ASSESSMENT OF SOIL DEGRADATION IN ZARIA AREA, KADUNA STATE, NIGERIA.

BY

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NIGERIA.

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DECLARATION

I declare that the work in this dissertation entitled ‘ assessment of soil degradation in Zaria Area, Kaduna state, Nigeria’ has been carried out by me in the Department of Geography. The information derived from the literature has been duly acknowledged in the text and a list of references provided. No part of this dissertation was previously presented for another degree or diploma at this or any other institution.

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CERTIFICATION

This dissertation entitled 'ASSESSMENT OF SOIL DEGRADATION IN ZARIA AREA, KADUNA STATE, NIGERIA' by Zuni AMINU meets the regulations governing the award of the degree of PhD Geography of the Ahmadu Bello University, and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

I dedicate this work to the Almighty Allah, my beloved parents, brothers and sister.

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TABLE OF CONTENTS

Page

Title page..... i

Approval Page..... ii

Certification..... iii

Dedication..... iv

Acknowledgement..... v

Table of Contents..... vi

List of Tables..... x

List of Figures..... xii

List of Appendices..... xiv

Abstract..... xv

1.0 CHAPTER ONE: INTRODUCTION..... 1

1.1 Background 1

1.2 Statement of Research Problem..... 4

1.3 Aim and Objectives..... 6

1.4 Research Hypothesis..... 7

1.5 Scope of the Study..... 7

1.6 Justification..... 8

2.0 CHAPTERTWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW..... 9

2.1 The Concepts of Soil Quality, Health and Degradation..... 9

2.2 Soil Degradation..... 10

2.2.1 Types of soil degradation..... 13

2.2.2 Causes of soil degradation..... 14

2.2.3 Effects of soil degradation..... 17

2.3 Assessment of Soil Degradation..... 20

2.3.1 Expert opinions..... 20

2.3.2 Use of models..... 21

2.3.3 Use of remote sensing and GIS..... 22

2.3.4 Measurements of soil loss in the field..... 23

2.3.5 Soil Survey..... 24

2.3.6 Land user approach..... 24

2.4 Global Assessment of Soil Degradation..... 26

2.4.1 Summary of soil degradation assessment in Nigeria..... 29

3.0 CHAPTER THREE: THE STUDY AREA..... 33

3.1 Location and Historical Background of Zaria..... 33

3.2 The Physical Environment..... 33

3.2.1 Climate..... 33

3.2.2 Geology..... 38

3.2.3 Geomorphology, relief and drainage..... 40

3.2.4 Soils..... 45

3.3 Plant and Animal Species..... 48

3.3.1 Ecosystem and vegetation community..... 48

3.4 Population and Settlement 51

3.5 Land use..... 52

3.6 Socio-economic and Cultural Conditions..... 56

3.7 Environmental Problems..... 56

4.0 CHAPTER FOUR: MATERIALS AND METHODS..... 60

4.1 Data Required and Sources..... 60

4.2 Research Design and Methodology..... 60

4.2.1 Reconnaissance survey..... 60

4.2.2 Assessment of land use and land cover..... 61

4.2.2.1 Analysis of remote sensing data..... 61

4.2.2.2 Land use classification scheme..... 64

4.2.3 Soil degradation and farmers survey..... 70

4.2.3.1 Selection of study sites..... 70

4.2.3.2 Soil degradation survey..... 70

4.2.3.3 Farmers survey..... 72

4.3 Laboratory Analysis of Samples..... 73

4.3.1 Particle size distribution..... 74

4.3.2 Bulk density and moisture content..... 75

4.3.3 Soil pH (1:2.5)..... 76

4.3.4 Organic carbon..... 76

4.3.5 Cation exchange capacity..... 77

4.3.6 Exchangeable bases..... 78

4.3.7 Exchange acidity..... 79

4.4 Data Analysis..... 79

5.0 CHAPTER FIVE: RESULTS AND DISCUSSION..... 81

6.0 CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATIONS..... 148

REFERENCES..... 157

APPENDICES..... 169

LIST OF TABLES

4.1 Data Required for the Study and Sources..... 60

4.2 Characteristics of Satellite Imageries Used for the Study..... 61

4.3 Confusion Matrix for SAT-1 2009 Classified LULC Map..... 63

4.4 Land Use Classification Scheme Adopted for the Study..... 65

5.1 Spatial Extent and Percentage Coverage of Land Use/Cover from 1990-2009..... 81

5.2 Land Use/Land Cover Change Detection Between 1999 and 2009..... 87

5.3 Rate of Change in Land Use/Land Cover between 1990 and 2009..... 91

5.4 Forms of Soil Degradation in Communities..... 96

5.5 Variations of soil physical and chemical properties over different land uses..... 99

5.6 Result of Student t-test Between Pairs of Land Uses..... 100

5.7 Soil Quality Classification Scheme for Tropical Soils..... 105

5.8 Demographic and Socio-economic Characteristics of Respondents..... 109

5.9 Farmers' Awareness of Causes of Soil Degradation..... 111

5.10 Awareness of Consequences of Soil Degradation..... 112

5.11 Farmers' Awareness of Soil Management Practices..... 116

5.12 Farmers' Identification of Soil Management Practices and Extent of Use..... 119

5.13(a) Respondents' Attitude Towards Agricultural Land Management Practices..... 122

5.13(b) Farmers' Attitude Towards Agricultural Land Management Practices..... 124

5.14 Relationship Between Respondents' Age and Adaptation Strategy..... 126

5.15 Relationship Between Respondents' Household Size and Actual Adaptation..... 128

5.16 Relationship Between Education and Actual Adaptation Strategy..... 130

5.17 Relationship Between Income and Actual Adaptation Strategy..... 131

5.18 Relationship Between Land Ownership and Actual Adaptation Strategy..... 133

5.19 Relationship Between Land Ownership and Actual Adaptation Strategy..... 134

5.20 Soil Degradation Indicators and Perceived Causes for Their Development..... 143

5.21 Farmers' Classification of Soil Degradation Indicators..... 145

LIST OF FIGURES

2.1 Result – Effects of Soil Degradation..... 12

3.1 Location of the Study Area..... 34

3.2 Geology of the Study Area..... 39

3.3 Relief of the Study Area..... 41

3.4 Drainage of the Zaria Area..... 45

4.1 Methodology Workflow Employed in the Study..... 66

4.2 Land Use/Land Cover Imagery of the Study Area, TM 1990..... 67

4.3 Land Use/Land Cover Imagery of the Study Area, ETM 1999..... 68

4.4 Land Use/Land Cover Imagery of the Study Area, Nigeria SAT-1, 2009..... 69

5.1 Classified TM Image of Study Area..... 82

5.2 Classified ETM 1999 Image of the Study Area..... 83

5.3 Classified 2009 Nigeria SAT-1 Image of the Study Area..... 84

5.4 TM- ETM Cross Map of the Study Area..... 86

5.5 ETM- SAT-1 Crossed Map of the Study Area..... 86

5.6 Trend of Change in Respective Land Use/Land Cover Types in the Study Area..... 90

5.7 Farmers' Information Sources on Soil Management Practices..... 118

5.8 Farmers' Perceived Adaptation Strategies..... 136

5.9 Farmers' Actual Adaptation Strategies..... 137

5.10 Barriers to Adoption of Land/Soil Conservation Techniques..... 139

LIST OF PLATES

I A Dome-shaped Inselberg in Danmagaji, Zaria..... 42

II *Magnifera indica* Plantation in Saye and *Delonix regia* Plantation in Dambo, Zaria..... 50

III Scrubland Vegetation in Biye..... 50

IV (A) Examples of Vegetables Found in Zaria Area..... 53

IV (B) Examples of Vegetables Found in Zaria Area..... 54

V Cultivated Land Use in Dambo..... 58

VI Fadama Land Use in Kakeyi..... 58

VII Typical Badlands Found in Dakaci and Hunkuyi..... 59

VIII Forest Plantation in Dakaci Replaced by Cultivated Lands..... 95

IX Presence of Weeds and Gravelly surfaces..... 114

X Focus Group Discussion With Farmers in Saye and One-on-One Interview in Dambo... 147

APPENDICES

Appendix I..... 169

Appendix II..... 170

Appendix III..... 171

ABSTRACT

This study aimed at an assessment of soil degradation in the Zaria area. Land degradation was assessed through a time- series analysis of Landsat Thematic Mapper 1990, Enhanced Thematic Mapper+, 1999 and NigeriaSat-1 2009 satellite imageries of the study area. The imageries were classified into seven different land use/cover types using the Maximum Likelihood Classifier. The second part of the research entailed field assessment of the physico–chemical status of the surface soils of the area with a view to demonstrating its degradation. Twenty five composite soil samples comprising of four sub-samples were taken from five different land uses (plantation, badland, fadama, cultivated and scrubland land uses) and analysed for key soil physico-chemical properties, including particle size distribution, bulk density, porosity, moisture content, organic matter content, exchangeable cations, CEC and pH. The third part of this research involved a farm-level survey of farmers perception of soil degradation problem and coping strategies through the use of structured questionnaires and focus group discussions. The analysis of variance (F-ratio) was used to test for variations in the selected soil properties over the five different land uses while the students t-test was used to test for significant association between pairs of land uses. Chi square analysis was used to test for significant changes in landuse/ land cover over the period under study, significant associations between farmers' socio-demographic characteristics and coping strategies adopted. In addition, a Likert scale test was used to analyse respondents' attitudes to soil degradation and perceptions of the severity of soil degradation. The result of LULC showed that land use changes/ exchanges are occurring at rates not lower than 1.6% per annum. The results also show an upward trend for built up area. Result of Chi-square analysis carried out to determine the level of significant changes in the areal coverage of the different land use and land cover types for the periods studied showed statistical significance at $p< 0.01$, with a calculated X^2 value of 612.09 and a table value of 26.2.

The results of soil physic-chemical analysis show soils in the study area are generally sandy, have high bulk density and medium to low mean porosity values. The mean moisture content range between 14.88-25.02% , with the highest value in Fadama land use and plantation (17.6%) and the lowest moisture contents are found within the degraded land (16.8%) and cultivated land (14.9%). The low CEC values over cultivated and badlands show that soils under these land uses have been degraded. However, the range of the pH values over the different land uses show that the soils are slightly acidic. The differences in the soil organic matter content amongst the different landuses, by analysis of variance are statistically significant at the 0.01 level. The value is lowest over the badland ($0.25g/kg^{-1}$) and highest over the plantation ($1.77g/kg^{-1}$). The result of soil quality ratings shows that soils in the study area have been degraded. Similarly, results of soil management survey show respondents between the ages of 20 to 60 are actively engaged in farming and family sizes are large. Major soil management practices are mixed cropping and crop rotation. Results show statistically significant association between respondents' level of education, income, landownership and actual coping strategies adopted. Farmers' most commonly observed soil degradation indicators are erosion-based and include rills, stoniness , loose soils, sheetwash, infestation by parasitic angiosperms, root exposure and red soil. The findings show that both the scientific and farmers views agree that soil degradation is pervasive in the study area but unlike the scientific assessment of degradation, the most commonly recognised soil degradation indicators for farmers are plant/production related.

CHAPTER ONE: INTRODUCTION

1. 1 Background of the Study

Soil is one of the world's greatest resource. It has been described as a natural body of animal, mineral and organic constituents, differentiated into horizons of variable depth which differ in morphology and physical, chemical and biological characteristics (Joffe, 1948). It is an important natural resource that either directly or indirectly supports most of the planet's life. A major function of soil on man is that it supports food supply and food security. Soils affect food security directly because it supports agriculture. Agriculture produces the food we eat and provides the primary source of livelihood for 36% of the world's total workforce (ILO, 2007). Therefore, threat to soil is threat to food security and economies which rely on agriculture. Food security is directly linked to the ability of the land to support populations (Scherr and Yadav, 1996).

Global concern about soil degradation has grown because of its threat to agriculture and food security. Low agricultural production, food insecurity, low income of the rural population and poverty are consequences of soil degradation (Junge, Deji, Abaidoo, Chikoye and Stahr, 2008). Agcaoili, Perez and Rosegrant (1995) estimated that increasing degradation would lead to as much as 10% decline in productivity in the developing countries and could lead to worsening malnutrition in the developing world.

Some of the challenges posed by soil degradation to food security in the developing countries are; long-term investment and appropriate technology development, dampened economic growth effects of lower farm incomes in irrigated, high quality rain fed and densely populated marginal lands due to lost soil productivity and threat to nutrition and deaths from malnutrition

and diseases associated with poor diets (Eswaran, Almaraz, Van den Berg and Reich, 1997; Swift and Shepherd, 2007).

Soil degradation is a loss of soil function. It is a serious and most common form of land degradation because the soil is the basis for production (Blum, 1998). It encompasses physical, chemical and biological deterioration. Examples of soil degradation are loss of organic matter, decline in soil fertility, decline in structural condition, erosion, adverse changes in salinity, acidity or alkalinity, and the effects of toxic chemicals, pollutants or excessive flooding. Soil degradation is the decline in soil quality caused by its improper use, usually for agricultural, pastoral, industrial or urban purposes. A soil is said to be degraded if the loss of basic qualities which manifest in reduced yields, is permanent (Mbagwu, 2003). Soil degradation occurs globally but its negative impacts are most felt in regions which depend solely on agriculture for its income (Swift and Shepherd, 2007). Increased pressure on land as a result of increasing world population has led to increased degradation of world soils. Soil degradation may be exacerbated by climate change.

Soil erosion by water is the commonest way in which soils are degraded and many forms of soil loss are most easily seen during or shortly after periods of heavy rains (Stocking and Murnaghan, 2000). Soil erosion associated with poor land use and management practices is one of the main factors causing degradation (Gessess, Klik and Hurni, 2009). Bridges and Van Baren (1997) observed that the presence of erosion is an indication of an underlying problem. They observed that though soil erosion is a cause and effect of soil degradation, it is easier to treat the cause than the effect. Any negative change in soil properties may lead to decline in soil quality and its ability to resist degradation. Soil degradation processes can occur without human interference but accelerated rates of degradation are often influenced by man's intervention in natural

processes. Over grazing, over cultivation, water logging and deforestation are some of the main causes of soil degradation. Soil degradation is defined by reference to productivity. Studies show that farmers' perception of declining soil quality are tied to agricultural productivity (Bridges and Van Baren, 1997). Studies also show that soil erosion reduces soil quality (Barrow, 1991; Sanchez, Recalata, Antolin, Carbo' and Depaz, 2004). Doran and Parkin (1994) define soil quality as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health and promote plant and animal health. Sensitivity and resilience are measures of the vulnerability of soils (Doran and Parkin, 1994; Stocking and Murnaghan, 2000). This vulnerability is affected by factors such as topography, soil properties and human influence (Stocking and Murnaghan, 2000). Soil resilience is defined as the ability of a soil to restore its living systems after disturbance while sensitivity is the degree to which a soil undergoes change due to natural forces, human intervention or a combination of both (Bridges and Van Baren,1997; Stocking and Murnaghan, 2000).

Soil compaction is a major form of soil degradation. It is estimated that soil compaction has resulted in reduction of yields by 20% to 50% in Europe and North America and 40% to 90% in West Africa (Oldeman, Hakkeling and Somboek,1991). Nutrient depletion is another form of soil degradation with serious economic implications for many regions of the world. Experts estimate that soil erosion in Zimbabwe result in an annual loss of P and N (totaling $1.5 billion), while in Asia annual economic loss is estimated at $600 million. In Nigeria, Lal (1995) observed dramatic reductions in maize yields ranging between 30-100% after simulating the effects of soil erosion by artificially removing topsoil on plots. In the same study, yields of cassava also reduced by 14-31% and observations showed that fertilizer amendments did not appear capable of restoring the yields where 10-20cm of top soil had been removed. Egboka and

Okpoko (1984) observed that though the development of gullies in Angulu-Nanka region of Anambra state had been attributed to the influence of human activities on geomorphological processes, observations also showed that the hydrogeological and geotechnical properties of the complex aquifer system underlying the affected areas were also responsible for the degradation of soils in the region. Similarly, Junge (2010) observed that land use intensification led to increased soil erosion and depletion of soil organic matter and nutrients which invariably led to decrease in arable and grazing land, crop production, diary produce and dwindling income for local farmers. Some implications of land scarcity include rural-urban migration, conflicts between land users over scarce productive lands, food insecurity and poverty.

1.2 Statement of the Research Problem

Due to rapid population growth, land use is being intensified the world over with severe consequences on land resources. In Nigeria where the population dramatically rose from 116million in 1991 to 140million in 2006 (Federal Republic of Nigeria, 2007) human-induced soil degradation has intensified, due mainly to expansion of agricultural lands into marginal areas. In the developing countries, such as Nigeria, poor rural households are often found in the marginal agricultural lands where land productivity and income are stagnant or declining. There is, however, very limited data on the processes and impact of soil degradation in many regions of the world especially in Africa where many economies and livelihood depend on agriculture.

In Zaria, various studies have been carried out to assess soil degradation. Kowal (1970) used experimental plots to assess soil loss in a sub basin in Samaru. Odunze (2002) estimated the magnitude and timing of soil loss from cultivated lands under mulch conditions in Zaria and observed that soil erosion is most prominent in cultivated areas during the early part of the rain-

fed crop production season when most soils are bare. Similarly, Yusuf (2006) in his study of the magnitude of suspended sediment production by a tributary of the Kubanni river, observed that poor conservation and land use practices were responsible for extensive rilling and gullying of the Kubanni river in the Zaria area. However, Iguisi (1996) in his study of variations of soil loss in two sub-basins in Zaria, observed that results obtained from the use of experimental plots in assessing soil loss was not representative of the entire basin and could not be used to assess soil loss in the basin.

One other major weakness of estimating soil loss from a field is that the estimates of soil removed from fields are subject to uncertainties about where and when the sediments are derived (Stringer and Reed, 2006). The universal soil loss equation often predicts soil moved on to a field but not from a field and may over state the amount of soil lost to productivity. Stringer and Reed (2006) in assessing land degradation in South Africa, pointed out that using scientific methods such as remote sensing and GIS in measurements of soil properties have limitations. They observed that satellite imageries may guide the sampling of fields but are often not as effective as on-field erosion assessment. Thus, while a number of studies on soil degradation have been carried out in Zaria, most of such studies are centred on use of experimental plots. Consequently, such studies are not representative of the entire basin. Further more, none of these studies have looked at the problem of degradation from the land users point of view. Similarly, the dynamics and extent of soil degradation are changing with time and there is need for participatory approach to soil degradation assessment and providing a holistic and up to date picture of the problem. Few attempts have been made to assess the extent and severity of soil degradation in the study area and tackle the problem at a broader scale. These are the gaps that the study intends to fill.

A careful observation of the landscape of the study area raises the following research questions:

i. What are the implications of changing landuse/cover for soil degradation?

ii. What are the forms of soil degradation in the study area?

iii. What are the extent and severity of soil degradation in the study area?

iv. What are the causes of soil degradation?

v. What are the indicators farmers use to assess soil degradation on their farms?

vi. What are farmers' perceptions of soil degradation?

vii. What are the coping strategies of farmers in response to soil degradation?

1.3 Aim and Objectives of the Study

This study aimed at an assessment of soil degradation in the Zaria area. This was achieved through the following set of objectives:

(i) Identifying the land use and land cover change patterns of the area using satellite imageries for three periods (1990, 1999 and 2009).

(ii) Assessment of the land use and land cover changes in the area from the multi-temporal land use and land cover data with a view to establishing land/soil degradation trend in the study area.

(iii) Identifying the forms of soil degradation in the study area.

(iv) Determination of key soil physico-chemical indicators of soil degradation over major land uses in the area.

(v) Assessment of farmers' awareness of the causes and consequences of soil degradation as well as attitude towards land management practices.

(vi) Examination of the indicators farmers uses to assess soil degradation on their farms and coping strategies to soil degradation.

1.4 Research Hypotheses

Deriving from the objectives of the study are the following hypotheses:

i. There has not been any significant change in land use/land cover in Zaria area in the past 20 years.

ii. There are no significant variations in the severity of soil degradation in the Zaria area.

iii. There are no significant relationships between farmers' socio-demographic characteristics and coping strategies adopted by farmers in response to soil degradation in the Zaria area.

1.5 Scope of the Study

The spatial scope of the study is the Zaria area, centred specifically on Biye, Hunkuyi, Kakeyi, Dambo and Saye. The study entailed the use of remote sensing and GIS for the establishment of changing pattern of land degradation and other land uses between 1990 and 2009. This was followed by field assessment of the nature and severity of soil degradation and physico–chemical status of the soils. The farmers perception of soil degradation problem and coping strategies was sought through the use of structured questionnaires and focus group discussions. In assessing the physico-chemical indicators of soil degradation only the surface horizons of soils were considered. Similarly, the soil properties that were considered are those that are key to degradation process, including particle size distribution, bulk density, porosity, moisture content, organic matter content, exchangeable cations, CEC and pH.

1.6 Justification

The need to understand the dynamics of soil degradation in terms of extent and severity cannot be overemphasized. Knowledge about the dynamics of soil degradation is important in the sustainable use and management of soil resource. Soil resource is essentially non-renewable. Therefore, avoidance of soil loss by improved management and conservation of the natural resources through sustainable use of land resources is important in combating low agricultural production, food insecurity and its associated negative effects on poverty levels and population drift (Tekwa, Belel and Alhassan, 2010).

The challenge of African agriculture is not only to enhance food production to meet the growing needs of its expanding population, but also to maintain the productive capacities of soils into the future. Although land use intensification can increase food production in the 'high potential' areas (Barbier, 1997) evidence also shows that the extension of agricultural activities into marginal lands have tremendous negative effects on the quality of soils (Abubakar,1995; Sherr and Yadav, 1996). Rehabilitation of degraded lands must be comprehensive and in line with the principle of sustainable development. A good way of tackling the menace of soil degradation in Africa in general and Nigeria in particular, is to provide adequate, accurate and relevant information on the forms, extent and severity of soil degradation. This can be achieved by incorporating farmers' knowledge and perceptions of soil degradation phenomena into science based methods (quantification and analysis) of soil degradation assessment. This will provide a realistic and holistic means of assessing soil degradation while taking full advantage of the farmers' experience and dynamic knowledge of their environment (Vigiak, Okoba, Sterk, and Stroosnijder, 2005; Stringer and Reed, 2006).

CHAPTER TWO: CONCEPTUAL FRAMEWORK AND LITERATURE REVIEW

2.1 The Concepts of Soil Quality, Health and Degradation

Soil quality is defined as the capacity of a soil to function within ecosystem boundaries to sustain biological productivity, maintain environmental health, and promote plant and animal health (Doran and Parkin, 1994; Lal, 1997). It is the ability of a soil to function in a sustainable manner. Soil quality indicators include soil texture, bulk density, porosity, soil organic matter content, acidity, among others. The concept of soil quality and soil health are often used interchangeably (Lal, 1997). However soil health defines a soil's capacity to sustain productivity (Lal, 1993) and given in a model as;

Soil health = (Pi × Sc × Rd × P × Ed × Nc × Bd) T

Where

Pi= productivity

Sc= soil structure

Rd = effective rooting depth

P = total porosity and pore size distribution

Ed = charge density

Nc = plant available reserves

Bd = biodiversity

T= time

The basic assessment of soil health and soil quality is necessary to evaluate the degradation status and changing trends following different land use and smallholder management interventions (Lal, 1993). For instance, linking soil health measurements with farmer perceptions

of soil quality can bridge the gap between scientific assessments and farmer perceptions of soil degradation. For example, in Africa studies show that by using local knowledge, smallholder farmers are able to accurately predict soil quality differences of productive and non-productive fields (Okoba and Sterk, 2006; Chizana, Mapfumo, Albrecht, Van Wijk and Giller, 2007; Raji, Malgwi, Berding and Chude, 2011). Soil degradation is defined by reference to productivity (Stocking and Murnagham, 2000). For example, studies show that farmers' perception of declining soil quality are tied to agricultural productivity (Bridges and Van Baren, 1997). Lindert (2000) observed that agricultural productivity is synonymous with soil quality, and in turn, its resilience to change.

Soil resilience describes the soil's ability to restore its living systems after disturbance (Doran and Parkin, 1994). It is that soil property which allows a land to absorb and utilise change, including resistance to shocks such as drought (Stocking and Murnagham, 2000). A Soil's resilience to natural and anthropogenic perturbations depends on its physical, chemical and biological processes (Lal, 2009). Favorable chemical and biological processes enhance resilience only under optimal soil physical properties, e.g., soil structure and tilt, aeration, water retention and transmission. A degraded soil is less resilient than an un-degraded soil. It is less able to recover from shocks, leading to more degradation (Stocking and Murnagham, 2000).

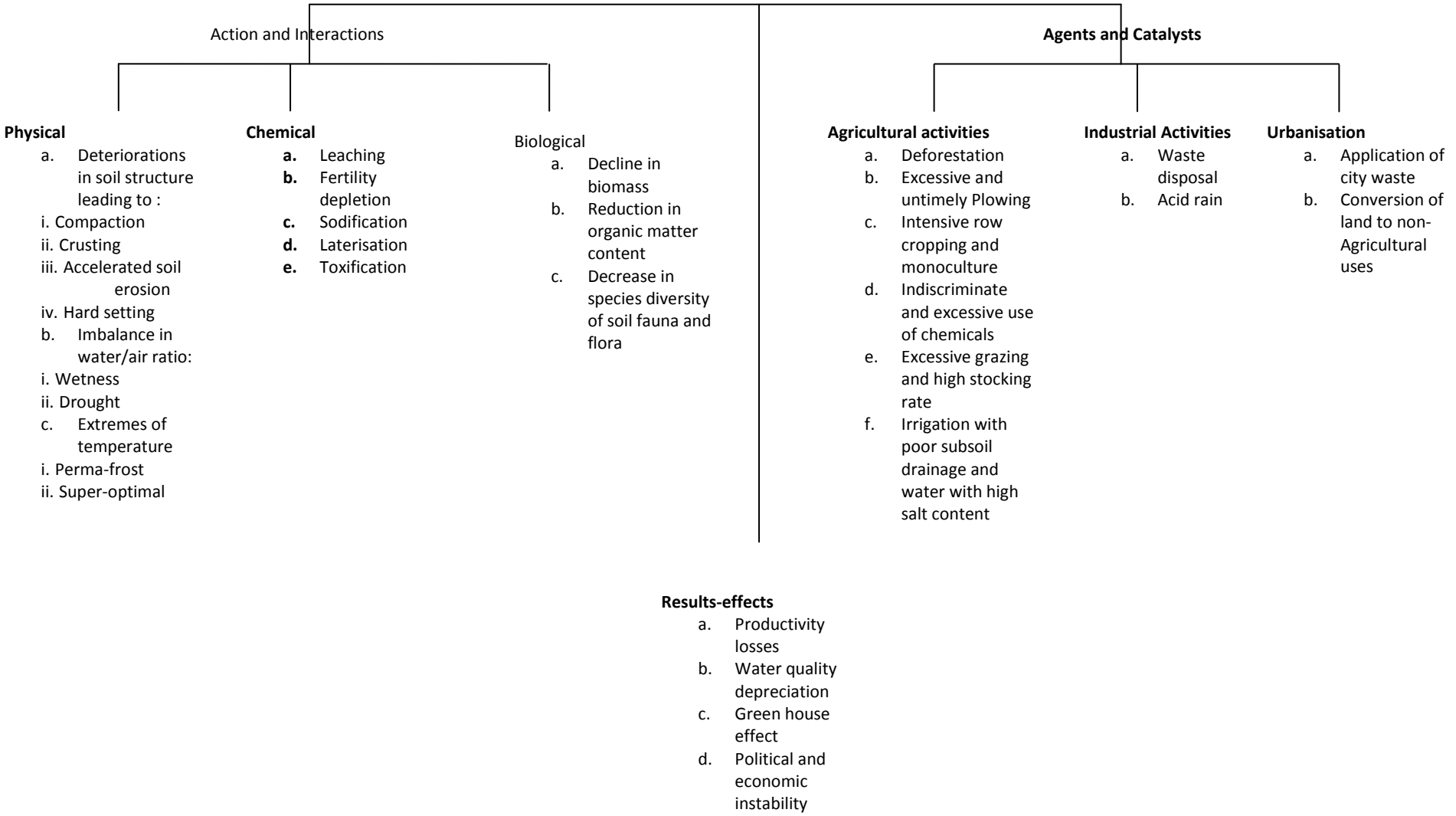
2.2 Soil Degradation

Soil degradation is a major environmental problem threatening agriculture and food security. Oldeman (1991) observed that the effects of soil degradation are critical because humans depend on soils to provide a wide range of essential functions such as providing support to food production and the water cycle, biological regulation of pests and diseases, regulation of major greenhouse gases such as carbon dioxide and methane. Soil supports agriculture, rural

livelihoods and global food security. Agriculture is very essential in ensuring effective food security and it is the principal employer of labour in the poorer countries of the world. Not only is it a source of food for mankind, it also provides a source of livelihood for an estimated 36% of the world's work force (ILO, 2007). As farmlands are degraded, poor rural farmers are further impoverished by failing crop yields, expensive soil management techniques and the adverse effects of climate change. Soil resources can never be taken for granted, given its importance to human survival and dependence of all terrestrial life on it (Lal, 2009). Soil is formed slowly, but can be easily destroyed. Therefore, soil conservation is important for continued support of life.

Soil degradation is a fundamental component of land degradation. Lindert (2000) defines soil degradation as any chemical, physical or biological change in the soil's condition that lowers its agricultural productivity, defined as its contribution to the economic value of yields per unit of land area. Through out history, humans have had impact on soils. Ashaye (1978) and Scherr and Yadav (1996) reported that uncontrolled soil loss had been responsible for the collapse of once flourishing empires in different regions of the world. They observed that several civilizations in the Nile Valley, Mesopotamia and the Mediterranian regions had disappeared due to soil degradation. Bridges and Van Baren (1997) observed that soil degradation in the past was mainly loss of soil through water or wind erosion, induced by cultivation and deforestation, but in recent times problem of chemical and biological degradation are of increasing concern. In the developing world, soil degradation is a symptom of under-development. It results from a combination of social and economic factors, such as poverty and inequitable distribution of the land resources, inappropriate land use systems and farming methods (Scherr and Yadav,1996; Berry, Olson and Campbell, 2003).

Figure 2.1 shows examples of the types, causes and effects of soil degradation.



SOURCE: Lal *et al.,*(1989)

Fig. 2.1: Actions, Interactions, Agents, Catalysts and Result- Effect of Soil Degradation

2.2.1 Types of soil degradation

Soil degradation involves both the physical loss and the reduction in quality of topsoil and nutrient decline. Main types of soil degradation include chemical, physical and biological degradation.

a. Chemical degradation:

This refers to a negative change in the chemical properties of soil. Vargras, Omuto, Alim, Ismail and Njeru (2009) observed that fertility decline and reduced organic matter content of soils in agriculture-productive areas are the most common types of chemical degradation. Similarly, Bridges and Van Baren (1997) observed that two common problems associated with chemical degradation of soils were nutrient depletion and contamination. The natural depletion of soluble elements occurs from soils through the process of leaching by rain water. This form of degradation may also occur whenever soils bear crops or are grazed. Depleting plant nutrients from soils is an obstacle to food production and therefore, a threat to food security (Bridges and VanBaren,1997). Chemical pollution of soils is a direct result of human activity and various studies have shown that it is a major cause of soil degradation. Many agricultural soils have been contaminated by the addition of sewage sludge containing toxic metals such as cadmium or zinc (Haruna, Uzairu and Harrison, 2009).

b. Physical degradation

This refers to a deterioration in physical properties of soil. It includes compaction and hard setting of soil caused by elimination or reduction of structural pores (Karkee, 2004). Compaction of soils has become a problem in recent years as the size and weight of farm machinery has increased (Bridges and Van Baren, 1997). Subsoil compaction may occur below

the plough-layer through frequent use of heavy machinery and this may be difficult and expensive to rectify. Compaction decreases infiltration capacity and porosity and increases bulk density and resistance to plant root penetration (Bridges and Van Baren, 1997). In soil with a reduced infiltration capacity, saturation is reached quickly and surface flow is generated which can cause erosion. Hard setting is a problem of soils which contain low organic matter (Karkee, 2004).

c . Biological degradation

This refers to a reduction in soil organic matter, decline in biomas carbon and decrease in activity and diversity of soil fauna (Karkee, 2004). It is generally associated with the decline in micro-biological biomass, decline in quantity and quality of soil organic matter (Karkee, 2004). Soils are agents for decomposition of organic matter and its conversion into an innocuous, semi-stable material referred to as humus (Bridges and Van Baren, 1997). Soil fauna are at risk of extinction and/or destruction from the barrage of toxic chemicals which are used in high technology agriculture and pesticides applied to crops which are absorbed by soils. When chemical fertilizers are over used, the soils cannot retain the excess which is leached and this can cause pollution in the aquatic environment (Bridges and Van Baren, 1997; Stocking and Murnaghan, 2000).

2.2.2 Causes of soil degradation

Soil degradation processes can occur without human interference but accelerated rates of degradation are often influenced by man's intervention in natural processes. Human activities such as over cultivation, deforestation etc are some of the main causes of soil degradation. For example, Abubakar (1995) observed that continuous cultivation involves processes such as

tillage, bush burning and harvesting which lead to soil degradation. Similarly, Gessess *et al.*, (2009) observed that poor land use practices and lack of effective planning and implementation approaches for soil conservation are responsible for accelerating degradation of agricultural lands and siltation of dams and reservoirs down stream. Similarly, Tekwa *et al.*, (2006) observed that land use types such as farming practices and livestock production degrade soils in varying degrees. The Global Assessment of Human-Induced Soil Degradation (GLASOD) reports that soil degradation in Europe accounted for 25%, Asia 18% and Africa 16%. In Nigeria, human-induced soil degradation is a common phenomenon. Its severity is light for 37.5% of the area (342,917 km^2), moderate for 4.3% (39,440 km^2), high for 26.3% (240,495 km^2) and very high for 27.9% or 255,167 km^2 (FAO, 2005). Swift and Shepherd also observed that agricultural systems with insufficient nutrient input on land with poor to moderate potential are the root cause of human-induced soil degradation in Africa.

Barbier (1997) identified deforestation as a major source of human-induced land degradation in the developing regions of the world. In both Asia and south America, deforestation accounts for 40% of erosion, in central America and Mexico 22% and in Africa 14%. Experiments on land clearing through out the tropics have shown that deforestation leads directly to degradation of soil structure, changes in the chemical and biological properties of the soil, a decrease in the porosity of the surface layer, an increase in soil compaction and decreases in infiltration rates (Lal,1995). Leonard, Yudelman, Stryker, Browder, De Boer, Campbell, and Jolly (1989) found that the poorest 20% of the rural population in the developing countries was mainly concentrated on 'low potential' lands, which are described as marginal agricultural lands. Barbier (1997) observed that three quarters of the poorest 20% of the rural population in latin America, 57% in Asia and 51% in Africa, can be found on low potential lands. Similarly, Leonard *et al*., (1989)

and Barbier (1997) observed that there is a 'cumulative causation' link between rural poverty, deforestation and land degradation ; poor rural house holds abandon degraded lands for 'frontier' forested lands, deforestation and cropping of poor soils lead to further degradation which in turn leads to land abandonment and additional forest land conversion and so on. These support several studies which have observed that increasing food demand cannot be met by expanding the agricultural areas because available lands are often not suitable for sustainable crop production and that intensification is often the only viable means of meeting food demand (Barbier,1997; Dregne,1997; Eswaran *et al.*,1997; Pagiola,1998).

