.322	-.0662	.0229
		PHR	.01333	.02136	.539	-.0312	.0579
	NT	Traditional	.01333	.02136	.539	-.0312	.0579
		PH	.02167	.02136	.322	-.0229	.0662
		PHR	.03500	.02136	.117	-.0095	.0795
	PHR	Traditional	-.02167	.02136	.322	-.0662	.0229
		PH	-.01333	.02136	.539	-.0579	.0312
		NT	-.03500	.02136	.117	-.0795	.0095
Calcium	Traditional	PH	.03167	.03957	.433	-.0509	.1142
		NT	.04000	.03957	.324	-.0426	.1226

		PHR	.05833	.03957	.156	-.0242	.1409
	PH	Traditional	-.03167	.03957	.433	-.1142	.0509
		NT	.00833	.03957	.835	-.0742	.0909
		PHR	.02667	.03957	.508	-.0559	.1092
	NT	Traditional	-.04000	.03957	.324	-.1226	.0426
		PH	-.00833	.03957	.835	-.0909	.0742
		PHR	.01833	.03957	.648	-.0642	.1009
	PHR	Traditional	-.05833	.03957	.156	-.1409	.0242
		PH	-.02667	.03957	.508	-.1092	.0559
		NT	-.01833	.03957	.648	-.1009	.0642
Magnesium	Traditional	PH	.04000	.03402	.253	-.0310	.1110
		NT	.04500	.03402	.201	-.0260	.1160
		PHR	.03167	.03402	.363	-.0393	.1026
	PH	Traditional	-.04000	.03402	.253	-.1110	.0310
		NT	.00500	.03402	.885	-.0660	.0760
		PHR	-.00833	.03402	.809	-.0793	.0626
	NT	Traditional	-.04500	.03402	.201	-.1160	.0260
		PH	-.00500	.03402	.885	-.0760	.0660
		PHR	-.01333	.03402	.699	-.0843	.0576
	PHR	Traditional	-.03167	.03402	.363	-.1026	.0393
		PH	.00833	.03402	.809	-.0626	.0793
		NT	.01333	.03402	.699	-.0576	.0843
Copper	Traditional	PH	.26833	.12874	.050	-.0002	.5369
		NT	.25667	.12874	.060	-.0119	.5252
		PHR	.34500*	.12874	.014	.0764	.6136
	PH	Traditional	-.26833	.12874	.050	-.5369	.0002
		NT	-.01167	.12874	.929	-.2802	.2569
		PHR	.07667	.12874	.558	-.1919	.3452
	NT	Traditional	-.25667	.12874	.060	-.5252	.0119
		PH	.01167	.12874	.929	-.2569	.2802
		PHR	.08833	.12874	.501	-.1802	.3569
	PHR	Traditional	-.34500*	.12874	.014	-.6136	-.0764
		PH	-.07667	.12874	.558	-.3452	.1919
		NT	-.08833	.12874	.501	-.3569	.1802
Manganese	Traditional	PH	-.10333	.05554	.078	-.2192	.0125
		NT	.01167	.05554	.836	-.1042	.1275
		PHR	.00333	.05554	.953	-.1125	.1192
	PH	Traditional	.10333	.05554	.078	-.0125	.2192
		NT	.11500	.05554	.052	-.0008	.2308
		PHR	.10667	.05554	.069	-.0092	.2225
	NT	Traditional	-.01167	.05554	.836	-.1275	.1042
		PH	-.11500	.05554	.052	-.2308	.0008
		PHR	-.00833	.05554	.882	-.1242	.1075
	PHR	Traditional	-.00333	.05554	.953	-.1192	.1125
		PH	-.10667	.05554	.069	-.2225	.0092
		NT	.00833	.05554	.882	-.1075	.1242
Lead	Traditional	PH	.10000	.07416	.193	-.0547	.2547
		NT	.14000	.07416	.074	-.0147	.2947
		PHR	-.01167	.07416	.877	-.1664	.1430
	PH	Traditional	-.10000	.07416	.193	-.2547	.0547
		NT	.04000	.07416	.596	-.1147	.1947
		PHR	-.11167	.07416	.148	-.2664	.0430
	NT	Traditional	-.14000	.07416	.074	-.2947	.0147
		PH	-.04000	.07416	.596	-.1947	.1147
		PHR	-.15167	.07416	.054	-.3064	.0030
	PHR	Traditional	.01167	.07416	.877	-.1430	.1664
		PH	.11167	.07416	.148	-.0430	.2664
		NT	.15167	.07416	.054	-.0030	.3064
Iron	Traditional	PH	2.96167	3.77054	.441	-4.9035	10.8269
		NT	2.45833	3.77054	.522	-5.4069	10.3235
		PHR	3.31000	3.77054	.390	-4.5552	11.1752

	PH	Traditional	-2.96167	3.77054	.441	-10.8269	4.9035
		NT	-.50333	3.77054	.895	-8.3685	7.3619
		PHR	.34833	3.77054	.927	-7.5169	8.2135
	NT	Traditional	-2.45833	3.77054	.522	-10.3235	5.4069
		PH	.50333	3.77054	.895	-7.3619	8.3685
		PHR	.85167	3.77054	.824	-7.0135	8.7169
	PHR	Traditional	-3.31000	3.77054	.390	-11.1752	4.5552
		PH	-.34833	3.77054	.927	-8.2135	7.5169
		NT	-.85167	3.77054	.824	-8.7169	7.0135
Zinc	Traditional	PH	-.31667	.15885	.060	-.6480	.0147
		NT	-.06500	.15885	.687	-.3963	.2663
		PHR	-.23667	.15885	.152	-.5680	.0947
	PH	Traditional	.31667	.15885	.060	-.0147	.6480
		NT	.25167	.15885	.129	-.0797	.5830
		PHR	.08000	.15885	.620	-.2513	.4113
	NT	Traditional	.06500	.15885	.687	-.2663	.3963
		PH	-.25167	.15885	.129	-.5830	.0797
		PHR	-.17167	.15885	.293	-.5030	.1597
	PHR	Traditional	.23667	.15885	.152	-.0947	.5680
		PH	-.08000	.15885	.620	-.4113	.2513
		NT	.17167	.15885	.293	-.1597	.5030

*. The mean difference is significant at the 0.05 level.

ANOVA FOR 15-30cm SOIL DEPTH AT UTRF EXPERIMENTAL PLOT

		Sum of Squares	df	Mean Square	F	Sig.
SoilTemp	Between Groups	2.125	3	.708	1.024	.403
	Within Groups	13.833	20	.692		
	Total	15.958	23			
SoilWater	Between Groups	1.172	3	.391	1.693	.201
	Within Groups	4.615	20	.231		
	Total	5.787	23			
PH	Between Groups	.780	3	.260	2.746	.070
	Within Groups	1.893	20	.095		
	Total	2.673	23			
BulkDensity	Between Groups	.000	3	.000	.261	.852
	Within Groups	.011	20	.001		
	Total	.011	23			
OrganicMatter	Between Groups	.002	3	.001	.300	.825
	Within Groups	.034	20	.002		
	Total	.035	23			
NitrateNitrogen	Between Groups	.000	3	.000	.044	.987
	Within Groups	.047	20	.002		
	Total	.047	23			
Phosphorous	Between Groups	.004	3	.001	.010	.999
	Within Groups	2.587	20	.129		
	Total	2.590	23			
Potassium	Between Groups	.037	3	.012	1.279	.309
	Within Groups	.194	20	.010		
	Total	.231	23			
Sodium	Between Groups	.066	3	.022	8.527	.001
	Within Groups	.052	20	.003		
	Total	.118	23			
Calcium	Between Groups	.034	3	.011	2.369	.101
	Within Groups	.097	20	.005		
	Total	.131	23			
Magnesium	Between Groups	.004	3	.001	.286	.835
	Within Groups	.092	20	.005		
	Total	.096	23			
Copper	Between Groups	.225	3	.075	2.886	.061
	Within Groups	.520	20	.026		
	Total	.745	23			
Manganese	Between Groups	.029	3	.010	1.504	.244
	Within Groups	.127	20	.006		
	Total	.156	23			
Lead	Between Groups	.027	3	.009	.698	.564
	Within Groups	.254	20	.013		
	Total	.281	23			
Iron	Between Groups	3.204	3	1.068	.105	.956
	Within Groups	203.781	20	10.189		
	Total	206.985	23			
Zinc	Between Groups	.191	3	.064	1.389	.275
	Within Groups	.918	20	.046		
	Total	1.110	23			

POST HOC TESTS FOR MULTIPLE COMPARISONS USING LEAST SIGNIFICANCE DIFFERENCE (LSD) FOR 15-30CM SOIL DEPTH FOR UTRF EXPERIMENTAL SITE

Dependent Variable	(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
SoilTemp	Traditional	PH	.83333	.48016	.098	-.1683	1.8349
		NT	.33333	.48016	.496	-.6683	1.3349
		PHR	.33333	.48016	.496	-.6683	1.3349
	PH	Traditional	-.83333	.48016	.098	-1.8349	.1683
		NT	-.50000	.48016	.310	-1.5016	.5016
		PHR	-.50000	.48016	.310	-1.5016	.5016
	NT	Traditional	-.33333	.48016	.496	-1.3349	.6683
		PH	.50000	.48016	.310	-.5016	1.5016
		PHR	.00000	.48016	1.000	-1.0016	1.0016
	PHR	Traditional	-.33333	.48016	.496	-1.3349	.6683
		PH	.50000	.48016	.310	-.5016	1.5016
		NT	.00000	.48016	1.000	-1.0016	1.0016
SoilWater	Traditional	PH	.50500	.27735	.084	-.0735	1.0835
		NT	.04500	.27735	.873	-.5335	.6235
		PHR	.41167	.27735	.153	-.1669	.9902
	PH	Traditional	-.50500	.27735	.084	-1.0835	.0735
		NT	-.46000	.27735	.113	-1.0385	.1185
		PHR	-.09333	.27735	.740	-.6719	.4852
	NT	Traditional	-.04500	.27735	.873	-.6235	.5335
		PH	.46000	.27735	.113	-.1185	1.0385
		PHR	.36667	.27735	.201	-.2119	.9452
	PHR	Traditional	-.41167	.27735	.153	-.9902	.1669
		PH	.09333	.27735	.740	-.4852	.6719
		NT	-.36667	.27735	.201	-.9452	.2119
PH	Traditional	PH	.30000	.17764	.107	-.0705	.6705
		NT	-.20000	.17764	.274	-.5705	.1705
		PHR	.10000	.17764	.580	-.2705	.4705
	PH	Traditional	-.30000	.17764	.107	-.6705	.0705
		NT	-.50000*	.17764	.011	-.8705	-.1295
		PHR	-.20000	.17764	.274	-.5705	.1705
	NT	Traditional	.20000	.17764	.274	-.1705	.5705
		PH	.50000*	.17764	.011	.1295	.8705
		PHR	.30000	.17764	.107	-.0705	.6705
	PHR	Traditional	-.10000	.17764	.580	-.4705	.2705
		PH	.20000	.17764	.274	-.1705	.5705
		NT	-.30000	.17764	.107	-.6705	.0705
BulkDensity	Traditional	PH	.00500	.01331	.711	-.0228	.0328
		NT	-.00667	.01331	.622	-.0344	.0211
		PHR	-.00167	.01331	.902	-.0294	.0261
	PH	Traditional	-.00500	.01331	.711	-.0328	.0228
		NT	-.01167	.01331	.391	-.0394	.0161
		PHR	-.00667	.01331	.622	-.0344	.0211
	NT	Traditional	.00667	.01331	.622	-.0211	.0344
		PH	.01167	.01331	.391	-.0161	.0394
		PHR	.00500	.01331	.711	-.0228	.0328
	PHR	Traditional	.00167	.01331	.902	-.0261	.0294
		PH	.00667	.01331	.622	-.0211	.0344
		NT	-.00500	.01331	.711	-.0328	.0228
OrganicMatter	Traditional	PH	.00833	.02366	.728	-.0410	.0577
		NT	.01000	.02366	.677	-.0394	.0594
		PHR	-.01000	.02366	.677	-.0594	.0394
	PH	Traditional	-.00833	.02366	.728	-.0577	.0410
		NT	.00167	.02366	.945	-.0477	.0510
		PHR	-.01833	.02366	.447	-.0677	.0310

	NT	Traditional	-.01000	.02366	.677	-.0594	.0394
		PH	-.00167	.02366	.945	-.0510	.0477
		PHR	-.02000	.02366	.408	-.0694	.0294
	PHR	Traditional	.01000	.02366	.677	-.0394	.0594
		PH	.01833	.02366	.447	-.0310	.0677
		NT	.02000	.02366	.408	-.0294	.0694
NitrateNitrogen	Traditional	PH	.009500	.028043	.738	-.04900	.06800
		NT	.004500	.028043	.874	-.05400	.06300
		PHR	.007667	.028043	.787	-.05083	.06616
	PH	Traditional	-.009500	.028043	.738	-.06800	.04900
		NT	-.005000	.028043	.860	-.06350	.05350
		PHR	-.001833	.028043	.949	-.06033	.05666
	NT	Traditional	-.004500	.028043	.874	-.06300	.05400
		PH	.005000	.028043	.860	-.05350	.06350
		PHR	.003167	.028043	.911	-.05533	.06166
	PHR	Traditional	-.007667	.028043	.787	-.06616	.05083
		PH	.001833	.028043	.949	-.05666	.06033
		NT	-.003167	.028043	.911	-.06166	.05533
Phosphorous	Traditional	PH	.02500	.20763	.905	-.4081	.4581
		NT	.02667	.20763	.899	-.4064	.4598
		PHR	.03333	.20763	.874	-.3998	.4664
	PH	Traditional	-.02500	.20763	.905	-.4581	.4081
		NT	.00167	.20763	.994	-.4314	.4348
		PHR	.00833	.20763	.968	-.4248	.4414
	NT	Traditional	-.02667	.20763	.899	-.4598	.4064
		PH	-.00167	.20763	.994	-.4348	.4314
		PHR	.00667	.20763	.975	-.4264	.4398
	PHR	Traditional	-.03333	.20763	.874	-.4664	.3998
		PH	-.00833	.20763	.968	-.4414	.4248
		NT	-.00667	.20763	.975	-.4398	.4264
Potassium	Traditional	PH	.07333	.05680	.211	-.0451	.1918
		NT	-.02333	.05680	.686	-.1418	.0951
		PHR	-.02167	.05680	.707	-.1401	.0968
	PH	Traditional	-.07333	.05680	.211	-.1918	.0451
		NT	-.09667	.05680	.104	-.2151	.0218
		PHR	-.09500	.05680	.110	-.2135	.0235
	NT	Traditional	.02333	.05680	.686	-.0951	.1418
		PH	.09667	.05680	.104	-.0218	.2151
		PHR	.00167	.05680	.977	-.1168	.1201
	PHR	Traditional	.02167	.05680	.707	-.0968	.1401
		PH	.09500	.05680	.110	-.0235	.2135
		NT	-.00167	.05680	.977	-.1201	.1168
Sodium	Traditional	PH	.06333*	.02943	.044	.0020	.1247
		NT	.05167	.02943	.094	-.0097	.1130
		PHR	-.07000*	.02943	.027	-.1314	-.0086
	PH	Traditional	-.06333*	.02943	.044	-.1247	-.0020
		NT	-.01167	.02943	.696	-.0730	.0497
		PHR	-.13333*	.02943	.000	-.1947	-.0720
	NT	Traditional	-.05167	.02943	.094	-.1130	.0097
		PH	.01167	.02943	.696	-.0497	.0730
		PHR	-.12167*	.02943	.001	-.1830	-.0603
	PHR	Traditional	.07000*	.02943	.027	.0086	.1314
		PH	.13333*	.02943	.000	.0720	.1947
		NT	.12167*	.02943	.001	.0603	.1830
Calcium	Traditional	PH	-.03000	.04011	.463	-.1137	.0537
		NT	.05500	.04011	.186	-.0287	.1387
		PHR	-.04333	.04011	.293	-.1270	.0403
	PH	Traditional	.03000	.04011	.463	-.0537	.1137
		NT	.08500*	.04011	.047	.0013	.1687
		PHR	-.01333	.04011	.743	-.0970	.0703
	NT	Traditional	-.05500	.04011	.186	-.1387	.0287

		PH	-.08500*	.04011	.047	-.1687	-.0013
		PHR	-.09833*	.04011	.024	-.1820	-.0147
	PHR	Traditional	.04333	.04011	.293	-.0403	.1270
		PH	.01333	.04011	.743	-.0703	.0970
		NT	.09833*	.04011	.024	.0147	.1820
Magnesium	Traditional	PH	-.01667	.03916	.675	-.0984	.0650
		NT	.01167	.03916	.769	-.0700	.0934
		PHR	.01667	.03916	.675	-.0650	.0984
	PH	Traditional	.01667	.03916	.675	-.0650	.0984
		NT	.02833	.03916	.478	-.0534	.1100
		PHR	.03333	.03916	.405	-.0484	.1150
	NT	Traditional	-.01167	.03916	.769	-.0934	.0700
		PH	-.02833	.03916	.478	-.1100	.0534
		PHR	.00500	.03916	.900	-.0767	.0867
	PHR	Traditional	-.01667	.03916	.675	-.0984	.0650
		PH	-.03333	.03916	.405	-.1150	.0484
		NT	-.00500	.03916	.900	-.0867	.0767
Copper	Traditional	PH	-.02333	.09308	.805	-.2175	.1708
		NT	-.23333*	.09308	.021	-.4275	-.0392
		PHR	-.00833	.09308	.930	-.2025	.1858
	PH	Traditional	.02333	.09308	.805	-.1708	.2175
		NT	-.21000*	.09308	.035	-.4042	-.0158
		PHR	.01500	.09308	.874	-.1792	.2092
	NT	Traditional	.23333*	.09308	.021	.0392	.4275
		PH	.21000*	.09308	.035	.0158	.4042
		PHR	.22500*	.09308	.025	.0308	.4192
	PHR	Traditional	.00833	.09308	.930	-.1858	.2025
		PH	-.01500	.09308	.874	-.2092	.1792
		NT	-.22500*	.09308	.025	-.4192	-.0308
Manganese	Traditional	PH	.06500	.04605	.173	-.0311	.1611
		NT	.08333	.04605	.085	-.0127	.1794
		PHR	.08500	.04605	.080	-.0111	.1811
	PH	Traditional	-.06500	.04605	.173	-.1611	.0311
		NT	.01833	.04605	.695	-.0777	.1144
		PHR	.02000	.04605	.669	-.0761	.1161
	NT	Traditional	-.08333	.04605	.085	-.1794	.0127
		PH	-.01833	.04605	.695	-.1144	.0777
		PHR	.00167	.04605	.971	-.0944	.0977
	PHR	Traditional	-.08500	.04605	.080	-.1811	.0111
		PH	-.02000	.04605	.669	-.1161	.0761
		NT	-.00167	.04605	.971	-.0977	.0944
Lead	Traditional	PH	.01667	.06510	.801	-.1191	.1525
		NT	.08833	.06510	.190	-.0475	.2241
		PHR	.04167	.06510	.529	-.0941	.1775
	PH	Traditional	-.01667	.06510	.801	-.1525	.1191
		NT	.07167	.06510	.284	-.0641	.2075
		PHR	.02500	.06510	.705	-.1108	.1608
	NT	Traditional	-.08833	.06510	.190	-.2241	.0475
		PH	-.07167	.06510	.284	-.2075	.0641
		PHR	-.04667	.06510	.482	-.1825	.0891
	PHR	Traditional	-.04167	.06510	.529	-.1775	.0941
		PH	-.02500	.06510	.705	-.1608	.1108
		NT	.04667	.06510	.482	-.0891	.1825
Iron	Traditional	PH	-.28667	1.84292	.878	-4.1309	3.5576
		NT	.67500	1.84292	.718	-3.1693	4.5193
		PHR	.37833	1.84292	.839	-3.4659	4.2226
	PH	Traditional	.28667	1.84292	.878	-3.5576	4.1309
		NT	.96167	1.84292	.608	-2.8826	4.8059
		PHR	.66500	1.84292	.722	-3.1793	4.5093
	NT	Traditional	-.67500	1.84292	.718	-4.5193	3.1693
		PH	-.96167	1.84292	.608	-4.8059	2.8826

		PHR	-.29667	1.84292	.874	-4.1409	3.5476
	PHR	Traditional	-.37833	1.84292	.839	-4.2226	3.4659
		PH	-.66500	1.84292	.722	-4.5093	3.1793
		NT	.29667	1.84292	.874	-3.5476	4.1409
Zinc	Traditional	PH	-.19333	.12372	.134	-.4514	.0648
		NT	.03000	.12372	.811	-.2281	.2881
		PHR	.00333	.12372	.979	-.2548	.2614
	PH	Traditional	.19333	.12372	.134	-.0648	.4514
		NT	.22333	.12372	.086	-.0348	.4814
		PHR	.19667	.12372	.128	-.0614	.4548
	NT	Traditional	-.03000	.12372	.811	-.2881	.2281
		PH	-.22333	.12372	.086	-.4814	.0348
		PHR	-.02667	.12372	.832	-.2848	.2314
	PHR	Traditional	-.00333	.12372	.979	-.2614	.2548
		PH	-.19667	.12372	.128	-.4548	.0614
		NT	.02667	.12372	.832	-.2314	.2848

*. The mean difference is significant at the 0.05 level.

ANOVA FOR 0-15cm SOIL DEPTH AT NCAM EXPERIMENTAL PLOT

		Sum of Squares	Df	Mean Square	F	Sig.
SoilTemp	Between Groups	7.125	3	2.375	3.000	.055
	Within Groups	15.833	20	.792		
	Total	22.958	23			
SoilWater	Between Groups	1.633	3	.544	2.063	.137
	Within Groups	5.278	20	.264		
	Total	6.911	23			
PH	Between Groups	.088	3	.029	.847	.484
	Within Groups	.692	20	.035		
	Total	.780	23			
BulkDensity	Between Groups	.002	3	.001	1.028	.401
	Within Groups	.013	20	.001		
	Total	.015	23			
OrganicMatter	Between Groups	.001	3	.000	1.678	.204
	Within Groups	.005	20	.000		
	Total	.006	23			
NitrateNitrogen	Between Groups	.003	3	.001	1.366	.282
	Within Groups	.016	20	.001		
	Total	.019	23			
Phosphorous	Between Groups	.231	3	.077	2.770	.068
	Within Groups	.556	20	.028		
	Total	.787	23			
Potassium	Between Groups	.046	3	.015	4.848	.011
	Within Groups	.063	20	.003		
	Total	.108	23			
Sodium	Between Groups	.041	3	.014	6.085	.004
	Within Groups	.044	20	.002		
	Total	.085	23			
Calcium	Between Groups	.127	3	.042	4.648	.013
	Within Groups	.182	20	.009		
	Total	.309	23			
Magnesium	Between Groups	.021	3	.007	1.030	.400
	Within Groups	.138	20	.007		
	Total	.159	23			
Copper	Between Groups	.793	3	.264	1.924	.158
	Within Groups	2.747	20	.137		
	Total	3.540	23			
Managanese	Between Groups	.174	3	.058	3.808	.026
	Within Groups	.304	20	.015		
	Total	.478	23			
Lead	Between Groups	.144	3	.048	21.855	.000
	Within Groups	.044	20	.002		
	Total	.188	23			
Iron	Between Groups	288.856	3	96.285	16.231	.000
	Within Groups	118.647	20	5.932		
	Total	407.503	23			
Zinc	Between Groups	.366	3	.122	3.768	.027
	Within Groups	.648	20	.032		
	Total	1.014	23			

POST HOC TESTS FOR MULTIPLE COMPARISONS USING LEAST SIGNIFICANCE DIFFERENCE (LSD) FOR 0-15CM ON NCAM EXPERIMENTAL SITE

Dependent Variable	(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
SoilTemp	Traditional	PH	-.83333	.51370	.120	-1.9049	.2382
		NT	-1.50000*	.51370	.008	-2.5716	-.4284
		PHR	-.50000	.51370	.342	-1.5716	.5716
	PH	Traditional	.83333	.51370	.120	-.2382	1.9049
		NT	-.66667	.51370	.209	-1.7382	.4049
		PHR	.33333	.51370	.524	-.7382	1.4049
	NT	Traditional	1.50000*	.51370	.008	.4284	2.5716
		PH	.66667	.51370	.209	-.4049	1.7382
		PHR	1.00000	.51370	.066	-.0716	2.0716
	PHR	Traditional	.50000	.51370	.342	-.5716	1.5716
		PH	-.33333	.51370	.524	-1.4049	.7382
		NT	-1.00000	.51370	.066	-2.0716	.0716
SoilWater	Traditional	PH	.37667	.29659	.219	-.2420	.9953
		NT	-.33500	.29659	.272	-.9537	.2837
		PHR	.17167	.29659	.569	-.4470	.7903
	PH	Traditional	-.37667	.29659	.219	-.9953	.2420
		NT	-.71167*	.29659	.026	-1.3303	-.0930
		PHR	-.20500	.29659	.497	-.8237	.4137
	NT	Traditional	.33500	.29659	.272	-.2837	.9537
		PH	.71167*	.29659	.026	.0930	1.3303
		PHR	.50667	.29659	.103	-.1120	1.1253
	PHR	Traditional	-.17167	.29659	.569	-.7903	.4470
		PH	.20500	.29659	.497	-.4137	.8237
		NT	-.50667	.29659	.103	-1.1253	.1120
PH	Traditional	PH	.10000	.10737	.363	-.1240	.3240
		NT	-.01667	.10737	.878	-.2406	.2073
		PHR	-.06667	.10737	.542	-.2906	.1573
	PH	Traditional	-.10000	.10737	.363	-.3240	.1240
		NT	-.11667	.10737	.290	-.3406	.1073
		PHR	-.16667	.10737	.136	-.3906	.0573
	NT	Traditional	.01667	.10737	.878	-.2073	.2406
		PH	.11667	.10737	.290	-.1073	.3406
		PHR	-.05000	.10737	.646	-.2740	.1740
	PHR	Traditional	.06667	.10737	.542	-.1573	.2906
		PH	.16667	.10737	.136	-.0573	.3906
		NT	.05000	.10737	.646	-.1740	.2740
BulkDensity	Traditional	PH	-.02333	.01450	.123	-.0536	.0069
		NT	-.01167	.01450	.431	-.0419	.0186
		PHR	-.02000	.01450	.183	-.0502	.0102
	PH	Traditional	.02333	.01450	.123	-.0069	.0536
		NT	.01167	.01450	.431	-.0186	.0419
		PHR	.00333	.01450	.821	-.0269	.0336
	NT	Traditional	.01167	.01450	.431	-.0186	.0419
		PH	-.01167	.01450	.431	-.0419	.0186
		PHR	-.00833	.01450	.572	-.0386	.0219
	PHR	Traditional	.02000	.01450	.183	-.0102	.0502
		PH	-.00333	.01450	.821	-.0336	.0269
		NT	.00833	.01450	.572	-.0219	.0386
OrganicMatter	Traditional	PH	.00833	.00904	.367	-.0105	.0272
		NT	.01167	.00904	.211	-.0072	.0305
		PHR	.02000*	.00904	.039	.0011	.0389
	PH	Traditional	-.00833	.00904	.367	-.0272	.0105
		NT	.00333	.00904	.716	-.0155	.0222
		PHR	.01167	.00904	.211	-.0072	.0305

	NT	Traditional	-.01167	.00904	.211	-.0305	.0072
		PH	-.00333	.00904	.716	-.0222	.0155
		PHR	.00833	.00904	.367	-.0105	.0272
	PHR	Traditional	-.02000*	.00904	.039	-.0389	-.0011
		PH	-.01167	.00904	.211	-.0305	.0072
		NT	-.00833	.00904	.367	-.0272	.0105
Nitrate Nitrogen	Traditional	PH	-.017833	.016417	.290	-.05208	.01641
		NT	-.033167	.016417	.057	-.06741	.00108
		PHR	-.018333	.016417	.277	-.05258	.01591
	PH	Traditional	.017833	.016417	.290	-.01641	.05208
		NT	-.015333	.016417	.361	-.04958	.01891
		PHR	-.000500	.016417	.976	-.03475	.03375
	NT	Traditional	.033167	.016417	.057	-.00108	.06741
		PH	.015333	.016417	.361	-.01891	.04958
		PHR	.014833	.016417	.377	-.01941	.04908
	PHR	Traditional	.018333	.016417	.277	-.01591	.05258
		PH	.000500	.016417	.976	-.03375	.03475
		NT	-.014833	.016417	.377	-.04908	.01941
Phosphorous	Traditional	PH	-.07500	.09627	.445	-.2758	.1258
		NT	.04333	.09627	.657	-.1575	.2442
		PHR	-.21500*	.09627	.037	-.4158	-.0142
	PH	Traditional	.07500	.09627	.445	-.1258	.2758
		NT	.11833	.09627	.233	-.0825	.3192
		PHR	-.14000	.09627	.161	-.3408	.0608
	NT	Traditional	-.04333	.09627	.657	-.2442	.1575
		PH	-.11833	.09627	.233	-.3192	.0825
		PHR	-.25833*	.09627	.014	-.4592	-.0575
	PHR	Traditional	.21500*	.09627	.037	.0142	.4158
		PH	.14000	.09627	.161	-.0608	.3408
		NT	.25833*	.09627	.014	.0575	.4592
Potassium	Traditional	PH	-.11833*	.03231	.002	-.1857	-.0509
		NT	-.03000	.03231	.364	-.0974	.0374
		PHR	-.05500	.03231	.104	-.1224	.0124
	PH	Traditional	.11833*	.03231	.002	.0509	.1857
		NT	.08833*	.03231	.013	.0209	.1557
		PHR	.06333	.03231	.064	-.0041	.1307
	NT	Traditional	.03000	.03231	.364	-.0374	.0974
		PH	-.08833*	.03231	.013	-.1557	-.0209
		PHR	-.02500	.03231	.448	-.0924	.0424
	PHR	Traditional	.05500	.03231	.104	-.0124	.1224
		PH	-.06333	.03231	.064	-.1307	.0041
		NT	.02500	.03231	.448	-.0424	.0924
Sodium	Traditional	PH	.06000*	.02720	.039	.0033	.1167
		NT	.10833*	.02720	.001	.0516	.1651
		PHR	.09000*	.02720	.004	.0333	.1467
	PH	Traditional	-.06000*	.02720	.039	-.1167	-.0033
		NT	.04833	.02720	.091	-.0084	.1051
		PHR	.03000	.02720	.283	-.0267	.0867
	NT	Traditional	-.10833*	.02720	.001	-.1651	-.0516
		PH	-.04833	.02720	.091	-.1051	.0084
		PHR	-.01833	.02720	.508	-.0751	.0384
	PHR	Traditional	-.09000*	.02720	.004	-.1467	-.0333
		PH	-.03000	.02720	.283	-.0867	.0267
		NT	.01833	.02720	.508	-.0384	.0751
Calcium	Traditional	PH	-.06833	.05506	.229	-.1832	.0465
		NT	-.02000	.05506	.720	-.1349	.0949
		PHR	.12833*	.05506	.030	.0135	.2432
	PH	Traditional	.06833	.05506	.229	-.0465	.1832
		NT	.04833	.05506	.390	-.0665	.1632
		PHR	.19667*	.05506	.002	.0818	.3115
	NT	Traditional	.02000	.05506	.720	-.0949	.1349

		PH	-.04833	.05506	.390	-.1632	.0665
		PHR	.14833*	.05506	.014	.0335	.2632
	PHR	Traditional	-.12833*	.05506	.030	-.2432	-.0135
		PH	-.19667*	.05506	.002	-.3115	-.0818
		NT	-.14833*	.05506	.014	-.2632	-.0335
Magnesium	Traditional	PH	.01500	.04793	.758	-.0850	.1150
		NT	.02000	.04793	.681	-.0800	.1200
		PHR	.07833	.04793	.118	-.0216	.1783
	PH	Traditional	-.01500	.04793	.758	-.1150	.0850
		NT	.00500	.04793	.918	-.0950	.1050
		PHR	.06333	.04793	.201	-.0366	.1633
	NT	Traditional	-.02000	.04793	.681	-.1200	.0800
		PH	-.00500	.04793	.918	-.1050	.0950
		PHR	.05833	.04793	.238	-.0416	.1583
	PHR	Traditional	-.07833	.04793	.118	-.1783	.0216
		PH	-.06333	.04793	.201	-.1633	.0366
		NT	-.05833	.04793	.238	-.1583	.0416
Copper	Traditional	PH	-.13667	.21397	.530	-.5830	.3097
		NT	.23333	.21397	.288	-.2130	.6797
		PHR	.32000	.21397	.150	-.1263	.7663
	PH	Traditional	.13667	.21397	.530	-.3097	.5830
		NT	.37000	.21397	.099	-.0763	.8163
		PHR	.45667*	.21397	.045	.0103	.9030
	NT	Traditional	-.23333	.21397	.288	-.6797	.2130
		PH	-.37000	.21397	.099	-.8163	.0763
		PHR	.08667	.21397	.690	-.3597	.5330
	PHR	Traditional	-.32000	.21397	.150	-.7663	.1263
		PH	-.45667*	.21397	.045	-.9030	-.0103
		NT	-.08667	.21397	.690	-.5330	.3597
Manganese	Traditional	PH	.08167	.07119	.265	-.0668	.2302
		NT	.20333*	.07119	.010	.0548	.3518
		PHR	-.00833	.07119	.908	-.1568	.1402
	PH	Traditional	-.08167	.07119	.265	-.2302	.0668
		NT	.12167	.07119	.103	-.0268	.2702
		PHR	-.09000	.07119	.221	-.2385	.0585
	NT	Traditional	-.20333*	.07119	.010	-.3518	-.0548
		PH	-.12167	.07119	.103	-.2702	.0268
		PHR	-.21167*	.07119	.008	-.3602	-.0632
	PHR	Traditional	.00833	.07119	.908	-.1402	.1568
		PH	.09000	.07119	.221	-.0585	.2385
		NT	.21167*	.07119	.008	.0632	.3602
Lead	Traditional	PH	.11167*	.02709	.001	.0552	.1682
		NT	.17500*	.02709	.000	.1185	.2315
		PHR	-.01000	.02709	.716	-.0665	.0465
	PH	Traditional	-.11167*	.02709	.001	-.1682	-.0552
		NT	.06333*	.02709	.030	.0068	.1198
		PHR	-.12167*	.02709	.000	-.1782	-.0652
	NT	Traditional	-.17500*	.02709	.000	-.2315	-.1185
		PH	-.06333*	.02709	.030	-.1198	-.0068
		PHR	-.18500*	.02709	.000	-.2415	-.1285
	PHR	Traditional	.01000	.02709	.716	-.0465	.0665
		PH	.12167*	.02709	.000	.0652	.1782
		NT	.18500*	.02709	.000	.1285	.2415
Iron	Traditional	PH	-2.89333	1.40622	.053	-5.8267	.0400
		NT	2.67500	1.40622	.072	-.2583	5.6083
		PHR	6.52333*	1.40622	.000	3.5900	9.4567
	PH	Traditional	2.89333	1.40622	.053	-.0400	5.8267
		NT	5.56833*	1.40622	.001	2.6350	8.5017
		PHR	9.41667*	1.40622	.000	6.4833	12.3500
	NT	Traditional	-2.67500	1.40622	.072	-5.6083	.2583
		PH	-5.56833*	1.40622	.001	-8.5017	-2.6350