Several studies have identified soil erosion as a major cause of soil degradation, accounting for about 83% of the degradation in the world (Oldeman *et al*.,1991). GLASOD's expert based survey also reported that soil erosion by water is a principal cause of cropland degradation affecting about 1.6 billion hectares mostly in Asia and China. Studies show that soil erosion is the most common form of soil degradation in Nigeria (Junge, Deji, Abaidoo, Chikoye, and Stahr, 2008). These studies showed that by 1989, 693,000km^2 were already characterized by runoff-induced soil loss in the south and 231,000km^2 were degraded, mainly, by wind erosion in the north. Sheet erosion dominates all over the country, where as rill and gully erosion are common in the eastern parts and along rivers in Northern Nigeria (Ologe,1988; Igbozurike, 1989). Similarly, Mbagwu (2003) observed that 80% of land degradation world wide are caused by soil erosion (by water or wind). He also agreed that major causes of land degradation in Nigeria were bush burning, erosion, deforestation, construction activities, intensification of farming activities among others. Experts estimate that soil erosion in Zimbabwe result in an annual loss of P and N (totalling $ 1.5 billion), while in Asia annual economic loss is estimated at $600 million (Lal,1995). In Nigeria, Maiangwa, Ogungbile, Olukosi and Atala, (2007), in their study on land

degradation in the north-west zone of Nigeria, observed that existence of attenuated property rights over land, erosion, overgrazing, wood land destruction (by burning), poor agricultural practices and absence of regulations on land use were some of the major causes of land degradation in northern Nigeria. Barbier (1997) also agreed that land and tax policies are some of the factors which encourage the degradation of existing agricultural lands. Lal (2009) observed that most soils are prone to degradation by land misuse and mismanagement. He pointed out that anthropogenic factors leading to soil degradation are driven by desperate situations and helplessness in the case of resource-poor farmers and small landholders; and greed, short sightedness, poor planning and cutting corners for quick returns in the case of large scale and commercial enterprises.

2.2.3 Effects of soil degradation

Soil degradation is a global problem which affects agronomic productivity, food security and quality of life. Its impact are felt all over the world especially in the developing countries with largely agrarian economies (Eswaran *et al.*, 1997). Information on the economic impact of soil degradation on a global scale is only available for few regions (developed countries). GLASOD (Oldeman *et al.*,1991) estimates degradation of cropland to be most extensive in Africa, affecting 65% of cropland area compared with 51% in Latin America and 38% in Asia. It also estimates that degradation of pasture is also most extensive in Africa, affecting 31% compared with 20% in Asia and 14% in Latin America. However, forest land degradation is most extensive in Asia, affecting 27% of forestlands, compared with 19% in Africa and 14% in Latin America. The most important on-farm effects of soil degradation are declining yields (Scherr and Yadav, 1996). For example, it is observed that serious soil degradation often lead to temporary or permanent abandonment of farmlands and/or induces land users to convert lands to lower-value

uses; for example, less demanding cassava may be substituted for maize (Scherr and Yadav, 1996). Negative off-farm effects of degradation (externalities) include deposition of eroded soils in streams or dams and contamination of drinking water by agricultural chemicals (Sherr and Yadav,1996). Barbier (1997) observed that the impacts of depleting soil resources have economic implications for low-income countries and poor rural regions of the world. Loss of means of livelihoods of poor rural farmers due to declining agricultural production brought about by soil degradation often lead to rural-urban migration as young people search for employment and 'better' lives in cities.

Apart from low food production, Swift and Shepherd (2007) observed that soil degradation has serious implications for other natural resources such as water. They observed that increased sediment loads degrade surface water quality and pose health risks to humans. Similarly, Lal (1995) observed that the expansion of agriculture into marginal lands, deforestation, elimination of fallows, inappropriate farming practices etc have several environmental and economic impacts, especially in sub-Saharan Africa where the resilience ability of the soil is limited. Pagiola (1998) observed that land degradation contributes to the degradation of biodiversity, directly through the degradation and destruction of lands and indirectly by accentuating the need to expand cropping into natural forests and rangelands. The expansion of agricultural lands causes on-site degradation of natural resources and productivity decline (Junge *et al*., 2008). Off-site problems of soil degradation include siltation of reservoirs, chemical and biological pollution of water and land resources (Stocking andMurnaghan,2000). Egboka and Okpoko (1984) observed that the development of gullies in Angulu-Nanka region of Anambra state caused extensive damage to the environment and had driven many people away from their homes and farmlands.

However, some studies suggest that soil degradation has had significant impact on productivity or quality of land in some areas but not in others (Pimental *et al.*,1995; pagiola,1998). Crosson (1994) argued soil degradation is overestimated and relatively unimportant to global food supplies. Pagiola (1998) equally suggests that erosion problems in El Savador have been exaggerated and that productivity losses are difficult to quantify due to a lack of data but that it is possible to counter these effects by increase in input use. Agcaoili *et al*., 's (1995) model suggests that declining food supply from specific regions due to degradation will only have a modest effect on global food supplies due to substitution from other producing areas and that poverty caused by structural under- and unemployment is responsible for malnutrition in the developing world.

Studies show that impacts of soil degradation are sensitive to location-specific biophysical and economic factors (Stocking and Murnaghan, 2000). GLASOD (Oldeman *et al*.,1991) estimated that 38% of the world's cropland had been degraded to some extent since 1945. It identified erosion as the principal cause of cropland degradation, affecting 1.6 billion hectares (mostly in Asia and Africa); loss of soil nutrients was the primary cause of degradation on 136 million hectares (mostly in south America and Africa); salinization affects 77 million hectares (mostly in Asia); compaction, sealing or crusting affected 68 million hectares (mostly in Europe); and other physical and chemical processes affected 42 million hectares. However, a related study, the Assessment of Human-induced soil Degradation in South and Southeast Asia (Dregne and Chou,1992) applied a similar methodology at a finer spatial scale. Defining degradation in terms of the impact of soil quality changes on crop yields, ASSOD identified more degraded land in south east Asia than GLASOD but found that this land was often degraded to a lesser degree than had been reported by GLASOD (Wood, Sebastian and Scherr, 2000).

2.3 Assessment of Soil Degradation Methods

2.3.1 Expert opinions

Soil erosion prediction and assessment has been a challenge to researchers and various techniques/ methods have been developed (Lal, 2001). The most important studies on land degradation designed for purposes of international comparison are the Global Assessment of Degradation (GLASOD) mapping exercise by Oldeman, *et al*., (1990) and the comparative study of dry lands by Dregne and Chou (1992). Both depend on expert judgment (Scherr and Yadav, 1996). GLASOD maps identify areas with a subjectively similar severity of erosion risk, irrespective of the conditions which produce such degradation (Oldeman *et al.*,1991) and provides basic data on the world distribution and intensity of erosion types. The survey enables comparison to be made between degraded soils of different continents. However, the study made no use of remote sensing or actual field measurements, but based only on expert opinions. Consequently, results obtained from such assessment may be difficult to use for comparative assessments else where.

The Assessment of the Status of Human-Induced soil Degradation (ASSOD) is a follow up of GLASOD (Scherr and Yadav,1996). Wood *et al*., (2000) observed that ASSOD applied similar methodology as GLASOD, but on a finer spatial scale, and identified more degraded land in South and Southeast Asia than GLASOD. They reported that the degraded land was degraded to a lesser degree than had been reported by GLASOD. Although, the expert's opinion is fast and involves relative low cost, it is however, subjective and difficult to replicate elsewhere.

2.3.2 Use of models

Estimation of soil loss is the technique of obtaining soil loss data without actual field experimentation and measurements. Soil erosion models may be empirical, semi-empirical and physical process-based models. Empirical models are primarily based on observation and are usually statistical in nature. USLE is the most widely used empirical overland flow or sheet-rill erosion equation. It is used for assessing long-term annual soil loss. The RUSLE still primarily meets the needs of the USLE user, concentrating on predicting long-term average soil erosion loss by water on disturbed slopes (Yoder, Foster, Weesies, McCool and Lown, 2004). A principal modification is in the R factor which includes rainfall and runoff erosivity factor. There are also changes in C factor which is based on computation of sub-factor called soil loss ratios (SLR).

Semi-empirical models lie between physical process-based model and empirical model and are based on spatially lumped forms of water and sediment continuity equations. These include Modified Universal Soil Loss Equation (MUSLE) and Morgan, Morgan and Finney (MMF) models. Physical process-based models represent the essential mechanism controlling erosion. These models were developed to fill the gap associated with empirical based models (Lal, 2001). They use established laws of physical processes to derive equations that relate the factors which control soil loss to the processes responsible for soil loss. These models have strong physical basis which enables them to estimate soil loss very close to measured data (Iguisi, 1996). They are able to relate factors, processes and rates of soil loss. Some of the models include WEPP,WEM, among others. Empirical models have constraints of applicability. This is because the USLE model was developed for a local scale assessment of soil erosion by sheet and rill erosion, thus its applicability is limited (Cebecauer and Hofierka, 2007). Similarly, majority of

the soil loss estimation models operate on a field scale and often have no application at the reconnaissance scale where other factors such as socio-economic factors need to be taken into consideration (Millington, 1984). Trimble and Crosson (2000) observed that the universal soil loss equation (USLE) predicts the amount of soil moved on a field but not the amount removed from a field, suggesting that USLE results may overstate the amount of soil actually lost to erosion, while estimates of soil removed from fields are also subjected to uncertainties about where and when sediment is ultimately delivered down stream (Trimble and Crosson, 2000).

Most estimates of soil erosion are based on predictions using USLE or other models and often do not reflect actual field observations of soil loss. There are consequently large differences between estimates of areas at risk and areas actually affected by soil degradation (Nachtergaele, 2010). Similarly, erosion hazard maps which show potential soil loss areas often do not show the soil sedimentation patterns, which is important for assessing off-site effects of soil loss because not all transported soil is bound to end up in rivers and dams or to be lost forever (Nachtergaele, 2010).

2.3.3 Use of remote sensing and GIS

Satellite Remote Sensing (RS) and Geographic Information Systems (GIS) are widely used tools in various fields including land cover assessment and land use change (Eswaran, *et al.*,1997). The use of remote sensing provides timely and reasonably reliable information for large areas monitoring supported by sufficient ground data (Eswaran *et al*., 1997). Large scale monitoring needs considerable amount of human resources and time if generated through field studies only. Remote sensing can facilitate studying the factors which influence land/soil degradation processes such as soil type, slope gradient, geology and land cover changes. Satellite imageries can be used for studying erosional features such as gullies and vegetation cover. A major

advantage of remote sensing over other systems is its cost effectiveness for large area monitoring, geo-referencing and near real-time monitoring of land degradation (Eswaran *et al*., 1997). Geographic Information System (GIS) has emerged as a powerful tool for handling spatial and non-spatial geo-referenced data for preparation and visualization of input and output and for interaction with models. There is considerable potential for the use of GIS technology as an aid to the soil erosion inventory with reference to soil erosion modelling and risk assessment.

Shortcomings of the Remote Sensing and GIS technique include temporal resolution of most of the high-resolution sensors which may not be efficient in capturing critical greening of vegetation, selection of appropriate analytical technique, timely data availability and delivery while using the remotely sensed data for land degradation studies (Eswaran *et al*., 1997). It is argued too, that GIS and Remote Sensing techniques may not detect sheet erosion and nutrient depletion which are also very serious forms of soil degradation (Stringer and Reed, 2006).

2.3.4 Measurements of soil loss in the field

Soil loss assessment in the field is done by using bounded or unbounded strips of landscape instrumented with erosion pins and wash traps located at the down slopes of fields. Bounded strips are usually called erosion plots. Actual field measurements make it possible to know the rate of soil loss within the erosion plots. Morgan (1995) argued that although air photos may guide sampling of fields or transects, field work is still the most consistent method of soil degradation assessment. Field studies for assessment and prediction of soil loss are expensive, time consuming and need to be collected over a long period (years). Though they provide detailed understanding of the erosional processes, they have limitations because of the complexity of interactions and difficulty of generalizing from the results. Soil loss data obtained

from one erosion plot cannot be representative of the entire basin due to varying environmental conditions (Iguisi, 1996). Another problem associated with the use of erosion plots is that they are usually too small to reproduce the true erosive effects of the entire basin (Gregory and Walling, 1973) and consequently, may be ineffective for sustainable planning and management purposes on the entire drainage basin other than that from which such measurements were taken.

2.3.5 Soil survey

Major advantages of soil surveys are that it is involves direct field monitoring and is objective. However, some disadvantages of soil surveys are that it is slow and laborious and expensive. Soil surveys are limited by the chemical and physical data that are obtained from specific sites. Samples obtained for analysis may or may not be representative of the entire basin due to climatic or physiographic variations and presents problems if results of analysis from one area is extrapolated to other areas. Soil surveys represent landscapes and soils as they were at the time of mapping while recent changes related to human activities or natural events are not reflected (Muckel, 2004).

2.3.6 Land user approach

The land user approach is being recognized as an effective method of assessing soil degradation (Stocking and Murnaghan, 2000). This method utilizes and integrates the view of the farmer who is the ultimate user of the soil and technologies developed (Stocking and Murnighan, 2000; Chizana *et al.,* 2007). Research has shown the usefulness of employing farmer's knowledge to assessing soil degradation. This approach takes advantage of farmers' experiences and local knowledge of the environment. High levels of variation in the properties of African soils is a major challenge in assessing soil degradation (Sherr and Yadav, 1996; Swift and Shepherd,

2007). This variation is often highest at the smallest scale, which is the farmers' field. Therefore links between indigenous knowledge and science based assessments are critical at the local level (Sherr and Yadav, 1996; Swift and Shepherd, 2007). Most soil conservation planning approaches rely on empirical assessment methods or experts' opinion and hardly consider the farmer's knowledge of soil erosion (Gessess *et al*., 2009). Many soil conservation projects in the developing countries do not take into account the factors determining farmers' land management decisions and tend to fail after intensive technical assistance and special incentives and subsidies provided by the projects are no longer available (Barbier, 1995).

The major advantage of adopting the land user approach in studying soil degradation is that results from field assessments using this approach provide more practical views of the types of interventions or solutions that are more acceptable to land users (Stocking and Murnaghan, 2000). Land user approach enables local people share in identifying the problem, assessing its impact on their lives and choosing the most appropriate solution to the problem identified. This provides translation between descriptive and analytical measures and will facilitate the transfer of information between scientists and farmers with the goal of promoting sustainable soil management (Bennet, Meister and Wilkinson, 1999). For example, farmers may observe poor crop growth on certain soils and not on others but without scientific testing, may not know that the cause is strong acidity and the solution is to lime the soil or grow tolerant crops (Swift and Shepherd, 2007). Some of the limitations of local knowledge are that they are primarily based on contextual analysis and are often embedded in socio-cultural beliefs and can lead to inaccurate accounts of the extent and magnitude of any environmental change (Stringer and Reed, 2006). Apart from being subjective, participatory surveys are slow and expensive.

2.4 Global Assessment of Soil Degradation

The importance of soil degradation among global issues is enhanced because of its impact on world's food security and environmental quality (Eswaran *et al.,* 1997). GLASOD (Oldeman *et al,*1991) revealed that considerable damage had occurred on world soils. The survey revealed that about 1965 million hectares (15 percent of the world's soils) had been degraded and that soil erosion by water accounted for the degradation of 1094 million hectares (55 percent). ASSOD (Dregne and Chou, 1992) observed that changes in soil and terrain properties (such as soil loss, development of rills and gullies) may reflect the occurrence and intensity of soil degradation but not necessarily the impacts on productivity of the soil.

Swift and Shepherd also observed that agricultural systems with insufficient nutrient input on land with poor to moderate potential are the root cause of human-induced soil degradation in Africa. Studies show that female-headed households in Malawi make up about 42% of the core-poor house holds and are often marginalized onto the less fertile soils and steeper slopes, are unable to finance agricultural inputs such as fertilizers which result in declining soil fertility and crop yield (Barbier, 1997). These factors exacerbate poverty and causes increased dependence on land which in turn leads to soil degradation (Barbier, 1997). Similarly, Junge (2010) observed that land use intensification led to increased soil erosion and depletion of soil organic matter and nutrients which invariably led to decrease in arable and grazing land, crop production, dairy produce and dwindling income for local farmers.

Some implications of land scarcity include rural-urban migration, conflicts between land users over scarce productive lands, food insecurity and poverty (Scherr and Yadav, 1996; Junge, 2010). Scherr and Yadav (1996) argued that further expansion and intensification of food

production could have a potentially degrading effect on the environment but that land use intensification can increase food production in the 'high potential' areas, simultaneously strengthening the regional and national economies and providing more food on a regional or national scale. However, the land users in the marginal agricultural lands (also known as 'low potential' areas) are the most affected by land degradation. In the developing countries, poor rural households are often found in the marginal agricultural lands where land productivity and income are stagnant or declining (Bennet *et al.*,1999).

Various studies show that as world population increases so also does the menace of soil degradation (as a result of the impact man has on the environment). This human impact is evident as increasing population density increases forest clearance (Barbier,1997; Bridges and VanBaren, 1997). Studies also show that many regions with the highest levels of land degradation have some of the highest rural population densities dependent on the productivity of the land (Berry *et al*., 2003). Millington (1984) observed that land use in tropical environments is manifest in the notion of population pressure on the land which has often been described by population density. He observed that it is usually assumed that an increase in population density leads to an increase in soil degradation and argued that population density is a poor indicator of population pressure on lands, especially given the migrant nature of farming populations in rural Africa. However, Barbier (1997) argued that while increased population density increases forest clearance, rising per capita income and agricultural yields reduce the demand for forest conversion. Berry *et al*., (2003) observed that china, with 22 percent of the world's population, has only 6.4 percent of the global land area and that 40 percent of the country was adversely affected by land degradation.

Several studies have identified soil erosion as a major cause of soil degradation, accounting for about 83% of the degradation in the world (Bridges and vanBaren, 1997; Gessess *et al*., 2009; Stocking and Murnaghan, 2000). GLASOD's expert based survey reported that soil erosion by water is a principal cause of cropland degradation affecting about 1.6 billion hectares mostly in Asia and China (Oldeman *et al*., 1991). GLASOD estimates that water erosion in South and Central America is the major process of soil degradation in the region and accounts for more than 50 percent of total degraded lands, followed by loss of nutrients.

Berry *et al*., (2003) observed that 64 percent of agricultural lands and forests in Mexico have been damaged by erosion, with more than 20million hectares loosing between 40-60 percent of their capacity to retain water. They equally observed that the rate of deforestation in Mexico was between 0.9 – 1.3 annually and that a significant proportion of land degradation there was human-induced. Eswaran *et al.*, (1997) observed that on-farm effects of land degradation in Canada were estimated to range from $700 to $915million in 1984. They also observed that severe compaction due to mechanized agriculture caused yield reductions of 25 – 50% in regions of Europe and North America. On- farm losses due to land compaction alone in the United States have been estimated at $1.2 billion yr^{-1} (Eswaran *et al*., 1997). Lal (1995) observed that the expansion of agriculture into marginal lands, deforestation, elimination of fallows, inappropriate farming practices, among others, have several environmental and economic impacts, especially in sub-Saharan Africa where the resilience ability of the soil is limited. The expansion of agricultural land causes on-site degradation of natural resources and productivity decline (Junge *et al*., 2008).

GLASOD survey (Oldeman *et al*., 1991) show that about 30 percent of total agriculture, permanent pasture, forests and woodland areas in Africa are affected by soil degradation. The

survey found that soils in semi-arid cropping regions such as Burkina Faso, Niger and Senegal are facing serious land degradation due to nutrient depletion and that nutrient mining is occurring over significant areas of croplands under fallow or permanent cropping systems. Stringer and Reed (2006) observed that Botswana is one of the most desertified countries in sub-saharan Africa and that privatization of rangelands was exacerbating the problem of land degradation in the country. They also identified severe gullying, nutrient loss and parasitic weed infestation as major forms of land degradation in Swaziland.

Gessesse *et al.,* (2009) identified poor land and water management practices and ineffective planning and implementation approaches as major causes of accelerating degradation of agricultural lands in Ethiopia. Sanchez *et al*., (2004) in their assessment of soil degradation in the Mediterranean region, used the USLE model to spatially analyze soil degradation processes using soil quality indicators. They observed that this environmental approach takes into account soil functions and expands the concept of soil quality beyond one of soil productivity. They observed that soil erosion is a slow process and farmers need to perceive its severity before they can consider implementing soil conservation practices.

2.4.1 Summary of soil degradation assessment in Nigeria

Studies show that soil erosion is the most common form of soil degradation in Nigeria. For example, studies by Junge *et al.,* (2008) showed that by 1989, 693,000 km^2 were already characterized by runoff-induced soil loss in the south and 231,000 km^2 were degraded, mainly by wind erosion, in the north. Sheet erosion dominates all over the country, where as rill and gully erosion are common in the eastern parts and along rivers in northern Nigeria (Ologe, 1988; Igbozurike, 1989; Oldeman *et al.,* 1991).

Various methods have been used to assess soil degradation in Nigeria. For example, Igwe, Akamigbo and Mbagwu (1999) used the soil loss estimation model for Southern Africa (SLEMSA) and USLE to quantify erosion and produce soil erosion hazard maps of Anambra and Enugu states. Similarly, Adediji, Tukur and Adepoju (2010) assessed the Revised Universal Soil Loss Equation (RUSLE) in Katsina state using Remote sensing and Geographic Information System (GIS) and estimated that 65.47% of the area was moderately eroded with erosion rates of about 10 ton/ac/yr while about 32.65% of the area was severely eroded with erosion rates of between 104.8 and 305.5 tons/ac/yr.

Jibrin (2009), using remotely sensed data to assess the extent of forest degradation in the Kpashimi forest reserve of Niger state, observed that degraded forests expanded by 48.6% while bare surfaces followed by a 40% increase. Similarly, Daniel and Ayobami (2007) assessed changes in land use/land cover in a part of south western Nigeria over a 16 year period, using landsat imageries of 1986 and 2002. Their results showed that disturbed/degraded forest constituted the most extensive type of land use/land cover change in the study area. However, the study states nothing of the impact of the degradation on the human population and what coping strategies (if any) are employed by the population. Junge (2010) also monitored land use change and soil degradation in Nigeria and Benin using remotely sensed data. His results showed that the area of all settlements expanded within the last decades, the areas covered with shrubs decreased and gully erosion increased from 37.9 ha (in 2000) to 45.1 ha (in 2006). Some of the advantages of the use of Remote Sensing and GIS is that it is rapid and saves cost as large (and inaccessible) areas can be assessed within a short time. However, the disadvantages of the use of this technology in Nigeria include very high cost and unavailability of high resolution imageries and the fact that it focuses mainly on land use/cover change detection.

In Zaria, Kowal (1970), in his study on surface runoff from soils under varied land management and vegetation cover, used experimental plots to assess soil loss in a sub basin in Samaru. He calculated a mean soil loss of 10.8 tonnes/ha/yr and found that about 10-34 kg of cations and between 8-21 kg of nitrogen per hectare was lost from the experimental plots. While Iguisi (1996) focused on variations of soil loss in two sub-basins in Zaria, Odunze (2002) estimated the magnitude and timing of soil loss from cultivated lands under mulch conditions in Zaria. Abubakar (1995) studied soil conditions under different land use types in a part of Nigeria's semi-arid savannah and observed that soils of the Kabomo basin of Katsina state had undergone degradation following natural vegetation clearance**.** His studies revealed a general decrease in coarsening of soil texture and bulk density and an increase in organic matter, nitrogen, CEC, soil moisture content, etc., with increased length of fallow periods. In Ibadan, South West of Nigeria, Salau, Opara-Nadi and Swennen (1992) observed that intense mechanized tillage practices have caused significant declines in soil faunal density, rate of organic matter mineralization and total porosity. Also in Ibadan, Juo and Lal (1977) observed that after 3 years of forest clearance, soil organic matter declined from about 1.74% to 1.2%. Similarly, Akogun's (1986) assessment of the effects of land use changes on selected soil properties in parts of the Northern Guinea Savannah also observed that when a virgin land is subjected to tillage activities, it loosens the soil and breaks down its aggregates, thus making the soil materials more susceptible to removal by runoff water.

Soil degradation assessment is a complex phenomena (complicated by factors such as climate, soil types and socio-economic characteristics) and therefore difficult to assess with just a single tool or method. while scientific techniques such as Remote Sensing and GIS, ecological assessment, economic analysis etc., have all been used to identify, measure and monitor land

degradation, many assessments have dealt with degradation risks rather than with degradation status, its socio-economic causes or its political driving forces. Several studies have observed that the various tools available for land degradation assessment all have advantages and disadvantages but overall, show a clear complimentarity with each other (Nachtegaele, 2010; Eswaran *et al*., 1997; Rhoda *et al.*, 1999; Stringer and Reed, 2006; Swift and Shepherd, 2007). From the foregoing review, it can be observed that although several studies on soil degradation have been carried out in Nigeria, observation shows that soil degradation assessments are skewed towards the use of models and GIS/ remote sensing techniques to assess land use/land cover changes (Igwe *et al*., 1999; Daniel and Ayobami, 2007; Jibrin, 2009; Adediji *et al*., 2010; Junge, 2010) and use of experimental plots to assess soil loss and soil nutrient depletion (Kowal, 1970; Abubakar,1995; Iguisi,1996; Odunze, 2002; Jaiyeoba, 2003).

However, the dynamics and extent of soil degradation are changing with time and there is need for participatory approach to soil degradation assessment and providing a holistic approach to the problem. This involves integrating results from scientific assessments with land users' opinions to make results acceptable to land users, since they are the end users, for sustainable use of land resources. Few attempts have been made to assess the extent and severity of soil degradation in the study area and tackle the problem at a broader scale. These are the gaps that the study intends to fill.

CHAPTER THREE: THE STUDY AREA

3.1 Location and Historical Background of Zaria

Zaria lies on the High plains of Northern Nigeria between latitude $11^{0}00^{'}\ 00^{''}$ to $11^{o}28^{'}$ North and longitude $7^{o}31^{'}00^{''}$ to $7^{o}53^{'}$ East (Fig.3.1). It lies at an altitude of about 670m above sea level. The early history of Hausa land is shrouded in the legend of an ancient Kingdom (Daura), in the eleventh century. Zaria (Zazzau) is one of the seven Hausa Kingdoms (Hausa Bakwai). The core of the kingdom was surrounded by rock outcrops rising abruptly several hundred meters above the country side (Urquhart, 1977 and Idris, 2004) and fortified by high city walls and gates (kofa).

3.2 The Physical Environment

3.2.1 Climate

The climate of the Zaria area is dominated by seasonal shifting of pressure belts: the continental air mass blows southwards from the north-east from November to March, during the harmattan season while the Tropical Maritime air mass blows northwards from the southwest in May to September to create the rainy season, thus developing monsoon characteristics during the northern Nigerian summer. Schwedtferger (2007) observed that the local people distinguish four seasons as follows:

"Bazara" (hot and dry): Mid–February to mid–May, the hot dry season of the harmattan;

"Damina" (wet)" Mid-May to the end of September, the rainy season;

"Kaka" (dry): October to mid-December, the harvest season; and

"Rani" (cold and dry): Mid-December to mid February, the cold dry season of the harmattan.

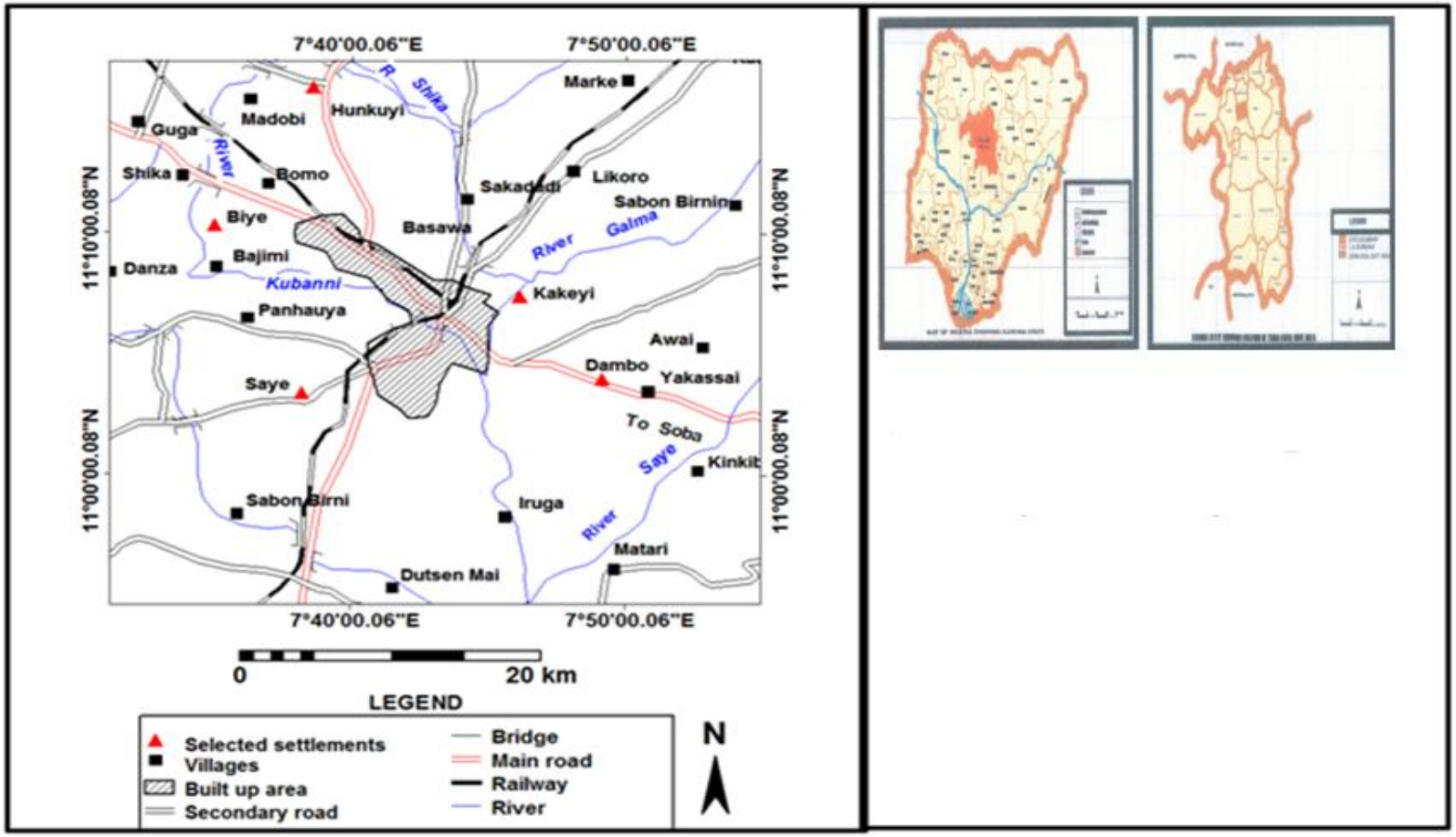


Fig. 3.1 Location of the Study Area
Source: Topographic Maps of Zaria Sheet 102 SW and Igabi Sheet 124

However, two distinct seasons are identifiable in the Zaria area and they are the dry and rainy seasons. Both seasons are dictated by the movement of the Inter Tropical Zone of Discontinuity (ITD) that is in turn controlled by the movement and dominance of the two contrasting air masses: the dry tropical continental (cT) air mass which originates from the high pressure cell located over the Sahara desert to the north and the cool moist tropical maritime (mT) air mass which originates from the Atlantic ocean. From early or late November till late March/ early April, Zaria lies north of the surface position of the ITD within the domain of the dry continental air mass which reaches Zaria as North-Easterly or Easterly wind depending on the synoptic condition over northern Africa. From the rest of the year, the surface air in Zaria is the south westerly equatorial maritime air. The depth of this moist air over Zaria varies according to the distance of Zaria from the surface position of the ITD and attains its maximum of about 1970m when the ITD is at its northern most position in August. These movements have strong influences on the length and intensity of the rainfall occurrences over Zaria and it varies from one year to another (Hore, 1970).

The wet season lasts from April to October, with the maximum rainfall in August. In July, the ITD moves further north, squally winds become less frequent, the south – westerly air over Zaria becomes thicker and the wet season is fully established (Hore, 1970). With the onset of the wet season the daily maximum temperature drops. Zaria has a mean annual rainfall of 1082mm. Rainfall intensities range between 25mm/hr and 125mm/hr. The rainfalls occur mostly in the afternoons due to the convective nature of the processes involved. Thundering, lighting and squalls with prolonged heavy falls sometimes characterize the storm events during the peak period in August – September. With the onset of the wet season, the daily maximum temperature drops and the diurnal range of temperatures become low (Hore, 1970). July and August are the

months with the mildest temperatures (Hore, 1970). The mean daily maximum temperatures during July – August is about 27^0C. The highest daily maximum temperature in August rarely reaches 30^0C.

The first rain of the year falls as thunderstorm showers in March or April (Hore, 1970). The frequency of these showers increases during May and June. Rains in the hot and thunderstorm seasons are very localized. In the wet season, rains are widespread. The duration of rain is longer but the intensity is lower. From March onward, the monthly rainfall increases in each successive month till August which is the wettest (Hore, 1970). The rainfall decreases in September and there may be a few scattered showers associated with thunderstorms in October. Rainfall is not continuous during the wet season. There are dry days in between successive falls and dry spells of more than 7 days are few and mostly occur at the beginning or end of the rainy season (Hore, 1970).

The dry season generally begins in November and lasts to March. By the middle of November, ITD moves south of Zaria and the dry continental north-easterly or easterly air replaces the moist south-westerly air from the surface. The ITD oscillates, moving back and forth before it finally moves south of Zaria. In the beginning of the dry season, the 'sticky' heat of September- October is replaced by the cool harmattan wind. The dry season is marked by a drop in the moisture content of the surface air and a change in the direction of the surface winds. The relative humidity drops abruptly from 60-65% in October to about 25-30 % in November and drops again from 15-20% in December to 10-15% in January. The atmospheric humidity over this area can be as low as 15% in the dry season gradually rising to about 60% during the rainy season (Kowal and Omolokun, 1970). The surface turbulence produced by the dry easterly wind, known as the 'harmattan', produces a suspension of fine dust particles in the air which attains its

maximum intensity in Zaria during December– January. The thickness of the haze and dust layer of the harmattan rarely exceeds 1524m and affects visibility while it is on. Hore (1970) characterizes the harmattan as:

i. The general direction of the winds, ranging between north and east with varying speed
ii. A very low moisture content
iii. A large diurnal temperature range
iv. The absence of the convective type of cloud.

While the Zaria region is characterized by high temperatures throughout the year, the mean daily minimum values sometime dip as low as 11^{o}c but gradually rising from about 22^{o}c in January and attaining a maximum of about 33^{o}c in March/April. These climatic characteristics have implications on geomorphological processes. Soil particle detachment due to raindrop impact, formation of surface capping in the Zaria area soils by high intensity rains, water logging, etc., during the rainy season cause soil erosion and leaching of soil nutrients. Similarly, the high temperature of the area coupled with sparse vegetation are likely causes of high soil temperature which may keep soil moisture content low for most parts of the year (Abubakar, 1995). Tattah, (1985) observed that atmospheric temperature contributes to changes in soil temperature between rains and determines the absorptive properties of soil. However, the humidity pattern of the Zaria area influences the life cycle of vegetation because the increase in humidity level before onset of the wet season and the first showers in the period between April to May causes many trees to turn green. This invariably means that humidity pattern indirectly influences soil development processes in the area (Abubakar, 1995).

3.2.2 Geology

Geologically, Zaria belongs to the Basement Complex rocks. Russ (1957) described the geology of Zaria as high grade metamorphosed gneisses interspersed by belts of Younger Meta sediments. Wright and McCurry (1970) classified the Basement Complex rocks of the Zaria region into three principal groups;

1. Younger meta-sediments found in a north-south trending belt, west of the region. These younger meta-sediments include quartzites (forming ridges), schists and phyllites.
2. A re-mobilized older crystalline complex made up of gneisses, migmatites and ancient meta sediments.
3. Granites and granodiorites of late Precambrian to lower Paleozoic age.