		PHR	3.84833*	1.40622	.013	.9150	6.7817
	PHR	Traditional	-6.52333*	1.40622	.000	-9.4567	-3.5900
		PH	-9.41667*	1.40622	.000	-12.3500	-6.4833
		NT	-3.84833*	1.40622	.013	-6.7817	-.9150
Zinc	Traditional	PH	-.13167	.10389	.220	-.3484	.0850
		NT	-.34000*	.10389	.004	-.5567	-.1233
		PHR	-.21167	.10389	.055	-.4284	.0050
	PH	Traditional	.13167	.10389	.220	-.0850	.3484
		NT	-.20833	.10389	.059	-.4250	.0084
		PHR	-.08000	.10389	.450	-.2967	.1367
	NT	Traditional	.34000*	.10389	.004	.1233	.5567
		PH	.20833	.10389	.059	-.0084	.4250
		PHR	.12833	.10389	.231	-.0884	.3450
	PHR	Traditional	.21167	.10389	.055	-.0050	.4284
		PH	.08000	.10389	.450	-.1367	.2967
		NT	-.12833	.10389	.231	-.3450	.0884

*. The mean difference is significant at the 0.05 level.

ANOVA FOR15-30cm SOIL DEPTH AT NCAM EXPERIMENTAL PLOT

		Sum of Squares	Df	Mean Square	F	Sig.
SoilTemp	Between Groups	3.000	3	1.000	2.222	.117
	Within Groups	9.000	20	.450		
	Total	12.000	23			
SoilWater	Between Groups	.610	3	.203	.578	.636
	Within Groups	7.034	20	.352		
	Total	7.644	23			
PH	Between Groups	.575	3	.192	1.544	.234
	Within Groups	2.482	20	.124		
	Total	3.056	23			
BulkDensity	Between Groups	.001	3	.000	.644	.595
	Within Groups	.009	20	.000		
	Total	.010	23			
OrganicMatter	Between Groups	.003	3	.001	2.245	.114
	Within Groups	.009	20	.000		
	Total	.012	23			
NitrateNitrogen	Between Groups	.000	3	.000	.081	.969
	Within Groups	.008	20	.000		
	Total	.008	23			
Phosphorous	Between Groups	.026	3	.009	.288	.834
	Within Groups	.597	20	.030		
	Total	.622	23			
Potassium	Between Groups	.055	3	.018	2.303	.108
	Within Groups	.160	20	.008		
	Total	.215	23			
Sodium	Between Groups	.001	3	.000	.133	.939
	Within Groups	.031	20	.002		
	Total	.032	23			
Calcium	Between Groups	.013	3	.004	.222	.880
	Within Groups	.394	20	.020		
	Total	.407	23			
Magnesium	Between Groups	.007	3	.002	.726	.548
	Within Groups	.062	20	.003		
	Total	.068	23			
Copper	Between Groups	.275	3	.092	1.528	.238
	Within Groups	1.200	20	.060		
	Total	1.475	23			
Manganese	Between Groups	.014	3	.005	.902	.458
	Within Groups	.107	20	.005		
	Total	.121	23			
Lead	Between Groups	.374	3	.125	15.253	.000
	Within Groups	.163	20	.008		
	Total	.537	23			
Iron	Between Groups	244.280	3	81.427	2.103	.132
	Within Groups	774.268	20	38.713		
	Total	1018.548	23			
Zinc	Between Groups	.326	3	.109	1.357	.284
	Within Groups	1.603	20	.080		
	Total	1.929	23			

POST HOC TESTS FOR MULTIPLE COMPARISONS USING LEAST SIGNIFICANCE DIFFERENCE (LSD) AT 15-30CM SOIL DEPTH ON NCAM EXPERIMENTAL SITE

Dependent Variable	(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
SoilTemp	Traditional	PH	.00000	.38730	1.000	-.8079	.8079
		NT	-.50000	.38730	.211	-1.3079	.3079
		PHR	-.83333*	.38730	.044	-1.6412	-.0254
	PH	Traditional	.00000	.38730	1.000	-.8079	.8079
		NT	-.50000	.38730	.211	-1.3079	.3079
		PHR	-.83333*	.38730	.044	-1.6412	-.0254
	NT	Traditional	.50000	.38730	.211	-.3079	1.3079
		PH	.50000	.38730	.211	-.3079	1.3079
		PHR	-.33333	.38730	.400	-1.1412	.4746
	PHR	Traditional	.83333*	.38730	.044	.0254	1.6412
		PH	.83333*	.38730	.044	.0254	1.6412
		NT	.33333	.38730	.400	-.4746	1.1412
SoilWater	Traditional	PH	-.10333	.34240	.766	-.8176	.6109
		NT	-.25333	.34240	.468	-.9676	.4609
		PHR	.18500	.34240	.595	-.5292	.8992
	PH	Traditional	.10333	.34240	.766	-.6109	.8176
		NT	-.15000	.34240	.666	-.8642	.5642
		PHR	.28833	.34240	.410	-.4259	1.0026
	NT	Traditional	.25333	.34240	.468	-.4609	.9676
		PH	.15000	.34240	.666	-.5642	.8642
		PHR	.43833	.34240	.215	-.2759	1.1526
	PHR	Traditional	-.18500	.34240	.595	-.8992	.5292
		PH	-.28833	.34240	.410	-1.0026	.4259
		NT	-.43833	.34240	.215	-1.1526	.2759
PH	Traditional	PH	.01667	.20337	.936	-.4076	.4409
		NT	.33333	.20337	.117	-.0909	.7576
		PHR	.30000	.20337	.156	-.1242	.7242
	PH	Traditional	-.01667	.20337	.936	-.4409	.4076
		NT	.31667	.20337	.135	-.1076	.7409
		PHR	.28333	.20337	.179	-.1409	.7076
	NT	Traditional	-.33333	.20337	.117	-.7576	.0909
		PH	-.31667	.20337	.135	-.7409	.1076
		PHR	-.03333	.20337	.871	-.4576	.3909
	PHR	Traditional	-.30000	.20337	.156	-.7242	.1242
		PH	-.28333	.20337	.179	-.7076	.1409
		NT	.03333	.20337	.871	-.3909	.4576
BulkDensity	Traditional	PH	.00667	.01208	.587	-.0185	.0319
		NT	-.00833	.01208	.498	-.0335	.0169
		PHR	-.00667	.01208	.587	-.0319	.0185
	PH	Traditional	-.00667	.01208	.587	-.0319	.0185
		NT	-.01500	.01208	.229	-.0402	.0102
		PHR	-.01333	.01208	.283	-.0385	.0119
	NT	Traditional	.00833	.01208	.498	-.0169	.0335
		PH	.01500	.01208	.229	-.0102	.0402
		PHR	.00167	.01208	.892	-.0235	.0269
	PHR	Traditional	.00667	.01208	.587	-.0185	.0319
		PH	.01333	.01208	.283	-.0119	.0385
		NT	-.00167	.01208	.892	-.0269	.0235
OrganicMatter	Traditional	PH	-.01500	.01201	.226	-.0400	.0100
		NT	-.02833*	.01201	.029	-.0534	-.0033
		PHR	-.02500	.01201	.050	-.0500	.0000
	PH	Traditional	.01500	.01201	.226	-.0100	.0400
		NT	-.01333	.01201	.280	-.0384	.0117
		PHR	-.01000	.01201	.415	-.0350	.0150
	NT	Traditional	.02833*	.01201	.029	.0033	.0534

		PH	.01333	.01201	.280	-.0117	.0384
		PHR	.00333	.01201	.784	-.0217	.0284
	PHR	Traditional	.02500	.01201	.050	.0000	.0500
		PH	.01000	.01201	.415	-.0150	.0350
		NT	-.00333	.01201	.784	-.0284	.0217
NitrateNitrogen	Traditional	PH	.005500	.011741	.645	-.01899	.02999
		NT	.003833	.011741	.747	-.02066	.02832
		PHR	.002000	.011741	.866	-.02249	.02649
	PH	Traditional	-.005500	.011741	.645	-.02999	.01899
		NT	-.001667	.011741	.889	-.02616	.02282
		PHR	-.003500	.011741	.769	-.02799	.02099
	NT	Traditional	-.003833	.011741	.747	-.02832	.02066
		PH	.001667	.011741	.889	-.02282	.02616
		PHR	-.001833	.011741	.877	-.02632	.02266
	PHR	Traditional	-.002000	.011741	.866	-.02649	.02249
		PH	.003500	.011741	.769	-.02099	.02799
		NT	.001833	.011741	.877	-.02266	.02632
Phosphorous	Traditional	PH	-.05667	.09972	.576	-.2647	.1513
		NT	-.01167	.09972	.908	-.2197	.1963
		PHR	.03500	.09972	.729	-.1730	.2430
	PH	Traditional	.05667	.09972	.576	-.1513	.2647
		NT	.04500	.09972	.657	-.1630	.2530
		PHR	.09167	.09972	.369	-.1163	.2997
	NT	Traditional	.01167	.09972	.908	-.1963	.2197
		PH	-.04500	.09972	.657	-.2530	.1630
		PHR	.04667	.09972	.645	-.1613	.2547
	PHR	Traditional	-.03500	.09972	.729	-.2430	.1730
		PH	-.09167	.09972	.369	-.2997	.1163
		NT	-.04667	.09972	.645	-.2547	.1613
Potassium	Traditional	PH	-.01333	.05158	.799	-.1209	.0943
		NT	-.02000	.05158	.702	-.1276	.0876
		PHR	.09833	.05158	.071	-.0093	.2059
	PH	Traditional	.01333	.05158	.799	-.0943	.1209
		NT	-.00667	.05158	.898	-.1143	.1009
		PHR	.11167*	.05158	.043	.0041	.2193
	NT	Traditional	.02000	.05158	.702	-.0876	.1276
		PH	.00667	.05158	.898	-.1009	.1143
		PHR	.11833*	.05158	.033	.0107	.2259
	PHR	Traditional	-.09833	.05158	.071	-.2059	.0093
		PH	-.11167*	.05158	.043	-.2193	-.0041
		NT	-.11833*	.05158	.033	-.2259	-.0107
Sodium	Traditional	PH	-.01167	.02272	.613	-.0591	.0357
		NT	-.01000	.02272	.665	-.0574	.0374
		PHR	-.00167	.02272	.942	-.0491	.0457
	PH	Traditional	.01167	.02272	.613	-.0357	.0591
		NT	.00167	.02272	.942	-.0457	.0491
		PHR	.01000	.02272	.665	-.0374	.0574
	NT	Traditional	.01000	.02272	.665	-.0374	.0574
		PH	-.00167	.02272	.942	-.0491	.0457
		PHR	.00833	.02272	.718	-.0391	.0557
	PHR	Traditional	.00167	.02272	.942	-.0457	.0491
		PH	-.01000	.02272	.665	-.0574	.0374
		NT	-.00833	.02272	.718	-.0557	.0391
Calcium	Traditional	PH	-.01000	.08105	.903	-.1791	.1591
		NT	-.00500	.08105	.951	-.1741	.1641
		PHR	.04833	.08105	.558	-.1207	.2174
	PH	Traditional	.01000	.08105	.903	-.1591	.1791
		NT	.00500	.08105	.951	-.1641	.1741
		PHR	.05833	.08105	.480	-.1107	.2274
	NT	Traditional	.00500	.08105	.951	-.1641	.1741
		PH	-.00500	.08105	.951	-.1741	.1641

		PHR	.05333	.08105	.518	-.1157	.2224
	PHR	Traditional	-.04833	.08105	.558	-.2174	.1207
		PH	-.05833	.08105	.480	-.2274	.1107
		NT	-.05333	.08105	.518	-.2224	.1157
Magnesium	Traditional	PH	-.02000	.03206	.540	-.0869	.0469
		NT	-.01667	.03206	.609	-.0835	.0502
		PHR	-.04667	.03206	.161	-.1135	.0202
	PH	Traditional	.02000	.03206	.540	-.0469	.0869
		NT	.00333	.03206	.918	-.0635	.0702
		PHR	-.02667	.03206	.415	-.0935	.0402
	NT	Traditional	.01667	.03206	.609	-.0502	.0835
		PH	-.00333	.03206	.918	-.0702	.0635
		PHR	-.03000	.03206	.361	-.0969	.0369
	PHR	Traditional	.04667	.03206	.161	-.0202	.1135
		PH	.02667	.03206	.415	-.0402	.0935
		NT	.03000	.03206	.361	-.0369	.0969
Copper	Traditional	PH	.25833	.14143	.083	-.0367	.5534
		NT	.13333	.14143	.357	-.1617	.4284
		PHR	.00167	.14143	.991	-.2934	.2967
	PH	Traditional	-.25833	.14143	.083	-.5534	.0367
		NT	-.12500	.14143	.387	-.4200	.1700
		PHR	-.25667	.14143	.085	-.5517	.0384
	NT	Traditional	-.13333	.14143	.357	-.4284	.1617
		PH	.12500	.14143	.387	-.1700	.4200
		PHR	-.13167	.14143	.363	-.4267	.1634
	PHR	Traditional	-.00167	.14143	.991	-.2967	.2934
		PH	.25667	.14143	.085	-.0384	.5517
		NT	.13167	.14143	.363	-.1634	.4267
Manganese	Traditional	PH	.03833	.04218	.374	-.0497	.1263
		NT	.00833	.04218	.845	-.0797	.0963
		PHR	.06167	.04218	.159	-.0263	.1497
	PH	Traditional	-.03833	.04218	.374	-.1263	.0497
		NT	-.03000	.04218	.485	-.1180	.0580
		PHR	.02333	.04218	.586	-.0647	.1113
	NT	Traditional	-.00833	.04218	.845	-.0963	.0797
		PH	.03000	.04218	.485	-.0580	.1180
		PHR	.05333	.04218	.221	-.0347	.1413
	PHR	Traditional	-.06167	.04218	.159	-.1497	.0263
		PH	-.02333	.04218	.586	-.1113	.0647
		NT	-.05333	.04218	.221	-.1413	.0347
Lead	Traditional	PH	-.24500*	.05218	.000	-.3539	-.1361
		NT	.09500	.05218	.084	-.0139	.2039
		PHR	-.08167	.05218	.133	-.1905	.0272
	PH	Traditional	.24500*	.05218	.000	.1361	.3539
		NT	.34000*	.05218	.000	.2311	.4489
		PHR	.16333*	.05218	.005	.0545	.2722
	NT	Traditional	-.09500	.05218	.084	-.2039	.0139
		PH	-.34000*	.05218	.000	-.4489	-.2311
		PHR	-.17667*	.05218	.003	-.2855	-.0678
	PHR	Traditional	.08167	.05218	.133	-.0272	.1905
		PH	-.16333*	.05218	.005	-.2722	-.0545
		NT	.17667*	.05218	.003	.0678	.2855
Iron	Traditional	PH	4.51667	3.59228	.223	-2.9767	12.0100
		NT	-1.14667	3.59228	.753	-8.6400	6.3467
		PHR	-4.38833	3.59228	.236	-11.8817	3.1050
	PH	Traditional	-4.51667	3.59228	.223	-12.0100	2.9767
		NT	-5.66333	3.59228	.131	-13.1567	1.8300
		PHR	-8.90500*	3.59228	.022	-16.3984	-1.4116
	NT	Traditional	1.14667	3.59228	.753	-6.3467	8.6400
		PH	5.66333	3.59228	.131	-1.8300	13.1567
		PHR	-3.24167	3.59228	.378	-10.7350	4.2517

	PHR	Traditional	4.38833	3.59228	.236	-3.1050	11.8817
		PH	8.90500*	3.59228	.022	1.4116	16.3984
		NT	3.24167	3.59228	.378	-4.2517	10.7350
Zinc	Traditional	PH	-.22500	.16344	.184	-.5659	.1159
		NT	.07500	.16344	.651	-.2659	.4159
		PHR	-.13667	.16344	.413	-.4776	.2043
	PH	Traditional	.22500	.16344	.184	-.1159	.5659
		NT	.30000	.16344	.081	-.0409	.6409
		PHR	.08833	.16344	.595	-.2526	.4293
	NT	Traditional	-.07500	.16344	.651	-.4159	.2659
		PH	-.30000	.16344	.081	-.6409	.0409
		PHR	-.21167	.16344	.210	-.5526	.1293
	PHR	Traditional	.13667	.16344	.413	-.2043	.4776
		PH	-.08833	.16344	.595	-.4293	.2526
		NT	.21167	.16344	.210	-.1293	.5526

*. The mean difference is significant at the 0.05 level.

APPENDIX II

WATER QUALITY FOR UTRF EXPERIMENTAL PLOT

ANOVA

		Sum of Squares	df	Mean Square	F	Sig.
Turbidity	Between Groups	.056	3	.019	1.609	.191
	Within Groups	1.354	116	.012		
	Total	1.410	119			
Carbon	Between Groups	.132	3	.044	2.711	.048
	Within Groups	1.883	116	.016		
	Total	2.015	119			
Sodium	Between Groups	.036	3	.012	2.062	.109
	Within Groups	.667	116	.006		
	Total	.703	119			
Pottasium	Between Groups	.117	3	.039	14.142	.001
	Within Groups	.320	116	.003		
	Total	.436	119			
Zinc	Between Groups	.005	3	.002	.912	.438
	Within Groups	.221	116	.002		
	Total	.226	119			
Nitrate	Between Groups	298.265	3	99.422	62.152	.001
	Within Groups	185.560	116	1.600		
	Total	483.825	119			
Phosphorous	Between Groups	.134	3	.045	2.616	.054
	Within Groups	1.985	116	.017		
	Total	2.120	119			
PH	Between Groups	.245	3	.082	6.237	.001
	Within Groups	1.518	116	.013		
	Total	1.763	119			
Conductivity	Between Groups	.001	3	.001	.467	.706
	Within Groups	.122	116	.001		
	Total	.124	119			
Chlorine	Between Groups	4.233	3	1.411	6.970	.001
	Within Groups	23.486	116	.202		
	Total	27.720	119			
Coliform	Between Groups	.915	3	.305	36.742	.001
	Within Groups	.963	116	.008		
	Total	1.878	119			
Copper	Between Groups	3.558	3	1.186	15.230	.001
	Within Groups	9.033	116	.078		
	Total	12.591	119			
TotalDissolvedSolid	Between Groups	.003	3	.001	1.245	.297
	Within Groups	.105	116	.001		
	Total	.109	119			
Calcium	Between Groups	.049	3	.016	1.941	.127
	Within Groups	.980	116	.008		
	Total	1.029	119			
Magnesium	Between Groups	.027	3	.009	5.622	.001
	Within Groups	.187	116	.002		
	Total	.215	119			
DisolvedOxygen	Between Groups	161.267	3	53.756	7.171	.001
	Within Groups	869.533	116	7.496		
	Total	1030.800	119			
Lead	Between Groups	.080	3	.027	15.481	.001
	Within Groups	.200	116	.002		
	Total	.280	119			
Iron	Between Groups	15.079	3	5.026	34.773	.001
	Within Groups	16.768	116	.145		
	Total	31.847	119			

Multiple Comparisons For UTRF Experimental Site

Least Significant Difference (LSD)

Dependent Variable	(I) TillageMethods	(J) TillageMethods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Turbidity	Traditional	Plough/Harrow	-.004233	.027896	.880	-.05948	.05102
		No Till	-.050900	.027896	.071	-.10615	.00435
		Plough/Harrow/Ridge	.001033	.027896	.971	-.05422	.05628
	Plough/Harrow	Traditional	.004233	.027896	.880	-.05102	.05948
		No Till	-.046667	.027896	.097	-.10192	.00858
		Plough/Harrow/Ridge	.005267	.027896	.851	-.04998	.06052
	No Till	Traditional	.050900	.027896	.071	-.00435	.10615
		Plough/Harrow	.046667	.027896	.097	-.00858	.10192
		Plough/Harrow/Ridge	.051933	.027896	.065	-.00332	.10718
	Plough/Harrow/Ridge	Traditional	-.001033	.027896	.971	-.05628	.05422
		Plough/Harrow	-.005267	.027896	.851	-.06052	.04998
		No Till	-.051933	.027896	.065	-.10718	.00332
Carbon	Traditional	Plough/Harrow	-.04000	.03289	.226	-.1052	.0252
		No Till	-.08000*	.03289	.017	-.1452	-.0148
		Plough/Harrow/Ridge	.00100	.03289	1.001	-.0652	.0652
	Plough/Harrow	Traditional	.04000	.03289	.226	-.0252	.1052
		No Till	-.04000	.03289	.226	-.1052	.0252
		Plough/Harrow/Ridge	.04000	.03289	.226	-.0252	.1052
	No Till	Traditional	.08000*	.03289	.017	.0148	.1452
		Plough/Harrow	.04000	.03289	.226	-.0252	.1052
		Plough/Harrow/Ridge	.08000*	.03289	.017	.0148	.1452
	Plough/Harrow/Ridge	Traditional	.00100	.03289	1.001	-.0652	.0652
		Plough/Harrow	-.04000	.03289	.226	-.1052	.0252
		No Till	-.08000*	.03289	.017	-.1452	-.0148
Sodium	Traditional	Plough/Harrow	.04133*	.01959	.037	.0025	.0801
		No Till	.00733	.01959	.709	-.0315	.0461
		Plough/Harrow/Ridge	-.00167	.01959	.973	-.0395	.0381
	Plough/Harrow	Traditional	-.04133*	.01959	.037	-.0801	-.0025
		No Till	-.03400	.01959	.085	-.0728	.0048
		Plough/Harrow/Ridge	-.04200*	.01959	.034	-.0808	-.0032
	No Till	Traditional	-.00733	.01959	.709	-.0461	.0315
		Plough/Harrow	.03400	.01959	.085	-.0048	.0728
		Plough/Harrow/Ridge	-.00800	.01959	.684	-.0468	.0308
	Plough/Harrow/Ridge	Traditional	.00167	.01959	.973	-.0381	.0395
		Plough/Harrow	.04200*	.01959	.034	.0032	.0808
		No Till	.00800	.01959	.684	-.0308	.0468
Pottasium	Traditional	Plough/Harrow	.08133*	.01355	.001	.0545	.1082

		No Till	.01500	.01355	.271	-.0118	.0418
		Plough/Harrow/Ridge	.01800	.01355	.187	-.0088	.0448
		Traditional	-.08133*	.01355	.001	-.1082	-.0545
	Plough/Harrow	No Till	-.06633*	.01355	.001	-.0932	-.0395
		Plough/Harrow/Ridge	-.06333*	.01355	.001	-.0902	-.0365
		Traditional	-.01500	.01355	.271	-.0418	.0118
	No Till	Plough/Harrow	.06633*	.01355	.001	.0395	.0932
		Plough/Harrow/Ridge	.00300	.01355	.825	-.0238	.0298
		Traditional	-.01800	.01355	.187	-.0448	.0088
	Plough/Harrow/Ridge	Plough/Harrow	.06333*	.01355	.001	.0365	.0902
		No Till	-.00300	.01355	.825	-.0298	.0238
		Plough/Harrow	.01667	.01126	.141	-.0056	.0390
	Traditional	No Till	.01500	.01126	.185	-.0073	.0373
		Plough/Harrow/Ridge	.00800	.01126	.479	-.0143	.0303
		Traditional	-.01667	.01126	.141	-.0390	.0056
	Plough/Harrow	No Till	-.00167	.01126	.883	-.0240	.0206
		Plough/Harrow/Ridge	-.00867	.01126	.443	-.0310	.0136
Zinc		Traditional	-.01500	.01126	.185	-.0373	.0073
	No Till	Plough/Harrow	.00167	.01126	.883	-.0206	.0240
		Plough/Harrow/Ridge	-.00700	.01126	.535	-.0293	.0153
		Traditional	-.00800	.01126	.479	-.0303	.0143
	Plough/Harrow/Ridge	Plough/Harrow	.00867	.01126	.443	-.0136	.0310
		No Till	.00700	.01126	.535	-.0153	.0293
		Plough/Harrow	.80533*	.32656	.015	.1585	1.4521
	Traditional	No Till	4.19100*	.32656	.001	3.5442	4.8378
		Plough/Harrow/Ridge	1.40667*	.32656	.001	.7599	2.0535
		Traditional	-.80533*	.32656	.015	-1.4521	-.1585
	Plough/Harrow	No Till	3.38567*	.32656	.001	2.7389	4.0325
		Plough/Harrow/Ridge	.60133	.32656	.068	-.0455	1.2481
Nitrate		Traditional	-4.19100*	.32656	.001	-4.8378	-3.5442
	No Till	Plough/Harrow	-3.38567*	.32656	.001	-4.0325	-2.7389
		Plough/Harrow/Ridge	-2.78433*	.32656	.001	-3.4311	-2.1375
		Traditional	-1.40667*	.32656	.001	-2.0535	-.7599
	Plough/Harrow/Ridge	Plough/Harrow	-.60133	.32656	.068	-1.2481	.0455
		No Till	2.78433*	.32656	.001	2.1375	3.4311
		Plough/Harrow	.09333*	.03378	.007	.0264	.1602
	Traditional	No Till	.03333	.03378	.326	-.0336	.1002
		Plough/Harrow/Ridge	.04000	.03378	.239	-.0269	.1069
		Traditional	-.09333*	.03378	.007	-.1602	-.0264
Phosphorous	Plough/Harrow	No Till	-.06000	.03378	.078	-.1269	.0069
		Plough/Harrow/Ridge	-.05333	.03378	.117	-.1202	.0136
		Traditional	-.03333	.03378	.326	-.1002	.0336
	No Till	Plough/Harrow	.06000	.03378	.078	-.0069	.1269
		Plough/Harrow/Ridge	.00667	.03378	.844	-.0602	.0736

		Traditional	-.04000	.03378	.239	-.1069	.0269
	Plough/Harrow/Ridge	Plough/Harrow	.05333	.03378	.117	-.0136	.1202
		No Till	-.00667	.03378	.844	-.0736	.0602
		Plough/Harrow	.01333	.02954	.653	-.0452	.0718
	Traditional	No Till	-.09333*	.02954	.002	-.1518	-.0348
		Plough/Harrow/Ridge	-.07000*	.02954	.019	-.1285	-.0115
		Traditional	-.01333	.02954	.653	-.0718	.0452
	Plough/Harrow	No Till	-.10667*	.02954	.001	-.1652	-.0482
		Plough/Harrow/Ridge	-.08333*	.02954	.006	-.1418	-.0248
PH		Traditional	.09333*	.02954	.002	.0348	.1518
	No Till	Plough/Harrow	.10667*	.02954	.001	.0482	.1652
		Plough/Harrow/Ridge	.02333	.02954	.431	-.0352	.0818
		Traditional	.07000*	.02954	.019	.0115	.1285
	Plough/Harrow/Ridge	Plough/Harrow	.08333*	.02954	.006	.0248	.1418
		No Till	-.02333	.02954	.431	-.0818	.0352
		Plough/Harrow	-.00733	.00838	.383	-.0239	.0093
	Traditional	No Till	-.00667	.00838	.428	-.0233	.0099
		Plough/Harrow/Ridge	.00100	.00838	1.001	-.0166	.0166
		Traditional	.00733	.00838	.383	-.0093	.0239
	Plough/Harrow	No Till	.00167	.00838	.937	-.0159	.0173
		Plough/Harrow/Ridge	.00733	.00838	.383	-.0093	.0239
Conductivity		Traditional	.00667	.00838	.428	-.0099	.0233
	No Till	Plough/Harrow	-.00167	.00838	.937	-.0173	.0159
		Plough/Harrow/Ridge	.00667	.00838	.428	-.0099	.0233
		Traditional	.00100	.00838	1.001	-.0166	.0166
	Plough/Harrow/Ridge	Plough/Harrow	-.00733	.00838	.383	-.0239	.0093
		No Till	-.00667	.00838	.428	-.0233	.0099
		Plough/Harrow	.19767	.11618	.092	-.0324	.4278
	Traditional	No Till	.51833*	.11618	.001	.2882	.7484
		Plough/Harrow/Ridge	.16333	.11618	.162	-.0668	.3934
		Traditional	-.19767	.11618	.092	-.4278	.0324
	Plough/Harrow	No Till	.32067*	.11618	.007	.0906	.5508
		Plough/Harrow/Ridge	-.03433	.11618	.768	-.2644	.1958
Chlorine		Traditional	-.51833*	.11618	.001	-.7484	-.2882
	No Till	Plough/Harrow	-.32067*	.11618	.007	-.5508	-.0906
		Plough/Harrow/Ridge	-.35500*	.11618	.003	-.5851	-.1249
		Traditional	-.16333	.11618	.162	-.3934	.0668
	Plough/Harrow/Ridge	Plough/Harrow	.03433	.11618	.768	-.1958	.2644
		No Till	.35500*	.11618	.003	.1249	.5851
		Plough/Harrow	.141433*	.023527	.001	.09484	.18803
	Traditional	No Till	.244667*	.023527	.001	.19807	.29126
Coliform		Plough/Harrow/Ridge	.107667*	.023527	.001	.06107	.15426
	Plough/Harrow	Traditional	-.141433*	.023527	.001	-.18803	-.09484
		No Till	.103233*	.023527	.001	.05664	.14983

		Plough/Harrow/Ridge	-.033767	.023527	.154	-.08036	.01283
		Traditional	-.244667*	.023527	.001	-.29126	-.19807
	No Till	Plough/Harrow	-.103233*	.023527	.001	-.14983	-.05664
		Plough/Harrow/Ridge	-.137000*	.023527	.001	-.18360	-.09040
		Traditional	-.107667*	.023527	.001	-.15426	-.06107
	Plough/Harrow/Ridge	Plough/Harrow	.033767	.023527	.154	-.01283	.08036
		No Till	.137000*	.023527	.001	.09040	.18360
		Plough/Harrow	.385400*	.072052	.001	.24269	.52811
	Traditional	No Till	.404700*	.072052	.001	.26199	.54741
		Plough/Harrow/Ridge	.401800*	.072052	.001	.25909	.54451
		Traditional	-.385400*	.072052	.001	-.52811	-.24269
	Plough/Harrow	No Till	.019300	.072052	.789	-.12341	.16201
		Plough/Harrow/Ridge	.016400	.072052	.820	-.12631	.15911
Copper		Traditional	-.404700*	.072052	.001	-.54741	-.26199
	No Till	Plough/Harrow	-.019300	.072052	.789	-.16201	.12341
		Plough/Harrow/Ridge	-.002900	.072052	.968	-.14561	.13981
		Traditional	-.401800*	.072052	.001	-.54451	-.25909
	Plough/Harrow/Ridge	Plough/Harrow	-.016400	.072052	.820	-.15911	.12631
		No Till	.002900	.072052	.968	-.13981	.14561
		Plough/Harrow	.00667	.00778	.393	-.0087	.0221
	Traditional	No Till	.00333	.00778	.669	-.0121	.0187
		Plough/Harrow/Ridge	.01433	.00778	.068	-.0011	.0297
		Traditional	-.00667	.00778	.393	-.0221	.0087
	Plough/Harrow	No Till	-.00333	.00778	.669	-.0187	.0121
		Plough/Harrow/Ridge	.00767	.00778	.326	-.0077	.0231
Total Dissolved Solid		Traditional	-.00333	.00778	.669	-.0187	.0121
	No Till	Plough/Harrow	.00333	.00778	.669	-.0121	.0187
		Plough/Harrow/Ridge	.01100	.00778	.160	-.0044	.0264
		Traditional	-.01433	.00778	.068	-.0297	.0011
	Plough/Harrow/Ridge	Plough/Harrow	-.00767	.00778	.326	-.0231	.0077
		No Till	-.01100	.00778	.160	-.0264	.0044
		Plough/Harrow	-.03103	.02373	.194	-.0780	.0160
	Traditional	No Till	-.05437*	.02373	.024	-.1014	-.0074
		Plough/Harrow/Ridge	-.04270	.02373	.075	-.0897	.0043
		Traditional	.03103	.02373	.194	-.0160	.0780
	Plough/Harrow	No Till	-.02333	.02373	.328	-.0703	.0237
		Plough/Harrow/Ridge	-.01167	.02373	.624	-.0587	.0353
Calcium		Traditional	.05437*	.02373	.024	.0074	.1014
	No Till	Plough/Harrow	.02333	.02373	.328	-.0237	.0703
		Plough/Harrow/Ridge	.01167	.02373	.624	-.0353	.0587
		Traditional	.04270	.02373	.075	-.0043	.0897
	Plough/Harrow/Ridge	Plough/Harrow	.01167	.02373	.624	-.0353	.0587
		No Till	-.01167	.02373	.624	-.0587	.0353
Magnesium	Traditional	Plough/Harrow	.01267	.01038	.225	-.0079	.0332