The younger meta-sediments are preserved as discontinuous north-south belts of isoclinally folded rocks with steep axial planes, alternating with gneisses of the original basement. Wright and McCurry (1970) observed that biotite – gneisses predominate under most of the eastern part of Zaria (Fig.3.2), outcropping mainly in stream valleys, where they are deeply weathered. They are medium- to coarse-grained and moderately to weakly foliated rocks principally composed of quartz, oligoclase, biotite and occasionally porphyro-blastic microcline. Older granites form groups of inselbergs and low whalebacks and are also seen in stream sections where they are sometimes difficult to distinguish from porphyro-blastic gneiss. The granite contains quartz, turbid oligoclase, and accessory apatite, oxide and zircon. Quartzites are granular, massive to fissile rocks in outcrop. They contain few impurities apart from muscovite, hematite and rare concentrations of garnet crystals.

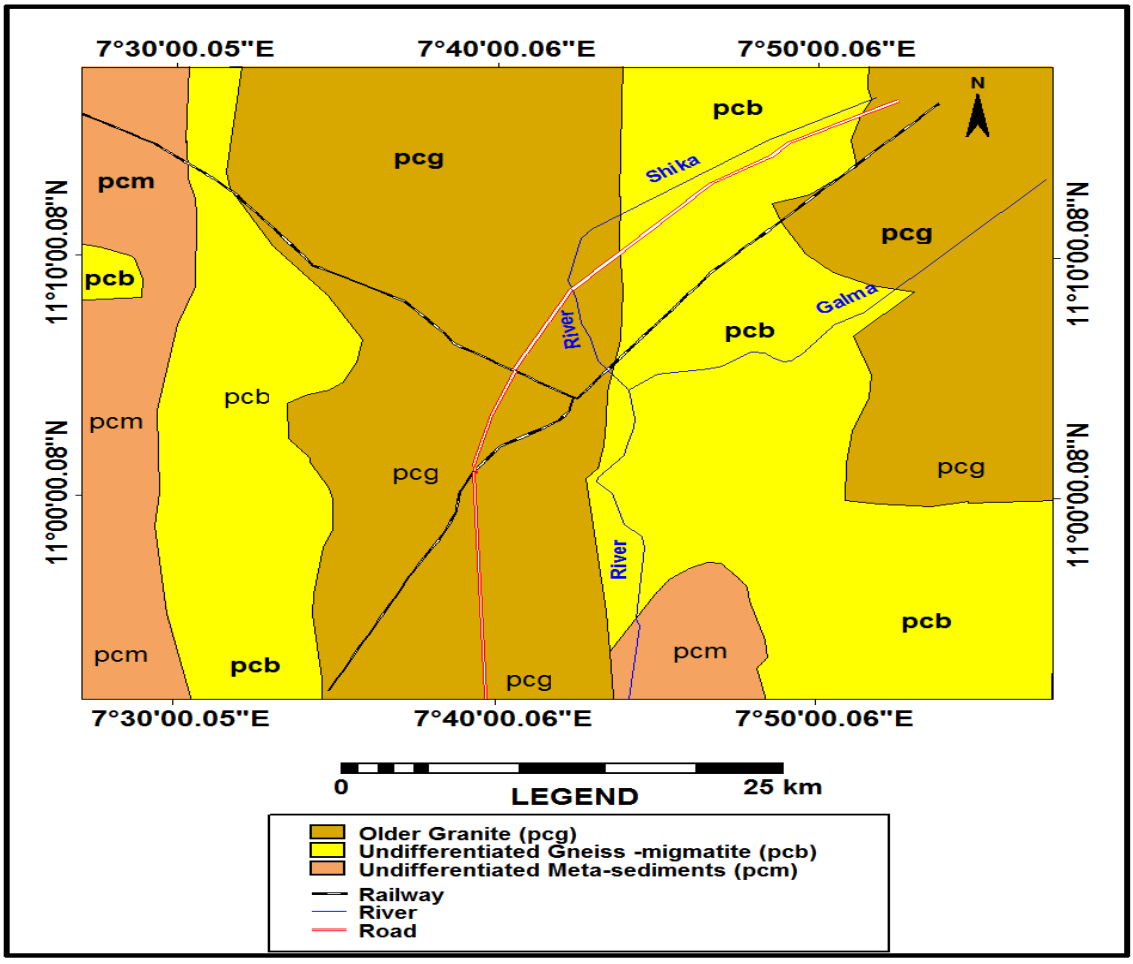


Fig. 3.2: Geology of the study area

Source: Adapted from Geological map of Nigeria, 1984.

Among the granite outcrops are in the study area are Kufena, Tukur-Tukur and Madarkaci hills. Laterite was formerly used as an iron ore, but the iron content is far too low for industrial exploitation. The laterite, is however, used for road surfacing (Wright and McCurry, 1970). Superficial deposits, mainly of Older Alluvium are extensively dug out and made locally into bricks for house building. The laterite soil ("Jar kasa") found in the Zaria area has high clay content (clay is a major constituent of the Younger Alluvium) and it is poorly drained because of the high percentage of fine silty materials in the upper layers which results in water logging condition during the rainy season (Wright and McCurry, 1970; Schwerdtfeger, 2007).

Continuous and uncontrolled mining of the iron content of laterite found in Zaria for construction and building activities further aggravates the problem of soil degradation in the Zaria area.

3.3.3 Geomorphology, relief and drainage

Zaria lies at an altitude of about 670m above sea level and is characterized by gentle rolling plains surrounded by rocky residual hills (inselbergs of different sizes and configurations). These inselbergs tower between 30-45 meters high above the surrounding plains (Fig.3.3). The latter dip gently to the Kubanni – Saye – Galma valley system with long valley-side slopes. The valley bottoms, slightly incised into the plains, are micro-worlds having their own distinctive landforms. Alluvial terraces and gullies are often present in the valleys. Other residual hills have developed and are found on deeply weathered materials and are called lateritic mesas and buttes. The slope is generally less than 4^{o} with the exception of those of inselbergs, lateritic mesas and river valleys. Inselbergs and ruwares are distinctively shaped hills of more or less bare rock. They belong to the general category of residual hills (Thorp, 1970).

In the Zaria area, there are three main groups of inselbergs; Farakwai, Hange and Dunbi, though prominent hills also occur in Zaria city. Their sizes range from 3- 3.7 meter high and 6-9 meters diameter to 152 meter high. The shape of the inselbergs vary but a common characteristic is a convex or dome shape which can be almost perfectly symmetrical or hardly apparent within a pile of rectangular joint blocks (Plate I). Simple but assymetrical domical inselbergs are exhibited at Tukur Tukur. Compound domical inselbergs are exemplified in Kufena and Farakwai. The ruware is a low whaleback feature, usually longer than it is broad or high. A good example occurs at the old Kano road junction and several others can be found around Kufena and in Hange and Dunbi inselberg groups (Thorp, 1970).

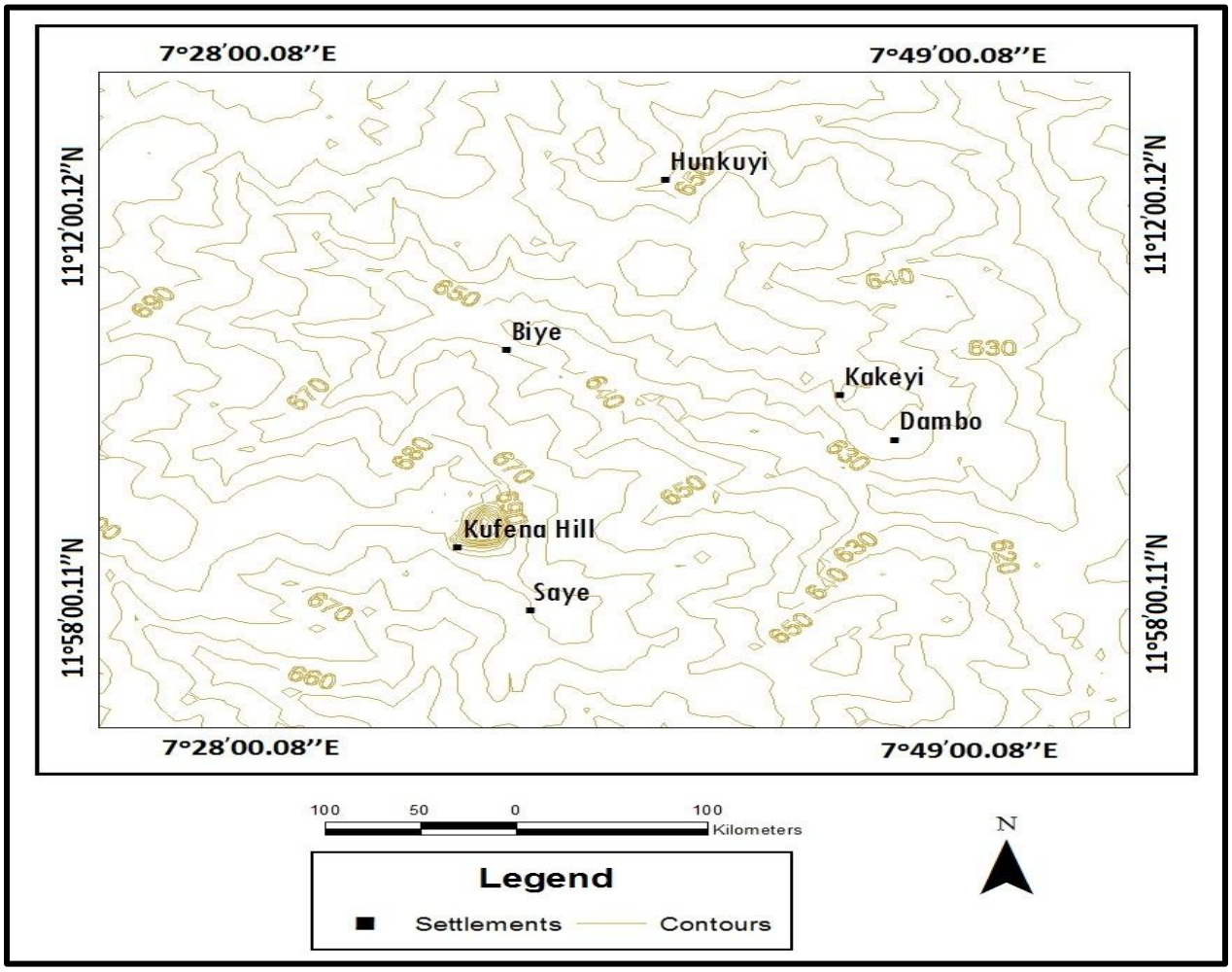


Fig. 3.3: Relief of the study area
Source: Modified from Topographic maps, Zaria sheet 102 SW and Igabi sheet 124

Other micro forms associated with inselbergs and ruwares in Zaria are weather pits, lapies, perched boulders, exfoliation sheets and scales. Weather pits are depressions of varied sizes and shapes which have been hollowed out of fresh sound rock. They fall into two main categories: armchair-shaped hollows on slopes of more than $5\text{-}10^0$, and pits on the flatter areas of inselbergs and ruwares. Lapies are gnarled, rough flutings, channels and grooves in granite. They develop at the base of the weathering profile. They can be seen on the top of the inselbergs at Tukur Tukur and on the ruware at the west end of Wusasa.

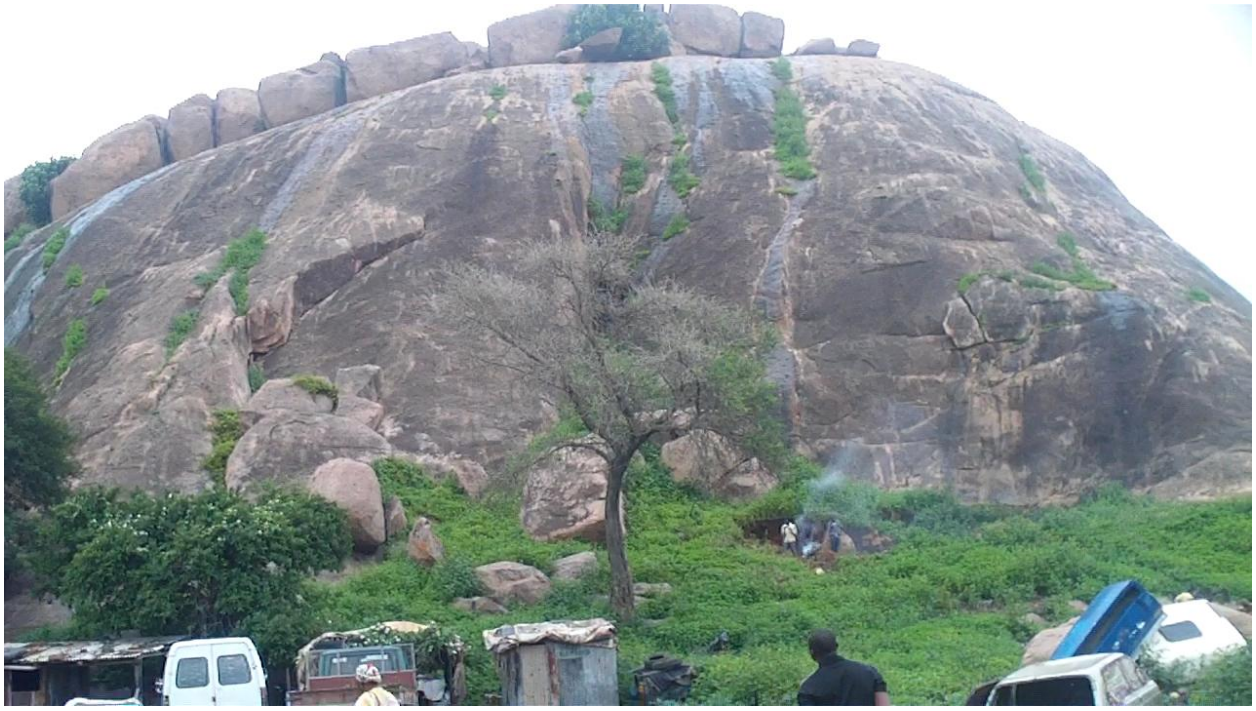


PLATE I: A dome-shaped inselberg in Danmagaji, Zaria.

These mesas are residuals of a once much more extensive sheet of decomposed rock, in which iron oxides had accumulated in a distinct upper horizon by two processes. First, the removal in solution of much of the original rock leads to a relative accumulation of the insoluble kaolin and iron oxides; and second, the chemical transportation of soluble iron hydroxides from the more elevated areas in a drainage basin followed by their oxidation and precipitation in lower lying areas leads to 'absolute accumulation' (Thorp, 1970). Upon exposure to the atmosphere by erosion, through vegetation clearance and through drying out of the weathered profile, the iron oxides crystallize into a continuous crystalline structure thereby producing the concrete hard substances referred to as ironstone. The watershed ironstones are sometimes referred to as primary ironstones to distinguish them from valley bottom kinds referred to as secondary ironstones. The latter are found lower down the valley side slopes outcropping as a thin ledge or

just above an incised valley or forming a thin indurate gravel. The secondary ironstone is a colluvial deposit derived from the erosion of the primary ironstone and transported down slope by sheet wash and re-cemented by its own iron hydroxides or by iron oxides precipitated from evaporated soil water.

Gullying in the Zaria area is especially pronounced in the Saye and Kubani valleys. Thorp (1970) observed that the high incidence of gullies in the area is responsible for the unusual characteristics of high stream frequency and wide sandy channels in these basins. Gullies are the result of very rapid channel erosion and slope retreat on slopes which were produced by more gentle, diffuse erosion processes. Slumping and rain wash erosion increase gully width. Slumps are common in many of the larger gullies and gully walls collapse and slide towards the channel. Such slumping is favoured by very steep to vertical walls and basal undercutting by the gully channel. Rain impact and rill erosion are also very effective on friable material during intense storms. Pillars capped with indurate gravel can develop as gully walls retreat. Gullies result from a change in the total erosion system. The change to this rapidity and linearity in erosion is favoured by; the development of initial water focusing channels such as footpaths, the suppression of the factor which diffuses erosion over the land surface (i.e. vegetation) so that runoff can collect into rills and channels and an increase in the runoff : percolation ratio by slope steeping through basal undercutting (Thorp, 1970). These three account for gully initiation on land slope. Gullying is a highly effective means of land form modification on the weathered plains, can affect vast areas of land (Thorp, 1970) and often causes extensive soil degradation. This may be attributed to the relief of the Zaria area which provides an easy platform for endogenesis.

The Galma river is the major river system that drains the region. Its tributaries, Kubanni, Shika and Saye are ephemeral carrying storm runoff only during and immediately following rainfall events. They form strings of pools separated by sand/gravel bars (Wright and Mc Curry, 1970). The drainage system focuses on the Galma river which is a major tributary of river Kaduna. The Galma river carries water throughout the year unlike its tributaries which dry up during the dry season. Wright and McCurry (1970) observed the rivers Kubani and Saye are characterized by large numbers of un-branched first order tributaries producing high stream frequencies and drainage densities. These basins are also characterized by gullying and intense head water erosion.

The Awai, Marmara, Kinkiba, Tubo and Kudan basins, to the east of Zaria, are characterized by low stream frequencies and drainage densities. The valley bottoms contain wide marshy floodplains with intricately developed river meanders. The fairly homogenous fine sand alluvial material favors the meandering form. Channel patterns consist of straight streams in non-gullying basins of order 1-3 and meanders. Many of the larger streams such as the Galma, Mariga and Kinkiba have wide floodplains and well developed meanders. Drainage patterns are commonly dendritic (Fig.3.4), reflecting an absence of structural control over drainage lines on these deeply weathered plains. Meta-sediments beds such as the quartzite ridge south-west of Shika can impart a rectilinear pattern. The Kubanni river is dammed by the Ahmadu Bello University and supplies the campus and university staff quarters with portable drinking water while river Galma is dammed by the state government to supply water to most parts of urban Zaria.

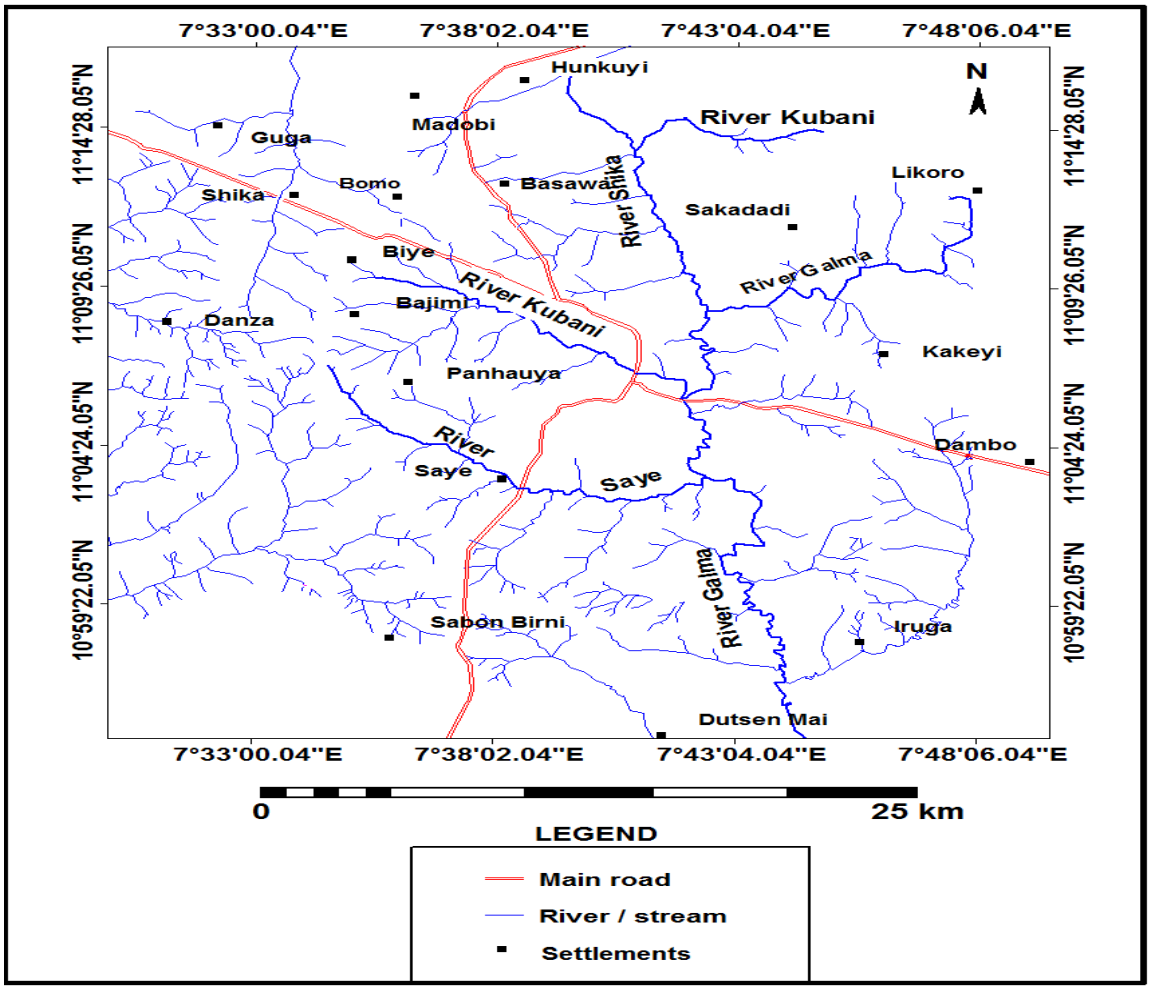


Fig. 3.4: Drainage of the Zaria Area
Source: Adapted from Wright and McCurry (1970)

3.2.4 Soils

Zaria soils are classified as leached ferruginous tropical soils developed on weathered regolith overlain by a thin deposit of wind-blown silt from the Sahara desert during many decades of propagation of the tropical continental air mass into the area (Wright and McCurry,1970). Most of the soils have a sandy loam texture (Jaiyeoba, 1995). Leaching of clay materials and ions down the soil profiles is a major soil development process. The soil exhibit a marked horizon differentiation with iron oxide deposits in the clay-rich B-horizon, underlying the A-horizon in

forms of mottles, concretions or ferruginous hard pans called duricrusts (Klinkenberg, 1970). The top soil is rather coarse due to eluviations of the fines of the A-horizon (Jaiyeoba and Ologe, 1990).

Klikenberg (1970) described major soils in the study area as:

i) Fadama Soils : These are soils which occur in the bottoms of extensive wide valley systems. They are generally classified as Hydromorphic soils. Fadama soils are mostly dark grey clays with poor to very poor drainage, most of which have been formed in alluvial material and there are some variations in the texture of these soils. The soils tend to be better in cases where the stream has been some what incised in the valleys. They occur widely in the Galma, Shika and Kubanni basins. Klinkenberg (1970) observed that this class of soils are rich in nutrients and have adequate drainage which makes all year cultivation possible but low temperatures during the dry season can be harmful to some crops.

ii) Soils developed on meta-sediments (Schists and Quartzites) : As a result of the widespread elongated quartzite ridges to the west of Zaria, soils are shallow and stony in the interfluves crests. On the middle and lower slopes, soil profiles are deeper, become reddish-grey in color, exhibit signs of clay accumulation and hard iron concretions. On the lower slope, the soils gradually become greyer in colour while the number of iron concretions also increases, in some places iron pans can be seen outcropping at lower slope positions. Some of the higher parts of the study area (about 700m high) are characterized by a lateritic iron pan. This pan can be seen outcropping in many places and is very hard and vesicular in appearance, with small cavities. Sometimes quartz is embedded in the iron pan. The pan is underlain by a thick layer of clayey material which is very mottled in red, yellow, grey and pink. At such depth, it gradually gives

way to the weathered rock. Thorp (1970) observed that the iron pan is a remnant of an older erosion surface. However, in many places where local erosion and deposition have occurred the pan has been wholly or partially covered by the Aeolian drift material, in which case the soil is very red.

iii) Soils developed on granites: The soils contain many un-weathered material and do not show distinct soil profile development. These soils contain many un-weathered fragments of quartz and feldspar. Further away from the granitic inselbergs, very deep red clay soils are found. As in the other areas, on lower slopes and in poorly drained sites, the soils are mottled and of grey colour. All these soils frequently contain fragments of quartz and feldspar.

The soil is observed to be relatively low in nitrogen, organic matter content and cation exchange capacity (Jaiyeoba,1986) resulting from frequent bush burning overgrazing, over cultivation and rapid oxidation of the organic matter of the soil. Soil profiles are usually less than 150 cm deep, below which occurs partially weathered rocks of the parent material. The soil does not support intensive agriculture for long periods without the use of fertilizers (Klinkenberg, 1970). Abubakar (1995) observed that under intensive irrigation without subsoil drainage, the slowly permeable soils of the Zaria region may give rise to perched water tables thereby causing water logging and uneven distribution of the irrigation water, which may also cause evaporation from slowly subsiding water table which leads to a progressive accumulation of salts in the root zones of crops. Klinkenberg (1970) observed that an important problem with the Zaria area soils is that the high clay content and the overlying drift material results in the formation of surface 'cap' by high intensity rains which lower infiltration rates and give rise to increased runoff with high erosion risk.

3.3 Plant and Animal Species

There are different types of plant species in Zaria area. They include Bush bitter leaf (*Vernonia kotschyana*), PittWeed (*Aeschynomene uniflora*), Spanish needle (*Bidens bipinnata*), Melon (*Colocynthis citrullus*), Fodder tree (*Pithecellobium dulce*), Locust bean tree (*Parkia biglobossa*), Broom weed (*Sida acuta*), Gall plant (*Guiera senegalensis*), Banana (*Musa sapientum*), Yellow Senna (*Senna siamea*), White Alba (*Ruta alba*) etc. Animal species include Roan Antelop (*Hippotragus equinus*), Lion (*Panthera leo*), African giant rats (*Cricetomys gambianus*), mole rat (*Africanthus niloticus*),village weaver bird (*Ploceus cucullatus*), Columbid species (pigeons and doves), rats (*Ratus ratus*), guinea fowl (*Guinea numida meleagris*), sheep (*Ovis vigne*), local and hybrid species of chickens (*Gallus domesticus*) monkeys, Pigs (*Susscufa domesticus*), goats (*Capra hircus*), cows (*Bos primigenius*), duck (*Muscovy cairina moschata*) hyenas, dogs etc.

3.3.1 Ecosystem and vegetation community

Vegetation in the Zaria area is of the Guinea Savannah type. It is typically deciduous woodland type, shedding their leaves annually during the dry season to conserve water. Vegetation pattern follows closely the gradient of rainfall (Jackson, 1970). Land management practices have resulted in the evolution of thorny shrubs interspersed with short annual grasses. Trees have developed some adaptive features such as thick cuticle and thick young twigs to enable them survive the high evapo-transpiration and annual bush burning.

The most dominant tree specie found in the Zaria region is the *Isoberlinia doka, Terminalia avicennioides, Combretum binderianum, Bridelia ferruginia, Butyrospermum paradoxum, Vitex doniana, Acacia sieberiana* and *Parinari curatellifolia.* Smaller trees include *Ximenia*

americana, Stereospermum kunthianum, Nauclea latifolia, Annona senegalensis and *Dichrostachys cinerea* (Jackson, 1970). The common grass communities in the study area are *Andropogon spp*., *Hyparrhenia spp*., *Schizachyrium semiberbe* and *Monocymbium ceresiiforme spp.* The natural vegetation types are those communities in which the flora is largely indigenous and self established and includes long-established vegetation as well as recent adventives communities which follow on any type of disturbance. The communities of primary, secondary and biotically influenced successions fall into this category.

Non- natural communities are considered as those deliberately established by man (Plate II). The most obvious non-natural communities are those connected with the city and its environs (Jackson, 1970). In the city proper, within the walls are farms and gardens with old established Date palms, Mangoes, Silk cottons and Baobab trees. *Ceiba parkland, Ceiba pentandra* (Silk cotton tree) which is often trimmed and pruned regularly dominates the landscape around the city). Other cultivated tree species include *Tamarindus indica* (Tamarind), *Dalbergia sissoo, Adansonia digitata* (Baobab) and *Mangifera indica* (Mango). *Daniella oliveri* and *Khaya senegalensis* are trees which are considered of the Guinea Savanna zone but they are grown under protection in Zaria Government Reserved Areas and flourish well. Many savannah trees and shrubs are able to re-grow after being cut down or burnt. In local agricultural systems fire plays a large part in the clearance and preparation of cultivation (Jackson, 1970). Thus, many Savanna trees and other species have corky barks and thick young twigs. Shrubs found in the study area are *Terminalia avicenniodes* which appear to replace *Isoberlinia doka* shrub in areas where fires have been more fierce and frequent and it forms the next most common shrub after *Isoberlinia doka.* Others include *Entada africana* and *Aristida spp.* (Plate III).



(a) (b)

PLATE II: (a) *Magnifera indica* plantation in Saye (b) Combination of *Delonix regia* and *Spathodea campanulata* plantation in Dambo, Zaria area.



PLATE III: Scrubland vegetation in Biye

However, the natural vegetation has been greatly altered by human interference such as cultivation, bush burning, overgrazing and construction activities (Rains, 1963; Iguisi, 1996). This exposes the soil to degradation through erosion and consequent depletion of its nutrients.

3.4 Population and Settlement

Zaria is a fast growing urban area with a population of about 1,490,000 inhabitants (FRN, 2007) . The native population of the Zaria area is predominantly Hausa and Muslims and the cultural aspects of the area consist mainly of an agricultural background. The presence of educational institutions also greatly influences the pattern of settlement as the large heterogeneous city attracts population from all over the world. However, the settlement pattern has been influenced by relief and drainage characteristics of the study area. Alluvial soil is formed along the flood plains of Galma, Kubanni and Saye rivers. Along the gentle rolling plains are human settlement and agricultural activities. This is because of the presence of rich soils and available water for irrigation purposes (Fadama farming).

The pattern of human settlement in Zaria is tied to its historical background, political and socio – economic factors (Smith,1954; Urquhart, 1977). Prior to the British occupation in 1901, the basic unit of human settlement was the extended family compounds. As these compounds (‘‘Sassa’’, in Hausa) grew, the need for security and defence led to a higher hierarchy of settlements called ‘‘Garuruka’’(towns, in Hausa). These towns were protected by walls with a titled/administrative head appointed by higher political authority, the ‘‘Sarki’’, in the various wards in Zaria. City walls associated with ditches built and maintained by the Emirs, sharply define the Hausa states. The practice of purdah or the sequestration of women has resulted in a great degree of privacy and partially explains the inward orientation of the walled compounds which blank-facedly line

foot paths and roads (Smith, 1954; Urquhart, 1977). The demand for privacy probably increases the need for walls and numerous reception areas (‘‘Zaure’’, in Hausa) and are indirectly responsible for the proliferation of burrow pits in the Zaria area. These extensive soil excavations and numerous burrow pits result in increased risk of flooding and erosion which contribute to the soil degradation menace. Similarly, Ajayi (1986) observed that rapid population growth in the Zaria area has resulted in more intensive farming to meet the population demand , disappearance of the traditional fallow system of agriculture due to scarce land resources and intense competition for land at the urban fringe with severe consequences for soils in the area.

3.5 Land Use

The economic characteristics of land use in any given town or area are often influenced by its physical, ethnic and socio-cultural characteristics. The way in which land is put into use is often determined by the culture and religion of indigenes of that area. In Zaria, however, there are different types of land uses. These include agricultural, commercial, residential, institutional land uses and open spaces (Plates III-VII) .

i) Agricultural land use : Land use practices in Zaria are mainly intensive farming activities which include rain fed and dry season farming in the fadamas and artificially irrigated fields, all year round grazing of animals, establishment of new settlements as well as expansion of old ones. Two main types of farmlands are found in Zaria; Tudu or upland fields (Plate V) which are cultivated during the rainy season and fadama farmlands or lowland fields (Plate VI). Usually, the rainy season farming takes place in the upland fields and support crops such as maize, guinea corn, millet, beans and groundnuts which have relatively low value per area. The irrigated farming is conducted all year round on low land fields which support high value per hectare

crops such as sugarcane, onions, pepper, tomatoes, yams and potatoes. Uneven rainfall distribution causes agricultural production to be seasonal and is responsible for intensive irrigated agriculture. Irrigated agricultural practice ensure availability of these crops and makes farming an all year activity and occupation.

There are various crops and vegetables in Zaria. These include maize, guinea corn, cotton, millet, groundnuts, beans etc. There is an abundance of Yams, Sweet Potatoes, Irish Potatoes and Cassava found in the Zaria area. Vegetables found here include Spinach, Carrots, Tomatoes, Pepper and Okro (Plates IVa and IVb). Soil management and conservation methods include bush fallowing, mulching, crop rotation, multiple cropping system, bush burning. There is a relative soil buffering by the application of organic manure and inorganic fertilizers (Jaiyeoba,1995).



PLATE IV a: Favourable climatic conditions favour large scale production of vegetables



PLATE IV b: Examples of vegetables found in the Zaria area.

ii) Commercial land use: This land use type includes all forms of business, both wholesales and retail. The bulk of commercial activities are carried out in the Sabon Gari main market. Sand mining is commonly practiced in the study area for moulding bricks for mud houses and road construction. Minor fishing, fish farming and poultry activities also take place in the study area on commercial and consumption scales.

iii) Residential land use: This is the second largest land use type after agricultural land use in the study area. Various residential units are recognizable (both rural and urban settlements). Prominent settlements include Zaria City, Sabon Gari, Tudun Wada, Wusasa, Kongo, Magume, Samaru, Bassawa, Biye, Bomo, Palladan and Shika.

iv) Institutional land use: These are also known as public lands. There are generally five main areas where several institutions are located. These are Kongo, Gaskiya/Magume, Samaru, Palladan and Bassawa. Kongo houses staff and students of Federal College of Education (FCE) and Ahmadu Bello University (Kongo campus). Samaru houses staff and students of Ahmadu

Bello University (ABU) main campus and also staff and students of Leather Research Institute (LERIN), Samaru. Gaskiya/Magume houses staff and students of Kaduna state Polytechnic, Zaria. Palladan accommodate staff and students of the Nigerian College of Aviation Technology (NCAT) while Bassawa (and Palladan) houses staff and students of National institute of Transport Technology (NITT) and the Nigeria Military School (NMS). Shika houses staff and students of the Ahmadu Bello University Teaching Hospital (ABUTH) and the National Animal Production Research Institute (NAPRI). Zaria is known for her high number of educational institutions, both tertiary and several secondary and primary schools and has earned the name ‘‘Gidan Boko’’(home of knowledge). The are two main areas in Zaria which accommodate the military and their families; the Military Depot at PZ and the Bassawa barracks.

v) Open spaces: These are vacant lands that are ‘ripening’ for a higher use. Open spaces are vacant lands awaiting development . These are being rapidly acquired and built up as a result of rapid population growth.

vi) Industrial land use: most industrial areas are located away from residential and educational areas and are located close to accessible roads. There are two main industrial layouts in Zaria; Chikaji and Dakace.

Cattle and sheep rearing by the nomadic Fulani/settled rearers is also a major activity in the Zaria area. During the dry season, livestock are subjected to long treks in search of water and lush vegetation due to increasing dryness and receding grassland areas. These livestock graze along as they move through uncultivated (and sometimes cultivated) lands, destroying the vegetative cover of such lands and causing soil compaction. Grazing, deforestation for construction,

agricultural and industrial activities modify the character of the vegetation in the Zaria area and contribute to the problem of soil degradation.

3.6 Socio-economic and Cultural Conditions

The economy is primarily based on agricultural and industrial development. The main agricultural produce in Zaria are cotton, peanuts, hides and skins, sugarcane, ginger, beeswax, millet, maize, guinea corn, potatoes, carrots, and garden eggs . Its strategic location and good transport network (including feeder roads to rural areas and the presence of a railroad) enhance and boost active trading activities in the area. The industrial activities in the study area include cotton seed- oil milling, cotton ginning, peanut and shea nut milling, tanning and shoe making, groundnut oil production. Tobacco, cement block, bicycle, perfumes and soaps manufacturing industries are also located in the study area. Local industries include local smelting for making farm implements such as hoes, cutlasses, ridgers (*garma*, in Hausa) aluminium pots, spoons, buckets, etc pottery and manufacturing of mud bricks for local animal and human shelter. Apart from its industrial growth, Zaria is also known for its educational growth. It is home to many federal and state institutions such as the Ahmadu Bello University (ABU), Institute for Agricultural Research(IAR), National Animal Production Research Institute (NAPRI), Nigerian College of Aviation Technology (NCAT), Nigerian Military School (NMS), National Institute of Transport Technology (NITT), College of Leather Technology, Federal College of Education (FCE) and Kaduna state polytechnic.

3.7 Environmental Problems

Rapid population expansion has led to increasing demand for food in both rural and urban areas. Rapid urban growth and its associated increase in population cannot be met by expanding

agricultural areas because in most areas, the land available is not suitable for sustainable crop production due to erosion. Industrial expansion coupled with rising population have a direct and adverse effect on the available agricultural land. Some problems associated with population growth, urban and industrial expansion are pollution due to automobile exhaust, industrial waste from industries, poor waste disposal habits which often clog drains and lead to localized flooding and water pollution, and unsustainable use of land resources. Haruna *et al.,* (2003) observed levels of trace metals in sewage water and some vegetables cultivated with contaminated water from sewage irrigated areas. Unsustainable use of land resources due to over cultivation and bad farming practices such as bush burning, lead to the degradation of soils by erosion. Aminu (2008) observed that burrow pits dug out as a result of excavations for clay and other building materials are used to conserve water and these often breached their lower rims during storm runoff or flood events. Vegetation clearance, cultivation and over grazing are some of the factors which lead to erosion in the Zaria area (Jaiyeoba, 2003) .

From the fore going analysis, it is clear that Zaria region is naturally well endowed. The Zaria environment is, however, under increasing threat from human and natural disasters. There are already certain ominous problems with the environment and visible scars associated with the destruction of the natural resource base (land, water and air) upon which all life depend are being noted. Of the various environmental problems faced by the region in the present time, soil degradation is perhaps the most significant. Land is by far the most important resource necessary for subsistence. Yet much of the region's arable land is being sapped insidiously of its productive potential through over use, inappropriate technologies and urbanization. Rapid deforestation, resulting from multiple uses of forest resources for human survival is a major factor for land

degradation. The end result of deforestation and other agricultural activities, including intensive grazing and over-cultivation is severe land degradation (Plate VII).



Plate V: Cultivated land use in Dambo



Plate VI: Fadama land use in Kakeyi



Plate VII: Typical badlands found in Dakaci (above) and Hunkuyi (below)

CHAPTER FOUR: MATERIALS AND METHODS

4.1 Data Required and Sources

Data required for this study (as summarized in Table 4.1) include data on land use and land cover change (LULC) over a three time period, key soil physical and chemical properties (organic matter content, cation exchange capacity, soil pH, exchangeable cations and bases, particle size distribution, bulk density, porosity and soil moisture content) and field survey of farmers' perceptions using questionnaires.

Table 4.1: Data Required for the Study and Sources

S/N	Data Required	Sources of Data
1.	Data On LULC for three time periods (using Landsat TM of 1990 and Landsat ETM of 1999 with 30m resolution and NigeriaSat-1of 2009 with 32m resolution). Maps (topographic, administrative and land use)	National Centre for Remote sensing (NCRS) Jos, Ministry of land and survey, Kaduna state and University libraries.
2.	Physico- chemical indicators of soil degradation (particle size distribution, bulk density, porosity, soil moisture, CEC, organic matter content, soil pH and Exchangeable bases and base saturation).	Field survey and sampling, Laboratory analysis
3.	Farmers perception and coping strategy for soil degradation	Field survey of farmers perception using questionnaires.
4.	Environment of the study area	Desk-top review of literature and field survey.

4.2 Research Design and Methodology

4.2.1 Reconnaissance survey

The reconnaissance survey was conducted between 14 to 21 May, 2012. This was done to:

i. explain the objectives of the study to various community leaders in the study area and seek their permission and cooperation for the study.

ii. familiarize with the study area.

iii. acquire relevant data on the environment of the study area.

The outcome of the reconnaissance survey is the selection of five villages (Fig 3.1) for the study.

4.2.2 Assessment of land use and land cover change

For the purpose of this research, the LULC change in Zaria of between 1990, 1999 and 2009 was determined using remotely sensed data and GIS for changes of the three time periods. Table 4.2 summarizes the characteristics of the imageries used for this study.

Table 4.2: Characteristics of Satellite Imageries Used for the Study

Type of satellite imagery	Date of acquisition	Spatial resolution (m)	Bands combination
NigeriaSat-1	10/9/2009	32	3,2,1
Enhanced thematic mapper (ETM)	19/10/1999	30	3,2,1
Thematic mapper (TM)	27/11/1990	30	4,3,2

4.2.2.1 Analysis of remote sensing data

The first stage in the analysis of the image data involved a preliminary visual analysis. Image visual analysis is an on-screen or analogue visual observation of the spectral characteristics of the imagine in order to extract relevant information. The processes involved in remote sensing and GIS analysis are image sampling, image classification, image crossing, change detection and change analysis (Fig. 4.1). Sub-setting was carried out in order to cut out the area of interest from the larger data. This is necessary to save time and effort. This analysis was carried out in the Integrated Land and Water Information System (ILWIS) 3.3 academic environment. The data was geo-referenced by sampling each data set to a uniform pixel size that is registered to a geographic co-ordinate system. Since the images acquired were displayed in different projections, there was need for image rectification. The purpose of image rectification is to help bring the data sets of the different periods to a common co-ordinate system in order to make

analysis of surface changes possible (Elvidge, Miura, Jansen, Groeneveld and Ray 1998). Ground control points (GCPS) which can be identified on the images and assigned co-ordinates from existing maps and GPS information was used to achieve this. The original image pixel was re-sampled into the specified map projection (Sabin,1999). The resulting false colour composite maps for the three images are presented in Figs.4.2, 4.3 and 4.4.

Each of the data sets was classified into various LULC types. The supervised classification was adopted using training sets constructed through ground truthing (Castelli, Elvidge, Li and Turek, 1998). The supervised classification was based on the maximum Likelihood classifier (MLC) algorithm (ERDAS field guide, 1997). The Maximum Likelihood Classifier assumes that a pixel has certain probability of belonging to a particular class. These probabilities are equal for all classes and the input data in each band follows the Gaussian distribution function (Lillesand and Kiefer, 2004).

This was followed by post classification, involving the change detection analysis. The classified images were then combined to create a new change image classification which showed the changes that have occurred within the time in question. The accuracy of the classification was verified by field check. There is, however, need for quantitative assessment of the degree of accuracy. This is necessary because post classification change detection may exhibit inaccuracies due to miscalculation or quality of satellite imageries used. The most common method used to assess classification accuracy is the use of error or confusion matrix (Congalton and Green, 1999). It is calculated for the most recent imagery since it is the only one that can be verified by field check. It involves a measure of user's accuracy, producer accuracy and the Kappa coefficient. Table 4.3 shows the confusion matrix generated for the study.

Table 4.3: Confusion Matrix for SAT-1 2009 Classified LULC Map

LULC	BS	BU	CU	FA	PL	SC	WB	Total	User's accuracy
BS	3	-	-	-	-	-	-	3	1.0
BU	1	3	-	-	1	-	-	5	0.60
CU	-	-	3	1	-	1	-	5	0.60
FA	-	1	-	2	-	-	1	4	0.50
PL	-	-	-	-	3	-	-	3	1.0
SC	-	-	1	1	-	3	-	5	0.60
WB	-	-	-	-	-	-	3	3	1.0
Total	4	4	4	4	4	4	4	28	
Producer's accuracy	0.75	0.75	0.75	0.5	0.75	0.75	0.75		

***** BS= bare surfaces, BU= built up areas, CU=cultivated areas, FA= fadama, PL= plantation/ forest, SC= scrubland, WB= water bodies

Producer's accuracy is the probability of a reference site being correctly classified, i.e., a measure of omission error. It is the number of sites correctly classified as a land cover divided by the total number of reference sites for that land cover (Congalton, 1991). The producer's accuracy for this study is 0.71 or 71%. User's accuracy, on the other hand, indicates reliability, or the probability that a site classified on the image is really that land cover type on the ground. It is the number of sites correctly classified as a land cover divided by the total number of sites classified in that category (Congalton, 1991). The user's accuracy calculated is 0.76 or 76%.

The Kappa statistics is a of measure of overall agreement between image data and the reference (ground truth) data. It is on a scale of 0 and 1, where the later indicates complete agreement. The Kappa Coefficient is given as;

$$K = \frac{N\sum_{i=1}^{r} Xii \; - \; \sum_{i=1}^{r} (X_{i+} \times X_{+i})}{N^2 - \sum (X_{i+} \times X_{+i})}$$

Where:

r = The number of rows in the error matrix

Xii =The number of observations in row i column i (along the major diagonal)

X_{i+}= The Marginal total of row

X_{+i}= The Marginal total of column

N = The total number of observations included in the matrix

(Congalton and Green, 1999).

The Kappa coefficient calculated for the classification is 0.67

The overall accuracy is represented by the ratio of the number of correctly classified pixels by the total number of pixels sampled. A total of 28 sample points were used in this study (Appendix I). The overall accuracy of the classification is 0.71 or 71%.

4.2.2.2 Land Use Classification Scheme

A total of seven land use categories were adopted for the study. These include bare surfaces, built-up areas, cultivated land, fadama (wet lands), plantation, scrublands and water bodies and are described in Table 4.4.

Table 4.4: Land Use/Land Cover Classification Scheme Adopted for the Study

S/N	Land use/land cover type	Description
1.	Bare surfaces	All bare surfaces, degraded lands, sites of building under construction, dilapidated buildings and harvested farms left bare or to fallow. It also includes areas with scanty or no vegetation cover including rock outcrops.
2.	Built up areas	Built up areas indicate settlements both in urban and rural areas. They include residential, administrative, educational, commercial and industrial land uses.
3.	Cultivated area	These include all agricultural land uses such as farm lands under cultivation.
4.	Forest plantation	Areas planted with trees which are protected by law from exploitation. It could be natural (forest) or non-natural (plantation). Non- natural communities are considered as those deliberately established by man.
5.	Scrubland	These are areas covered mainly with shrubby plants and low height trees, usually less than 2 meters tall. They are also important as green pastures for livestock farming in Nigeria
6.	Water bodies	Areas covered by water bodies such as streams, rivers, dams and ponds.
7.	Fadama	Areas bordering streams, rivers and dams whose soils are often flooded and used for cultivation. The Galma river and its tributaries, Kubanni, Shika and Saye, form extensive flood plains in the Zaria area.

Adopted from Jibrin (2009).

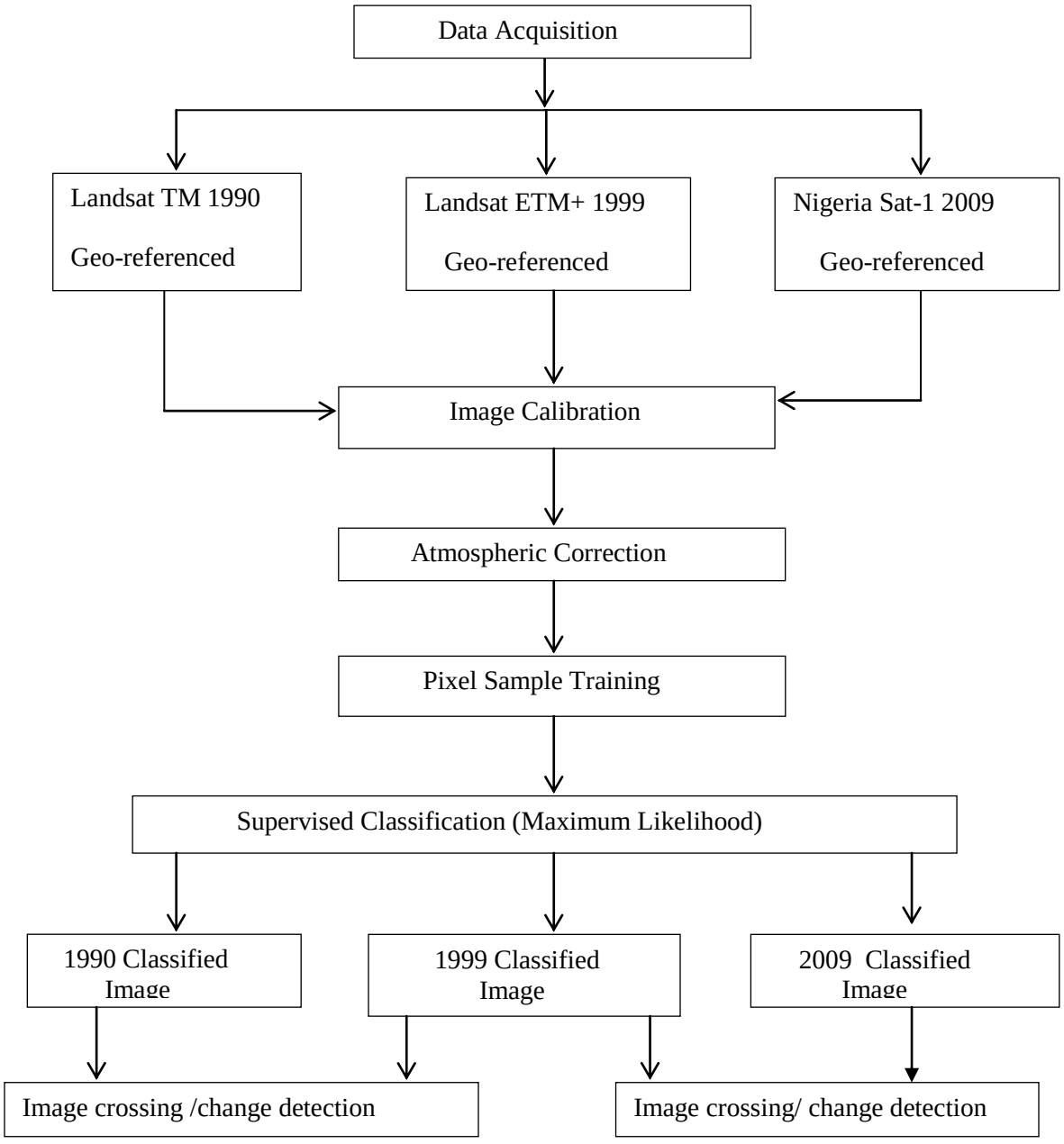


Fig. 4.1: Methodology Workflow for Landuse/Land Cover Assessment

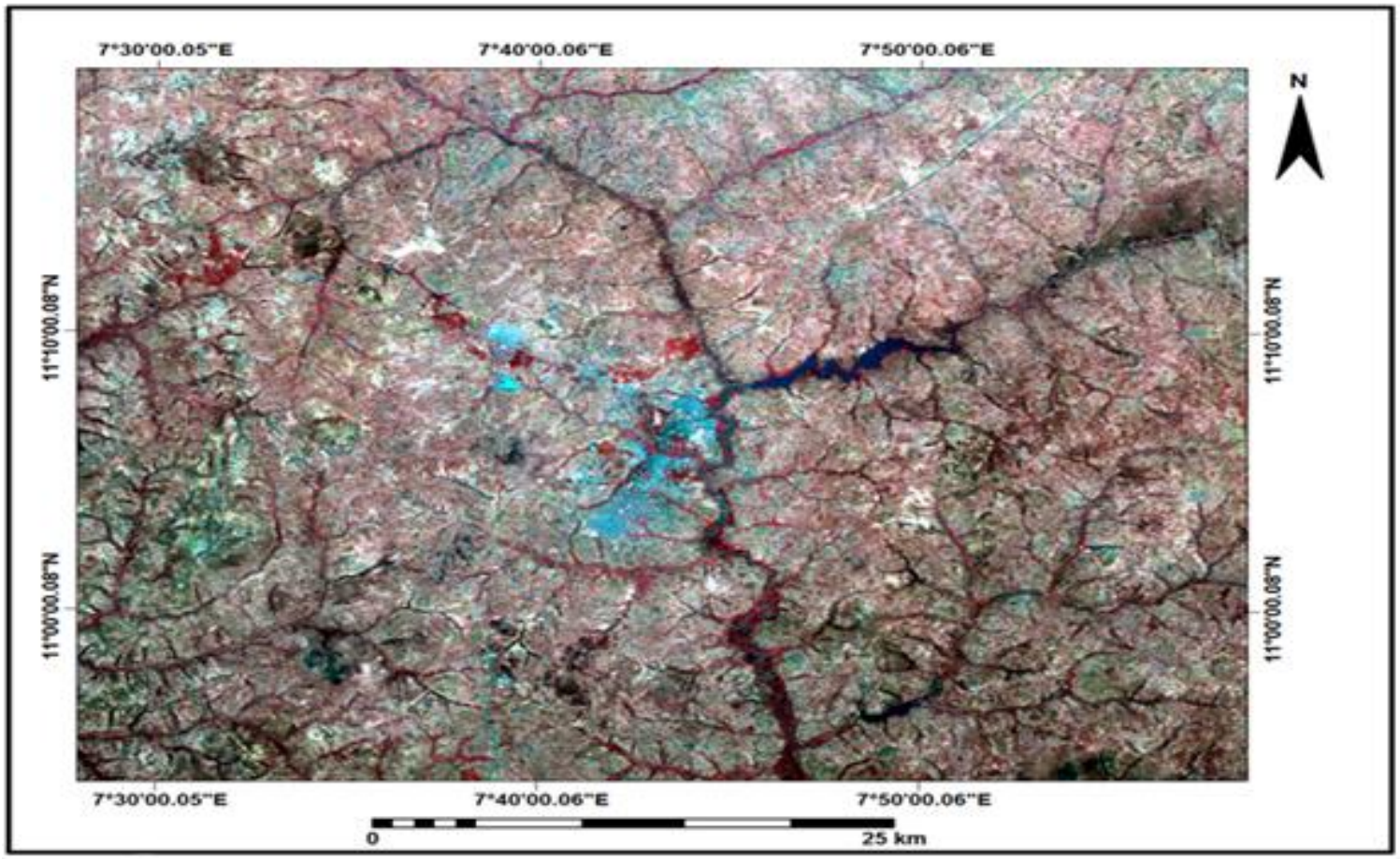


FIG. 4.2: LAND USE/LAND COVER IMAGERY OF THE STUDY AREA, TM 1990
Source: National Center for Remote Sensing (NCRS), Jos. 2011

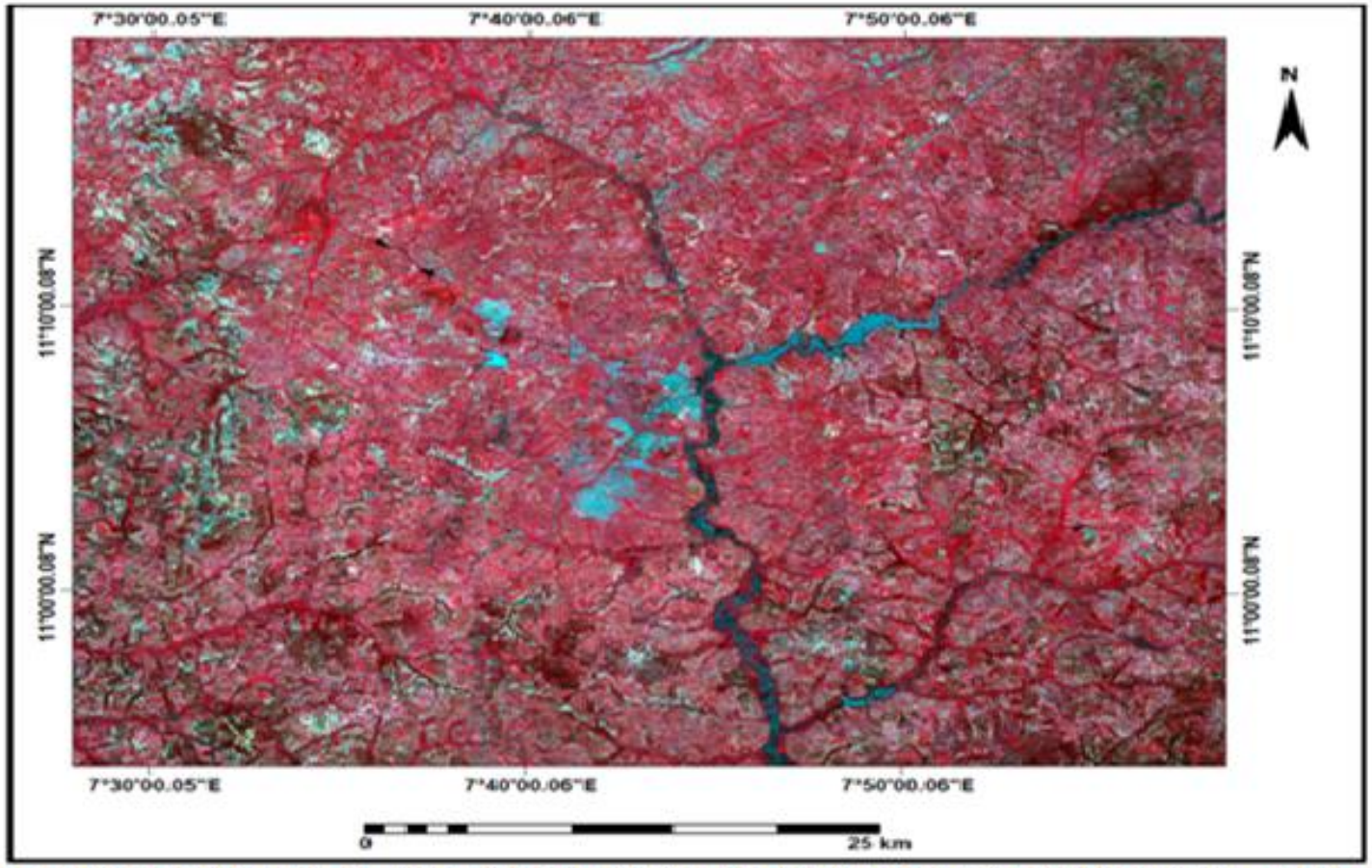


FIG.4.3: LAND USE/LAND COVER IMAGERY OF THE STUDY AREA, ETM+1999

Source: National Centre for Remote Sensing (NCRS), Jos. 2011

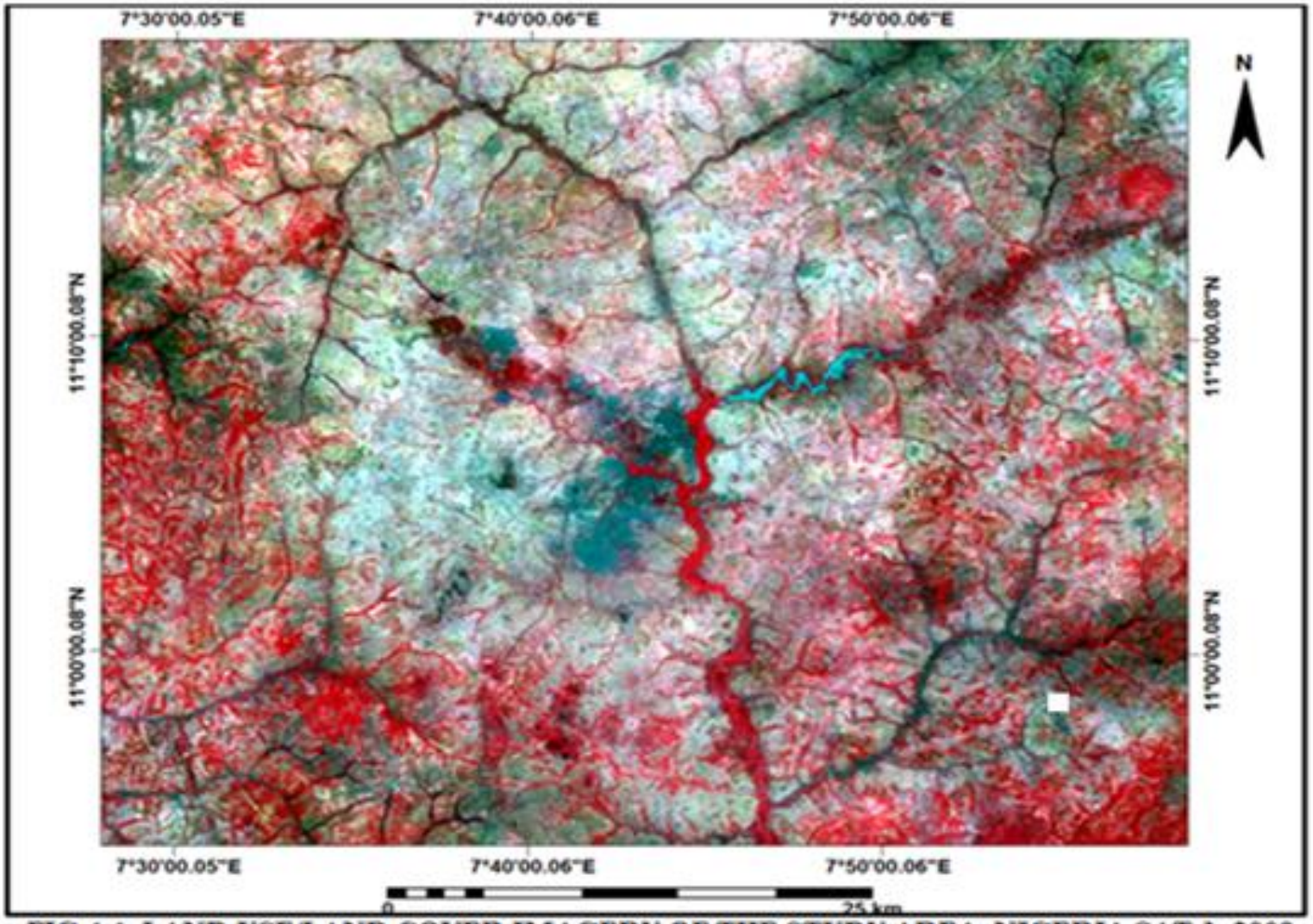


FIG.4.4: LAND USE/LAND COVER IMAGERY OF THE STUDY AREA, NIGERIA SAT-1, 2009

Source: National Centre for Remote Sensing (NCRS), Jos. 2011

4.2.3 Soil degradation and farmers' survey

4.2.3.1 Selection of study sites

Based on the result of the land use and land cover analysis carried out, representative sites were selected over the dominant land use categories. A total of 5 study locations (villages) were selected for the study, all lie within 25 km^2 of Zaria urban Area (with PZ as the reference point). Of the seven major landuses identified in the land cover analysis, only 5 were appropriate for further study and so were selected. These landuses are cultivated land, scrubland, badland, forest/plantation and fadama. The remaining two that could not be used are water bodies and built–up area. The field survey was carried out during the rainy season between July and September, 2012 when a reasonable number of farmers were on their farms.

4.2.3.2 Soil degradation survey

Soil degradation is conceptually rather wide and difficult to accommodate in a few simple measures. Soil erosion by water is, for most landscapes, the commonest way in which soil degradation occurs. Again, there is considerable linkage between erosion and other types of degradation. An eroded soil will almost always have less organic matter (biological soil degradation), increased bulk density (physical soil degradation) and other problems such as water logging (Stocking and Murnaghan, 2000). Since soil erosion by water is the most visible way in which soil and land degradation affects the direct production of land users, this project has deliberately taken evidence of soil erosion as the main set of indicators of the seriousness of soil degradation. This is done not to imply that soil erosion is the only (or even the single most important) evidence of soil degradation which affects farmers. But there are many experiences to indicate that soil erosion acts as the single best proxy for most of the other aspects of degradation (Stocking and Murnaghan, 2000).

Experience has suggested that where one indicator is identified, the keen observer then starts to see many more (Stocking and Murnaghan, 2000). It will be seen that the indicators apply to different timescales: an armour layer forms after one or two heavy storms in the early growing season, while tree mounds may take 50 or more years to form (Stocking and Murnaghan, 2000). They apply to different spatial scales: a soil pedestal may be only 3 mm across, whereas a gully can in exceptional cases be 5 km long. It should be clear, then, that none of these measures are directly comparable with each other. However, after careful scrutiny, they can be used to ascertain general trends in land degradation.

The soil degradation survey comprised transects walks in four equi-angular directions from the village centre, and up to 2 km distance. During the walks, the researcher and research assistants observed and took note of the forms and level of soil degradation and associated indicators: erosion, compaction, water logging, soil deposition and the like.

In this study, the farmer's interview and field assessment of soil loss indicators exercise were supplemented by actual determination of a limited number of physico-chemical indicators of soil health. The samples for the determination of such properties were drawn from cultivated land, scrubland, badland, forest/plantation and fadama land uses during the field survey. For each land use category, at each study location (village), composite soil sample was taken at the 0-10cm depth. Each composite sample comprises of four sub-samples drawn at four different points within each landuse category, which were bulked to give one sample per landuse. Thus, in all, bulked 5 samples per study location, and per land use category, were taken, giving a total of 25 samples.

4.2.3.3 Farmers survey

Both purposeful and accidental (i.e. non-probability sampling) methods of selection of respondents for questionnaire administration were employed. The purposefully selected respondents included community leaders, agricultural/forestry advisory staff and prominent farmers. The accidental samples on the other hand comprised farmers that were on their farms at the time of the survey. Thus, the field survey carried out served dual purposes: the physical assessment of soil degradation and farmer perception survey. That is, occasionally, during the transect walk, formal interviews, using structured questionnaires, were carried out with farmers who were met on their farms. The interview aimed at an assessment of individual farmer's awareness of the cause and consequences of soil degradation, attitude towards land management practices, coping strategies, as well as opinions on identification and perceptions of soil degradation indicators on their fields.

The structured questionnaire used is a mixture of close and open ended questions (Appendix III). There are four main parts to the questionnaire. The first part focuses on socio - demographic characteristics of the respondents, while the second part focuses on awareness and attitude tests for farmers towards soil degradation. Information solicited for in this segment centred on items such as:

(i) Awareness of causes of soil degradation
(ii) Awareness of consequences of soil degradation
(iii) Awareness of land management practices
(iv) Farmers information sources about land management practices
(v) Farmers identification and extent of use of land management practices
(vi) Attitude towards on land management practices

The thrd part contains farmers' perceptions of and coping strategies to soil degradation, while the fourth part focused on barriers to adoption of soil conservation measures. The basic sampling unit in the interview survey was the farmers' household who derive their livelihood entirely from agricultural activities. Thirty farmers were interviewed in each of the selected five locations. Thus, overall, a total of 150 farmers were interviewed individually for this study, and in all cases, they are the head or most senior household member.

The individual farmer survey was supplemented by farmer' group discussion sessions organized for each village. The focus of such meetings was on farmers' knowledge and capability to identify existing soil degradation indicators on the cultivated landscape. The meetings were arranged for afternoons or evenings, and were attended by between 33 and 50 farmers per village on various days. At the meetings, farmers enumerated the known soil degradation indicators. They also described appearance of each of the indicators in their fields and their causes. Other issues discussed in the meeting included: categorisation of indicators into those that were observable during a rainy season (i.e. current indicators), or because of long-term erosion effects (i.e. past indicators). In another separate meeting, the key informants analysed all the erosion indicators generated by the village groups, to establish a consensus list of erosion indicators for the study area (Okoba and Sterk, 2006).

4.3 Laboratory Analysis of Samples:

Each composite soil sample collected from the field survey was air- dried, crushed and sieved through a 2mm sieve and used for the assessment of selected soil physico-chemical properties as described below.

4.3.1 Particle size distribution

This was determined using Bouyoucos hydrometer method (Agbenin, 1995). To this end, 50g of air – dried soil sample was weighed into a plastic beaker and 100ml sodium hexa-meta-phosphate solution (calgon) added. The use of this salt is to ensure the dispersion of soil particles i.e. to ensure that the various binding agents, e.g. organic matter or sesqui-oxides are broken and the individual soil particles left loose. The soil solution in the plastic container was then placed on an end to end mechanical shaker for about 5-10 minutes to complete the dispersion process of the individual soil particles. Thereafter , the solution was transferred into a measuring cylinder and distilled water added to make up to 1000ml mark.

The suspension was vigorously mixed or disturbed using a long handle plunger and then a standard Bouyoucos hydrometer inserted, being gently lowered into the suspension and readings made at the top of the meniscus. The first hydrometer reading was taken at 40 seconds to obtain the concentration of clay and silt. The suspension left to stand for 2 hours and second reading taken to obtain the concentration of clay.

A blank was prepared by making 100ml of the 50% calgon solution up to the 1Ltr mark with water, and the hydrometer readings taken. The temperatures of both the suspension and the blank are noted in each case.

Calculations:

The corrected hydrometer readings C (g/l) were obtained by subtracting the blank reading R (g/l) from the hydrometer readings in the soil suspension R (g/l) and adding 0.36g/l for every degree above 20^0c.

$C = R-RL+ (0.36T)$

Where, T= Room temperature minus 20

The percentages by weight of the silt + clay and sand fractions are given by:

$$\%clay = \frac{\text{corrected 2 hours reading- blank} \times 100}{\text{Weight of soil taken}}$$

$$\%\ silt = \frac{\text{corrected 40 seconds reading} - \text{blank} \times 100 - \%\ clay}{\text{Weight of soil taken}}$$

% sand = 100 - % clay + % silt

The USDA textural triangle was used to convert the resultant particle- size distributions into textural classes.

4.3.2 Bulk density and moisture content

The bulk density (BD) ring containing the collected soil sample was put into crucibles, weighed and oven dried at 105^0C for 24 hours after which it was re-weighed. The bulk density value for each sample was determined as follows:

$$BD\ (gm/cm^3) = \frac{\text{weight of the soil (g)}}{\text{Volume of the soil } (cm^3)}$$

Where, weight of soil (g) = weight of the ring plus the bulk sample after oven- drying minus weight of the ring.

Volume of the soil (cm^3) = πr^2h of core sampler.

$$\pi = \frac{22}{7}$$

r = radius of core sampler

h= height of core sampler (cm)

Gravimetric moisture content was determined as :

$$GWC = \frac{WW}{WS}$$

Where,

GCW = gravimetric moisture content

WW = weight of water (g)

WS = weight of oven-dried soil (g)

The result is expressed as g/g or can be multiplied by 100 and expressed as a percentage.

The percent pore space was determined by:

$$\text{Porosity} = \left(1 - \frac{BD}{PD}\right) \times 100$$

Where,

BD = bulk density of the soil

PD = particle density, given as 2.65g/cm^3

4.3.3 Soil pH (1:2.5)

This was determined by the use of pH meter and glass electrode inserted into soil solution of 1 :2.5. 10g of air dried soil sample was weighed into two plastic beakers containing water and $CaCl_2$. 25ml of distilled water and 25ml of $CaCl_2$ was added to the respective beakers. The two solutions were stirred vigorously using a glass rod and allowed to stand for 30 minutes before stirring again. Each suspension was left to stand for 30 minutes to allow suspended clay particles to settle beneath the beakers. The electrode of pH meter standardized at neutral pH 7 was then carefully inserted into the respective suspensions and the pH was then measured (Agbenin, 1995).