		No Till	.03033*	.01038	.004	.0098	.0509
		Plough/Harrow/Ridge	.03867*	.01038	.001	.0181	.0592
		Traditional	-.01267	.01038	.225	-.0332	.0079
	Plough/Harrow	No Till	.01767	.01038	.091	-.0029	.0382
		Plough/Harrow/Ridge	.02600*	.01038	.014	.0054	.0466
		Traditional	-.03033*	.01038	.004	-.0509	-.0098
	No Till	Plough/Harrow	-.01767	.01038	.091	-.0382	.0029
		Plough/Harrow/Ridge	.00833	.01038	.424	-.0122	.0289
		Traditional	-.03867*	.01038	.001	-.0592	-.0181
	Plough/Harrow/Ridge	Plough/Harrow	-.02600*	.01038	.014	-.0466	-.0054
		No Till	-.00833	.01038	.424	-.0289	.0122
		Plough/Harrow	-.23333	.70692	.742	-1.6335	1.1668
	Traditional	No Till	2.60000*	.70692	.001	1.1999	4.0011
		Plough/Harrow/Ridge	.03333	.70692	.962	-1.3668	1.4335
		Traditional	.23333	.70692	.742	-1.1668	1.6335
	Plough/Harrow	No Till	2.83333*	.70692	.001	1.4332	4.2335
		Plough/Harrow/Ridge	.26667	.70692	.707	-1.1335	1.6668
DisolvedOxygen		Traditional	-2.60000*	.70692	.001	-4.0011	-1.1999
	No Till	Plough/Harrow	-2.83333*	.70692	.001	-4.2335	-1.4332
		Plough/Harrow/Ridge	-2.56667*	.70692	.001	-3.9668	-1.1665
		Traditional	-.03333	.70692	.962	-1.4335	1.3668
	Plough/Harrow/Ridge	Plough/Harrow	-.26667	.70692	.707	-1.6668	1.1335
		No Till	2.56667*	.70692	.001	1.1665	3.9668
		Plough/Harrow	.01933	.01072	.074	-.0019	.0406
	Traditional	No Till	.07000*	.01072	.001	.0488	.0912
		Plough/Harrow/Ridge	.03820*	.01072	.001	.0170	.0594
		Traditional	-.01933	.01072	.074	-.0406	.0019
	Plough/Harrow	No Till	.05067*	.01072	.001	.0294	.0719
		Plough/Harrow/Ridge	.01887	.01072	.081	-.0024	.0401
Lead		Traditional	-.07000*	.01072	.001	-.0912	-.0488
	No Till	Plough/Harrow	-.05067*	.01072	.001	-.0719	-.0294
		Plough/Harrow/Ridge	-.03180*	.01072	.004	-.0530	-.0106
		Traditional	-.03820*	.01072	.001	-.0594	-.0170
	Plough/Harrow/Ridge	Plough/Harrow	-.01887	.01072	.081	-.0401	.0024
		No Till	.03180*	.01072	.004	.0106	.0530
		Plough/Harrow	.33500*	.09817	.001	.1406	.5294
	Traditional	No Till	.06433	.09817	.514	-.1301	.2588
		Plough/Harrow/Ridge	-.63233*	.09817	.001	-.8268	-.4379
		Traditional	-.33500*	.09817	.001	-.5294	-.1406
Iron	Plough/Harrow	No Till	-.27067*	.09817	.007	-.4651	-.0762
		Plough/Harrow/Ridge	-.96733*	.09817	.001	-1.1618	-.7729
		Traditional	-.06433	.09817	.514	-.2588	.1301
	No Till	Plough/Harrow	.27067*	.09817	.007	.0762	.4651
		Plough/Harrow/Ridge	-.69667*	.09817	.001	-.8911	-.5022

	Traditional	.63233*	.09817	.001	.4379	.8268
Plough/Harrow/Ridge	Plough/Harrow	.96733*	.09817	.001	.7729	1.1618
	No Till	.69667*	.09817	.001	.5022	.8911

*. The mean difference is significant at the 0.05 level.

WATER QUALITY FOR NCAM EXPERIMENTAL SITE

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Turbidity	Between Groups	.051	3	.017	2.236	.088
	Within Groups	.879	116	.008		
	Total	.930	119			
Carbon	Between Groups	1.487	3	.496	3.460	.019
	Within Groups	16.617	116	.143		
	Total	18.104	119			
Sodium	Between Groups	.030	3	.010	3.105	.029
	Within Groups	.373	116	.003		
	Total	.403	119			
Pottasium	Between Groups	.005	3	.002	.838	.476
	Within Groups	.230	116	.002		
	Total	.235	119			
Zinc	Between Groups	.003	3	.001	.521	.669
	Within Groups	.196	116	.002		
	Total	.199	119			
Nitrate	Between Groups	274.927	3	91.642	7.351	.001
	Within Groups	1446.117	116	12.467		
	Total	1721.044	119			
Phosphorous	Between Groups	.071	3	.024	1.347	.262
	Within Groups	2.035	116	.018		
	Total	2.106	119			
PH	Between Groups	.122	3	.041	4.270	.007
	Within Groups	1.107	116	.010		
	Total	1.229	119			
Conductivity	Between Groups	7.936	3	2.645	1.376	.254
	Within Groups	222.998	116	1.922		
	Total	230.934	119			
Chlorine	Between Groups	2.019	3	.673	.003	1.001
	Within Groups	24317.799	116	209.636		
	Total	24319.819	119			
Coliform	Between Groups	2.249	3	.750	24.415	.001
	Within Groups	3.562	116	.031		
	Total	5.811	119			
Copper	Between Groups	.002	3	.001	9.004	.001
	Within Groups	.009	116	.001		
	Total	.011	119			
TotalDissolvedSolid	Between Groups	.008	3	.003	1.526	.211
	Within Groups	.195	116	.002		
	Total	.203	119			
Calcium	Between Groups	.007	3	.002	1.894	.134
	Within Groups	.151	116	.001		
	Total	.159	119			
Magnesium	Between Groups	.013	3	.004	3.172	.027
	Within Groups	.156	116	.001		
	Total	.169	119			
DisolvedOxygen	Between Groups	14.200	3	4.733	.591	.622
	Within Groups	929.667	116	8.014		
	Total	943.867	119			
Lead	Between Groups	.033	3	.011	6.810	.001
	Within Groups	.186	116	.002		
	Total	.218	119			
Iron	Between Groups	.283	3	.094	.565	.639
	Within Groups	19.374	116	.167		
	Total	19.658	119			

Multiple Comparisons For NCAM Experimental Site

Least Significant Difference (LSD)

Dependent Variable	(I) TillageMethods	(J) TillageMethods	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
						Lower Bound	Upper Bound
Turbidity	Traditional	Plough/Harrow	-.044267	.022475	.051	-.08878	.00125
		No Till	.001767	.022475	.973	-.04375	.04528
		Plough/Harrow/Ridge	.007567	.022475	.737	-.03695	.05208
	Plough/Harrow	Traditional	.044267	.022475	.051	-.00125	.08878
		No Till	.045033*	.022475	.047	.00152	.08955
		Plough/Harrow/Ridge	.051833*	.022475	.023	.00732	.09635
	No Till	Traditional	-.001767	.022475	.973	-.04528	.04375
		Plough/Harrow	-.045033*	.022475	.047	-.08955	-.00152
		Plough/Harrow/Ridge	.006800	.022475	.763	-.03771	.05131
	Plough/Harrow/Ridge	Traditional	-.007567	.022475	.737	-.05208	.03695
		Plough/Harrow	-.051833*	.022475	.023	-.09635	-.00732
		No Till	-.006800	.022475	.763	-.05131	.03771
Carbon	Traditional	Plough/Harrow	.00333	.09772	.973	-.1902	.1969
		No Till	.00667	.09772	.946	-.1869	.2002
		Plough/Harrow/Ridge	.26033*	.09772	.009	.0668	.4539
	Plough/Harrow	Traditional	-.00333	.09772	.973	-.1969	.1902
		No Till	.00333	.09772	.973	-.1902	.1969
		Plough/Harrow/Ridge	.25700*	.09772	.010	.0634	.4506
	No Till	Traditional	-.00667	.09772	.946	-.2002	.1869
		Plough/Harrow	-.00333	.09772	.973	-.1969	.1902
		Plough/Harrow/Ridge	.25367*	.09772	.011	.0601	.4472
	Plough/Harrow/Ridge	Traditional	-.26033*	.09772	.009	-.4539	-.0668
		Plough/Harrow	-.25700*	.09772	.010	-.4506	-.0634
		No Till	-.25367*	.09772	.011	-.4472	-.0601
Sodium	Traditional	Plough/Harrow	.00267	.01464	.856	-.0263	.0317
		No Till	-.02900	.01464	.050	-.0580	.0010
		Plough/Harrow/Ridge	-.03133*	.01464	.034	-.0603	-.0023
	Plough/Harrow	Traditional	-.00267	.01464	.856	-.0317	.0263
		No Till	-.03167*	.01464	.033	-.0607	-.0027
		Plough/Harrow/Ridge	-.03400*	.01464	.022	-.0630	-.0050
	No Till	Traditional	.02900	.01464	.050	.0010	.0580
		Plough/Harrow	.03167*	.01464	.033	.0027	.0607
		Plough/Harrow/Ridge	-.00233	.01464	.874	-.0313	.0267
	Plough/Harrow/Ridge	Traditional	.03133*	.01464	.034	.0023	.0603
		Plough/Harrow	.03400*	.01464	.022	.0050	.0630
		No Till	.00233	.01464	.874	-.0267	.0313
Pottasium	Traditional	Plough/Harrow	-.01767	.01150	.127	-.0405	.0051
		No Till	-.00933	.01150	.419	-.0321	.0135

		Plough/Harrow/Ridge	-.01267	.01150	.273	-.0355	.0101
		Traditional	.01767	.01150	.127	-.0051	.0405
	Plough/Harrow	No Till	.00833	.01150	.470	-.0145	.0311
		Plough/Harrow/Ridge	.00500	.01150	.665	-.0178	.0278
		Traditional	.00933	.01150	.419	-.0135	.0321
	No Till	Plough/Harrow	-.00833	.01150	.470	-.0311	.0145
		Plough/Harrow/Ridge	-.00333	.01150	.773	-.0261	.0195
		Traditional	.01267	.01150	.273	-.0101	.0355
	Plough/Harrow/Ridge	Plough/Harrow	-.00500	.01150	.665	-.0278	.0178
		No Till	.00333	.01150	.773	-.0195	.0261
		Plough/Harrow	-.00133	.01063	.900	-.0224	.0197
	Traditional	No Till	.00900	.01063	.399	-.0120	.0300
		Plough/Harrow/Ridge	.00833	.01063	.435	-.0127	.0294
		Traditional	.00133	.01063	.900	-.0197	.0224
	Plough/Harrow	No Till	.01033	.01063	.333	-.0107	.0314
		Plough/Harrow/Ridge	.00967	.01063	.365	-.0114	.0307
Zinc		Traditional	-.00900	.01063	.399	-.0300	.0120
	No Till	Plough/Harrow	-.01033	.01063	.333	-.0314	.0107
		Plough/Harrow/Ridge	-.00167	.01063	.950	-.0217	.0204
		Traditional	-.00833	.01063	.435	-.0294	.0127
	Plough/Harrow/Ridge	Plough/Harrow	-.00967	.01063	.365	-.0307	.0114
		No Till	.00167	.01063	.950	-.0204	.0217
		Plough/Harrow	.13500	.91165	.883	-1.6706	1.9406
	Traditional	No Till	3.73900*	.91165	.001	1.9334	5.5446
		Plough/Harrow/Ridge	1.76533	.91165	.055	-.0403	3.5710
		Traditional	-.13500	.91165	.883	-1.9406	1.6706
	Plough/Harrow	No Till	3.60400*	.91165	.001	1.7984	5.4096
		Plough/Harrow/Ridge	1.63033	.91165	.076	-.1753	3.4360
Nitrate		Traditional	-3.73900*	.91165	.001	-5.5446	-1.9334
	No Till	Plough/Harrow	-3.60400*	.91165	.001	-5.4096	-1.7984
		Plough/Harrow/Ridge	-1.97367*	.91165	.032	-3.7793	-.1680
		Traditional	-1.76533	.91165	.055	-3.5710	.0403
	Plough/Harrow/Ridge	Plough/Harrow	-1.63033	.91165	.076	-3.4360	.1753
		No Till	1.97367*	.91165	.032	.1680	3.7793
		Plough/Harrow	-.01667	.03420	.627	-.0844	.0511
	Traditional	No Till	-.06333	.03420	.067	-.1311	.0044
		Plough/Harrow/Ridge	-.01000	.03420	.770	-.0777	.0577
		Traditional	.01667	.03420	.627	-.0511	.0844
	Plough/Harrow	No Till	-.04667	.03420	.175	-.1144	.0211
Phosphorous		Plough/Harrow/Ridge	.00667	.03420	.846	-.0611	.0744
		Traditional	.06333	.03420	.067	-.0044	.1311
	No Till	Plough/Harrow	.04667	.03420	.175	-.0211	.1144
		Plough/Harrow/Ridge	.05333	.03420	.122	-.0144	.1211
		Traditional	.01000	.03420	.770	-.0577	.0777
	Plough/Harrow/Ridge	Plough/Harrow	-.00667	.03420	.846	-.0744	.0611

		No Till	-.05333	.03420	.122	-.1211	.0144
		Plough/Harrow	-.04667	.02522	.067	-.0966	.0033
	Traditional	No Till	-.09000*	.02522	.001	-.1400	-.0400
		Plough/Harrow/Ridge	-.04000	.02522	.115	-.0900	.0100
		Traditional	.04667	.02522	.067	-.0033	.0966
	Plough/Harrow	No Till	-.04333	.02522	.088	-.0933	.0066
		Plough/Harrow/Ridge	.00667	.02522	.792	-.0433	.0566
PH		Traditional	.09000*	.02522	.001	.0400	.1400
	No Till	Plough/Harrow	.04333	.02522	.088	-.0066	.0933
		Plough/Harrow/Ridge	.05000*	.02522	.050	.0010	.1000
		Traditional	.04000	.02522	.115	-.0100	.0900
	Plough/Harrow/Ridge	Plough/Harrow	-.00667	.02522	.792	-.0566	.0433
		No Till	-.05000*	.02522	.050	-.1000	.0010
		Plough/Harrow	-.18800	.35799	.600	-.8971	.5211
	Traditional	No Till	-.59300	.35799	.100	-1.3021	.1161
		Plough/Harrow/Ridge	-.58867	.35799	.103	-1.2977	.1204
		Traditional	.18800	.35799	.600	-.5211	.8971
	Plough/Harrow	No Till	-.40500	.35799	.260	-1.1141	.3041
		Plough/Harrow/Ridge	-.40067	.35799	.265	-1.1097	.3084
Conductivity		Traditional	.59300	.35799	.100	-.1161	1.3021
	No Till	Plough/Harrow	.40500	.35799	.260	-.3041	1.1141
		Plough/Harrow/Ridge	.00433	.35799	.990	-.7047	.7134
		Traditional	.58867	.35799	.103	-.1204	1.2977
	Plough/Harrow/Ridge	Plough/Harrow	.40067	.35799	.265	-.3084	1.1097
		No Till	-.00433	.35799	.990	-.7134	.7047
		Plough/Harrow	-.12233	3.73842	.974	-7.5267	7.2821
	Traditional	No Till	.21767	3.73842	.954	-7.1867	7.6221
		Plough/Harrow/Ridge	.13500	3.73842	.971	-7.2694	7.5394
		Traditional	.12233	3.73842	.974	-7.2821	7.5267
	Plough/Harrow	No Till	.34000	3.73842	.928	-7.0644	7.7444
		Plough/Harrow/Ridge	.25733	3.73842	.945	-7.1471	7.6617
Chlorine		Traditional	-.21767	3.73842	.954	-7.6221	7.1867
	No Till	Plough/Harrow	-.34000	3.73842	.928	-7.7444	7.0644
		Plough/Harrow/Ridge	-.08267	3.73842	.982	-7.4871	7.3217
		Traditional	-.13500	3.73842	.971	-7.5394	7.2694
	Plough/Harrow/Ridge	Plough/Harrow	-.25733	3.73842	.945	-7.6617	7.1471
		No Till	.08267	3.73842	.982	-7.3217	7.4871
		Plough/Harrow	.259200*	.045245	.001	.16959	.34881
	Traditional	No Till	.378233*	.045245	.001	.28862	.46785
		Plough/Harrow/Ridge	.227400*	.045245	.001	.13779	.31701
		Traditional	-.259200*	.045245	.001	-.34881	-.16959
Coliform	Plough/Harrow	No Till	.119033*	.045245	.010	.02942	.20865
		Plough/Harrow/Ridge	-.031800	.045245	.484	-.12141	.05781
	No Till	Traditional	-.378233*	.045245	.001	-.46785	-.28862
		Plough/Harrow	-.119033*	.045245	.010	-.20865	-.02942