4.3.4 Organic carbon

The Walkley - Black digestion method was used to determine the soil organic carbon (Agbenin, 1995). 1gm of soil sample was weighed into a 250ml Erlenmeyer flask and 5ml of potassium dichromate ($K_2Cr_2O_7$) was pipette accurately into the solution and then swirled gently to disperse the soil. 10ml of concentrated sulphuric acid (H_2SO_4) was rapidly added from a measuring

cylinder and swirled gently for one minute to allow the soil and the reagents to mix properly. The flask was swirled again and allowed to stand on asbestos sheets for 30 minutes. 100ml of distilled water was added to the mixture and allowed to cool. This was followed by adding 3 drops of 1- 10- phenanthroline indicator to the solution in the flask and titrated with 0.5N ferrous sulphate ($FeSO_4$) solution on a white background. The end point is indicated by a change in colour: blue-green-dark green-red. The actual titre value was read and recorded. After this was done, a blank determination was made in the same way but without the soil, to standardise the dichromate. The percent carbon was determined thus:

$$\% \text{ organic carbon in soil} = \frac{(\text{Blank titre} - \text{Actual titre}) \times 0.3 \times m \times f}{\text{Weight of air-dried soil used}}$$

Where:

f = correction factor, 1.33

m = concentration of $FeSO_4$

Organic matter (%) was then calculated using the formula = % carbon × 1.724

4.3.5 Cation exchange capacity (CEC)

The CEC was determined using the ammonium acetate saturation method (Agbenin, 1995). 10g of air-dried 2mm sieved soil sample was weighed into a 500ml Erlenmeyer flask and 40ml of 1N neutral ammonium acetate (NH_4OAc) was added. The flask was shaken vigorously and allowed to stand over night. The soil solution was then filtered with a light suction using a 55mm Buchner funnel. The soil was then leached with neutral 1N NH_4OAc until 200ml extract is collected. Presence of calcium in the solution was tested by adding a few drops of 1N NH_4CL 10% ammonium oxalate, diluted with NH_4OH. The leacheate was preserved for the determination of exchangeable bases. The soil was leached with IN NH_4CL pH_7 four times with 25mls portion at a time and once with 25ml of 0.25N pH_7 NH_4CL. The electrolyte was washed

out with 200ml 99% ethanol. When the chloride in the leacheate (tested with 0.1N silver nitrate, $AgNO_3$) became negligible, the soil was allowed to drain thoroughly. The soil was then leached again, with acidified 1N NaCl to replace the NH_4^+ left in solution and the then the solution was made up to a volume of 250ml mark. The solution in the flask was placed on the distillation apparatus. 50ml of 2% boric acid was measured into the 250ml and 10 drops of mixed of indicator were added to it and ammonium borate was titrated, produced with standard 0.02 N sulphuric acid solution. This was followed

by running blanks on the reagents and the titre value was corrected with the blank result. The cation exchange capacity (CEC) was calculated using the formula:

$$CEC = \frac{(T - B) \times NA \times 100}{W}$$

Where:

T = Titre volume of the acid used

B = Titre value for blank

NA = Normality of the acid used

W = Weight of the sub- sample used

4.3.6 Exchangeable bases

The leacheate which was preserved during the CEC determination was used to determine the exchangeable bases (calcium, magnesium, potassium and sodium). The concentration of exchangeable Ca and Mg were read from an atomic absorption spectrophotometer (AAS), while K and Na were determined using the flame emission method. The exchangeable base in cmol/kg soil is calculated as:

$$\text{cmol/kg} = \frac{\text{ppm graph} \times \text{VE} \times \text{DF} \times 100}{1000 \times \text{W} \times \text{Equivalent wt of the element}}$$

Where,

VE = Volume of extractant

DF = Dilution factor

W = Weight of soil used

The percentage base saturation (expressed as %) was derived by dividing the sum of the values of the exchangeable bases by the CEC value and multiplied by 100.

4.3.7 Exchange acidity

This was determined by extraction with KCl (Agbenin, 1995). 10g of soil placed into a funnel fitted into a paper was leached with 100ml 1N KC1 solution after every 5 minutes for 2 hours. The leachate was collected into a 100m volumetric flask, and made to volume was 1N KC1 mixing the content well. 50ml of the was pipette into a 250ml beaker, 2 drops phenolphthalein indicator added and the solution titrated with 0.1N NaOH. The appearance of a permanent pink colour indicates the end point. The amount of 0.1N NaOH used in the titration corresponds to meq A1+ H or exchange acidity.

4.4 Data Analysis

Owing to the varied nature of data generated from the research, both descriptive and inferential statistics were employed in the data analysis. Frequency tables and histograms were used to summarize and describe farmers' responses. For the hypothesis testing, three major statistical techniques were employed. These are the Analysis of variance (ANOVA), students t-test and Chi-square.

The analysis of variance (F-ratio) is a parametric test for significance among three or more variables (Ebdon, 1977). In this study, it was used to test for variations in the selected soil properties over the five different land uses while the students t-test was used to test for

significant association between pairs of land uses. Chi square analysis was used to test for significant changes in landuse/ land cover over the period under study and significant associations between farmers' socio-demographic characteristics and coping strategies adopted by respondents. In addition, a Likert scale test was used to analyse respondents' attitudes to soil degradation and perceptions of the severity of soil degradation (Tekwa *et al*., 2010). It is expressed as;

Mean score= Σ(scale-grade × corresponding responses) / Total number of respondents

2.0 was taken as the base score, below which an attitude statement was considered negative.

All statistical results were tested at the 0.05 level.

CHAPTER FIVE: RESULTS AND DISCUSSION

5.1 Land Use and Land Cover Change

5.1.1 Pattern of land use/ land cover 1990-2009

Figures 5.1, 5.2 and 5.3 show the classified land use/land cover maps of the study area for the years between 1990 and 2009, while Table 5.1 shows the associated statistics.

Table 5.1: Spatial Extent and Percentage Coverage of Land Use/Cover From 1990-2009

Land use type	1990		1999		2009	
	Area (km^2)	%	Area (km^2)	%	Area (km^2)	%
Bare surface	94.60	3.8	37.33	1.41	95.59	3.62
Built-up area	220.02	8.34	243.88	9.24	289.70	10.98
Cultivated area	882.70	33.5	786.76	29.8	399.89	15.16
Fadama	129.48	4.9	479.71	18.28	471.36	17.87
Plantation/forest	49.17	1.86	176.95	6.71	110.15	4.18
Scrubland	1235.31	46.8	877.46	33.02	1255.95	47.6
Water bodies	26.92	1.02	36.13	1.36	15.56	0.59
Total	**2638.20**		**2638.20**		**2638.20**	

Source: Laboratory analysis, 2012.

The areal coverage of bare surfaces was about 95 km^2 (3.8%) in 1990. However, it decreased to 37.3km^2 (1.4%) in 1999 and again increased to about 96km^2 (3.6%) in 2009. The built up area increased steadily from 220km^2 (8.3%) in 1990, through 244km^2 (9.2%) in 1999 to about 300km^2 (11%) in 2009. The area covered by cultivated land decreased from about 883km^2

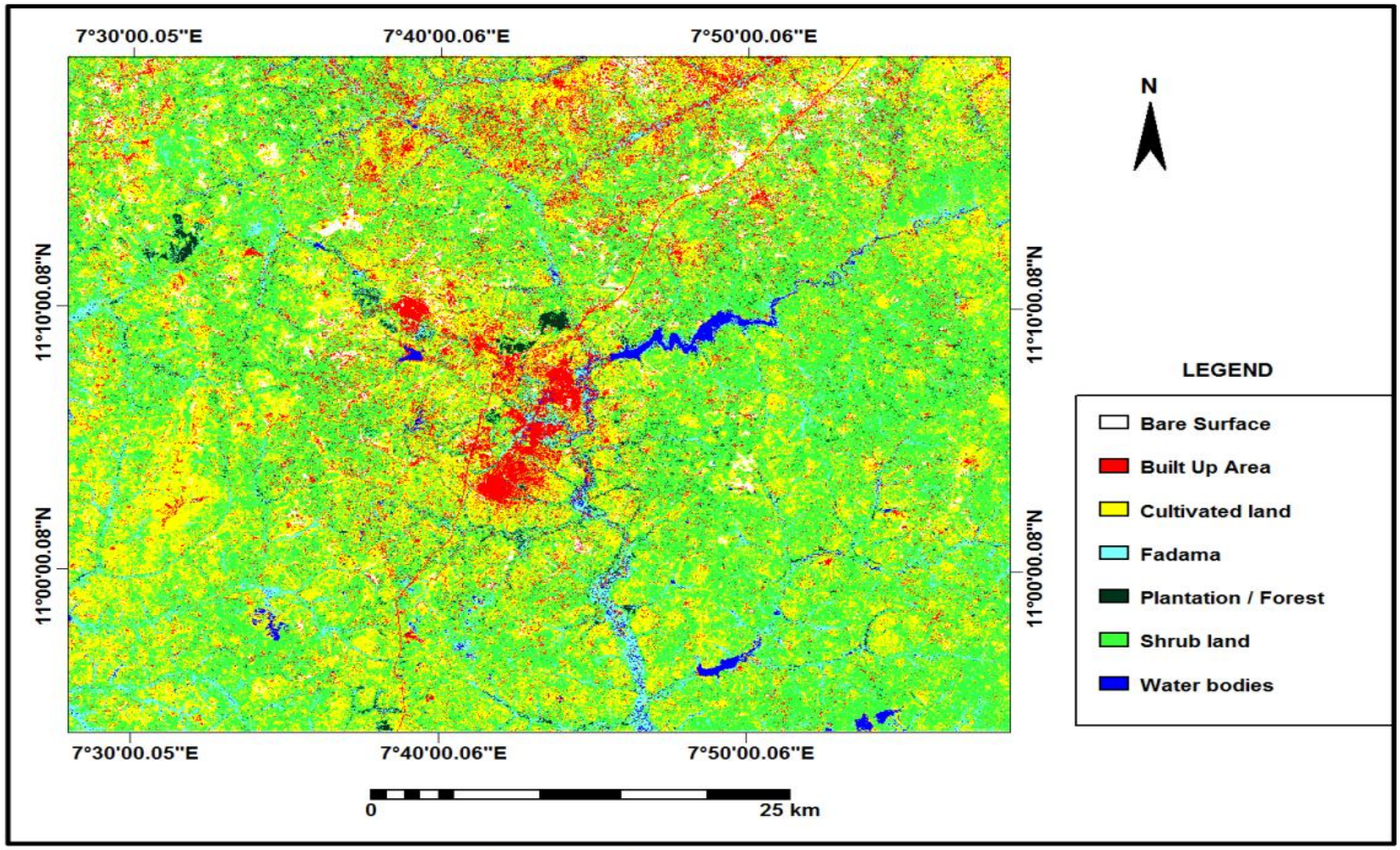


FIG.5.1: CLASSIFIED TM 90 IMAGE OF STUDY AREA

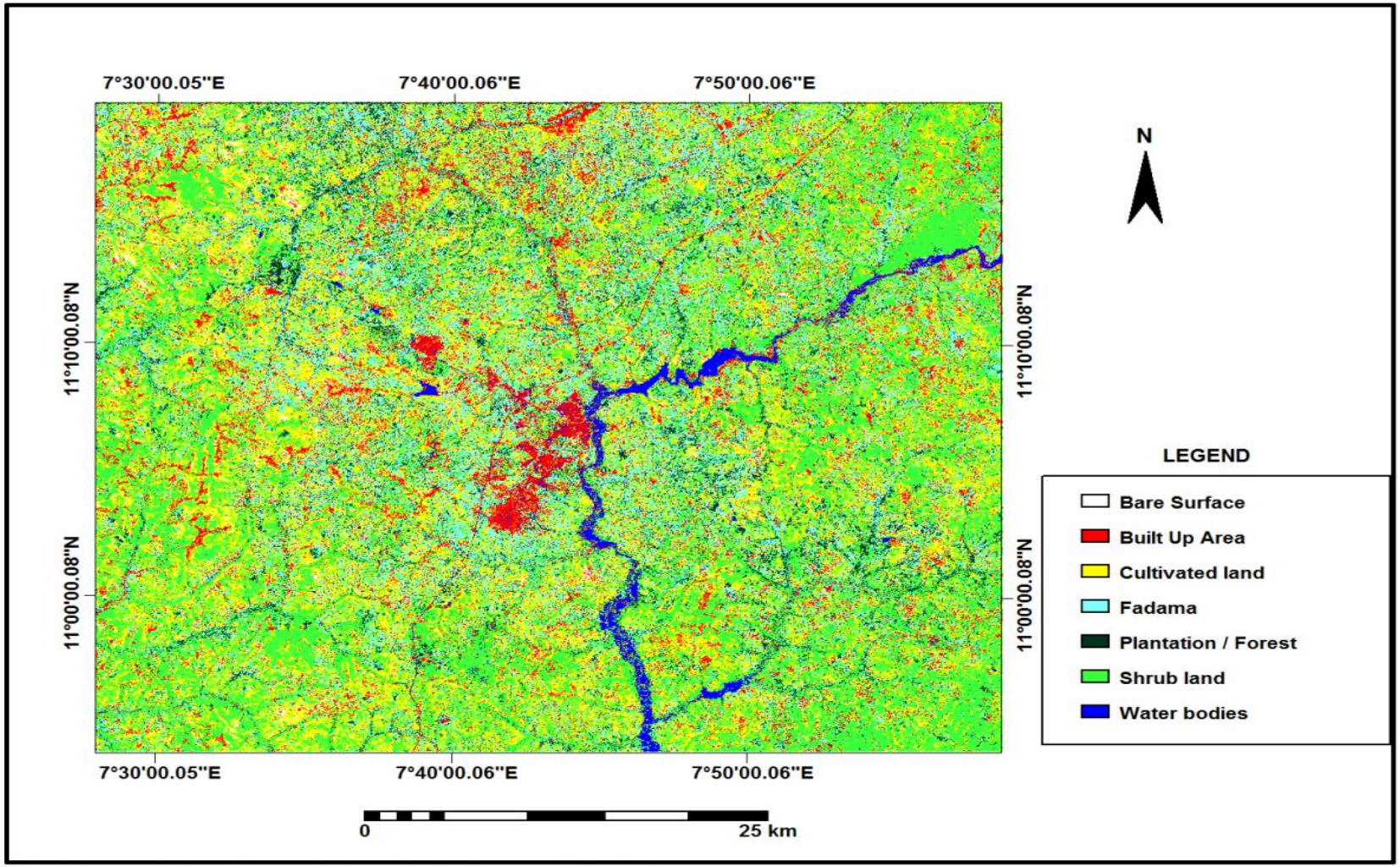


FIG.5.2: CLASSIFIED ETM1999 IMAGE OF THE STUDY AREA

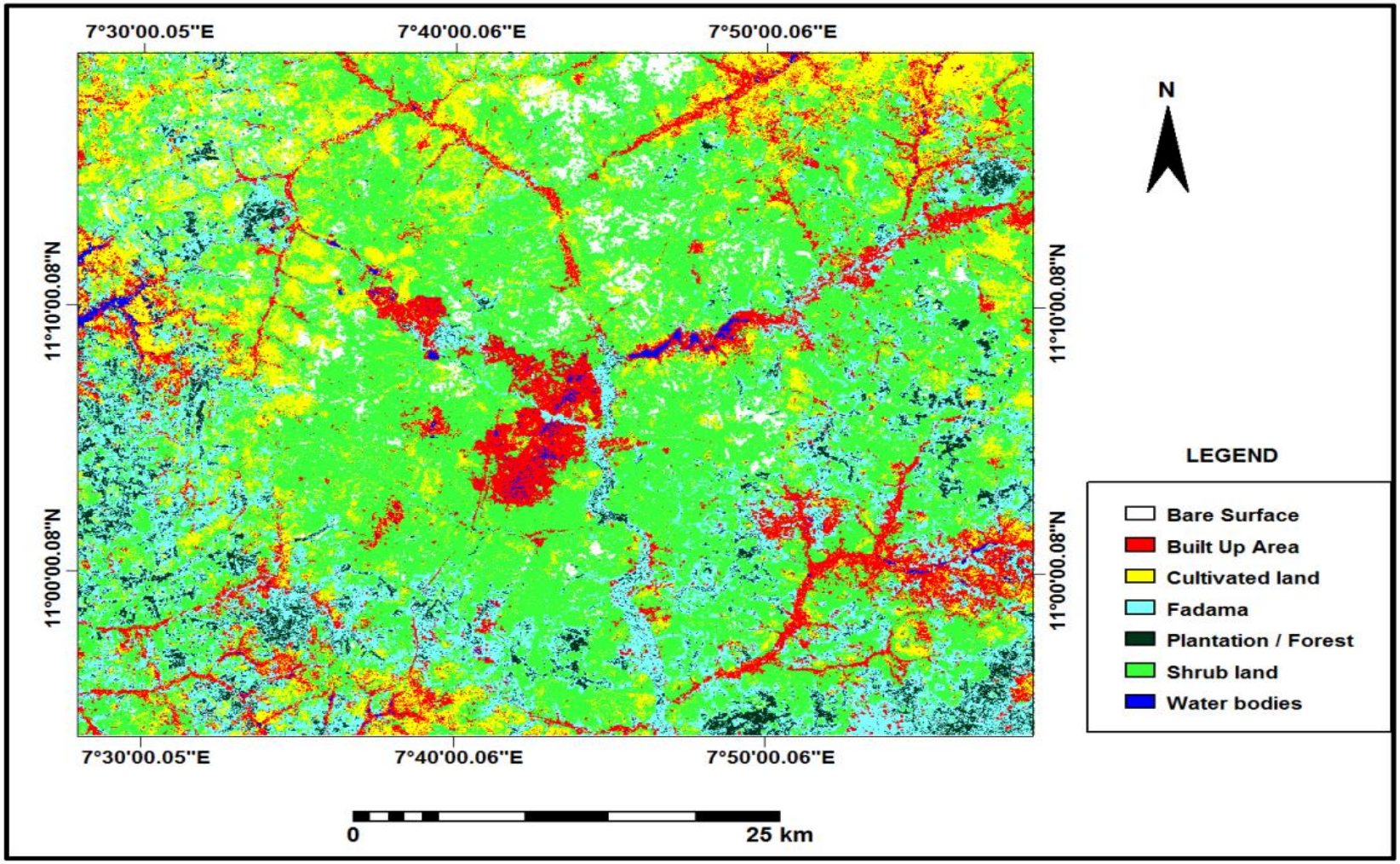


FIG.5.3: CLASSIFIED 2009 NIGERIASAT1 IMAGE OF THE STUDY AREA

(33.5%) in 1990 to about 787km^2 (30%) in 1999 and decreased sharply down to about 400km^2 (15%) in 2009. However, fadama land use spiked from 129km^2 (4.9%) in 1990 to about 480km^2 (18.3%) but decreased slightly to 471km^2 (17.9%) in 2009. Similarly, plantation/forest increased from 49km^2 (1.9%) in 1990 to about 177km^2 (6.7%) in 1999 but decreased again to about 110km^2 (4.2%) in 2009. Scrubland also decreased sharply from 1,235km^2 (46.8%) in 1990 to about 878km^2 (33%) in 1999 and increased sharply again to 1,256km^2 (47.6%). Water bodies increased from about 26.9km^2 (1%) in 1990 to 36km^2 (1.4%) in 1999 and decreased again to about 15.6km^2 (0.6%) in 2009. Thus, overall, the landuse cover in the study area, within the examined period is dominated by scrubland and cultivated land. This is followed by the built-up and fadama areas. The water bodies and bare surfaces consistently ranked the lowest.

5.1.2 Net change in land use and land cover, 1990-2009

Fig. 5.4 and 5.5 show the land use/land cover changes derived from crossing classified maps of TM 1990 over ETM+ 1999 and ETM+ 1999 over Nigeria Sat-1 2009, while Table 5.2 and Table 5.3 show the LULC change detection and the rate of change in the different land use/ land cover between 1990 and 2009 respectively. There is considerable variations in the net change in land use/ land cover type within the period under study. This may be attributed to seasonal variations (such as rainfall) and the dates of acquisition of the satellite imageries. For example, the Thematic Mapper (TM) satellite imagery was captured in November, the Enhanced Thematic Mapper (ETM) was captured in October, while the NigeriaSat-1 was captured September. An implication of these is a distortion in the trend of the different land use/cover types. For example, bare surfaces in 1990 covered about 94.6km^2, decreased to about 37.3km^2 in 1999 but again increased to 95.6km^2 in 2009.

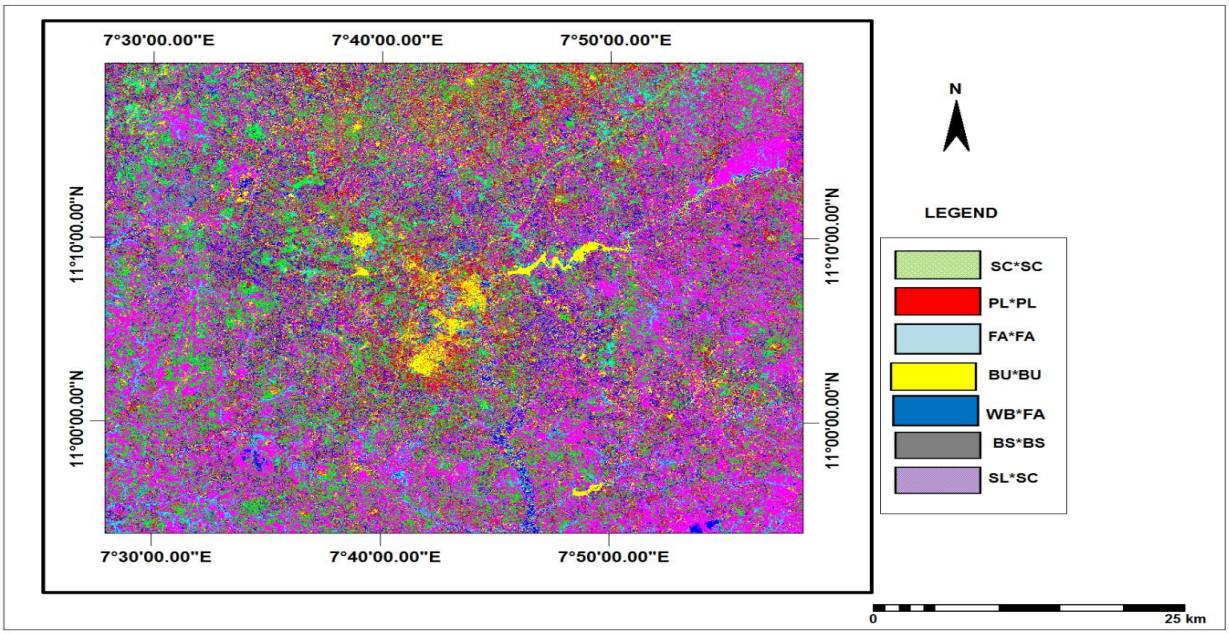


FIG.5.4: TM-ETM CROSS MAP OF THE STUDY AREA

*** BS= bare surfaces, BU= built up areas, CU=cultivated areas, FA= fadama, PL= plantation/ forest, SC= scrubland, WB= water bodies**

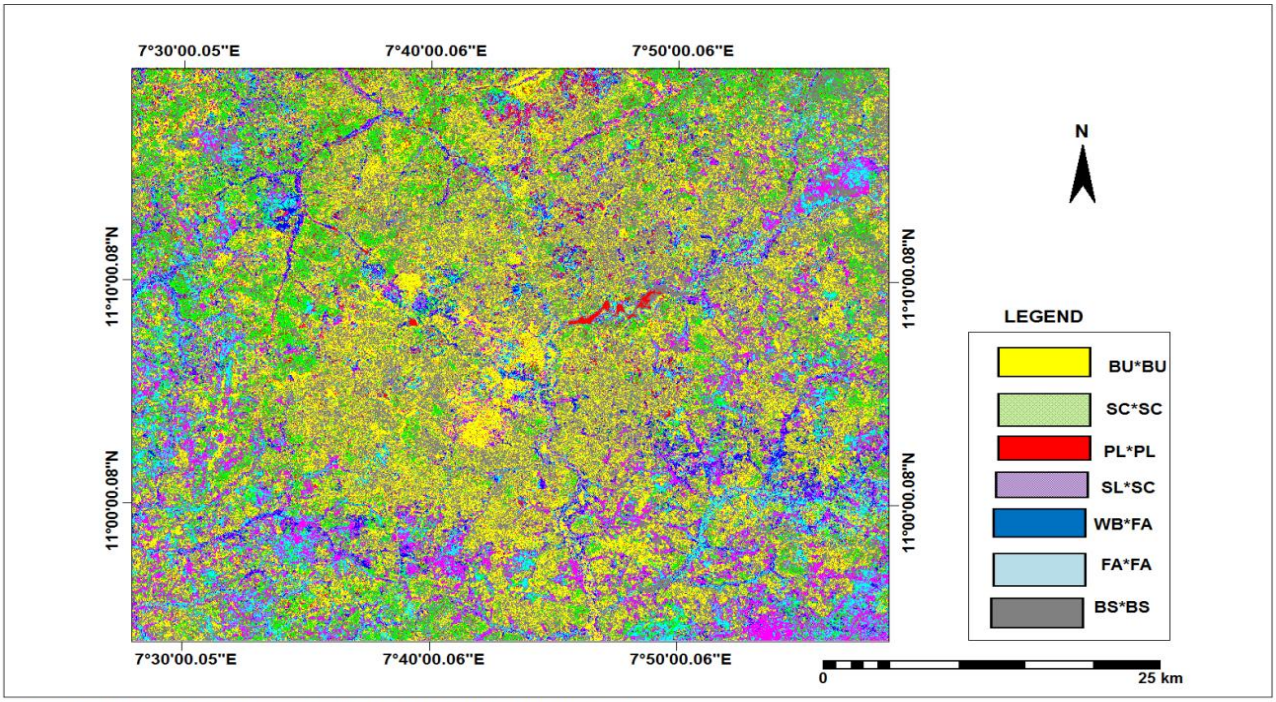


FIG.5.5: ETM-SAT1 CROSSED MAP OF THE STUDY AREA

*** BS= bare surfaces, BU= built up areas, CU=cultivated areas, FA= fadama, PL= plantation/ forest, SC= scrubland, WB= water bodies**

Table 5.2: Land use/land cover change detection between 1999 and 2009

LULC Units	LULC Units 2009 (KM^2)							
1999 (km^2)	BS	BU	CU	FA	PL	SC	WB	Total area
BS	**7.76**	0.61	11.08	2.39	0.26	15.15	0.08	37.3
	(20.8)	(1.6)	(29.7)	(6.40)	(0.70)	(40.6)	(0.2)	(100)
BU	13.89	**48.07**	25.69	21.38	3.13	128.82	2.89	243.88
	(5.7)	(19.7)	(10.5)	(8.8)	(1.3)	(52.8)	(1.2)	(100)
CU	35.99	45.28	**164.36**	112.08	16.88	411.17	1.01	786.76
	(4.6)	(5.8)	(20.9)	(14.2)	(2.1)	(52.3)	(0.13)	(100)
FA	20.88	58.18	71.47	**35.16**	3.71	287.87	2.44	479.7
	(4.4)	(12.1)	(14.9)	(7.3)	(0.8)	(60.0)	(0.51)	(100)
PL	4.37	28.47	23.85	28.95	**4.24**	85.11	1.95	176.9
	(2.5)	(16.1)	(13.5)	(16.4)	(2.3)	(48.1)	(1.1)	(100)
SC	12.67	94.57	102.27	259.34	79.72	**325.51**	3.36	877.5
	(1.4)	(10.8)	(11.7)	(29.6)	(9.1)	(37.1)	(0.4)	(100)
WB	0.03	14.52	1.17	12.05	2.21	2.34	**3.8**2	36.13
	(0.1)	(40.2)	(3.2)	(33.4)	(6.1)	(6.5)	(10.6)	(100)
Total area	95.59	289.70	399.89	471.36	110.15	1255.95	15.56	2638.20

*** BS=** bare surfaces**, BU=** built up areas**, CU=** cultivated areas**, FA=** fadama**, PL=** plantation/ forest**, SC=** scrubland**, WB=** water bodies

Bold figures are those LULC units which remained unchanged during the period under study

Figures in bracket show percentages of LULC conversions

This may be because the satellite imageries of 1990 and 2009 were captured during the dry season when most farmlands had been harvested and farmlands left bare, while in 1999 the imagery was acquired during the rainy season when all farmlands are under cultivation.

Irrespective of these climatic variations, however, there is no doubt that land use/land cover types are changing over time. For example, the decrease in the spatial coverage of bare surfaces in 1999 may be attributed to increasing population and the need for developing existing lands for private, commercial and industrial purposes. Similarly, spatial variations in fadama and water bodies in the period under study are affected by seasonal variations and also by the expansion of the built up areas. The decline in the spatial coverage of cultivated land may be attributed to urban expansion and development.

The overall changes in the land use/ land cover types could be expressed in terms of net changes over the twenty years period under study. By expansion, fadama land use has the highest change of about 264% and is followed by plantation/forest (124%) and built up area (34%). However, by shrinking, water bodies have the highest change (42%). Result from Table 5.3 show that only about 20% of the area covered by bare surfaces in 1999 remained as bare surfaces in 2009. The bulk of it was converted to scrubland (about 41%), cultivated area (about 30.0 %), fadama (6.4%), built up area (1.6%), plantation/forest (0.7%) and water bodies (0.2%). Similarly, about 18% of the area covered by built up area in 1999 remained built up in 2009. About 52% of it was converted to scrubland; cultivated area (11%), fadama (8.8%), bare surfaces (5.7%) and plantation/forest and water bodies (about 1%).

Only about 21% of the area covered by cultivated area in 1999 remained cultivated in 2009. The rest was converted to scrubland (about 52%), fadama (14%), built up area (about 6%), bare surfaces (4.5%), plantation/forest (about 2%) and water bodies (0.1%). 7.3% of the area covered by fadama land use in 1999 remained as fadama in 2009. The rest was converted to other land uses; scrubland (60%), cultivated (14%), built up area (12%), bare surfaces (4.4%), plantation/forest and water bodies (less than 1%). Area covered by plantation forest in 1999 which remained plantation forest in 2009 is only about 2%. The rest has been converted to scrubland (48%), built up and fadama (about16%), cultivated (about 14%), bare surfaces (2%) and water bodies (1%). However, only 37% of the area covered by scrubland in 1999 remained under the same cover in 2009. The rest (63%) was converted to other land uses/cover; fadama (about 30%), cultivated and built up (about 11%), plantation/forest (9%), bare surfaces (1.4%) and water bodies (0.4%). Similarly, area covered by water bodies in 1999 which still remained water bodies is only about 11%. The remaining portion of it was converted to built up area

(40%), fadama (33%), plantation/ forest and scrubland (about 6%), cultivated (3%) and bare surfaces (0.1%). In general, the analysis of data on land use/land cover change shows that both spatial and temporal changes in the LULC of the Zaria area over the examined period are significant. Result of Chi-square analysis carried out to determine the level of significant changes in the areal coverage of the different land use and land cover types for the three periods studied shows statistical significance at $p< 0.01$, with a calculated X^2 value of 612.09 and a table value of 26.2. This indicates significant changes in the different land use/cover types in the area studied.

5.1.3 The trend of land use and land cover change

The rate of change in land use/ land cover are presented in Table 5.3. Results from the table show that though plantation/forest lost about 67km^2 between 1999 and 2009, it has the highest average rate of change at +19.8% per annum. It is followed by fadama with a loss of about 8km^2 and an average rate of change of +13.8% per annum. It is followed by bare surfaces with +6.1% and water bodies with -5.53%, shrubland, +3.0%; cultivated, -2.73% and built-up,+1.58%. The results indicate that there is a positive change in net coverage for built up area, with consistent gains in spatial coverage from 1990 to 2009. There were also positive changes in bare surfaces, fadama, plantation/forest and scrubland use categories. However, there are negative changes in cultivated land use between 1990 to 2009 and water bodies, between 1999 to 2009. The general trend indicates that the various land use/ land cover are changing at a rate not lower than 1.6%. Fig. 5.6 show the trend of change in the respective land use types in the study area.



Fig 5.6: Trend of change in the respective land use/land cover types in the study area

Table 5.3: Rate of Change in Land use/Land Cover Between 1990 and 2009

Land use type	1990 and 1999		1999 and 2009		Average rate of change(yr)
	Area (Km^2)	%	Area (Km^2)	%	%
Bare surface	-57.29	60.6	+58.28	156.2	+6.1
Built-up area	+23.86	10.8	+45.82	18.8	+1.6
Cultivated area	-95.94	10.9	-386.87	49.2	-2.73
Fadama	+350.23	270.5	-8.35	1.74	+13.8
Plantation/forest	+127.78	259.9	-66.8	37.8	+19.8
Scrubland	-357.85	28.9	+378.49	43.1	+3.0
Water bodies	+9.21	34.2	-20.57	56.9	-5.53

* Positive(+) = increase in area
Negative(-) = decrease in area

Observations from Fig.5.6 show an upward trend for built up area. The upward trend in built up area is a reflection of population growth and conversion of other land uses to built up areas (Table 5.2). Conversely, there is a downward trend in cultivated land use. This may be as a result of conversion of cultivated areas to other land uses such built up area (due to urban expansion) and bare surfaces (due to soil degradation). Land use/cover changes for bare surfaces and scrubland showed concave patterns with decrease in spatial coverage in 1999 and increase in 2009, while plantation/forest and water bodies showed convex patterns of change within the period under study. The observed trend in the plantation/forest land use category is that of increase in the spatial coverage between 1990 to 1999, which may be attributed to the increased afforestation efforts by government establishments and academic institutions such as the Ahmadu Bello University and Government Reservation Areas (GRA) in the 90s'. However, between 1999 and 2009, there is a some what downward trend in the plantation/forest land use, which reflects high rates of deforestation for fuel wood, urban expansion and agricultural land. A good example of forest conversion to cultivated lands is seen in Dakaci (along Jos road), where

the plantation/forest has currently been replaced by farmlands (Plate VIII). Although fadama land use showed an initial upward increase in 1999, the land use category showed a some what downward trend in 2009. The commercial importance associated with wetland farming in the Zaria area is responsible for the increase in the spatial coverage of fadama land use. It is an important source of income to many people and provides food crops such as maize and vegetables all year round.

From the foregoing analysis, it is clear that the land use/land cover of Zaria area has undergone considerable changes in the last twenty years. While built up areas and fadama land uses show significant expansions, the cultivated areas have shrunken considerably. The results from the study also showed fluctuations in bare surfaces, scrubland, plantation/forest and water bodies. All over the region, there is general strong ecosystems perturbation and changes, accompanied by land resources loss and degradation problems. There is also high rate of transformation of canopy ecosystems (forests and woodlands) into scrubland (grasslands) and grazing areas, which strongly suggests loss of stability and resilience of the forest/woodland ecosystems. Quite a substantial percentage of the region water bodies have also been converted into agricultural lands by the intensification of the Fadama agriculture project. Over the region, an incontrovertible evidence of intense soil/land degradation is high level of fluctuation in the extent of exposed lands and water bodies. In specific terms, area covered by bare surfaces decreased from about 94km^2 (3.8%)in 1990 to 37 km^2 (1.4%) in 1999 and increased again to about 96 km^2 (3.6% in 2009. The area covered by water bodies, which include the fertile alluvial soils, increased from 27 km^2 (1.02%) in 1990 to 36 km^2.(1.36%) in 1999 and decreased sharply to about 16 km^2 (0.6%) in 2009. The results of the study also suggest that aside from very few point, forest

management has not been taken as a priority issue. No serious non-structural and sustainable efforts appear to be in place to control land degradation and mitigate its impacts.

The observed variations in land use/cover in the Zaria area may be ascribed to both climatic and anthropogenic factors. For example, the decline in the spatial cover of water bodies may be attributed to climatic variability (influenced by the time of the year in which the imageries were produced). With the exception of the Galma river in the study area, other tributaries such as Kubanni, Saye and Shika are ephemeral streams. Variability may be observed in the imageries due to the strong seasonality of the rivers and their tributaries. However, increased erosion from upstream and sedimentation may be attributed to the decline in spatial coverage of water bodies and an increase in the area covered by fadama land use category.

Similarly, human interference in the natural environment has implications for land use/land cover changes. Expansion in built up area and cultivated land uses are major factors responsible for land use/land cover changes in Nigeria (Mengistu and Salami, 2007; Jibrin, 2009; Abbas and Arigbede, 2011). Similarly, Adediji *et al*., (2010) identified increased population, overgrazing, large dependence on agriculture and use of fuel wood as factors responsible for land use/cover dynamics. Generally, natural forests have been exploited through tree felling to meet the increasing demands for firewood, timber and other construction materials (Jibrin, 2009; Islam and Weil, 2000; Mengistu and Salami, 2007). The net results of all the above is soil/land degradation.

The effects of vegetation on soil properties have been stressed by several studies (Abubakar, 1995; Islam and Weil, 2000; Aweto and Dikinya, 2003; Ayoubi, Khormali, Sahrawat, Rodrigues and de Lima, 2011; Senjobi and Ogunkunle, 2011). Soil properties are strongly influenced by the vegetation characteristics under which the soils are located. The addition of leaf and twig litters

to soil results in organic matter build-up in soils. Similarly, tree roots have a loosening up effect in soils and thus help to reduce bulk density and increase porosity of the soils. Tree canopies and litter protect soils from exposure to direct solar radiation. However, forest clearance and conversion to crop lands exposes soils to solar radiation which raises soil temperature and causes evaporation of soil moisture and shrinking of organic matter and clay colloids, causing soils to compact (Aweto and Dikinya, 2003).

Similarly, cropping causes decline in soil fertility by reducing organic and inorganic colloidal materials, flocculating cations contained in protected soils and reduction in soil microbial activities (Jaiyeoba and Leow, 1983). In contrast to bare cultivated and degraded lands, soil losses from lands with good vegetation cover are usually negligible (Jaiyeoba and Leow, 1983). Conversion of forest to cropland deteriorates soil physical properties and induces soil erosion (Foster, 2001; Celik, 2005).

Various studies have shown that land use/land cover changes are often driven by socio-economic factors. Mengistu and Salami (2007) observed that changes in socio-economic situations cause land use/land cover changes through their influence on land management practices and farming systems. Similarly, Barbier (1997) observed that there is a 'cumulative causation' link between rural poverty, deforestation and land degradation; poor rural house holds abandon degraded lands for 'frontier' forested lands, deforestation and cropping of poor soils lead to further degradation which in turn leads to land abandonment and additional forest land conversion and so on. Lal (2009) observed that anthropogenic factors leading to soil degradation are driven by desperate situations and helplessness in the case of resource-poor farmers and smaller landholders. For example, studies show that fadama land use is a source of income for the rural poor who are often small holders and cultivate small sized (and often inaccessible) farm lands

(Ibrahim, Rahman, Envulus and Oyewole, 2009; Lawal, Omotesho and Adewumi, 2010). It is an all-year activity with positive and negative consequences. On the one hand it ensures all year availability of food crops (such as maize which is a major food crop) and fresh vegetables and on the other hand ensures that the soils under this land use type are under continuous and intensive cultivation which may lead to degradation of the soils and land fragmentation.



Plate VIII: Forest plantation in Dakaci replaced by cultivated lands

5.2 Field Assessment of Soil Degradation

5.2.1 The scientific evaluation of soil degradation

5.2.1.1 Current extent of soil degradation and causative factors

Field inspection shows that sheet erosion is present almost everywhere, and is particularly severe on bare, compact ground near dwellings and other buildings. Similarly, it is the norm on most cropped land. Paths, tracks and road drains not near buildings also account for significant soil loss. No evidence of soil piping was noted. Table 5.4 shows the forms of soil degradation observed in the study area.

Table 5.4: Forms of Soil Degradation in Communities

Nature	Area most affected (built-up area, farmlands, rangeland etc	Severity (mild, moderate, severe, very severe)	Trigger factors
Sheet erosion	Farmlands, built-up areas	Moderate to severe	Rainfall, loose soils
Rill erosion	Farmlands and road tracks	moderate	Rainfall, loose soils
Gully erosion	Built-up areas, stream banks and farmlands	Moderate to severe	Rainfall
Compaction	Farmlands, road tracks	Moderate to	Over grazing, cultivation
Crusting	Farmlands	Mild to moderate	Erosion
Material deposition	Farmlands and drainages	Mild to moderate	Rainfall, erosion
Waterlogging	Farmlands	Moderate to severe	Rainfall, poor soil drainage

Source: Field work, 2012.

Geology, terrain and soil characteristics combine to make many areas erosion-prone. This means that even without human influence the region is likely to experience soil loss, which may be episodic and related to short term climatic trends and extreme meteorological events. However, this sensitivity is certainly exacerbated by current land use practices. Crop production of any sort on slopes and soils as susceptible to soil loss as those on cultivated soils is certain to result in sheet erosion, and there is no doubt that this kind of agricultural activity is causing considerable soil loss. Livestock density is difficult to assess, especially as it is a particularly sensitive and

emotive issue. Nevertheless, casual observation suggests that it is excessive and result in soil compaction. Similarly, other landuse types are also responsible for accelerating soil loss. Soil compaction by humans and animals in the vicinity of buildings is exacerbated by paths and tracks.

5.2.1.2 Physico-chemical characteristics of soils under different landuses

Table 5.5 summarizes the variation of the soil properties over the five major land use categories in the study area. In the table is indicated the mean value, the standard deviation and coefficient of variability of the soil respective parameters measured. Also indicated is the level of significance, where applicable, of the result of Analysis of Variance (ANOVA) performed to test for significant differences amongst the various land uses. Table 5.6 on the other hand summarizes the result of the t-test performed to detect properties that vary significantly between pairs of land uses.

a) Soil texture

The sand fraction is highest over the plantation (58%). This is followed by the badland site (56.6%). Value over the scrubland and the cultivated land are intermediate (55.2% and 55.6%, respectively). On the other hand, the fadama land recorded the least values (47.6%). Given the relatively similar amount, analysis of variance did not reveal significantly different values amongst the various landuses at the 0.05 level. This result is corroborated by the relatively low values of the coefficient of variability (less than 15%), which indicates relatively homogenous amounts within each landuse category. Unlike the sand fraction, the variation in the silt fraction is significantly different. The value ranged between about 23% over the badland and 38% over the fadama site, while values over the plantation (33%), scrubland (34%) and cultivated land

(30%) are intermediate. Compared to the sand fraction, the coefficient of variability percents are higher (10 - 32%), but the respective locations can still be said to display comparatively homogeneous amount within each land use category.

Like the silt fraction, the clay fraction shows statistically significant variation over the different land use types. The plantation site recorded the lowest amount at about 9%. This is followed by the scrubland at about 11%. The cultivated land and the fadama land recorded approximately the same value of 15%, while the badland site recorded the highest value at 21%. The value of the coefficient of variability ranged between about 20% over the badland site and 42% over the plantation site, all indicating relatively heterogeneous clay content within the respective land use type. When t- test was applied to detect the source of variation in the particle size fractions amongst the different landuse, the result obtained shows that only silt and clay show any significantly different value between pairs of land use categories (Table 5.6). For the silt fraction, this is between scrubland and badland.

For clay, this is between badland on the one hand and plantation and scrubland on the other hand. Thus, overall, the general impression is that of significant variation in the particle size distribution of the surface soils over the five land use types studied. In spite of this, however, except the badland topography, all soils are sandy, rarely heavier than a sandy clay loam. This could be as a result of the loss of the finer fractions in surface wash and/or translocation into the sub-soil (FitzPatrick, 1980; Jaiyeoba 1986; Brady, 1990). On the other hand, the feature could be a reflection, at least partly, of the granitic nature of soil parent material over the study area (Brady 1990; Young, 1976). The comparatively heavier soil texture over the badland topography can be explained by the fact that the relatively loose surface soils of the site have been removed

Table 5.5: Variations of Soil Physical and Chemical Properties Over Different Land Uses

	Soil properties														
Land uses	Sand %	Silt %	Clay %	Bulk density (g/cm^3)	Porosity %	GMC %	pH (1:2.5) (soil:H_2O)	Organic matter ($g/kg\text{-}^{1}$)	Ca	Mg	K	Na	CEC	H+AL	BS
									← ($cmol/kg^{-1}$) →						%
Plantation															
$\bar{x}$	58.00	32.8	9.20	1.45	45.4	17.6	6.54	1.77	2.68	0.76	0.35	0.66	6.76	0.09	63.8
SD	6.16	6.72	3.90	0.08	3.04	7.63	0.48	0.75	1.43	0.36	0.19	1.09	1.24	0.22	20.2
CV%	10.6	20.5	42.4	5.77	6.69	43.4	7.38	42.3	53.5	48.0	53.6	166.0	18.4	248.4	31.7
Scrubland															
$\bar{x}$	55.2	34.0	10.8	1.49	43.6	17.0	6.00	1.45	2.60	0.50	0.11	0.20	6.26	0.08	55.8
SD	5.93	4.90	2.28	0.09	3.41	4.26	0.51	0.65	0.62	0.12	0.06	0.06	2.25	0.36	4.00
CV%	10.8	14.4	21.1	5.90	7.82	25.1	8.50	44.6	23.7	24.5	54.5	31.0	35.9	426.0	7.16
Cultivated land															
$\bar{x}$	55.6	29.6	14.8	1.64	38.2	14.9	6.30	1.12	1.56	0.72	0.24	0.32	4.26	0.09	66.5
SD	2.61	3.00	4.6	0.10	3.84	2.24	0.32	0.41	0.26	0.19	0.08	0.10	0.86	0.02	18.4
CV%	4.6	10.0	31.1	6.14	10.1	15.1	5.02	33.4	16.7	26.7	31.9	32.1	20.1	248.4	27.7
Fadama															
$\bar{x}$	47.6	37.6	14.8	1.49	43.9	25.0	6.48	1.58	3.00	0.82	0.20	0.25	6.04	0.09	71.3
SD	12.8	12.1	4.15	0.09	3.38	4.85	0.36	0.43	0.62	0.08	0.10	0.06	0.77	0.02	13.3
CV%	26.8	32.2	28.0	5.98	7.70	19.4	5.00	27.3	20.6	10.2	47.3	25.73	12.8	248.4	18.7
Badland															
$\bar{x}$	56.6	22.6	20.8	1.52	42.7	9.75	5.44	0.25	0.65	0.15	0.10	0.12	4.31	0.30	53.8
SD	4.16	5.03	4.09	0.10	3.80	3.94	0.05	0.11	0.36	0.05	0.06	0.06	0.33	0.18	6.26
CV%	7.35	22.3	19.7	6.60	8.89	40.4	1.01	45.8	55.3	36.8	63.1	45.8	7.71	59.7	11.6
ANOVA (F-ratio)	1.58	3.19	6.69	3.03	3.06	6.32	7.00	6.72	7.90	9.75	4.50	0.89	4.21	6.43	1.36
Level of sig.	-	**	***	*	*	***	**	**	**	***	**	-	**	**	-

$\bar{x}$ = mean, SD= standard deviation, CV%= coefficient of variation

Level of significance:

*=0.05 **=0.01 ***= 0.001

Table 5.6 : Result of Student's t-test Analysis Between Pairs of Land Uses

Land uses	Soil properties														
	Sand %	Silt %	Clay %	BD g/cm^3	Porosity %	Gmc %	pH	OM (g/kg^{-1})	Ca	Mg	K	Na	CEC	H+AL $cmol/kg^{-1}$	BS %
									$Cmol/kg^{-1}$						
PL/SCR	0.73	-0.32	-0.79	-0.85	0.90	0.16	1.72	0.73	0.12	1.51	2.68	0.94	0.44	0.32	0.59
PL/CU	0.80	0.97	-2.08	-3.25 **	3.30 **	0.76	0.93	1.71	1.72	0.22	1.21	0.70	3.71 **	0.00	-0.41
PL/FA	1.64	-0.78	-2.20	-0.73	0.75	-1.84	0.22	0.50	-0.46	-0.36	1.54	0.84	1.10	0.00	-6.67
PL/BA	0.42	2.72 *	-4.59 **	1.33	1.39	2.04	5.06 **	4.50 **	3.08 **	3.72 *	2.84 *	1.09	4.26 **	-2.60	1.05
SCR/CU	-0.14	1.72	-1.74	-2.41	2.35	0.97	-1.12	0.96	3.47 **	-2.16 *	-2.89 *	-2.27	1.86	-0.32	-1.51
SCR/FA	1.21	-0.62	-1.89	0.11	-0.15	-2.79 *	-1.73	-0.37	-1.03	-4.82 **	-1.78	-1.32	0.21	-0.32	-1.66
SCR/BA	-0.43	3.63 **	-4.78 **	-0.54	0.52	2.78 *	2.44	4.10 **	6.13 ***	5.92 ***	0.36	1.94	1.92	-2.65	0.56
CU/FA	1.37	-1.43	0.00	2.50	-2.50	-4.25 **	-0.85	-1.73	-4.81 **	-1.07	0.66	1.27	-3.45 **	0.00	-0.50
CU/BA	-0.46	2.68	-2.18 *	1.76	-1.75	2.53	5.99 ***	4.63 ***	4.62 **	6.43 ***	3.20 **	3.69 **	-0.12	-2.60	3.04 **
FA/BA	-1.50	2.56	-2.30 *	-0.63	0.66	5.47 ***	6.45 ***	6.69 ***	7.39 ***	15.2 ****	2.04	3.25 **	4.60 ***	-2.60	2.65

PL plantation, CU= cultivated, SCR= scrubland, FA= fadama, BA= Badland
Level of significance: *=0.1, **=0.05, ***=0.01, ****=0.001

in water erosion, leading to the exposure of the subsoil, which over the study area have been found to be more clayey (Jaiyeoba, 1990; Obafemi, 1991; Jones and Wild, 1975).

b) Bulk density and porosity

The soil bulk density shows statistically significant differences amongst the various landuses. The lowest value is recorded over the plantation (1.45g/cm^3). This is followed by the same value (1.49g/cm^3) over the scrubland and the fadama land. The highest values of 1.52g/cm^3 and 1.64 are recorded over the badland site and the cultivated land, respectively. The coefficient of variability percent is consistently very low, less than 7%, an indication of relative homogeneity within each landuse category. Overall, all soils are very high in bulk density value. For a normal mineral soil, the value is about 1.25g/cm^3 (Brady, 1990). Such high value no doubt is a reflection of soil degradation that has taken place in the study area. On the other hand, the feature could be due partly to the granitic nature of soil parent material over the study area.

Reflecting the relatively high degree of compaction and sandy texture of soils over the study area, the soil total porosity is generally low. The coefficient of variation also reveals very low level of heterogeneity within the respective land use type; the value range between about 38% over the cultivated land and 45% over the plantation site. Analysis of variance reveals significantly different mean porosity value amongst the land uses at the 0.05 level. When t- test was applied to pairs of land uses, the result shows that only the plantation and cultivated land shows significantly different bulk density and porosity value.

c) Gravimetric moisture content (GMC)

Results show the mean values of gravimetric soil moisture content (GMC) over the different land uses. Mean values of Gmc range between 14.88-25.02%. Fadama land use has the highest

mean Gmc (25.2%), followed by plantation (17.6%), shrubland (16.9%), degraded land (16.8%), while cultivated land had the least Gmc (14.9%). The CV for Gmc are high at 40%. Results of analysis of variance show highly significant difference in Gmc over the different land uses at 0.001 (0.1%). The higher mean values of soil moisture content of the fadama land use may be attributed to the loamy nature of the soils. For example, Brady and Weil (2002) observed that fine textured soils retain more moisture than coarse-textured soils. Similarly, the high moisture content of the plantation land use may be attributed to a reduction in evaporation rates over soil surfaces in the plantation due to vegetation cover. Result of t-test shows significant difference in gravimetric moisture content value between fadama and badland land uses and between cultivated and fadama land uses.

d) Organic matter

The differences in the soil organic matter content amongst the different landuses, by analysis of variance are statistically significant at the 0.01 level. The value is lowest over the badland ($0.25g/kg^{-1}$) and highest over the plantation ($1.77g/kg^{-1}$). Values over the remaining land uses vary between these two figures (cultivated land $1.12g/kg^{-1}$, scrubland $1.4g/kg^{-1}$, fadama land $1.58g/kg^{-1}$). All landuse types are characterized by low coefficient of variation. When t- test was applied to detect the source of variation in the organic matter content, the result obtained point toward the bad land (table 5.5). The comparatively higher mean value over the plantation and the fadama land reflect greater vegetal cover, and or less oxidative decomposition. The comparatively low value over the badland on the other hand is a reflection of the scanty vegetal cover, and rapid oxidative decomposition due to high temperature (Brady, 1990).

e) Exchangeable cation and cation exchange capacity

The exchangeable Ca reveals significantly different amount amongst the various landuses. The value is highest over the fadama land (3.00 cmol/kg^{-1}). This is closely followed by the plantation and scrubland, where the values are approximately the same (2.68 cmol/kg^{-1}and 2.60 cmol/kg^{-1} respectively). The cultivated land and the badland recorded the lowest amount (1.56 cmol/kg^{-1} and 0.65 cmol/kg^{-1} respectively). The value of the coefficient of variation indicates that while measured amount are relatively homogenous over the cultivated (16.72%) and fadama (20.55%) they are heterogeneous over the plantation (53.45%) and badland (55.34%).

Similar to the exchangeable Ca, the soil exchangeable Mg is highest over the fadama land (0.82 cmol/kg^{-1}) and lowest over the badland (0.15 cmol/kg^{-1}), while values over the remaining land uses are intermediate. The differences amongst the various land uses are also highly significant, statistically. Unlike Ca, however, the coefficient of variation for the respective landuse type is generally less than 50%. The mean value of exchangeable K also shows significant differences amongst the landuse categories. Unlike both Ca and Mg, however, the value over the plantation site (0.35 cmol/kg^{-1}) and the cultivated land (0.24 cmol/kg^{-1}) are greater than those of the shrubland (0.11 cmol/kg^{-1}) and badland (0.10 cmol/kg^{-1}). The coefficient of variation is generally greater than 40%, ranging between about 32% over the cultivated land and 63% over the badland.

The exchangeable Na show fairly similar values over the different landuses, and as such did not reveal statistically significant differences amongst the landuses. The value ranged between 0.12 cmol/kg^{-1} over the badland and 0.66 cmol/kg^{-1} over the plantation. The coefficient of variation on the other hand shows considerable variability over the different landuses, ranging between 26%

over the fadama land and 166% over the plantation. The result obtained when the t-test was applied to differences in the respective exchangeable cation between pairs of land use category varies considerably. For example, whereas the differences between most pairs are statistically significant with respect to exchangeable Ca, only the differences between badland and cultivated are significant for exchangeable K. Overall, all soil are low in exchangeable cations. This is a reflection, presumably, of the high level of leaching that has taken place in the soils. The feature, however, may be partly due to the granitic nature of the soil parent materials.

The CEC reveals significantly different amount amongst the various landuses. The value is highest over the plantation (6.76 cmol/kg^{-1}). This is followed by the scrubland (6.26 cmol/kg^{-1}) and fadama land (6.04 cmol/kg^{-1}). The cultivated land and the badland recorded the lowest amount (4.26 cmol/kg^{-1} and 4.31cmol/kg^{-1} respectively). The coefficient of variation ranged between about 8% over the badland and 36% over the scrubland. The t-test result supports the result of analysis of variance; in that most pairs of landuses show statistically significant different values. Overall, all soils are low in CEC, a reflection presumably of the sandy texture and or low organic matter content of the soils.

f) Soil pH, exchangeable H+Al and base saturation

The mean value of the soil pH is highest over the plantation site (6.54). This is followed by values over fadama land (6.48) and cultivated land (6.30). Value over the scrubland (6.00) and the badland site (5.44) are the lowest. Analysis of variance reveals significant differences amongst the different landuses at 0.01 level. Furthermore, as the coefficient of variation indicated, the soil pH is relatively homogenous within landuse category. When t- test was

applied between pairs of landuses, the result obtained shows significant differences between badland on the one hand and plantation, cultivated and fadama on the other hand.

The soil exchangeable H+Al is lowest over the shrubland (0.08 cmol/kg^{-1}) and highest over the badland site (0.30 cmol/kg^{-1}). The values over the remaining landuse types are the same (0.09 cmol/kg^{-1}). Analysis of variance reveals significantly different value amongst the various landuses. The soil base saturation percent show rather similar values over the different land uses. The value range from about 54% over the badland, through 56% over shrubland, 64% over the plantation land and 67% over cultivated land, to 71% over the fadama land. Consequently, analysis of variance did not reveal significant differences amongst the various landuses. Similar result was obtained when t- test was applied to the pairs of landuses. The only exception is between cultivated and badland.

5.2.1.3 The magnitude of soil degradation

Soil quality comparison assessments was based on soil fertility rating for tropical soils by USDA soil conservation system modified by Malgwi (2007). This is summarized in Table 5.7.

Table 5.7: Soil Quality Classification Scheme for Tropical Soils

Soil Properties	Favourable	Unfavourable
Depth Texture	> 150 cm Loam, sandy clay loam, sandy clay, clay (with favourable structure and consistencies)	<150 cm Sand and heavy clay
Bulk density	1.0 -1.5g/cm^3	> 1.5g/cm^3
Porosity	>50% in top 30cm	< % 40%
Moisture content	Free drainage with moisture retention	Impeded, low moisture retention and rapid permeability
Organic matter	High	Low
Exchangeable cations	High levels	Low levels
Cation exchange capacity	> 25 cmol/kg^{-1}	< 6 cmol/kg^{-1}
Soil pH	Generally 5.6-6.5 5.0 – 8.0 but varies with crop	<4.5 >8.5
Base saturation	>50%	<50%

Source: Malgwi (2007)

The lack of neither control plot (due to lack of known natural ecosystem condition over the study area), nor available baseline values in the literature for the soil properties of the study area, preclude precise quantification of the magnitude of soil degradation in this study (Jaiyeoba, 2003). The results obtained, however, suggest pervasive high level of soil degradation over the study area (Jaiyeoba, 2003). All soils studied are sandy, rarely heavier than a sandy clay loam. They are also generally low in organic matter and are acidic. The soil exchangeable cations are low to moderate (Jaiyeoba, 1990). The generally sandy texture and acid reaction of all soil groups can be explained in terms of the mineralogical composition of the soil parent materials.

All soils have been formed from granitic lithology, which by definition is made up predominantly of quartz minerals, which upon decomposition give rise to sandy texture and acidic soils. Other factors that could contribute to acidic condition of the soils are the poor quality water being used for irrigation in the area during the dry season. The condition could also be partly due to intensive leaching in the soil because of the sandy texture (Jaiyeoba, 1986). The relatively low organic matter and nitrogen content of all soil groups is a reflection of intensive use of these soils and the rapid mineralization of humus under Savanna climate (Jaiyeoba,1995). Ratings of CEC results for top soils considers CEC values under 7 Cmol/kg to be low for tropical soils (Landon, 1991 and Moukam and Ngakanou, 1997). However, CEC values equal or greater than 8 cmol/kg^{-1} have been found to be suitable for cultivation (Raji *et al.*, 2011). The low CEC values over cultivated and badlands show that soils under these land uses have been degraded. Bulk density values over the cultivated, fadama and badlands are higher than the recommended value for tropical soils (Table 5.7).

The high bulk density values and low porosity over the different land uses, especially the cultivated and badlands, indicate deterioration of the soil properties due partly to trampling by

grazing cattle and scarification by farm implements due to cultivation (Jaiyeoba and Leow, 1983). There is significant variation between soil chemical and physical properties over the different land uses. This suggests a uniform rate of degradation in the cultivated and badlands. It also indicates that the deterioration of soil condition over the cultivated, fadama and badland uses is as a result of decreased microbial activities in the soils and an interruption of the biogeochemical cycling of matter (Abubakar, 1995; Madaki, 2011).

The high soil moisture in the fadama land use may be attributed to the high silt and clay content of the fadama soils. Fadama land use is located on flood plains and the proximity to water bodies causes frequent flooding and water logging of fadama soils. For example, Abubakar (1995) observed that water logging in poorly aerated irrigated soils may result in accumulation of salts in the hygromorphic soils. The high soil moisture over the plantation land use may be attributed to the high organic content of the soils because higher organic content encourages higher moisture retention by soils and less evaporation from soil surface because the soils are protected by tree canopies. However, the low moisture content in cultivated and degraded lands may be attributed to high bulk densities, low organic matter and high evaporation rates from the soil surfaces due to exposure to solar radiation.

The higher organic matter content over plantation land use may be attributed to continuous litter deposition (Abubakar, 1995) and minimum disturbance over time, while the lower organic matter content over cultivated land and badland may be attributed to continuous and persistent cultivation (Agboola and Corey, 1973). In the study area, both upland and lowland (fadama) cultivation are dominant landuses. Tillage practices destroy the soil body, loosen up the soil aggregates and make such soils susceptible to wash processes, leaching and compaction. Loss of organic matter accelerates soil compaction and loss of soil moisture. This may explain why the

soils of the Zaria area are generally acidic (especially over the badlands), a situation worsened by application of acidifying fertilizers which increases the acidity of Savannah soils (Lombin and Chude, 1988). However, the range of the pH values over the different landuses show that the soils are slightly acidic (Akogun, 1986; Abubakar, 1995) and reflects the humid tropic's strong leaching regime (Jim, 2003).

Grazing by cattle is a common activity in the study area. However, overgrazing destroys vegetation cover and is a major cause of soil compaction, through the trampling effect by livestock. This destroys soil structure and results in higher bulk densities over the different land use types. This may explain why even soils over forest plantation landuse have high bulk densities.

5.3 Farmers Perception and Adaptation Strategies to Soil Degradation

5.3.1 Demographic and socio-economic characteristics of the respondents

The summary results of demographic and socio-economic characteristics of the respondents in the sampled villages are presented in Table 5.8. The results show that there is an even spread between ages 20 and 60 among the respondents. This implies that over the study area, all categories of age groups are engaged in farming, including the elderly. The elderly between the ages of 51-60 years accounted for 13.3% in Biye and Hunkuyi, 20.0% in Dambo and Kakeyi and 30% in Saye. Results show that in Dambo and Saye, 97.7% of the respondents are married while 3.3% are single. In Biye and Kakeyi, 93.3% are married while 6.7% are single. In Hunkuyi, 86.7% are married while 13.3% are single. Results also show that mean household size is highest in Saye with 10.7, and least in Hunkuyi with 7.5., while values for the remaining villages are intermediate; 10.4 in Dambo, 8.03 in Kakeyi, and 7.7 in Biye.

Table 5.8: Demographic and Socio-economic Characteristics of the Respondents

Characteristics	Biye		Hunkuyi		Dambo		Kakeyi		Saye	
	n=30	(%)	n=30	(%)	n=30	(%)	n=30	(%)	n=30	(%)
Age group										
11-20	2	6.7	1	3.3	5	16.7	-	-	-	-
21-30	9	30.0	8	26.7	6	20.0	9	30.0	3	10.0
31-40	5	16.7	10	33.3	6	20.0	7	23.3	4	13.3
41-50	9	30.0	4	13.3	7	23.3	7	23.3	10	33.3
51-60	4	13.3	4	13.3	6	20.0	6	20.0	9	30.0
61-70	1	3.3	-		-	-	1	3.3	4	13.3
Marital status										
Single	2	6.7	4	13.3	1	3.3	2	6.7	1	3.3
Married	28	93.3	26	86.7	29	97.7	28	93.3	29	97.7
House hold size										
1-5	11	36.7	12	40	8	26.7	12	40.0	2	6.7
6-10	11	36.7	12	40	9	30.0	10	33.3	11	36.7
11-15	5	16.7	2	6.7	8	26.7	5	16.7	5	16.7
16-20	3	10.0	3	10.0	3	10.0	1	3.3	4	13.3
21-25	-	-	1	3.3	1	3.3	2	6.7	2	6.7
26-30	-	-	-	-	1	3.3	-	-	-	-
$\overline{x}$	7.73		7.50		10.4		8.03		10.7	
Level of Education										
Qur'anic	10	33.3	11	36.7	11	36.7	13	43.3	15	50
Adult	-	-	2	6.7	1	3.3	-	-	-	-
Primary	9	30.0	9	30.0	8	26.7	5	16.7	8	26.7
Secondary	7	23.3	7	23.3	7	23.3	8	26.7	7	23.3
Tertiary	4	13.3	1	3.3	3	10.0	4	13.3	-	-
Average monthly income										
≤10 000	9	30.0	20	66.7	19	63.3	20	66.7	21	70.0
10 001-20 000	15	50.0	9	30.0	10	33.3	7	23.3	8	26.7
20 001-30 000	5	16.7	1	3.3	1	3.3	3	10.0	1	3.3
30 001-40 000	1	3.3	-	-	-	-	-	-	-	-
$\overline{x}$ (N)	14833.33		9666.67		10800.00		11033.33		10233.33	
Land ownership										
Owned	14	46.7	13	43.3	22	73.3	24	80.0	22	73.3
Rented	16	53.3	17	56.7	8	26.7	6	20.0	8	26.7
Length of farming (yrs)										
≤ 5	13	43.3	17	56.7	10	33.3	11	36.7	5	16.7
6 -10	5	16.7	4	13.3	8	26.7	7	23.3	11	36.7
11 - 15	9	30.0	2	6.7	5	16.7	3	10.0	6	20.0
16 - 20	1	3.3	3	10.0	5	16.7	6	20.0	7	23.3
21 - 25	-	-	2	6.7	1	3.3	1	3.3	1	3.3
26 – 30	2	6.7	2	6.7	1	3.3	3	6.7	-	-
Membership of Agric Asso/CBO										
Yes	4	13.3	8	26.7	3	10	7	23.3	2	6.7
No	26	86.7	22	73.3	27	90.0	23	76.7	28	93.3

The highest educational level of majority of the respondents across all villages is Qur'anic education. In Saye, 50.0% of the respondents have Qur'anic education, 43.3% in Kakeyi, 36.7% in Hunkuyi and Dambo and 33.3% in Biye. Only 6.7% in Hunkuyi and 3.3% in Dambo had adult education, 30.0% of the respondents in Biye and Hunkuyi had primary education, Dambo and Saye has 26.7% each, while Kakeyi has 16.7%. Biye, Hunkuyi, Dambo and Saye each have 23.3% respondents with secondary education while Kakeyi has 26.7%.

The mean monthly income of respondents is low, with ₦14833.33 in Biye, ₦11033.33 in Kakeyi, ₦10800.00 in Dambo, ₦10233.33 in Saye and ₦9666.7 in Hunkuyi. Results show that majority of the famers across the sampled villages have cultivated their lands for over ten years.

Similarly, results of statistics on land ownership shows that respondents who owned farmlands accounted for 80% in Kakeyi, 73.3% in Dambo and Saye, while over 50% of the respondents in Hunkuyi and Biye cultivated rented lands. Results from the table also show that most farmers interviewed did not belong to any farmers' association. Only 26.7% in Hunkuyi, 23.3% in Kakeyi, 13% in Biye, 10% in Dambo and 6.7% in Saye, belonged to various farmers associations or community based associations. This may have implications for soil conservation as studies have found that membership of agricultural/community based organizations often influence farmers willingness to adopt and invest in conservation practices (Junge *et al.,* 2008; Gerbremariam, 2010).

5.3. 2 Awareness of causes of soil degradation

Table 5.9 shows the level of awareness of the respondent farmers to causes of soil degradation in the study area.

Table5.9: Farmers' Awareness of Causes of Soil Degradation

Awareness	Causes of Soil Degradation									
	DE	OG	SE	OC	LF	IFP	P	OP	BT	LI
Biye										
Aware	100	90	100	83.3	100	60	93.3	86.7	60.0	93.3
Not aware	-	10.0	-	16.7	-	40.0	6.7	13.3	40.0	6.7
Hunkuyi										
Aware	70.0	93.3	100	70.0	100	86.7	93.3	63.3	96.7	56.7
Not aware	30.0	6.7	-	30.0	-	13.3	6.7	36.7	3.3	43.3
Dambo										
Aware	96.7	93.3	100	70.0	100	93.3	76.7	60.0	90.0	80.0
Not aware	3.3	6.7	-	30.0	-	-	23.3	40.0	10.0	20.0
Kakeyi										
Aware	96.7	73.3	100	90.0	100	100	86.7	70.0	76.7	46.7
Not aware	3.3	26.7	-	10.0	-	-	13.3	30.0	23.3	53.3
Saye										
Aware	70.0	63.3	100	90.0	100	46.7	96.7	76.7	73.3	90.0
Not aware	30.0	36.7	-	10.0	-	53.3	3.3	23.3	26.7	10.0
All villages										
Aware	86.7	66.4	100	80.0	100	77.3	89.3	71.3	79.3	73.3
Not aware	13.3	33.6	-	19.3	-	22.7	10.7	28.7	20.7	26.7

***** **DE**= Deforestation, **OG**= Overgrazing, **SE**= Soil erosion, **OC**= Over cultivation, **LF**= Lack of fertilizers, **IFP** = Inappropriate farming practices, **P** = Poverty, **OP**= Over population, **BT**= Bad terrain **LI**= Lack of incentives from Govt.

The results show that in Biye, all the respondents are aware of deforestation as a cause of soil degradation. In Dambo and Kakeyi, awareness is 96.7%, while in Hunkuyi and Saye it is 70.0% For overgrazing, awareness ranged between 93.3% in Hunkuyi and Dambo, 90.0% in Biye, 73% in Kakeyi and 63.3% in Saye. Soil erosion was identified by respondents in all villages as a cause of soil degradation. Awareness of over cultivation as a cause of soil degradation ranged between 90% in Kakeyi and Saye, 83% in Biye and 70% in Hunkuyi and Dambo. All respondents in the sampled villages are aware that lack of fertilizers causes soil degradation. There is a generally high awareness across the studied villages that poor land uses cause soil degradation. The proportion ranged between 100% in Kakeyi, 93% in Dambo, 86% in Hunkuyi, 60% in Biye and 46.7% in Saye.

Similarly, majority of the respondents are aware of poverty as a cause of soil degradation. The awareness is highest in Saye (96.7%) and lowest in Dambo (76.7%). Awareness that over population causes soil degradation is highest in Biye (86.7%), Saye(76.7%), Kakeyi(70%), Hunkuyi (63.3%) and Dambo (60%). Farmers' awareness that bad terrain is a cause of soil degradation is also high and ranged between 96.7% in Hunkuyi, 90% in Dambo, 76.7% in Kakeyi, 73.3% in Saye and 60% in Biye. Awareness that lack of government incentives cause soil degradation is highest in Biye (93%) and least in Kakeyi (47%).

5.3.3 Awareness of consequences of soil degradation

Table 5.10 shows the level of awareness of the respondent farmers to consequences of soil degradation in the study area.