		Plough/Harrow/Ridge	-.150833*	.045245	.001	-.24045	-.06122
		Traditional	-.227400*	.045245	.001	-.31701	-.13779
	Plough/Harrow/Ridge	Plough/Harrow	.031800	.045245	.484	-.05781	.12141
		No Till	.150833*	.045245	.001	.06122	.24045
		Plough/Harrow	.004200	.002223	.061	-.00120	.00860
	Traditional	No Till	.003767	.002223	.093	-.00164	.00817
		Plough/Harrow/Ridge	.011300*	.002223	.001	.00690	.01570
		Traditional	-.004200	.002223	.061	-.00860	.00120
	Plough/Harrow	No Till	-.001433	.002223	.846	-.00484	.00397
Copper		Plough/Harrow/Ridge	.007100*	.002223	.002	.00270	.01150
		Traditional	-.003767	.002223	.093	-.00817	.00164
	No Till	Plough/Harrow	.001433	.002223	.846	-.00397	.00484
		Plough/Harrow/Ridge	.007533*	.002223	.001	.00313	.01194
		Traditional	-.011300*	.002223	.001	-.01570	-.00690
	Plough/Harrow/Ridge	Plough/Harrow	-.007100*	.002223	.002	-.01150	-.00270
		No Till	-.007533*	.002223	.001	-.01194	-.00313
		Plough/Harrow	.01600	.01059	.133	-.0050	.0370
	Traditional	No Till	.01900	.01059	.075	-.0020	.0400
		Plough/Harrow/Ridge	.01967	.01059	.066	-.0013	.0406
		Traditional	-.01600	.01059	.133	-.0370	.0050
	Plough/Harrow	No Till	.00300	.01059	.777	-.0180	.0240
TotalDissolvedSolid		Plough/Harrow/Ridge	.00367	.01059	.730	-.0173	.0246
		Traditional	-.01900	.01059	.075	-.0400	.0020
	No Till	Plough/Harrow	-.00300	.01059	.777	-.0240	.0180
		Plough/Harrow/Ridge	.00167	.01059	.950	-.0203	.0216
		Traditional	-.01967	.01059	.066	-.0406	.0013
	Plough/Harrow/Ridge	Plough/Harrow	-.00367	.01059	.730	-.0246	.0173
		No Till	-.00167	.01059	.950	-.0216	.0203
		Plough/Harrow	-.01833	.00932	.052	-.0368	.0011
	Traditional	No Till	.00133	.00932	.887	-.0171	.0198
		Plough/Harrow/Ridge	-.00833	.00932	.373	-.0268	.0101
		Traditional	.01833	.00932	.052	-.0011	.0368
	Plough/Harrow	No Till	.01967*	.00932	.037	.0012	.0381
		Plough/Harrow/Ridge	.01000	.00932	.286	-.0085	.0285
Calcium		Traditional	-.00133	.00932	.887	-.0198	.0171
	No Till	Plough/Harrow	-.01967*	.00932	.037	-.0381	-.0012
		Plough/Harrow/Ridge	-.00967	.00932	.302	-.0281	.0088
		Traditional	.00833	.00932	.373	-.0101	.0268
	Plough/Harrow/Ridge	Plough/Harrow	-.01000	.00932	.286	-.0285	.0085
		No Till	.00967	.00932	.302	-.0088	.0281
		Plough/Harrow	-.00267	.00948	.779	-.0214	.0161
	Traditional	No Till	-.02567*	.00948	.008	-.0444	-.0069
Magnesium		Plough/Harrow/Ridge	-.01567	.00948	.101	-.0344	.0031
		Traditional	.00267	.00948	.779	-.0161	.0214
	Plough/Harrow	No Till	-.02300*	.00948	.017	-.0418	-.0042

		Plough/Harrow/Ridge	-.01300	.00948	.173	-.0318	.0058
		Traditional	.02567*	.00948	.008	.0069	.0444
	No Till	Plough/Harrow	.02300*	.00948	.017	.0042	.0418
		Plough/Harrow/Ridge	.01000	.00948	.294	-.0088	.0288
		Traditional	.01567	.00948	.101	-.0031	.0344
	Plough/Harrow/Ridge	Plough/Harrow	.01300	.00948	.173	-.0058	.0318
		No Till	-.01000	.00948	.294	-.0288	.0088
		Plough/Harrow	.20000	.73095	.785	-1.2477	1.6477
	Traditional	No Till	-.50000	.73095	.495	-1.9477	.9477
		Plough/Harrow/Ridge	-.63333	.73095	.388	-2.0811	.8144
		Traditional	-.20000	.73095	.785	-1.6477	1.2477
	Plough/Harrow	No Till	-.70000	.73095	.340	-2.1477	.7477
		Plough/Harrow/Ridge	-.83333	.73095	.257	-2.2811	.6144
DisolvedOxygen		Traditional	.50000	.73095	.495	-.9477	1.9477
	No Till	Plough/Harrow	.70000	.73095	.340	-.7477	2.1477
		Plough/Harrow/Ridge	-.13333	.73095	.856	-1.5811	1.3144
		Traditional	.63333	.73095	.388	-.8144	2.0811
	Plough/Harrow/Ridge	Plough/Harrow	.83333	.73095	.257	-.6144	2.2811
		No Till	.13333	.73095	.856	-1.3144	1.5811
		Plough/Harrow	.02667*	.01033	.011	.0062	.0471
	Traditional	No Till	.01100	.01033	.289	-.0095	.0315
		Plough/Harrow/Ridge	-.01867	.01033	.073	-.0391	.0018
		Traditional	-.02667*	.01033	.011	-.0471	-.0062
	Plough/Harrow	No Till	-.01567	.01033	.132	-.0361	.0048
		Plough/Harrow/Ridge	-.04533*	.01033	.001	-.0658	-.0249
Lead		Traditional	-.01100	.01033	.289	-.0315	.0095
	No Till	Plough/Harrow	.01567	.01033	.132	-.0048	.0361
		Plough/Harrow/Ridge	-.02967*	.01033	.005	-.0501	-.0092
		Traditional	.01867	.01033	.073	-.0018	.0391
	Plough/Harrow/Ridge	Plough/Harrow	.04533*	.01033	.001	.0249	.0658
		No Till	.02967*	.01033	.005	.0092	.0501
		Plough/Harrow	.05100	.10552	.630	-.1580	.2600
	Traditional	No Till	-.05767	.10552	.586	-.2667	.1513
		Plough/Harrow/Ridge	.06633	.10552	.531	-.1427	.2753
		Traditional	-.05100	.10552	.630	-.2600	.1580
	Plough/Harrow	No Till	-.10867	.10552	.305	-.3177	.1003
		Plough/Harrow/Ridge	.01533	.10552	.885	-.1937	.2243
Iron		Traditional	.05767	.10552	.586	-.1513	.2667
	No Till	Plough/Harrow	.10867	.10552	.305	-.1003	.3177
		Plough/Harrow/Ridge	.12400	.10552	.242	-.0850	.3330
		Traditional	-.06633	.10552	.531	-.2753	.1427
	Plough/Harrow/Ridge	Plough/Harrow	-.01533	.10552	.885	-.2243	.1937
		No Till	-.12400	.10552	.242	-.3330	.0850

*. The mean difference is significant at the 0.05 level.

APPENDIX III

ANOVA FOR CROP YIELD PARAMETERS FOR 2015 PLANTING SEASON

UTRF 2015

ANOVA

Plant Height

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.094	3	.031	.481	.705
Within Groups	.524	8	.066		
Total	.619	11			

Multiple Comparisons

Dependent Variable: Plant Height
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
No Till	Traditional	-.16333	.20899	.861	-.8326	.5059
	Plough/Harrow	-.13667	.20899	.911	-.8059	.5326
	Plough/Harrow/Ridge	.04667	.20899	.996	-.6226	.7159
Traditional	No Till	.16333	.20899	.861	-.5059	.8326
	Plough/Harrow	.02667	.20899	.999	-.6426	.6959
	Plough/Harrow/Ridge	.21000	.20899	.751	-.4593	.8793
Plough/Harrow	No Till	.13667	.20899	.911	-.5326	.8059
	Traditional	-.02667	.20899	.999	-.6959	.6426
	Plough/Harrow/Ridge	.18333	.20899	.817	-.4859	.8526
Plough/Harrow/Ridge	No Till	-.04667	.20899	.996	-.7159	.6226
	Traditional	-.21000	.20899	.751	-.8793	.4593
	Plough/Harrow	-.18333	.20899	.817	-.8526	.4859

ANOVA

No of Leaves

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	3.583	3	1.194	2.867	.104
Within Groups	3.333	8	.417		
Total	6.917	11			

Multiple Comparisons

Dependent Variable: NoOfLeaves
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-1.33333	.52705	.129	-3.0211	.3545
No Till	Plough/Harrow	-1.33333	.52705	.129	-3.0211	.3545
	Plough/Harrow/Ridge	-1.00000	.52705	.301	-2.6878	.6878
	No Till	1.33333	.52705	.129	-.3545	3.0211
Traditional	Plough/Harrow	.00000	.52705	1.000	-1.6878	1.6878
	Plough/Harrow/Ridge	.33333	.52705	.919	-1.3545	2.0211
	No Till	1.33333	.52705	.129	-.3545	3.0211
Plough/Harrow	Traditional	.00000	.52705	1.000	-1.6878	1.6878
	Plough/Harrow/Ridge	.33333	.52705	.919	-1.3545	2.0211
	No Till	1.00000	.52705	.301	-.6878	2.6878
Plough/Harrow/Ridge	Traditional	-.33333	.52705	.919	-2.0211	1.3545
	Plough/Harrow	-.33333	.52705	.919	-2.0211	1.3545

ANOVA

LeaveLength

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.020	3	.007	1.062	.418
Within Groups	.051	8	.006		
Total	.071	11			

Multiple Comparisons

Dependent Variable: LeaveLength
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-.10333	.06528	.438	-.3124	.1057
No Till	Plough/Harrow	-.03000	.06528	.966	-.2390	.1790
	Plough/Harrow/Ridge	-.08333	.06528	.601	-.2924	.1257
	No Till	.10333	.06528	.438	-.1057	.3124
Traditional	Plough/Harrow	.07333	.06528	.686	-.1357	.2824
	Plough/Harrow/Ridge	.02000	.06528	.989	-.1890	.2290
	No Till	.03000	.06528	.966	-.1790	.2390
Plough/Harrow	Traditional	-.07333	.06528	.686	-.2824	.1357
	Plough/Harrow/Ridge	-.05333	.06528	.845	-.2624	.1557
	No Till	.08333	.06528	.601	-.1257	.2924
Plough/Harrow/Ridge	Traditional	-.02000	.06528	.989	-.2290	.1890
	Plough/Harrow	.05333	.06528	.845	-.1557	.2624

ANOVA

LeaveWidth

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.075	3	.025	.282	.837
Within Groups	.709	8	.089		
Total	.784	11			

Multiple Comparisons

Dependent Variable: Leave Width
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	.04000	.24306	.998	-.7384	.8184
No Till	Plough/Harrow	.20667	.24306	.830	-.5717	.9850
	Plough/Harrow/Ridge	.04667	.24306	.997	-.7317	.8250
	No Till	-.04000	.24306	.998	-.8184	.7384
Traditional	Plough/Harrow	.16667	.24306	.900	-.6117	.9450
	Plough/Harrow/Ridge	.00667	.24306	1.000	-.7717	.7850
	No Till	-.20667	.24306	.830	-.9850	.5717
Plough/Harrow	Traditional	-.16667	.24306	.900	-.9450	.6117
	Plough/Harrow/Ridge	-.16000	.24306	.910	-.9384	.6184
	No Till	-.04667	.24306	.997	-.8250	.7317
Plough/Harrow/Ridge	Traditional	-.00667	.24306	1.000	-.7850	.7717
	Plough/Harrow	.16000	.24306	.910	-.6184	.9384

ANOVA

LAI

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.044	3	.015	99.160	.001
Within Groups	.001	8	.000		
Total	.045	11			

Multiple Comparisons

Dependent Variable: LAI
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	.04000*	.00989	.016	.0083	.0717
No Till	Plough/Harrow	-.11333*	.00989	.000	-.1450	-.0817
	Plough/Harrow/Ridge	.02567	.00989	.117	-.0060	.0573
	No Till	-.04000*	.00989	.016	-.0717	-.0083
Traditional	Plough/Harrow	-.15333*	.00989	.000	-.1850	-.1217
	Plough/Harrow/Ridge	-.01433	.00989	.506	-.0460	.0173
	No Till	.11333*	.00989	.000	.0817	.1450
Plough/Harrow	Traditional	.15333*	.00989	.000	.1217	.1850
	Plough/Harrow/Ridge	.13900*	.00989	.000	.1073	.1707
	No Till	-.02567	.00989	.117	-.0573	.0060
Plough/Harrow/Ridge	Traditional	.01433	.00989	.506	-.0173	.0460
	Plough/Harrow	-.13900*	.00989	.000	-.1707	-.1073

*. The mean difference is significant at the 0.05 level.

Crop Yield

Tests of Between-Subjects Effects

Dependent Variable: Crop Yield

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	2223333.333[a]	3	741111.111	6.352	.016
Intercept	31363333.333	1	31363333.333	268.829	.000
Tillage Type	2223333.333	3	741111.111	6.352	.016
Error	933333.333	8	116666.667		
Total	34520000.000	12			
Corrected Total	3156666.667	11			

a. R Squared = .704 (Adjusted R Squared = .593)

Multiple Comparisons

Dependent Variable: Crop Yield
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-200.0000	278.88668	.888	-1093.0933	693.0933
No Till	Plough/Harrow	-1133.3333*	278.88668	.015	-2026.4266	-240.2400
	Plough/Harrow/Ridge	-333.3333	278.88668	.646	-1226.4266	559.7600
	No Till	200.0000	278.88668	.888	-693.0933	1093.0933
Traditional	Plough/Harrow	-933.3333*	278.88668	.041	-1826.4266	-40.2400
	Plough/Harrow/Ridge	-133.3333	278.88668	.962	-1026.4266	759.7600
	No Till	1133.3333*	278.88668	.015	240.2400	2026.4266
Plough/Harrow	Traditional	933.3333*	278.88668	.041	40.2400	1826.4266
	Plough/Harrow/Ridge	800.0000	278.88668	.080	-93.0933	1693.0933
	No Till	333.3333	278.88668	.646	-559.7600	1226.4266
Plough/Harrow/Ridge	Traditional	133.3333	278.88668	.962	-759.7600	1026.4266
	Plough/Harrow	-800.0000	278.88668	.080	-1693.0933	93.0933

Based on observed means.
The error term is Mean Square(Error) = 116666.667.
*. The mean difference is significant at the 0.05 level.