Table 5.10: Farmers' Awareness of Consequences of Soil Degradation

Awareness	Consequences of soil degradation												
	LCY	SPG	PP	UW	PPW	CP	SCC	SGS	LSO	RE	GE	SE	P
Biye													
Aware	100	90.0	60.0	76.7	100	93.3	80.0	63.3	73.3	40	60	73.3	93.3
Not aware	-	10.0	40.0	23.3	-	6.7	20.0	36.7	26.7	60	40	26.7	6.7
Hunkuyi													
Aware	100	100	76.7	93.3	93.3	63.3	53.3	86.7	80.0	20.0	73.3	83.3	100
Not aware	-	-	23.3	6.7	6.7	36.7	46.7	13.3	20.0	80.0	26.7	16.7	-
Dambo													
Aware	100	96.7	60.0	73.3	86.7	100	73.3	56.7	56.7	30.0	36.7	70.0	93.3
Not aware	-	3.3	40.0	26.7	13.3	-	26.7	43.3	43.3	70.0	63.3	30.0	6.7
Kakeyi													
Aware	100	100	63.3	76.7	100	96.7	70.0	70.0	73.3	36.7	46.7	70.0	100
Not aware	-	-	36.7	23.3	-	3.3	30.0	30.0	23.3	63.3	53.3	30.0	-
Saye													
Aware	100	93.3	63.3	60.0	100	100	56.7	60.0	76.7	16.7	23.7	60.0	100
Not aware	-	6.7	36.7	40.0	-	-	43.3	40.0	23.3	83.3	76.7	40.0	-
All villages													
Aware	100	96.0	64.7	76.0	96.0	90.7	66.7	67.3	72.0	28.7	48.1	71.3	97.3
Not aware	-	4.0	35.3	24.0	4.0	9.3	33.3	32.7	28.0	71.3	51.9	28.7	2.7

***LCY**= Low crop yield, **SPG**= Stunted plant growth, **PP**= Presence of pests, **UW**= Uncontrollable weeds, PPW= Presence of particular weeds, CP= Coloration of plants, SCC= Soil colour change, SGS= Stony/ gravelly surface, LSO= Low soil organic activities, RE= Rill erosion, GE= Gully erosion, SE= Sheet erosion, P = Poverty

The results show that all the respondents across the sampled villages are aware that low crop yield is a consequence of soil degradation. The high awareness of low crop yield as a consequence of soil degradation may be attributed to the fact that farmers' perception of soil degradation are strongly associated with declining yields (Stocking and Murnagham, 2000; Wezel, Steinmuller and Freidrchsen, 2002; Chizana *et al.,* 2007). Majority of the respondents are also aware that stunted plant growth is a consequence of soil degradation. The proportion of respondents aware that pests infestations is a consequence of soil degradation range between 77% in Hunkuyi, 63% in Kakeyi and Saye and 60% in Biye and Dambo.

A high proportion of the respondents are aware of uncontrollable weeds as a sign of soil degradation, with 93.3% awareness in Hunkuyi, 76.7% in Biye and Kakeyi, 73.3 in Dambo and 60% in Saye. Across the study area, there is high awareness of presence of particular weeds in the study area. Awareness is 100% among respondents in Biye, Kakeyi and Saye, 93.3% in Hunkuyi and 86.7% in Dambo. Farmers say the presence of weeds such as kiri-kiri (*Cynodon dactylon*), Aya-aya (*Cyperus rotundus,kyllinga*), Gamba grass (*Andropogon gayanus*), Harkiya (*Digitaria exilis*),Wuta-wuta (*Striga hermontheca*) are signs of soil fertility decline which result in yield decline (Plate X) and this agrees with various studies which have found that presence of weeds are linked to declining soil quality (Stocking and Murnagham, 2000; Wezel *et al.,* 2002; Mikkelsen and Langohr, 2004).



Plate IX: Presence of weeds and gravelly surfaces are important soil degradation indicators

Across the studied villages, respondents' awareness that plant coloration is a consequence of soil degradation is low. The proportion ranges between 40% in Biye, and about 26% in Saye. Awareness for soil colour change is highest in Biye (80%) and least in Hunkuyi (53%).

Awareness that stony/gravelly surface is a consequence of soil degradation is highest in Hunkuyi (86.7%) and least in Dambo (43.3%). Results also show that there is high awareness among respondents that low organic activities in soils is a consequence of soil degradation with 80% in Hunkuyi, 77% in Saye, 73% in Biye and Kakeyi and about 57% in Dambo. Awareness that rills are a consequence of soil degradation range between 80% in Saye and Hunkuyi, 70% in Dambo, 63% in Kakeyi and 60% in Biye. Similarly, awareness that gullies are a consequence of soil

degradation ranges between 77% in Saye and 53% in Kakeyi. Results also show that respondents are aware of sheet erosion. This is shown by the level of awareness in Hunkuyi (83%), Biye (73%), Dambo and Kakeyi (70%) and Saye (60%).

There is a high level of awareness across the study area of poverty as a consequence of soil degradation. This ranges between 100% awareness in Hunkuyi, Kakeyi and Saye and 93.3% in Biye and Dambo. This may be because poor yields and consequent low productivity are directly tied to farmers socio-economic well-being. Studies show that farmers' ability to manage soil degradation are constrained by poverty (Barbier,1997), unskilled labour, pressure on available land (Chizana *et al.*, 2007).

5.3.4 Awareness of soil management practices

Table 5.11 shows the level of respondent farmers' awareness of improved soil management practices. All the farmers across the studied villages are aware that application of chemical fertilizer help to improve soil health. Similarly, nearly all the farmers are aware that application of farm yard manure improves soil quality. The proportion of awareness ranged between 100% in Kakeyi and 93.3% in Saye. The proportion of respondents who are aware that mixed cropping improves soil fertility ranged between 100% in Dambo and 93% in Kakeyi. The results also show that most of the respondents in the studied villages are aware that mulching protects farmlands from soil loss. The awareness is highest in Hunkuyi (100%) and least in Kakeyi (83%). Similarly, almost all the respondents are aware that crop rotation maintains soil quality.

The level of awareness ranged between 100% in Dambo and 93% in Biye and Hunkuyi. Awareness of the use of composting to improve soil health ranges between 70% in Biye to about 97% in Dambo. All the respondents in the studied villages, with the exception of Dambo (with about 97%) are aware that animal dung improves soil fertility.

Table 5.11: Farmers Awareness of Soil Management Practices

Awareness	Land management practices												
	CF	FM	MXC	MU	CR	CO	AD	TE	MOC	AS	TP	ABL	BF
Biye													
Aware	100.0	96.7	96.7	90.0	93.3	70.0	100.0	83.3	33.3	3.3	73.3	3.3	96.7
Not aware	-	3.3	3.3	10.0	6.7	30.0	-	16.7	66.7	96.7	26.7	96.7	3.3
Hunkuyi													
Aware	100.0	97.0	97.0	100	93.3	90.0	100	73.3	46.7	56.7	73.3	3.3	96.7
Not aware	-	3.0	3.0	-	6.7	10.0	-	26.7	53.3	43.3	26.7	96.7	3.3
Dambo													
Aware	100	96.7	100	93.3	100	96.7	96.7	60.0	83.3	40.0	66.7	10.0	100
Not aware	-	3.3	-	6.7	-	3.3	3.3	40.0	16.7	60.0	3.3	90.0	-
Kakeyi													
Aware	100.0	100.0	93.3	83.3	96.7	83.3	100	60.0	33.3	46.3	20.0	3.3	100.0
Not aware	-	-	6.7	16.7	3.3	16.7	-	33.3	66.7	53.3	80.0	96.7	-
Saye													
Aware	100.0	93.3	100.0	86.7	100.0	93.3	100.0	50.0	93.3	6.7	40.0	6.7	100
Not aware	-	2.0	-	13.3	-	6.7	-	50.0	6.7	93.3	60.0	93.3	-
All villages													
Aware	100.0	96.7	97.4	90.7	96.7	86.7	99.3	65.3	58.0	30.6	54.7	5.3	98.7
Not aware	-	3.3	2.7	9.3	3.3	13.3	0.66	34.7	42.0	69.4	45.3	94.7	1.32

***** **CF**= Chemical fertilizer, **FM**= Farmyard manure, **MXC**= Mixed cropping, **MU**= Mulching, **CR**= Crop rotation, **CO**= Compost, **AD**= Animal dung, **TE**= Terracing, **MOC**= Mono cropping, **AS**= Ash, **TP**= Tree planting, **ABL**= Abandon land, **BF**= Bushfallowing

There is also high awareness among respondents that terracing helps to reduce runoff and soil loss from farmlands. The proportion of awareness ranged between 83% in Biye and 50% in Saye. However, across the studied villages, awareness among respondents on the use of ash is low. The proportion of awareness ranged between 56% in Hunkuyi and about 3% in Biye. Awareness that tree planting is a good land use practice is highest in Biye and Hunkuyi (about 73%) and least in Saye (20%). Results from oral interviews with farmers indicate that major trees grown across the studied villages (which include, Mango, Moringa, Locust bean, Neem, Kuka and Shea trees) are for domestic consumption, medicinal value and provision of shade on farm lands. Shrubs such as Gawo (*Faidherbia albida*) and Bini-dazugu (*Jatropha curcas*) are also grown on most farms and serve as fence post/boundary around farms.

Awareness for land abandonment among all respondents is low and ranged between 10% in Dambo, 7% in Saye and 3% in Biye, Hunkuyi and Kakeyi. Awareness that bush fallowing improves soil health is high across the studied villages and ranged between 100% in Dambo, Kakeyi and Saye and about 97% in Biye and Hunkuyi. However, discussions held with farmers indicate that land abandonment and bush fallowing are rare. This may also be attributed to scarcity of agricultural lands. Studies have shown that farmers react to soil fertility decline by modifying their cultivation pattern, intensifying production and reducing fallow (Gyasi *et al*., 1995).

5.3.5 Information sources on soil management practices

The result of the farmer survey (Fig.5.7) shows that all the respondents' across the sampled villages cited friends and family as the most important source of information.

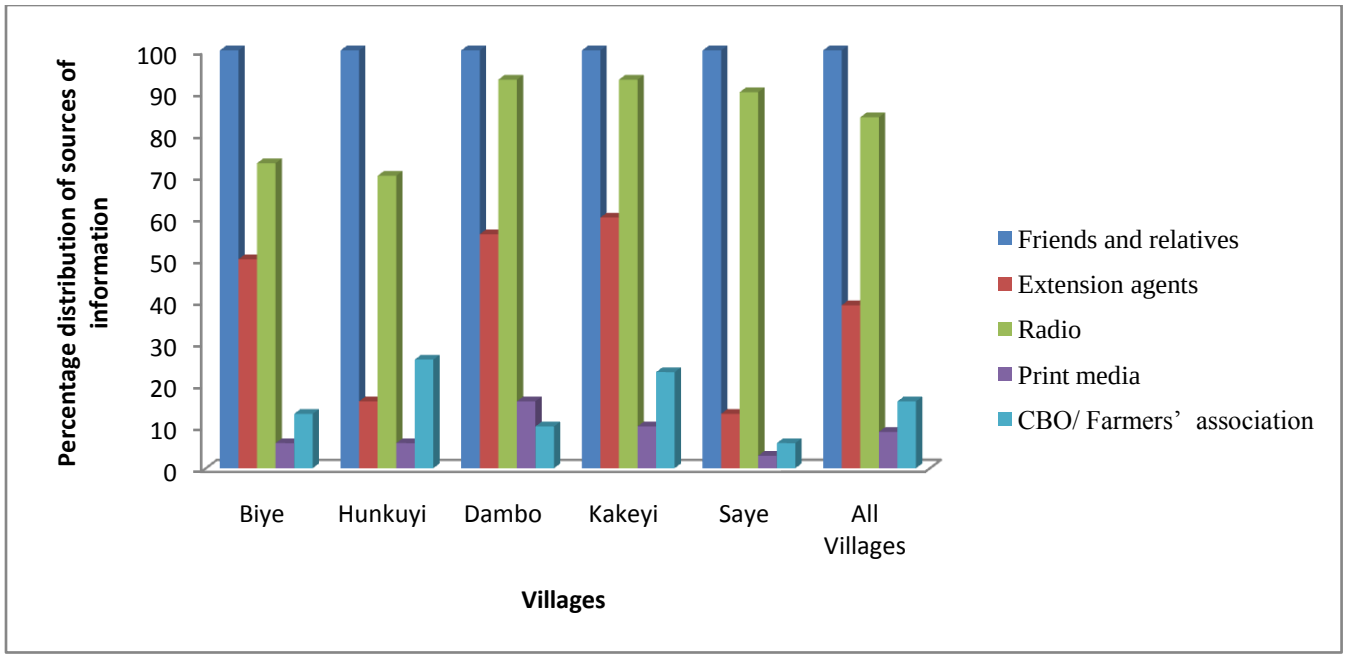


Fig. 5.7: Farmers' Information Sources on Soil Management Practices

The use of radio as a source of information is high and ranged between 93% in Dambo and Kakeyi, 90% in Saye, 73% in Biye and 70% in Hunkuyi. The use of extension agents as a source of information is low and ranged between 60% in Kakeyi, 56% in Dambo, 50% in Biye, 16% in Hunkuyi and only13% in Saye. The use of CBO/Farmers association as a source of information is also low with 26% in Hunkuyi, 23% in Kakeyi, 13% in Biye, 10% in Dambo and 6% in Saye. Print media is the least used source of information with 16% in Dambo, 10% in Kakeyi, 6% in Biye and Hunkuyi and 3% in Saye. While respondents cite irregular visits as reason for low use of extension agents, illiteracy and cost for low use of the print media, the low significance of farmers association as a source of information may be attributed to low membership of respondents in the associations. Variations across villages may be attributed to socio-demographic characteristic such as level of education and incomes of individual respondents.

5.3.6 Identification of soil management practices and extent of use

A 4-point likert-type scale was used to score respondents' identification and use of soil management practices. The scale ranges from 1= never used, 2= rarely used, 3= less used and 4= most used. The results are presented in Table 5.12.

Table 5.12: Farmers' Identification of Soil Management Practices and Extent of Use

Soil Management practices	Most used	Less used	Rarely used	Never used	$\bar{x}$ Score
Biye	**No. (%)**	**No. (%)**	**No. (%)**	**No. (%)**	
Chemical fertilizer	28 (93)	2 (6.7)	- -	- -	3.93
Mixed cropping	26 (86.7)	2 (6.7)	1 (3.3)	1 (3.3)	3.77
Mulching	10 (33.3)	11 (36.7)	6 (20)	3 (10)	2.93
Animal dung	3 (10)	22 (73.3)	5 (16.7)	- -	2.93
Crop rotation	11 (36.7)	4 (13.3)	13 (43.3)	2 (6.7)	2.80
Compost	12 (40)	5 (16.7)	4 (13.3)	9 (30)	2.67
Terracing	8 (26.7)	9 (30)	8 (26.7)	5 (16.7)	2.66
Farm yard manure	3 (10)	7 (23.3)	18 (60)	2 (6.7)	2.36
Mono cropping	5 (16.7)	8 (26.7)	7 (23.3)	10 (33.3)	2.27
Ash	6 (20)	2 (6.7)	4 (13.3)	1 (3.3)	1.30
Tree planting	- -	- -	8 (26.7)	22 (73.3)	1.26
Abandon land	- -	- -	1 (3.3)	29 (96.7)	1.03
Bush fallowing	- -	- -	1 (3.3)	29 (96.7)	1.03
Saye					
Crop rotation	24 (80)	6 (20)	- -	- -	3.80
Chem. Fertilizer	22 (73.3)	6 (20)	2 (6.7)	- -	3.67
Mixed cropping	19 (63.3)	10 (33.3)	1 (3.3)	- -	3.60
Compost	10 (33.3)	12 (40)	6 (20)	2 (6.7)	3.00
Mono-cropping	10 (33.3)	7 (23.3)	12 (40)	1 (3.3)	2.87
Farm yard manure	- -	24 (80)	4 (13.3)	2 (6.7)	2.73
Ash	2 (6.7)	20 (66.7)	6 (20)	2 (6.7)	2.73
Mulching	5 (16.7)	15 (50)	6 (20)	4 (13.3)	2.70
Animal dung	18 (60)	2 (6.7)	- -	- -	2.60
Tree planting	3 (10)	5 (16.7)	10 (33.3)	12 (40)	1.97
Terracing	2 (6.7)	2 (6.7)	11 (36.7)	15 (50)	1.70
Abandon land	- -	- -	2 (7.6)	28 (93.3)	1.07
Bush fallowing	- -	- -	- -	30 (100)	1.00
Hunkuyi					
Chemical fertilizer	27 (90)	3 (10)	- -	- -	4.00
Mixed cropping	21 (70)	6 (20)	2 (6.7)	1 (3.3)	3.57
Crop rotation	21 (70)	4 (13.3	3 (10)	2 (6.7)	3.46
Compost	12 (40)	12 (40)	3 (10)	3 (10)	3.10
Animal dung	6 (20)	18 (60)	6 (20)	- -	3.00
Mulching	7 (23.3)	13 (43.3)	7 (23.3)	3 (6.7)	2.80
Farm yard manure	- -	11 (36.7)	18 (60)	1 (3.3)	2.33
Tree planting	3 (10)	8 (26.7)	11 (36.7)	8 (26.7)	2.20
Terracing	4 (13.3)	6 (20)	12 (40)	8 (26.7)	2.20
Mono-cropping	9 (30)	1 (3.3)	4 (13.3)	16 (53.3)	2.10
Ash	- -	- -	17 (56.7)	13 (43.3)	1.56
Abandon land	- -	- -	1 (3.3)	29 (96.7)	1.03
Bush fallowing	- -	- -	1 (3.3)	29 (96.7)	1.03

Dambo					
Chemical fertilizer	27 (90)	3 (10)	- -	- -	3.90
Mixed cropping	26 (86.7)	2 (6.7)	2 (6.7)	- -	3.80
Crop rotation	23 (76.7)	7 (23.3)	- -	- -	3.76
Animal dung	16 (53.3)	7 (23.3)	6 (20)	1 (3.3)	3.26
Compost	15 (50)	7 (23.3)	7 (23.3)	1 (3.3)	3.20
Mulching	10 (33.3)	13 (43.3)	5 (16.7)	2 (6.7)	3.03
Farm yard manure	6 (20)	16 (53.3)	6 (20)	2 (6.7)	2.86
Mono-cropping	2 (6.7)	3 (10)	20 (66.7)	5 (16.7)	2.06
Tree planting	2 (6.7)	6 (20)	12 (40)	10 (33.3)	2.00
Terracing	2 (6.7)	7 (23.3)	9 (30)	12 (40)	1.96
Ash	2 (6.7)	2 (6.7)	8 (26.7)	18 (60)	1.46
Abandon land	- -	- -	3 (10)	29 (96.7)	1.16
Bush fallowing	- -	- -	- -	30 (100)	1.00
Kakeyi					
Chemical fertilizer	22 (73.3)	8 26.7)	- -	- -	3.73
Mixed cropping	24 (80)	2 (6.7)	2 (6.7)	2 (6.7)	3.60
Crop rotation	21 (70)	7 (23.3)	1 (3.3)	1 (3.3)	3.60
Farm yard manure	11 (36.7)	17 (56.7)	2 (6.7)	- -	3.30
Compost	13 (43.3)	10 (33.3)	2 (6.7)	5 (16.7)	3.03
Animal dung	7 (23.3)	13 (43.3)	10 (33.3)	- -	2.90
Mulching	7 (23.3)	13 (43.3)	5 (16.7)	5 (16.7)	2.73
Mono-cropping	2 (6.7)	8 (26.7)	12 (40)	10 (33.3)	2.20
Terracing	6 (20)	3 (10)	3 (10)	18 (60)	1.90
Ash	3 (10)	4 (13.3)	7 (23.3)	16 (53.3)	1.80
Tree planting	- -	- -	6 (20)	24 (80)	1.20
Abandon land	- -	- -	1 (3.3)	29 (96.7)	1.03
Bush fallowing	- -	- -	- -	30 (100)	1.00
All villages					
Mixed cropping	117 (78)	26 (17.3)	9 (6)	4 (2.7)	3.79
Crop rotation	100 (66.7)	28 (18.7)	17(11.3)	4 (2.7)	3.48
Compost	62 (41.3)	46(30.7)	22(14.7)	20(13.3)	3.00
Animal dung	50 (33.3)	62(41.3)	27 (18)	1 (0.7)	2.94
Chemical fertilizer	99(66)	21(14)	2 (1.3)	- -	2.83
Mulching	39 (26)	65 (43.3)	29(19.3)	15(10)	2.73
Farm yard manure	20(13.3)	75 (50)	48 (32)	7 (4.7)	2.72
Mono-cropping	28 (18.7)	27(18)	55(36.7)	32 (21.3)	2.23
Terracing	22 (14.7)	27 (18)	43 (28.7)	58 (38.7)	2.09
Tree planting	8 (5.3)	19 (12.7)	47 (31.3)	76 (50.7)	1.73
Ash	13 (8.7)	10 (6.7)	26 (17.3)	66 (44)	1.33
Abandon land	-	-	6 (4)	144 (96)	1.04
Bush fallowing	-	-	2 (1.3)	148 (98.7)	1.03

Result from Table 5.12 shows that commonly used agricultural land management practices in Biye are chemical fertilizer ($\bar{x} = 3.93$) and mixed cropping while the least used soil management practices are mono cropping ($\bar{x} = 2.27$), ash ($\bar{x} = 1.30$), tree planting ($\bar{x} = 1.26$) and abandon land ($\bar{x} = 1.03$). The commonly used soil management practices in Saye are crop

rotation ($\bar{x} = 3.80$) and chemical fertilizer ($\bar{x} = 3.67$). The least used practices are abandon land ($\bar{x} = 1.07$) and bush fallowing ($\bar{x} = 1.00$). Similarly, commonly used agricultural land management practices in Hunkuyi are chemical fertilizer ($\bar{x} = 4.00$) and mixed cropping ($\bar{x} = 3.57$), abandon land ($\bar{x} = 1.03$) and bush fallowing ($\bar{x} = 1.03$).

Commonly used agricultural land management practices in Dambo are chemical fertilizer ($\bar{x} = 3.90$), mixed cropping ($\bar{x} = 3.80$), crop rotation ($\bar{x} = 3.76$), animal dung ($\bar{x} = 3.26$), compost ($\bar{x} = 3.20$), mulching ($\bar{x} = 3.03$), farmyard manure ($\bar{x} = 2.86$), Least used soil management practices are mono cropping ($\bar{x} = 2.06$), tree planting ($\bar{x} = 2.00$), terracing ($\bar{x} = 1.96$), ash ($\bar{x} = 1.46$), abandon land ($\bar{x} = 1.16$) and bush fallowing ($\bar{x} = 1.00$). Similarly, in Kakeyi chemical fertilizer ($\bar{x} = 3.73$), mixed cropping ($\bar{x} = 3.60$), crop rotation ($\bar{x} = 3.60$), farmyard manure ($\bar{x} = 3.30$), compost ($\bar{x} = 3.03$), animal dung ($\bar{x} = 2.90$), mulching ($\bar{x} = 2.73$), mono cropping ($\bar{x} = 2.20$), terracing ($\bar{x} = 1.90$), ash ($\bar{x} = 1.80$) are the most used while the least used soil management practices are tree planting ($\bar{x} = 1.20$), abandon land ($\bar{x} = 1.03$) and bush fallowing ($\bar{x} = 1.00$).

The results of field survey and discussions with respondents show that farmers rarely use one means but often supplement chemical fertilizers with other measures such as mixed cropping and the use of farm yard manure. Farmers cite very high cost and scarcity of inorganic fertilizers as the reason for such practice. Again farmers' major worry about the use of compost is that it needs to be applied much earlier before cultivation because it is slow to act on soils. However, they say its fertilizing effects last longer in the soil than chemical fertilizer which is expensive and needs to be applied regularly. Similarly, major problems associated with the use of farm yard

manure and animal dung are availability and cost of transportation to farmlands. Generally, across the study area, the most used soil management practice is mixed cropping while the least used is bush fallowing. The low use of practices such as tree planting, bush fallowing and abandon land were attributed to scarcity of cultivable lands by farmers, while the use of ash is low because farmers say it is 'burns' crops when rain fall ceases and soil moisture is low. Farmers attribute the low use of practices such as mono cropping, bush fallowing and abandon land to scarcity of cultivable lands while the use of ash is also low because farmers consider it harmful to crops.

5.3.7 Attitude towards soil management practices

Soil management practices, presented in attitude statements (Table 5.13a), were used to determine farmers attitudes towards land management practices.

Table 5.13a: Respondents' Attitude Towards Soil Management Practices

Code	Statements
A_1	Mixed cropping reduces soil degradation
A_2	Crop residues protect soils from erosion
A_3	Terracing reduces soil erosion and helps to conserve soil
A_4	Crop rotation maintains soil structure and conserve soil moisture
A_5	Close growing crops are more effective for erosion control than inter tilled crops
A_6	It is unnecessary to use compost and animal dung if inorganic fertilizer are used
A_7	Shortened length of growing period minimizes soil loss
A_8	Grazing on farm lands by livestock destroys soil structure
A_9	Land fallowing is an effective way of maintaining soil fertility
A_{10}	Tree planting improves soil fertility
A_{11}	Controlled grazing minimizes soil degradation
A_{12}	Keeping lands permanently under forest cover is the best way to conserve lands
A_{13}	Deforestation, over cultivation and overgrazing are major causes of land degradation
A_{14}	There is need for stricter restrictions against deforestation

A 3-point Likert type scale test was used to analyse respondents' attitudes to agricultural land management practices. The statements' scale range from 1 (unfavourable) to 3 (favourable)

points where various attitudes were grouped into three categories (1= disagree, 2= undecided and agree= 3).

The attitude statements are represented by codes $A_1 - A_{14}$, presented in Tables 5.13b. 2.0 was taken as the base score, below which an attitude statement was considered negative. An agreement by respondents on any of the attitude statements is described as positive while a disagreement with any of the attitude statement is described as negative attitude towards soil management practices.

Results from the table show that in Biye statements A_1, A_2, A_3, A_4, A_7, A_8, A_9, A_{10}, A_{11}, A_{13} are positive statements while A_5, and A_6, A_{12}, A_{14} are negative statements. All the respondents agree with statement A_1 and A_9 with a mean score of 3.00. Similarly, other positive statements include A_4 (93%), A_3 (87%), A_8 (70%), A_7 and A_{11}(63%), A_{13} (57%) and A_{10} (50%). The proportion of negative statements range between 67% (A_6), 50% (A_{12}) and 43% (A_{10}). In Hunkuyi, only statements A_6, A_{12} and A_{14} are negative statements. The proportion of agreement ranges between 100% (A_3), 96% (A_9), 93% (A_1), 90% (A_2), 76% (A_7), 73% (A_{11}), 70% (A_4), 60% (A_8), 57% (A_{13}), 47% (A_5) and (A_{10}).

The proportion of disagreements range between 60% (A_6), 50% (A_{14}) and 43% (A_{12}). Majority of the respondents are of the opinion that inorganic fertilizers used in combination with compost and animal dung improves soil fertility. In Dambo, the proportion of agreements range between 96% (A_2), 90% (A_1), 86% (A_9), 76% ($A_3$and A_4), 70% (A_7), 67% (A_{13}), 57% (A_{10}) and 43% (A_5). The highest disagreements are for A_{12} (73.3%), A_6 (60%) and 57% (A_{14}). In Kakeyi, statements A_1, A_2, A_3, A_4, A_5, A_7, A_8, A_9, A_{11} ,A_{12}, and A_{13} are positive statements. The agreements range between 100% (A_2), 83% (A_1), 76% (A_9), 73% (A_3) , 70% (A_4) and (A_{13}), 63% (A_7 and A_8), 43% for (A_5) and 40% (A_{12}).

Table 5.13b: Farmers' Attitude Towards Agricultural Land Management Practices

	Attitudes													
	A1	A2	A3	A4	A5	A6	A7	A8	A9	A10	A11	A12	A13	A14
Biye														
Agree	30	23	26	28	12	8	19	21	30	15	19	10	17	11
Undecided	0	6	4	1	5	2	4	7	0	2	4	5	8	2
Disagree	0	1	0	1	13	20	7	2	0	13	7	15	5	17
X score	3.00	2.73	2.86	2.90	1.96	1.60	2.40	2.63	3.00	2.06	2.40	1.83	2.40	1.80
Hunkuyi														
Agree	28	27	30	21	14	10	23	18	29	13	22	9	17	8
Undecided	2	2	0	7	8	2	3	2	1	7	5	8	7	7
Disagree	0	1	0	2	8	18	4	10	0	10	3	13	6	15
X score	2.93	2.86	3.00	2.63	2.20	1.73	2.63	2.26	2.96	2.10	2.63	1.86	2.36	1.76
Dambo														
Agree	27	29	23	23	13	11	21	18	26	17	15	7	20	10
Undecided	1	1	5	6	10	1	3	4	3	10	10	1	7	3
Disagree	2	0	2	1	7	18	6	8	1	3	5	22	3	17
X score	2.80	2.96	2.70	2.73	2.20	1.76	2.50	2.33	2.83	2.46	2.33	1.50	2.66	1.76
Kakeyi														
Agree	25	30	22	21	13	8	19	19	23	13	23	12	21	6
Undecided	4	0	6	5	8	2	5	4	5	3	3	7	1	2
Disagree	1	0	2	4	9	20	6	7	2	14	2	11	8	22
X score	2.80	3.00	2.67	2.56	2.13	1.53	2.43	2.40	2.70	1.96	2.67	2.03	2.43	1.46
Saye														
Agree	28	21	14	18	8	3	21	14	27	12	13	20	22	10
Undecided	2	6	6	6	10	6	2	6	1	7	9	8	4	2
Disagree	0	3	10	6	12	21	7	10	2	11	8	2	4	18
X score	2.93	2.60	2.13	2.40	2.16	1.40	2.46	2.13	2.83	2.03	2.16	2.60	2.60	1.73
All villages														
Agree	138	130	115	111	60	40	103	90	135	70	92	58	97	45
Undecided	9	15	21	25	41	13	17	23	10	29	31	29	27	16
Disagree	3	5	14	14	49	97	30	37	5	51	25	63	26	89
X score	2.90	2.83	2.67	2.65	2.07	1.62	2.49	2.35	2.87	2.13	2.42	1.72	2.47	1.71

However, the highest disagreements range between 73% (A_{14}), 67% (A_6 and A_{10}). In Saye, the results show that statements A_1, A_2, A_3,A_4,A_5, A_7, A_8, A_9, A_{10}, A_{11}, A_{12} and A_{13}, are positive statements while A_6 and A_{14} are negative. The result shows that the highest agreements are 93% for statement (A_1), 90% (A_9) and 70% for statements A_2, A_{12}, A_{13}. However, A_6 and A_{14} have the highest disagreement at 70% and 60% respectively.

Across the study area, results from discussion with farmers indicate that majority of the respondents are of the opinion that inorganic fertilizers, used in combination with compost and animal dung increases soil fertility and maintains soil. While farmers agree that tree planting improves soil fertility, the major importance attached to presence of trees on farmlands are provision of shade, domestic and economic uses. Respondents' high level of disagreement with statements A_{10} and A_{14} may be attributed to farmers concern for land scarcity and fear that stricter restrictions against forest clearance may affect economic well-being of poor farmers.

5.3.8 Factors which influence farmers' attitude towards soil management practices

5.3.8.1 Age

The results of chi square analysis between farmers age and actual adaptations are presented in Tables 5.14. Results from the table show that there is no association between respondents ages and the adaptation strategies in Biye, Hunkuyi, Dambo, Kakeyi and Saye. The overall statistics shows significant relationship between age and coping strategies adopted by farmers.

Table 5.14: Relationship Between Respondents Age and Actual Adaptation Strategy

Adaption strategy	Age of Respondents								
Dambo	21-30	31- 40	41-50	51-60	61-70	Total	**Chi-Square**	**P Value**	**Df**
Multiple crop under irrigation	2	4	3	4	1	14	4.83	15.51	8
Specialized crop under irrigation	1	1	2	2	2	8			
Improved variety of crop	2	1	1	1	3	8			
Total	**5**	**6**	**6**	**7**	**6**	**30**			

Kakiye	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**Total**	**Chi-Square**	**P Value**	**Df**
Multiple crop under irrigation	3	5	5	4	0	17	8.23	21.03	12
Improved variety of crop	4	2	2	2	1	11			
Mixed multiple crop/livestock under irri	1	0	0	0	0	1			
Specialized crop under irrigation	1	0	0	0	0	1			
Total	9	7	7	6	1	30			

Saye	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**Total**	**Chi-Square**	**P Value**	**Df**
Multiple crops under irrigation	1	2	5	7	0	15	13.20	15.51	8
Improved variety of crop	1	2	3	2	1	9			
Specialized crop under irrigation	1	0	2	0	3	6			
Total	3	4	10	9	4	30			

Biye	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**Total**	**Chi-Square**	***p*Value**	**Df**
Specialized crop under irrigation	0	1	1	0	0	2	21.31	41.34	28
Mixed multiple crop/livestock under irrigation	0	1	2	1	1	5			
Improved variety of crops	1	5	1	6	2	15			
Specialized crop under dry land	0	1	0	0	0	1			
Multiple crop under irrigation	0	1	1	0	0	2			
Change crop	1	1	0	0	1	3			
Farm more	0	0	0	1	0	1			
multiple crop/livestock under dryland	0	0	0	1	0	1			
Total	2	10	5	9	4	30			

Hunkuyi	**11- 20**	**21-30**	**31-40**	**41-50**	**51-60**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	0	3	5	2	4	14	9.65	21.03	12
Improved variety of crop	1	2	2	1	2	8			
Mixed multiple crop/livestock under irri	0	1	3	1	1	6			
Specialized crop under irrigation	0	2	0	0	0	2			
Total	**1**	**8**	**10**	**4**	**7**	**30**			

All Villages	**11-20**	**21-30**	**31-40**	**41-50**	**51-60**	**61-70**	**Total**	**Chi-sq**	**pValue**	**Df**
Specialized crop under irrigation	0	7	2	4	2	5	20	40.5	49. 1	35
Mixed multiple crop/livestock under irrigation	0	3	5	2	2	0	12			
Improved variety of crops	2	13	8	13	9	5	50			
Specialized crops under dryland	0	1	0	0	0	0	1			
Multiple crop under irrigation	0	10	17	15	19	1	62			
Change crop	1	1	0	0	1	0	3			
Farm more	0	0	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	0	0	1	0	0	1			
Total	3	35	32	36	33	11	150			

The effect of age on farmers may be positive or negative (Gebremariam, 2010). For example, younger farmers are likely to invest more in long term soil conservation methods, while older farmers may take less risks (Gyasi *et al*., 1995; Mikkelsen and Langohr, 2004). On the other hand, older farmers with more experience and knowledge of the history of the land are likely to adopt and maintain sustainable cultural practices (Gyasi *et al*., 1995; Mikkelsen and Langohr, 2004). Similarly, Barbier, (1997) and Bennet *et al.,* (1999) observed that socio- demographic factors such as age, education, marital status, house-hold size, income and land ownership influence farmers' awareness and attitudes to soil degradation and land management practices.

5.3.8.2 Household size

Result of chi square analysis between respondents household size and respondents actual coping strategy are presented in Table 5.15. Results from the table show that there is no statistically significant association between household size and farmers actual coping strategies within the studied villages. This may be attributed to the fact that respondents household sizes, which are generally large, are often influenced by cultural and religious factors and not necessarily by incomes or economic factors. However, overall results shows statistically significant association between household size and coping strategies adopted by farmers. This supports studies which show that an increase in household size means more people to feed and indirectly reduces income per head and degrades soils (Oyedele, Akintola, Rahji, and Omonona, 2009). Where households depend on less productive agricultural land, this has implications on land use and land degradation because the level of soil degradation by farmers is often influenced by factors such as poverty (Current, Lutz and Sherr, 1995; Bridges and VanBarren, 1997; Oyedele *et al*., 2009).