NCAM 2015

ANOVA

Plant Height

	Sum of Squares	Df	Mean Square	F	Sig.
Between Groups	.087	3	.029	1.381	.317
Within Groups	.167	8	.021		
Total	.254	11			

Multiple Comparisons

Dependent Variable: Plant Height
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-.11333	.11804	.775	-.4913	.2647
No Till	Plough/Harrow	-.23667	.11804	.262	-.6147	.1413
	Plough/Harrow/Ridge	-.08333	.11804	.892	-.4613	.2947
Traditional	No Till	.11333	.11804	.775	-.2647	.4913

	Plough/Harrow	-.12333	.11804	.730	-.5013	.2547
	Plough/Harrow/Ridge	.03000	.11804	.994	-.3480	.4080
	No Till	.23667	.11804	.262	-.1413	.6147
Plough/Harrow	Traditional	.12333	.11804	.730	-.2547	.5013
	Plough/Harrow/Ridge	.15333	.11804	.588	-.2247	.5313
	No Till	.08333	.11804	.892	-.2947	.4613
Plough/Harrow/Ridge	Traditional	-.03000	.11804	.994	-.4080	.3480
	Plough/Harrow	-.15333	.11804	.588	-.5313	.2247

ANOVA

No of Leaves

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	4.250	3	1.417	2.833	.106
Within Groups	4.000	8	.500		
Total	8.250	11			

Multiple Comparisons

Dependent Variable: No of Leaves
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-1.00000	.57735	.369	-2.8489	.8489
No Till	Plough/Harrow	-1.00000	.57735	.369	-2.8489	.8489
	Plough/Harrow/Ridge	-1.66667	.57735	.078	-3.5155	.1822
	No Till	1.00000	.57735	.369	-.8489	2.8489
Traditional	Plough/Harrow	.00000	.57735	1.000	-1.8489	1.8489
	Plough/Harrow/Ridge	-.66667	.57735	.669	-2.5155	1.1822
	No Till	1.00000	.57735	.369	-.8489	2.8489
Plough/Harrow	Traditional	.00000	.57735	1.000	-1.8489	1.8489
	Plough/Harrow/Ridge	-.66667	.57735	.669	-2.5155	1.1822
	No Till	1.66667	.57735	.078	-.1822	3.5155
Plough/Harrow/Ridge	Traditional	.66667	.57735	.669	-1.1822	2.5155
	Plough/Harrow	.66667	.57735	.669	-1.1822	2.5155

ANOVA

Leave Length

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.036	3	.012	2.118	.176
Within Groups	.045	8	.006		
Total	.081	11			

Multiple Comparisons

Dependent Variable: LeaveLength
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	.00000	.06137	1.000	-.1965	.1965
No Till	Plough/Harrow	-.05667	.06137	.794	-.2532	.1399
	Plough/Harrow/Ridge	-.13333	.06137	.210	-.3299	.0632
	No Till	.00000	.06137	1.000	-.1965	.1965
Traditional	Plough/Harrow	-.05667	.06137	.794	-.2532	.1399

	Plough/Harrow/Ridge	-.13333	.06137	.210	-.3299	.0632
	No Till	.05667	.06137	.794	-.1399	.2532
Plough/Harrow	Traditional	.05667	.06137	.794	-.1399	.2532
	Plough/Harrow/Ridge	-.07667	.06137	.616	-.2732	.1199
	No Till	.13333	.06137	.210	-.0632	.3299
Plough/Harrow/Ridge	Traditional	.13333	.06137	.210	-.0632	.3299
	Plough/Harrow	.07667	.06137	.616	-.1199	.2732

ANOVA

Leave Width

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.191	3	.064	.731	.562
Within Groups	.695	8	.087		
Total	.885	11			

Multiple Comparisons

Dependent Variable: Leave Width
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-.15000	.24062	.922	-.9206	.6206
No Till	Plough/Harrow	-.19667	.24062	.845	-.9672	.5739
	Plough/Harrow/Ridge	-.35333	.24062	.496	-1.1239	.4172
	No Till	.15000	.24062	.922	-.6206	.9206
Traditional	Plough/Harrow	-.04667	.24062	.997	-.8172	.7239
	Plough/Harrow/Ridge	-.20333	.24062	.832	-.9739	.5672
	No Till	.19667	.24062	.845	-.5739	.9672
Plough/Harrow	Traditional	.04667	.24062	.997	-.7239	.8172
	Plough/Harrow/Ridge	-.15667	.24062	.912	-.9272	.6139
	No Till	.35333	.24062	.496	-.4172	1.1239
Plough/Harrow/Ridge	Traditional	.20333	.24062	.832	-.5672	.9739
	Plough/Harrow	.15667	.24062	.912	-.6139	.9272

ANOVA

Leaf Area Index(LAI)

	Sum of Squares	df	Mean Square	F	Sig.
Between Groups	.062	3	.021	12.621	.002
Within Groups	.013	8	.002		
Total	.075	11			

Multiple Comparisons

Dependent Variable: LAI
Tukey HSD

(I) TillageType	(J) TillageType	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	-.02667	.03308	.850	-.1326	.0793
No Till	Plough/Harrow	-.18667*	.03308	.002	-.2926	-.0807
	Plough/Harrow/Ridge	-.05000	.03308	.474	-.1559	.0559
	No Till	.02667	.03308	.850	-.0793	.1326
Traditional	Plough/Harrow	-.16000*	.03308	.006	-.2659	-.0541
	Plough/Harrow/Ridge	-.02333	.03308	.892	-.1293	.0826

	No Till	.18667*	.03308	.002	.0807	.2926
Plough/Harrow	Traditional	.16000*	.03308	.006	.0541	.2659
	Plough/Harrow/Ridge	.13667*	.03308	.014	.0307	.2426
	No Till	.05000	.03308	.474	-.0559	.1559
Plough/Harrow/Ridge	Traditional	.02333	.03308	.892	-.0826	.1293
	Plough/Harrow	-.13667*	.03308	.014	-.2426	-.0307

*. The mean difference is significant at the 0.05 level.

Crop Yield

Tests of Between-Subjects Effects

Dependent Variable: Crop Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	1589166.667[a]	3	529722.222	5.433	.025
Intercept	7520833.333	1	7520833.333	77.137	.000
Tillage Type	1589166.667	3	529722.222	5.433	.025
Error	780000.000	8	97500.000		
Total	9890000.000	12			
Corrected Total	2369166.667	11			

a. R Squared = .671 (Adjusted R Squared = .547)

Multiple Comparisons

Dependent Variable: Crop Yield
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
	Traditional	266.6667	254.95098	.729	-549.7761	1083.1094
No Till	Plough/Harrow	-666.6667	254.95098	.114	-1483.1094	149.7761
	Plough/Harrow/Ridge	166.6667	254.95098	.911	-649.7761	983.1094
	No Till	-266.6667	254.95098	.729	-1083.1094	549.7761
Traditional	Plough/Harrow	-933.3333*	254.95098	.026	-1749.7761	-116.8906
	Plough/Harrow/Ridge	-100.0000	254.95098	.978	-916.4428	716.4428
	No Till	666.6667	254.95098	.114	-149.7761	1483.1094
Plough/Harrow	Traditional	933.3333*	254.95098	.026	116.8906	1749.7761
	Plough/Harrow/Ridge	833.3333*	254.95098	.046	16.8906	1649.7761
	No Till	-166.6667	254.95098	.911	-983.1094	649.7761
Plough/Harrow/Ridge	Traditional	100.0000	254.95098	.978	-716.4428	916.4428
	Plough/Harrow	-833.3333*	254.95098	.046	-1649.7761	-16.8906

Based on observed means.
The error term is Mean Square(Error) = 97500.000.
*. The mean difference is significant at the 0.05 level.

ANOVA FOR CROP YIELD PARAMETERS FOR 2016 PLANTING SEASON

NCAM 2016

Tests of Between-Subjects Effects

Dependent Variable: Crop Yield

Source	Type III Sum of Squares	df	Mean Square	F	Sig.
Corrected Model	71466.667[a]	3	23822.222	.961	.457
Intercept	4514133.333	1	4514133.333	182.022	.000
Tillage Type	71466.667	3	23822.222	.961	.457
Error	198400.000	8	24800.000		
Total	4784000.000	12			
Corrected Total	269866.667	11			

a. R Squared = .265 (Adjusted R Squared = .011)

Multiple Comparisons

Dependent Variable: Crop Yield
Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval	
					Lower Bound	Upper Bound
No Till	Traditional	-66.6667	128.58201	.952	-478.4315	345.0982
	Plough/Harrow	-93.3333	128.58201	.884	-505.0982	318.4315
	Plough/Harrow/Ridge	-213.3333	128.58201	.402	-625.0982	198.4315
Traditional	No Till	66.6667	128.58201	.952	-345.0982	478.4315
	Plough/Harrow	-26.6667	128.58201	.997	-438.4315	385.0982
	Plough/Harrow/Ridge	-146.6667	128.58201	.677	-558.4315	265.0982
Plough/Harrow	No Till	93.3333	128.58201	.884	-318.4315	505.0982
	Traditional	26.6667	128.58201	.997	-385.0982	438.4315
	Plough/Harrow/Ridge	-120.0000	128.58201	.789	-531.7649	291.7649
Plough/Harrow/Ridge	No Till	213.3333	128.58201	.402	-198.4315	625.0982
	Traditional	146.6667	128.58201	.677	-265.0982	558.4315
	Plough/Harrow	120.0000	128.58201	.789	-291.7649	531.7649

Based on observed means.
The error term is Mean Square(Error) = 24800.000.

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Plant Height	Between Groups	2.186	3	.729	27.721	.001
	Within Groups	.210	8	.026		
	Total	2.396	11			
NO of Leave	Between Groups	34.250	3	11.417	22.833	.001
	Within Groups	4.000	8	.500		
	Total	38.250	11			
Leave Length	Between Groups	.079	3	.026	3.445	.072
	Within Groups	.061	8	.008		
	Total	.139	11			
Leave Width	Between Groups	5.057	3	1.686	24.079	.000
	Within Groups	.560	8	.070		
	Total	5.617	11			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	Upper Bound
Plant Height	No Till	Traditional	-.95000*	.13237	.000	-1.3739	-.5261
		Plough/Harrow	-1.04000*	.13237	.000	-1.4639	-.6161
		Plough/Harrow/Ridge	-.95667*	.13237	.000	-1.3806	-.5328
	Traditional	No Till	.95000*	.13237	.000	.5261	1.3739
		Plough/Harrow	-.09000	.13237	.902	-.5139	.3339
		Plough/Harrow/Ridge	-.00667	.13237	1.000	-.4306	.4172
	Plough/Harrow	No Till	1.04000*	.13237	.000	.6161	1.4639
		Traditional	.09000	.13237	.902	-.3339	.5139
		Plough/Harrow/Ridge	.08333	.13237	.920	-.3406	.5072
	Plough/Harrow/Ridge	No Till	.95667*	.13237	.000	.5328	1.3806
		Traditional	.00667	.13237	1.000	-.4172	.4306
		Plough/Harrow	-.08333	.13237	.920	-.5072	.3406
NO of Leave	No Till	Traditional	-4.00000*	.57735	.001	-5.8489	-2.1511
		Plough/Harrow	-3.66667*	.57735	.001	-5.5155	-1.8178
		Plough/Harrow/Ridge	-4.00000*	.57735	.001	-5.8489	-2.1511
	Traditional	No Till	4.00000*	.57735	.001	2.1511	5.8489
		Plough/Harrow	.33333	.57735	.936	-1.5155	2.1822
		Plough/Harrow/Ridge	.00000	.57735	1.000	-1.8489	1.8489
	Plough/Harrow	No Till	3.66667*	.57735	.001	1.8178	5.5155
		Traditional	-.33333	.57735	.936	-2.1822	1.5155
		Plough/Harrow/Ridge	-.33333	.57735	.936	-2.1822	1.5155
	Plough/Harrow/Ridge	No Till	4.00000*	.57735	.001	2.1511	5.8489
		Traditional	.00000	.57735	1.000	-1.8489	1.8489
		Plough/Harrow	.33333	.57735	.936	-1.5155	2.1822
Leave Length	No Till	Traditional	-.17667	.07122	.138	-.4047	.0514
		Plough/Harrow	-.08667	.07122	.634	-.3147	.1414
		Plough/Harrow/Ridge	-.20667	.07122	.076	-.4347	.0214
	Traditional	No Till	.17667	.07122	.138	-.0514	.4047
		Plough/Harrow	.09000	.07122	.608	-.1381	.3181
		Plough/Harrow/Ridge	-.03000	.07122	.973	-.2581	.1981
	Plough/Harrow	No Till	.08667	.07122	.634	-.1414	.3147
		Traditional	-.09000	.07122	.608	-.3181	.1381
		Plough/Harrow/Ridge	-.12000	.07122	.390	-.3481	.1081

	Plough/Harrow/Ridge	No Till	.20667	.07122	.076	-.0214	.4347
		Traditional	.03000	.07122	.973	-.1981	.2581
		Plough/Harrow	.12000	.07122	.390	-.1081	.3481
Leave Width	No Till	Traditional	-1.53333*	.21602	.000	-2.2251	-.8415
		Plough/Harrow	-1.16667*	.21602	.003	-1.8585	-.4749
		Plough/Harrow/Ridge	-1.63333*	.21602	.000	-2.3251	-.9415
	Traditional	No Till	1.53333*	.21602	.000	.8415	2.2251
		Plough/Harrow	.36667	.21602	.384	-.3251	1.0585
		Plough/Harrow/Ridge	-.10000	.21602	.965	-.7918	.5918
	Plough/Harrow	No Till	1.16667*	.21602	.003	.4749	1.8585
		Traditional	-.36667	.21602	.384	-1.0585	.3251
		Plough/Harrow/Ridge	-.46667	.21602	.214	-1.1585	.2251
	Plough/Harrow/Ridge	No Till	1.63333*	.21602	.000	.9415	2.3251
		Traditional	.10000	.21602	.965	-.5918	.7918
		Plough/Harrow	.46667	.21602	.214	-.2251	1.1585

*. The mean difference is significant at the 0.05 level.

UTRF 2016

Tests of Between-Subjects Effects

Dependent Variable: Crop Yield

Source	Type III Sum of Squares	Df	Mean Square	F	Sig.
Corrected Model	684266.667[a]	3	228088.889	3.801	.058
Intercept	9434133.333	1	9434133.333	157.236	.000
Tillage Type	684266.667	3	228088.889	3.801	.058
Error	480000.000	8	60000.000		
Total	10598400.000	12			
Corrected Total	1164266.667	11			

a. R Squared = .588 (Adjusted R Squared = .433)

Multiple Comparisons

Dependent Variable: Crop Yield

Tukey HSD

(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
No Till	Traditional	-666.6667*	200.00000	.042	-1307.1371	-26.1963
	Plough/Harrow	-293.3333	200.00000	.497	-933.8037	347.1371
	Plough/Harrow/Ridge	-240.0000	200.00000	.644	-880.4704	400.4704
Traditional	No Till	666.6667*	200.00000	.042	26.1963	1307.1371
	Plough/Harrow	373.3333	200.00000	.313	-267.1371	1013.8037
	Plough/Harrow/Ridge	426.6667	200.00000	.222	-213.8037	1067.1371
Plough/Harrow	No Till	293.3333	200.00000	.497	-347.1371	933.8037
	Traditional	-373.3333	200.00000	.313	-1013.8037	267.1371
	Plough/Harrow/Ridge	53.3333	200.00000	.993	-587.1371	693.8037
Plough/Harrow/Ridge	No Till	240.0000	200.00000	.644	-400.4704	880.4704
	Traditional	-426.6667	200.00000	.222	-1067.1371	213.8037
	Plough/Harrow	-53.3333	200.00000	.993	-693.8037	587.1371

Based on observed means.

The error term is Mean Square(Error) = 60000.000.

*. The mean difference is significant at the 0.05 level.

ANOVA

		Sum of Squares	Df	Mean Square	F	Sig.
Plant Height	Between Groups	.310	3	.103	.731	.562
	Within Groups	1.132	8	.141		
	Total	1.442	11			
NO of Leave	Between Groups	10.250	3	3.417	2.158	.171
	Within Groups	12.667	8	1.583		
	Total	22.917	11			
Leave Length	Between Groups	.021	3	.007	.744	.555
	Within Groups	.074	8	.009		
	Total	.095	11			
Leave Width	Between Groups	1.947	3	.649	2.704	.116
	Within Groups	1.920	8	.240		
	Total	3.867	11			

Multiple Comparisons

Tukey HSD

Dependent Variable	(I) Tillage Type	(J) Tillage Type	Mean Difference (I-J)	Std. Error	Sig.	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
Plant Height	No Till	Traditional	-.14333	.30708	.964	-1.1267	.8401
		Plough/Harrow	.28333	.30708	.794	-.7001	1.2667
		Plough/Harrow/Ridge	.15667	.30708	.954	-.8267	1.1401
	Traditional	No Till	.14333	.30708	.964	-.8401	1.1267
		Plough/Harrow	.42667	.30708	.539	-.5567	1.4101
		Plough/Harrow/Ridge	.30000	.30708	.766	-.6834	1.2834
	Plough/Harrow	No Till	-.28333	.30708	.794	-1.2667	.7001
		Traditional	-.42667	.30708	.539	-1.4101	.5567
		Plough/Harrow/Ridge	-.12667	.30708	.975	-1.1101	.8567
	Plough/Harrow/Ridge	No Till	-.15667	.30708	.954	-1.1401	.8267
		Traditional	-.30000	.30708	.766	-1.2834	.6834
		Plough/Harrow	.12667	.30708	.975	-.8567	1.1101
NO of Leave	No Till	Traditional	2.33333	1.02740	.184	-.9568	5.6234
		Plough/Harrow	2.00000	1.02740	.283	-1.2901	5.2901
		Plough/Harrow/Ridge	2.00000	1.02740	.283	-1.2901	5.2901
	Traditional	No Till	-2.33333	1.02740	.184	-5.6234	.9568
		Plough/Harrow	-.33333	1.02740	.987	-3.6234	2.9568
		Plough/Harrow/Ridge	-.33333	1.02740	.987	-3.6234	2.9568
	Plough/Harrow	No Till	-2.00000	1.02740	.283	-5.2901	1.2901
		Traditional	.33333	1.02740	.987	-2.9568	3.6234
		Plough/Harrow/Ridge	.00000	1.02740	1.000	-3.2901	3.2901
	Plough/Harrow/Ridge	No Till	-2.00000	1.02740	.283	-5.2901	1.2901
		Traditional	.33333	1.02740	.987	-2.9568	3.6234
		Plough/Harrow	.00000	1.02740	1.000	-3.2901	3.2901
Leave Length	No Till	Traditional	-.07333	.07863	.789	-.3251	.1785
		Plough/Harrow	.01667	.07863	.996	-.2351	.2685
		Plough/Harrow/Ridge	.03667	.07863	.964	-.2151	.2885
	Traditional	No Till	.07333	.07863	.789	-.1785	.3251
		Plough/Harrow	.09000	.07863	.675	-.1618	.3418
		Plough/Harrow/Ridge	.11000	.07863	.533	-.1418	.3618
	Plough/Harrow	No Till	-.01667	.07863	.996	-.2685	.2351

		Traditional	-.09000	.07863	.675	-.3418	.1618
		Plough/Harrow/Ridge	.02000	.07863	.994	-.2318	.2718
	Plough/Harrow/Ridge	No Till	-.03667	.07863	.964	-.2885	.2151
		Traditional	-.11000	.07863	.533	-.3618	.1418
		Plough/Harrow	-.02000	.07863	.994	-.2718	.2318
Leave Width	No Till	Traditional	-.73333	.40000	.326	-2.0143	.5476
		Plough/Harrow	-.33333	.40000	.837	-1.6143	.9476
		Plough/Harrow/Ridge	-1.06667	.40000	.106	-2.3476	.2143
	Traditional	No Till	.73333	.40000	.326	-.5476	2.0143
		Plough/Harrow	.40000	.40000	.754	-.8809	1.6809
		Plough/Harrow/Ridge	-.33333	.40000	.837	-1.6143	.9476
	Plough/Harrow	No Till	.33333	.40000	.837	-.9476	1.6143
		Traditional	-.40000	.40000	.754	-1.6809	.8809
		Plough/Harrow/Ridge	-.73333	.40000	.326	-2.0143	.5476
	Plough/Harrow/Ridge	No Till	1.06667	.40000	.106	-.2143	2.3476
		Traditional	.33333	.40000	.837	-.9476	1.6143
		Plough/Harrow	.73333	.40000	.326	-.5476	2.0143

APPENDIX IV

The SWAT modelled surface runoff (SURQ), soil loss (USLE), Evapotranspiration (ET) as well as sediment yield (SED) in the areas while also modelling the amount of Organic Nitrogen (ORGN) and NO3 as well as Biomass (BIOM) of the study areas.

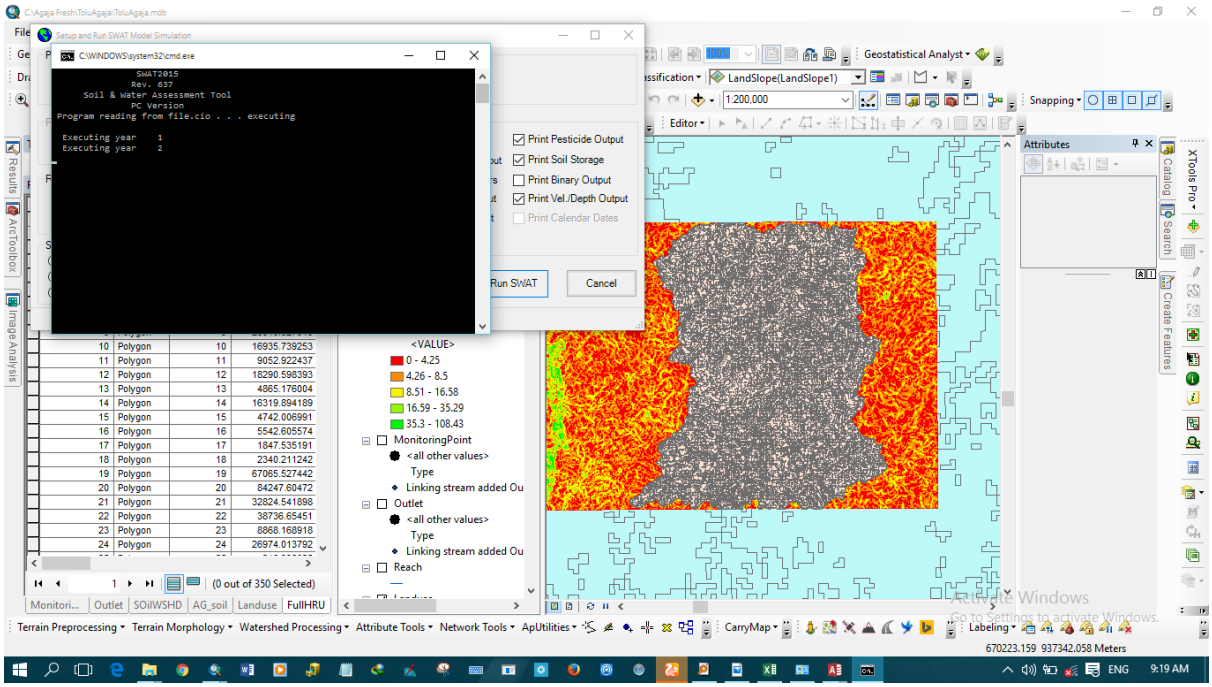
Name	HRU	SUB	Tillage method	PREC mm	SURQGEN mm	SED th	SURQ mm	USLE_LS	GWQ mm	ET mm
UTRF	44	18	PH	1314.21	372.91	5.31	372.91	1.05	171.19	724.79
UTRF	45	18	NT and T	1314.21	371.53	10.54	371.53	2.24	174.45	723.6
UTRF	46	18	PHR	1314.21	374.42	1.81	374.42	0.44	167.86	725.78
NCAM	103	42	NT and T	1113.86	281.94	10.46	281.94	2.31	96.32	696.6
NCAM	104	42	PH	1113.86	284.87	1.57	284.86	0.38	90.41	698.1
NCAM	105	42	PHR	1113.86	283.39	4.79	283.39	1	93.29	697.47

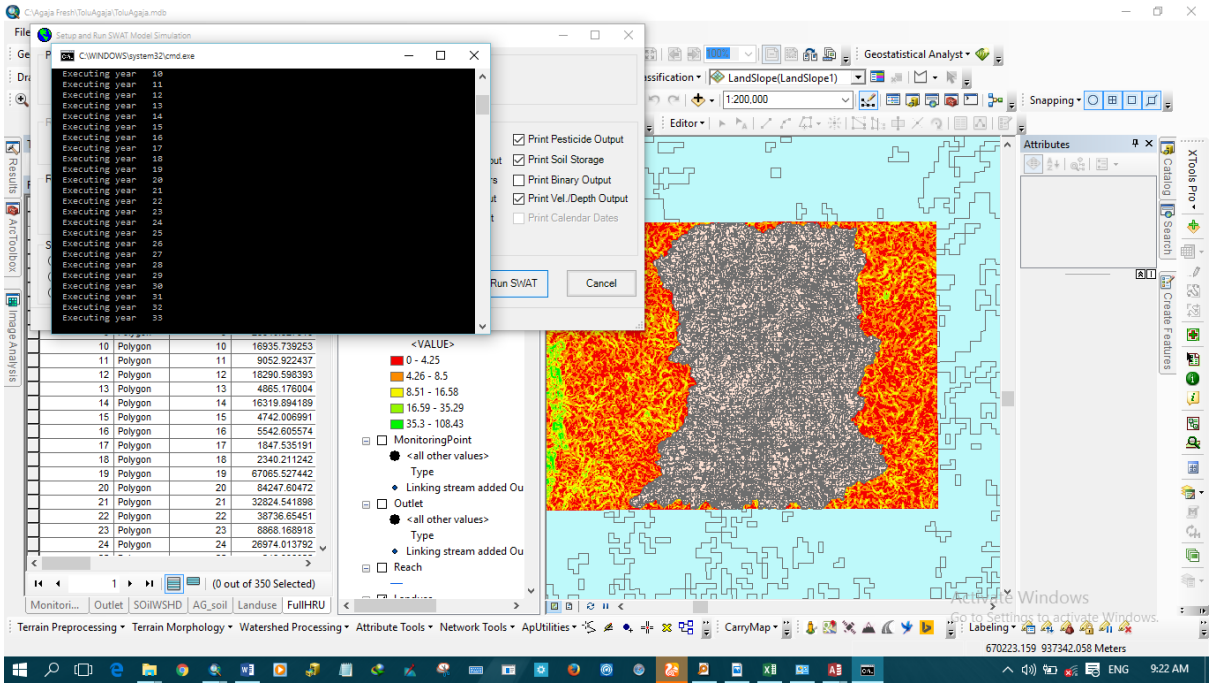
Source: Author's fieldwork (2016)

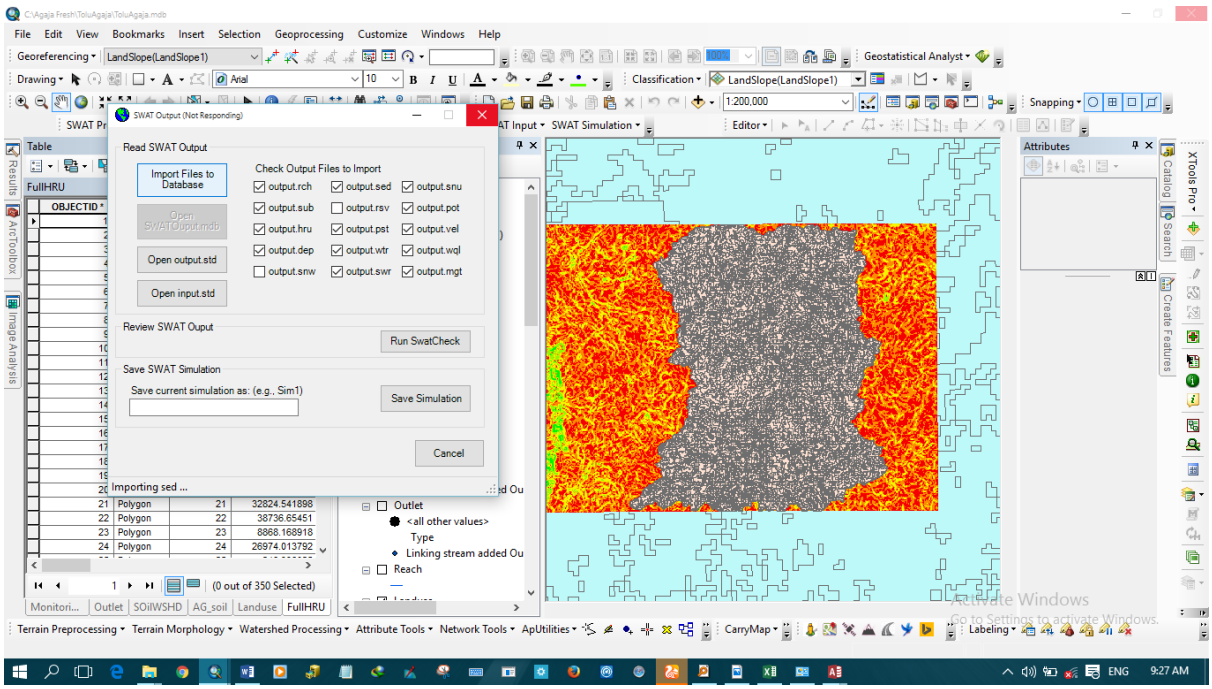
The table below shows the result of the analysis on some elements (Nitrogen, Organic Nitrogen) Biomass and Yield of the study areas.

Name	HRU	SUB	Tillage method	NO3 kgh	ORGN kgh	BIOM th	YLD th
UTRF	44	18	PH	4.41	50.94	13.54	4.31
UTRF	45	18	NT and T	5.15	62.62	13.57	4.32
UTRF	46	18	PHR	3.68	29.83	13.56	4.32
NCAM	103	42	NT and T	4.42	60.79	12.82	4.03
NCAM	104	42	PH	3.04	27.41	12.82	4.03
NCAM	105	42	PHR	3.89	48.38	12.82	4.03

Source: Author's fieldwork (2016)


SWAT2015
Rev. 637
Soil & Water Assessment Tool
PC Version
Program reading from file.cio . . . executing
Executing year 1
Executing year 2
Print Pesticide Output
Print Soil Storage
Print Binary Output
Print Vel./Depth Output
Print Calendar Dates
Run SWAT
Cancel
(0 out of 350 Selected)
Monitori...
Outlet
SOilWSHD
AG_soil
Landuse
FullHRU
Terrain Preprocessing
Terrain Morphology
Watershed Processing
Attribute Tools
Network Tools
ApUtilities
CarryMap
Labeling
670223.159 937342.058 Meters
ENG
9:19 AM


Executing year 10
Executing year 11
Executing year 12
Executing year 13
Executing year 14
Executing year 15
Executing year 16
Executing year 17
Executing year 18
Executing year 19
Executing year 20
Executing year 21
Executing year 22
Executing year 23
Executing year 24
Executing year 25
Executing year 26
Executing year 27
Executing year 28
Executing year 29
Executing year 30
Executing year 31
Executing year 32
Executing year 33
Print Pesticide Output
Print Soil Storage
Print Binary Output
Print Vel./Depth Output
Print Calendar Dates
Run SWAT
Cancel
(0 out of 350 Selected)
Monitori...
Outlet
SOilWSHD
AG_soil
Landuse
FullHRU
Terrain Preprocessing
Terrain Morphology
Watershed Processing
Attribute Tools
Network Tools
ApUtilities
CarryMap
Labeling
670223.159 937342.058 Meters
ENG
9:22 AM



Sediments	2013	2014	2015	Grand Total
1	496.102835	568.8174801	857.14	1922.060315
2	658.3890003	828.8607002	2193.81	3681.0597
3	2076.083522	2438.193601	5525.95	10040.22712
4	445.3624003	560.0789802	1485.33	2490.771381
5	504.150512	737.9721601	1054.582	2296.704672
6	813.1859004	1024.3126	2728.23	4565.728501
7	215.2363001	390.4730001	582.6551	1188.3644
8	1518.281324	1746.170403	3795.46	7059.911727
9	550.9398004	695.1509303	1860.58	3106.670731
10	641.8695003	813.3999002	2128.45	3583.7194
11	632.1426371	769.1277515	1811.65	3212.920389
12	417.0527841	478.9224403	821.13	1717.105224
13	1360.126109	1732.21629	3264.17	6356.512399
14	535.1547004	674.0788803	1799.35	3008.583581
15	859.6199004	1084.5231	2877.52	4821.663001
16	1295.525021	1581.50237	2920.53	5797.557391
17	545.2690921	637.7693622	1200.722	2383.760454
18	1186.145421	1234.8768	2261.61	4682.632221
19	561.2232004	707.1436703	1886.6	3154.966871
20	2.275334297	3.371820524	10.5381	16.18525482
21	1570.3783	1987.1867	5236	8793.565001
22	1555.369868	1862.0056	4135.57	7552.945468
23	451.0986971	513.2700914	827.449	1791.817788
24	567.5181004	714.9427603	1912.28	3194.740861

25	1933.828718	2253.884	5655	9842.712718
26	0.024384543	0.036502662	0.1148292	0.175716405
27	597.7211003	753.3439002	1986.99	3338.055
28	586.8563811	706.5560103	1551.64	2845.052391
29	2807.8116	3555.9269	9336.77	15700.5085
30	697.8492007	552.4830005	2197.6274	3447.959601
31	1169.8613	989.7500003	3777.1697	5936.781001
32	1144.4321	1453.5338	3789.29	6387.2559
33	826.3219004	708.1600003	2683.3473	4217.829201
34	871.8695004	755.3430003	2842.0687	4469.281201
35	1163.1906	962.3590003	3724.2768	5849.826401
36	44.56402723	28.19638028	98.58864	171.3490475
37	347.8687004	293.7370003	1122.8823	1764.488001
38	997.4213007	789.9380005	3140.8206	4928.179901
39	880.6632004	730.8600003	2819.7978	4431.321001
40	224.7530775	123.5460013	379.36104	727.6601188
41	195.1408476	113.7956003	346.28327	655.2197179
42	1285.575218	949.8103189	3641.6372	5877.022737
43	807.2359007	628.6350005	2525.6887	3961.559601
44	117.2929857	76.22690027	247.45516	440.975046
45	333.4119103	232.6174007	687.79037	1253.819681
46	3.920600744	1.23428058	13.68764	18.84252132
47	571.6541007	453.3900005	1802.7531	2827.797201
48	724.8133703	566.1337003	2048.655	3339.602071
49	798.784218	587.453407	2224.7544	3610.992025
Grand Total	**38591.36651**	**42051.3175**	**111821.7561**	**192464.4402**