Table 5.15: Relationship Between Respondents Household and Actual Adaptation Strategy

Adaptation Strategy	Household Size									
	1- 5	**6-10**	**11-15**	**16-20**	**21-25**	**31-35**	**Total**	**Chi-Square**	***p*Value**	**Df**
Dambo										
Multiple crop under irrigation	4	4	3	2	1	0	14	10.26	18.31	10
Specialized crop under irrigation	3	3	2	0	0	0	8			
Improved variety of crop	1	1	3	1	0	1	8			
Total	8	9	8	3	1	1	30			

Kakiye	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	7	6	2	0	2	17	10.63	15.51	8
Improved variety of crops	5	3	2	1	0	11			
Specialized crop under irrigation	0	0	1	0	0	1			
Mixed multiple crop/livestock under irri	0	1	0	0	0	1			
Total	12	10	5	1	2	30			

Biye	**1-5**	**6-10**	**11-15**	**16-20**	**Total**	**Chi-Square**	***p*Value**	**Df**
Specialized crop under irrigation	0	1	1	0	2	23.89	32.67	21
Mixed multiple crop/livestock under irrigation	1	2	1	1	5			
Improved variety of crop	7	6	1	1	15			
Specialized crop under dry land	0	1	0	0	1			
Multiple crop under irrigation	1	0	0	1	2			
Change crop	1	1	0	0	3			
Farm more	0	0	1	0	1			
Mixed multiple crop/livestock under dryland	1	0	1	0	1			
Total	11	11	5	3	30			

Saye	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crops under irrigation	1	10	3	1	0	15	10.47	15.51	8
Improved variety of crop	1	3	2	1	2	9			
Specialized crop under irrigation	0	4	0	2	0	6			
Total	2	17	5	4	2	30			

Hunkuyi	**1- 5**	**6-10**	**11-15**	**16-20**	**21-25**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	7	5	0	2	0	14	13.22	21.03	12
Improved variety of crop	4	1	1	1	1	8			
Mixed multiple crop/livestock under irrig.	0	5	1	0	0	6			
Specialized crop under irrigation	1	1	0	0	0	2			
Total	12	12	2	3	1	30			

All Villages	**1-5**	**6-10**	**11-15**	**16-20**	**21-25**	**31-35**	**Total**	**Chi-square**	***p*Value**	**Df**
Specialized crop under irrigation	4	9	4	2	0	0	19	111.2	59.2	35
Mixed multiple crop/livestock under irrig.	0	8	2	1	0	0	11			
Improved variety of crops	18	15	10	6	2	0	51			
Specialized crops under dryland	1	1	0	0	0	0	2			
Multiple crops under irrigation	20	25	8	6	3	1	63			
Change crop	1	0	0	0	0	0	1			
Farm more	0	0	1	0	0	0	1			
Mixed multiple crop/livestock under dryland	1	0	1	0	0	0	2			
Total	45	58	26	15	5	1	150			

For example, Lal (2009) observed that most soils are prone to degradation by land misuse and soil mismanagement driven by desperate situations and helplessness in the case of poor and smaller landholders.

5.3.8.3 Level of education

The results from Table 5.16 show statistically significant association between respondents' level of education and actual coping strategies. In Biye, the calculated chi square is 33.0 and significant at p=0.05. In Hunkuyi, the calculated chi square is 24.9 and significant at p=0.05. In Dambo, the result show calculated chi square value of 25.7 and significant association at p=0.01. In Kakeyi, the chi square value is 24.8 and significant at 0.05. Result of chi square analysis in Saye show that the calculated chi square value is 9.57 and significant at p=0.1. Overall chi-square analysis across the studied villages show statistically significant association exists between level of education and actual coping strategies adopted by farmers. This agrees with several studies which have found that better educated farmers are more likely to adopt soil conservation technologies (Junge *et al.,* 2008; Gebremariam, 2010).

Table 5.16: Relationship Between Level of Education and Actual Adaptation Strategy

Adaption strategy	Level Of Education							
Biye	**Quran**	**primary**	**Sec.**	**Ter.**	**Total**	**Chi-Square**	***p* Value**	**Df**
Specialized crop under irrigation	0	0	1	1	2	33.0	32.67	21
Mixed multiple crop/livestock under irrigation	5	0	0	0	5			
Improved variety of crops	4	6	4	1	15			
Specialized crop under dry land	0	0	0	1	1			
Multiple crop under irrigation	0	1	1	0	2			
Change crop	1	1	1	0	3			
Farm more	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	0	0	1	1			
Total	10	9	7	4	30			

Hunkuyi	**Qur.**	**Adult**	**Prim.**	**Sec.**	**Ter.**	**Total**	**Chi-square**	***p*Value**	**Df**
Multiple crop under irrigation	7	0	4	3	0	14	24.9	21.03	12
Improved variety of crop	2	2	2	2	0	8			
Mixed multiple crop/livestock under irri	2	0	3	1	0	6			
Specialized crop under irrigation	0	0	0	1	1	2			
Total	11	2	9	7	1	30			

Dambo	**Qur.**	**Adult**	**Prim.**	**Sec.**	**Ter.**	**Total**	**Chi-square**	***p*Value**	**Df**
Multiple crop under irrigation	0	1	6	7	0	14	25.7	20.1	8
Specialized crop under irrigation	6	0	0	0	2	8			
Improved variety of crop	5	0	2	0	1	8			
Total	11	1	8	7	3	30			

Kakiye	**Qur.**	**Prim.**	**Sec.**	**Ter.**	**Total**	**Chi-Square**	**P Value**	**Df**
Multiple crop under irrigation	12	0	3	2	17	24.8	16.92	9
Improved variety of crops	1	5	4	1	11			
Specialized crop under irrigation	0	0	1	0	1			
Mixed multiple crop/livestock under irri	0	0	0	1	1			
Total	13	5	8	4	30			

Saye	**Qur.**	**Prim.**	**Sec.**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crops under irrigation	8	5	2	15	9.6	9.49	4
Improved variety of crop	4	2	3	9			
Specialized crop under irrigation	3	1	2	6			
Total	15	8	7	30			

All Villages	**Qur.**	**Adult.**	**Prim.**	**Sec.**	**Ter.**	**Total**	**Chi-square**	***p*Value**	**Df**
Specialized crop under irrigation	9	0	1	5	4	19	50.2	48.3	28
Mixed multiple crop/livestock under irrigation	7	0	3	1	1	12			
Improved variety of crops	16	2	17	13	3	51			
Specialized crops under dryland	0	0	0	0	1	1			
Multiple crops under irrigation	27	1	16	16	2	62			
Change crop	1	0	1	1	0	3			
Farm more	0	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	0	0	0	1	1			
Total	60	3	39	36	12	150			

5.3.8.4 Income

Table 5.17: Relationship Between Respondents Income and Actual Adaptation Strategy

Adaption strategy	Income							
Biye	**≤10000**	**10001-20000**	**20001-30000**	**30001-40000**	**Total**	**Chi-Square**	***p*Value**	**Df**
Specialized crop under irrigation	0	2	0	0	2	30.3	29.62	21
Mixed multiple crop/livestock under irrigation	0	4	0	1	5			
Improved variety of crops	9	1	5	0	15			
Specialized crop under dry land	0	1	0	0	1			
Multiple crop under irrigation	0	2	0	0	2			
Change crop	0	3	0	0	3			
Farm more	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	1	0	0	1			
Total	9	15	5	1	30			
Hunkuyi	**≤10000**	**10001- 20000**	**20001- 30000**		**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	13	1	0		14	13.4	9.49	4
Improved variety of crop	3	5	0		8			
Mixed multiple crop/livestock under irrigation	3	2	1		6			
Specialized crop under irrigation	1	1	0		2			
Total	20	9	1		30			
	10000	**10001- 20000**	**20001- 30000**		**Total**	**Chi-Square**	***p*Value**	**Df**
Dambo								
Multiple crop under irrigation	13	0	1		14	3.4	9.49	4
Specialized crop under irrigation	3	5	0		8			
Improved variety of crop	3	5	0		8			
Total	19	10	1		30			
Kakeyi	**10000**	**10001- 20000**	**20001- 30000**		**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	14	3	0		17	21.6	12.6	6
Improved variety of crops	6	4	1		11			
Specialized crop under irrigation	0	0	1		1			
Mixed multiple crop/livestock under irrig	0	0	1		1			
Total	20	7	3		30			
Saye	**≤ 10000**	**10001- 20000**	**20001- 30000**		**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crops under irrigation	14	1	0		15	9.16	7.78	4
Improved variety of crop	4	4	1		9			
Specialized crop under irrigation	3	3	0		6			
Total	21	8	1		30			
All Villages	**10000**	**100001-20000**	**200001-30000**	**300001-40000**	**Total**	**Chi-sq**	***p*Value**	**Df**
Specialized crop under irrigation	7	11	1	0	19	102.3	41.4	21
Mixed multiple crop/livestock under irrig.	3	6	2	1	12			
Improved variety of crops	25	19	7	0	51			
Specialized crops under dryland	0	1	0	0	1			
Multiple crops under irrigation	54	7	1	0	62			
Change crop	0	3	0	0	3			
Farm more	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	1	0	0	1			
Total	89	49	11	1	150			

Results of chi square analysis in all the studied villages presented in table 5.17 show statistically significant relationship between farmers' coping strategies and income. Overall chi-square analysis across the studied villages show significant association exist at 0.005 level between respondents income levels and coping strategies adopted. This result is supported by findings of several authors (Junge *et al*., 2008; Oyedele *et al*., 2009; Gebremariam, 2010) which have found that farmers' incomes influence the adoption of soil and water conservation practices. This is because low income house-holds are generally small farm holders and are unable to finance agricultural inputs such as fertilizers (Current *et al.*,1995 and Barbier, 1997) and are forced to cultivate their lands more intensively and are unable to implement sustainable soil management practices (Barbier, 1997; Mikkelson and Langohr, 2004).

5.3.8.5 Land ownership

Results from the Table 5.18 show statistically significant association between land owner ship and coping strategies adopted by respondents across the studied villages. In Biye, the chi square value is 20.4 and significant at p=0.01. In Hunkuyi, the result shows a chi square value of 16.6 and significance at p=0.01. Result for Dambo show that the chi square value is 5.3 and significant at p=0.1. For Kakeyi, the chi square value is 11.2 and significant at p=0.05. The result of analysis in Saye shows a chi square value of 5.3 and significance at p=0.1. Overall analysis shows statiscally significant relationship between land ownership and farmers coping strategies. The results show that land ownership influences farmers' willingness to invest in or adopt new technologies. This finding is supported by previous findings (Maiangwa *et al*., 2007; Onu, 2013) and shows that most farmers who rent their lands from other individuals believe that long term investment on such lands may result in losses on their part given that they may be forced to hand over such lands at very short notices without compensation.

Table 5.18: Relationship Between Land Ownership and Actual Adaptation Strategy

Coping strategies	Land Ownership					
Biye	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*-Value**	**Df**
Specialized crop under irrigation	0	2	2	20.4	18.48	7
Mixed multiple crop/livestock under irrigation	0	5	5			
Improved variety of crops	12	3	15			
Specialized crop under dry land	0	1	1			
Multiple crop under irrigation	2	0	2			
Change crop	0	3	3			
Farm more	0	1	1			
Mixed multiple crop/livestock under dryland	0	1	1			
Total	14	16	30			
Hunkuyi	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	2	12	14	16.6	11.34	3
Improved variety of crop	6	2	8			
Mixed multiple crop/livestock under irrigation	3	3	6			
Specialized crop under irrigation	2	0	2			
Total	13	17	30			
Dambo	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	12	2	14	5.3	4.60	2
Specialized crop under irrigation	3	5	8			
Improved variety of crop	5	3	8			
Total	20	10	30			
Kakeyi	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	16	1	17	11.2	7.82	3
Improved variety of crops	5	6	11			
Specialized crop under irrigation	0	1	1			
Mixed multiple crop/livestock under irrigation	1	0	1			
Total	22	8	30			
Saye	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	16	1	17	5.32	4.60	2
Improved variety of crops	5	6	11			
Specialized crop under irrigation	0	1	1			
Mixed multiple crop/livestock under irrigation	1	0	1			
Total	25	5	30			
All Villages	**Owned**	**Rented**	**Total**	**Chi-Square**	***p*Value**	**Df**
Specialized crop under irrigation	8	11	19	21.3	20.3	7
Mixed multiple crop/livestock under irrigation	4	8	12			
Improved variety of crops	36	15	51			
Specialized crops under dryland	0	1	1			
Multiple crops under irrigation	46	16	62			
Change crop	0	3	3			
Farm more	0	1	1			
Mixed multiple crop/livestock under dryland	0	1	1			
Total	94	56	150			

5.3.8.6 Length of farming

Table 5.19: Relationship Between Length of Farming and Actual Adaptation Strategy

	Length of Farming								
Biye									
	1-5	**6-10**	**11-15**	**16-20**	**26-30**	**Total**	**Chi-square**	***p*Value**	**Df**
Specialized crop under irrigation	1	0	1	0	0	2	22.6	41.34	8
Mixed multiple crop/livestock under irrigation	1	2	1	1	0	5			
Improved variety of crops	9	2	4	0	1	15			
Specialized crop under dry land	1	0	0	0	0	1			
Multiple crop under irrigation	0	1	1	0	0	2			
Change crop	1	0	0	0	1	3			
Farm more	0	0	1	0	0	1			
Mixed multiple crop/livestock under dryland	0	0	1	0	0	1			
Total	13	5	9	1	2	30			

	0-5	**6-10**	**11-15**	**16-20**	**21-2**	**26-30**	**Total**	**Chi-square**	***p*Value**	**Df**
Hunkuyi										
Multiple crop under irrigation	9	0	2	1	1	1	14	28.47	25.00	15
Improved variety of crop	2	4	0	1	1	0	8			
Mixed multiple crop/livestock under irri	5	0	0	0	0	1	6			
Specialized crop under irrigation	1	0	0	1	0	0	2			
Total	17	4	2	3	2	2	30			

Kakeyi	**0-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crop under irrigation	10	3	2	2	0	0	17	18.1	22.3	15
Improved variety of crops	1	3	1	3	1	2	11			
Specialized crop under irrigation	0	0	0	1	0	0	1			
Mixed multiple crop/livestock under irri	0	1	0	0	0	0	1			
Total	11	7	3	6	1	2	30			

Dambo	**0-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**Total**	**Chi-Square**	***p*-Value**	**Df**
Multiple crop under irrigation	5	4	2	1	0	0	14	7.84	18.31	10
Specialized crop under irrigation	2	2	1	2	0	1	8			
Improved variety of crop	3	2	2	2	1	0	8			
Total	10	8	5	5	1	1	30			

Saye	**0-5**	**6-10**	**11-15**	**16-20**	**21-25**	**Total**	**Chi-Square**	***p*Value**	**Df**
Multiple crops under irrigation	5	9	1	0	0	15	22.9	20.09	8
Improved variety of crop	0	1	4	4	1	9			
Specialized crop under irrigation	0	1	1	3	0	6			
Total	5	11	6	7	1	30			

All Villages	**0-5**	**6-10**	**11-15**	**16-20**	**21-25**	**26-30**	**Total**	**Chi-Square**	***p*-Value**	**Df**
Specialized crop under irrigation	4	3	3	7	0	1	18	46.2	49.1	35
Mixed multiple crop/livestock under irrig.	6	3	1	1	0	1	12			
Improved variety of crops	15	12	11	10	4	3	55			
Specialized crops under dryland	1	0	0	0	0	0	1			
Multiple crops under irrigation	29	17	8	4	1	1	60			
Change crop	1	0	0	0	0	1	2			
Farm more	0	0	1	0	0	0	1			
Mixed multiple crop/livestock under dryland	0	0	1	0	0	0	1			
Total	56	35	25	22	5	7	150			

Result of chi square analysis between length of farming and coping strategy across the studied villages are presented in Table 5.19. Over all chi-square analysis over the studied villages show no statistical association between length of farming and coping strategies adopted by respondents. Similarly, results from the table show that there is no statistically significant relationship between length of farming and coping strategies adopted in Biye, Dambo and Kakeyi. However results show statistically significant association exist in Hunkuyi and Saye. In Hunkuyi, the calculated chi square value is 28.5 and significant at p= 0.05, while chi square value for Saye is 22.9 and significant at p= 0.01. The significant association between respondents' length of farming and coping strategies against degradation is supported by studies (Maiangwa *et al*., 2007; Onu, 2013) which have found that length of cultivation influences farmers' willingness to adopt and finance soil conservation practices . For example, Onu (2013) in a farm level analysis of investment behaviours in soil conservation and erosion control practices in the ecologically vulnerable communities in southeast Nigeria observed shorter length of land lease suggests uncertainty over continued use of rented lands, as it may result to shortened planning horizon for renters.

5.3.9 Perceived adaptation strategies

Results of farmers perceived adaptation strategies are presented in Fig.5.8. The results show that in Biye, change use of fertilizers and chemicals is the most favoured perceived adaptation strategy (70%), followed by increased prayers (60%), reduced length of growing season (56%) and no adaptation (3.33%). In Saye, change use of fertilizers and chemicals is 70%, followed by mixed cropping (66.7%), increased irrigation (56.7%) and changed variety of crops (50%), while the least is abandon farm (2%), use insurance (2%) and no adaptation (1%). In Dambo the highest perceived adaptation is mixed cropping (70%) and change use of fertilizers and

chemicals (53.3%), while the least are abandon farm (10%), plant trees (6.7%), increase family size (6.7%) and no adaptation (3.3%). In Hunkuyi, the most favoured options are mixed cropping (66.7%), change use of fertilizers and chemicals (56.7%), change variety (53.3%), changed crops and increased prayers (46.7% each) while the least favoured options are abandon farm and no adaptations at all (at 1% each). In Kakeyi, mixed cropping is highest at 63.3%, increased irrigation (46.7%), change use of fertilizer and chemicals (46.7%) and change variety (40%), while the least are use insurance (16.7%), plant trees and no adaptation (10% each) and increase family size (6.7%).

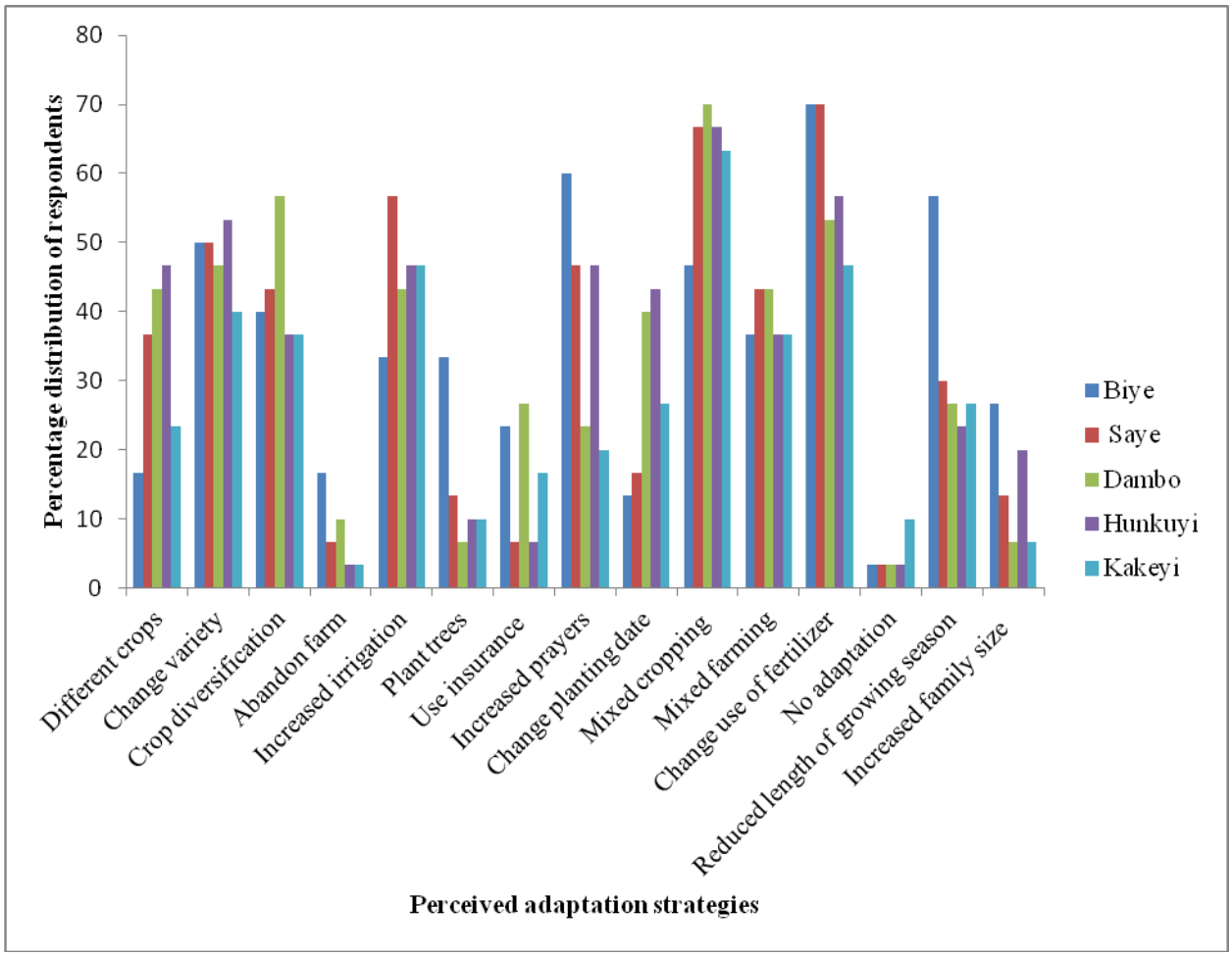


Fig. 5.8 : Farmers' Perceived Adaptation Strategies

5.3.10 Actual adaptation strategies

Results of respondents' actual adaptation strategies are presented in Fig. 5.9. The results in Biye show that actual strategies adopted ranged from the use of improved variety of crops (50%), mixed multiple crop/livestock under irrigation (16.7%) and change crop (10%), while the least used include multiple crop under irrigation (6.7%), specialized crop under irrigation (3.3%), farm more (3.3%) and mixed multiple crop/livestock under dry land (3.3%). In Hunkuyi, multiple crops under irrigation is highest (46.7%), improved variety of crop (26.7%), mixed multiple crop/livestock under irrigation (20%) and specialized crop under irrigation (6.7%).

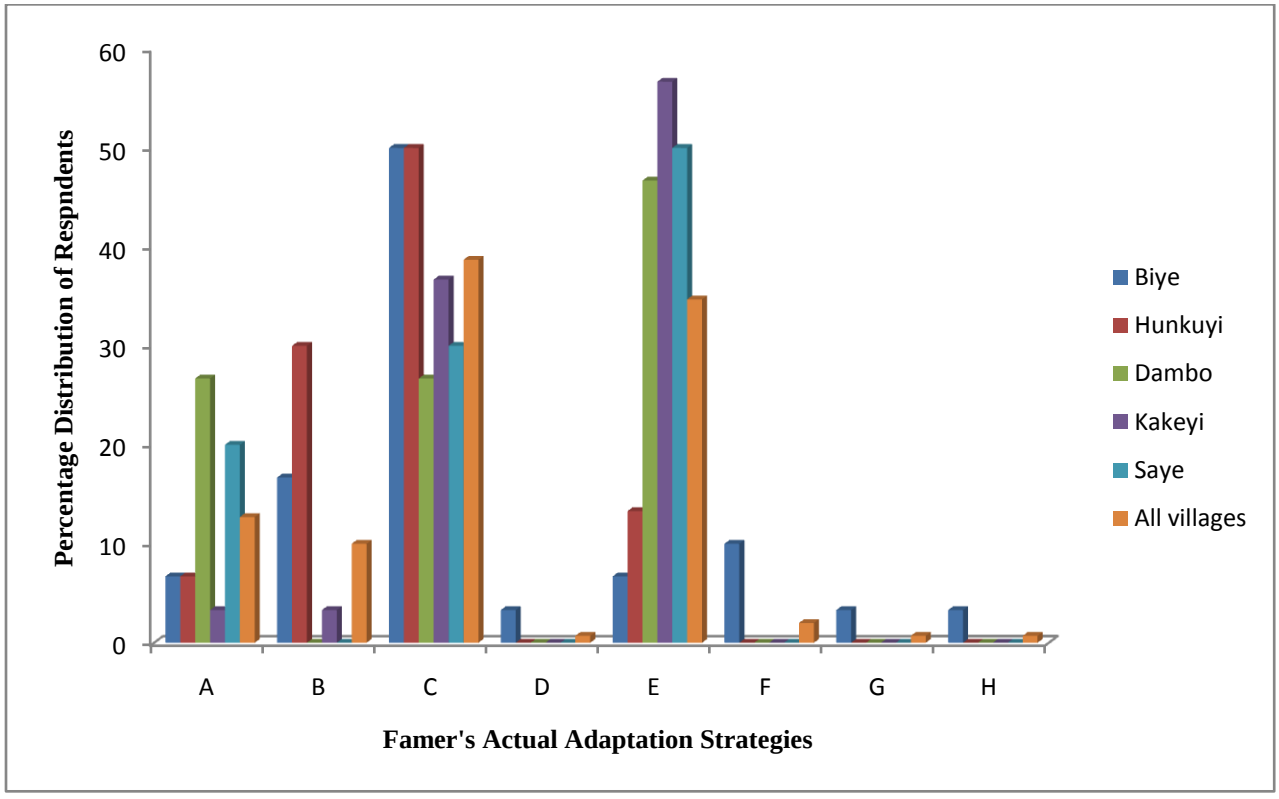


Fig. 5.9: Farmers' actual adaptation strategies

***A=** Specialized crop under irrigation, **B=** Mixed multiple crop/livestock under irrigation, **C=** Improved variety of crop, **D=** Specialized crop under dry land, **E=** Multiple crop under irrigation, **F=** Change crop, **G=** Farm more, **H=** Mixed multiple crop/livestock under dryland

In Dambo, results show that multiple crop under irrigation is highest at 46.7%, followed by improved variety of crop (26.7%), specialized crop under irrigation (26.7%). In Kakeyi, the most used strategy is multiple crop under irrigation (56.7%), improved variety of crops (36.7%), while the least used are specialized crop under irrigation (3.3%) and mixed multiple crop/livestock under irrigation (3.3%). In Saye, the most used strategies are multiple crops under irrigation (50%), improved variety of crop (30%) and specialized crop under irrigation (20%).

Generally, land users perceive degradation differently and often seek measures they are most comfortable with. Results show that across the study area, majority of the respondents will rather use more fertilizers, change crop variety, use improved varieties of crops, reduce length of growing season, insure their lands, abandon land, among others, but are often constrained by poverty, lack of education and competition for available lands. However, farmers avert risks by adopting those strategies which are affordable and result in high yields. This perhaps influences their decisions to adopt strategies such as multiple crops under irrigation and crop change.

5.3.11 Barriers to adoption of modern soil conservation measures

Farmers' identified barriers to adoption of modern land/soil conservation measures over the study area are presented Fig.5.10. Farmers across the study area view lack of capital as the most important constraint because it affects every other aspect of agricultural production and soil conservation measures. This concern ranks highest in Hunkuyi, Dambo, Kakeyi and Saye (100% each), while Biye has 96.7% . However, low farm input ranked second; 100% in Biye, Hunkuyi, Dambo, Kakeyi and 96.7% in Saye. Farmers cite high cost /scarcity of farm inputs such as inorganic fertilizers and herbicides/chemicals as a major constraint to production. High cost of transportation was also cited as an important constraint to accessibility to organic manure such as cow dung and farm yard manure from herds men who often live in remote or isolated villages or

from farm houses also located at considerable distances away from their farmlands. Lack of incentives from government is another constraint listed by respondents with 96.7% in Biye, 83.3% in Saye, 80% in Dambo, 76.7% in Kakeyi and 73.3% in Hunkuyi. Low prices which farmers are paid for their produce is another barrier and has 80% in Saye, 76.7% in Biye, 73.3% in Hunkuyi, 60% in Kakeyi and 50% in Dambo.

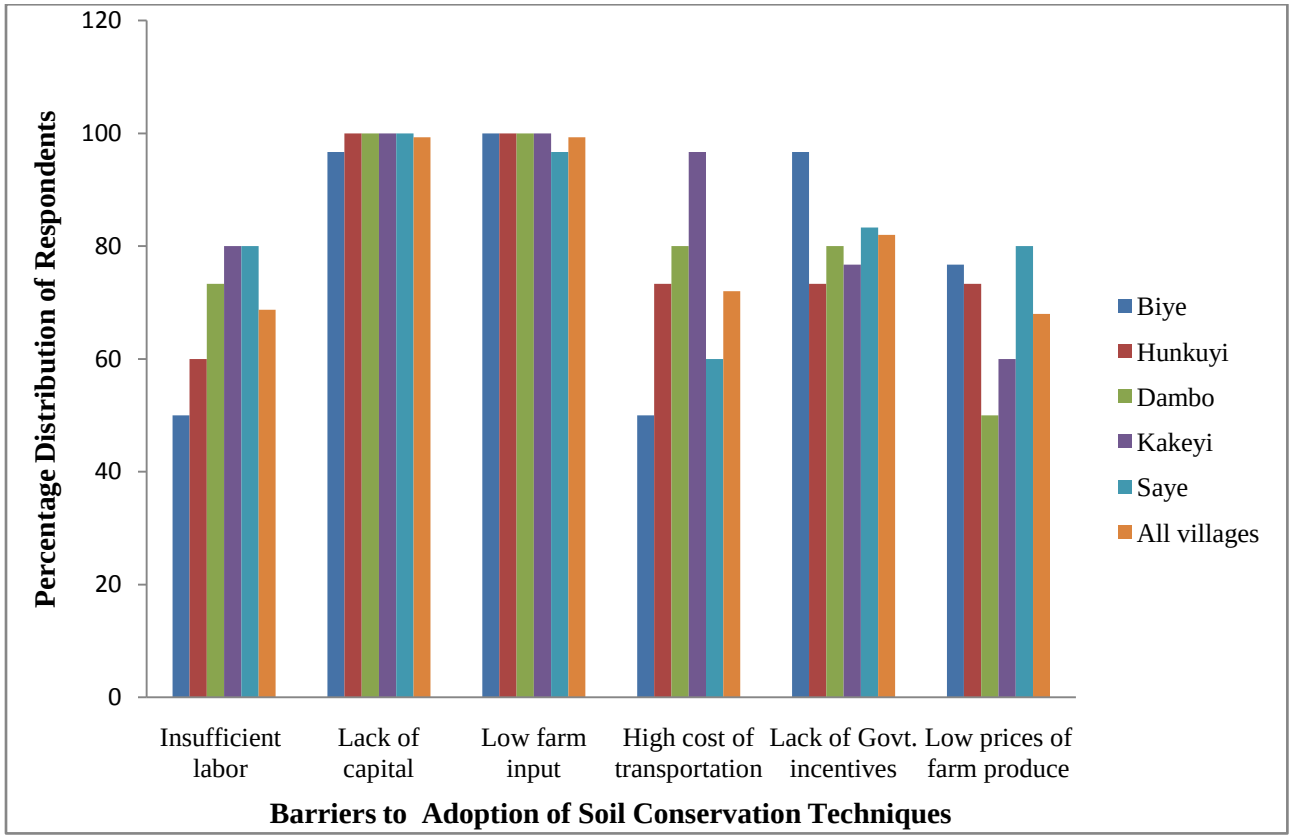


Fig. 5.10: Barriers to Adoption of Land/Soil Conservation Techniques

Generally, results from this study showed that majority of the respondents are married, with large family sizes (as indicated by the mean household sizes). With increase in population in the study area, more lands are increasingly acquired and cultivated. Existing farmlands are ploughed, tilled and cultivated year after year without effective measures of checking damages to these farmlands

(Aminu, 2011). Again, an increase in household size means more people to feed and indirectly reduces income per head. Where households depend on less productive agricultural land, this has implications on land use and land degradation because the level of soil degradation by farmers is often influenced by factors such as poverty (Bridges and Van Barren,1997). For example, Lal (2009) observed that most soils are prone to degradation by land misuse and soil mismanagement driven by desperate situations and helplessness in the case of poor and smaller landholders.

Across the study area, results show strong and positive relationship between income and farmers' actual adaptation strategies against soil degradation. This is supported by several studies (Current *et al*., 1995; Barbier, 1997; Junge *et al*., 2008; Oyedele *et al*.,2009; Gebremariam, 2010). For example, Current *et al*., (1995) observed that poor farmers may be willing to adopt agroforestry but the rate and scale of adoption is constrained by limited finances and the need to ensure food security. Similarly, land users are less likely to invest in lands which do not belong to them.

Results from this study show that there is significant relationship between level of education and farmers' adoption of sustainable soil management practices. This agrees with several studies which have found that better educated farmers are more aware of soil degradation and more likely to adopt soil conservation technologies (Junge *et al*., 2008; Gebremariam, 2010). Education enhances farmers' adoption and acquisition of new skills and understanding of benefits and constraints of soil conservation. However, studies have also shown that farmers often have knowledge and ability accumulated through years of experience and passed down through generations (Saidu, Kuyper, Kossou, Tossou and Richards, 2004; Mikkelson and Langohr,2004). Another effect of education on soil degradation is that if a sizeable number of the population can not find employment in the formal sectors because they are illiterate or not

educated enough, they have to rely on agriculture to feed their families and earn an income. This means more lands must be acquired and existing ones cultivated year after year (Aminu, 2011).

Land ownership may have implications for adoption of soil conservation measures because studies have shown that farmers are most unlikely to make long term soil fertility and soil erosion control investments in farms which do not belong to them for fear of losing the land (Mai angwa *et al*., 2007). Similarly, cost of rents on land may encourage excessive use of lands by tenants and result in degradation. Levels of use or adoption of sustainable soil management practices are directly influence by incomes and farmers willingness to take risks. This finding is supported by previous studies (Wilkinson, 1996; Townsley, Gardiner, Wilkinson and Meister, 1997) which have found farmers to be production/ output oriented rather than environmentally oriented.

Similarly, results from the study show that most respondents have cultivated their lands for more than ten years. One of the ways through which small farm holders adjust to soil degradation is by intensifying production through a reduction or elimination of fallow periods (Gyasi *et al*.,1995). Where soils are left to fallow, there is a decrease in bulk density, increased porosity, soil moisture, organic matter, CEC, among others, thereby rejuvenating the soil fertility status (Abubakar, 1995). Intensive cropping practices have been identified as an important factor in soil fertility decline and other forms of soil degradation. For example, Akogun (1986) observed that when a virgin land is subjected to tillage activities, it loosens the soil and breaks down its aggregates, thus making the soil materials more susceptible to removal by runoff water. Similarly, in Ibadan, South west of Nigeria, Salau *et al.,* (1992) observed that intense mechanized tillage practices have caused significant declines in soil faunal density, rate of organic matter mineralization and total porosity.

5.3.12 Farmer's soil degradation indicators

5.3.12.1 Soil degradation indicators and perceived causes

Because of the general high level of awareness of soil degradation across the studied villages, farmers over the years have recognized some indicators of soil degradation. However, this awareness did not differ across the study area, as indicated by the individual farmer respondents and the participants at the focus group discussions (Plate XI). Table 5.20 shows the result of the individual farmer survey, which is in general agreement with the list identified and described by consensus during the focus group discussion in the respective villages.

As is revealed in the table, the most commonly observed soil degradation indicators are erosion-based and include rills (72%), stoniness (69%), loose soils (74%), sheetwash (55%), infestation by parasitic angiosperms (67%), root exposure (55%) and red soil (38%). Result from the survey indicated that farmers believed sheetwash resulted in changes in topsoil colour and reduced soil depths,which often resulted in red soils, stoniness and root exposure. Similarly, respondents believed that sheetwash and runoff were responsible for development of rills and gullies, among others. Other authors have reported on farmer's knowledge of erosion processes that are in agreement with this finding (Okoba and Sterk, 2006). For example, Nepalese farmers observed formation of splash pedestals and runoff development underneath the tree canopies, which they attributed to wide tree canopies (Joshi and Sinclair, 1998), the Zulu community were quite aware of rills and gullies (Van Dissel and De Graaff, 1999), while the Rwandan farmers used soil surface characteristics that developed as a result of soil erosion to distinguish among different productivity field zones and types of soils (Steiner, 1998).

Table 5.20: Soil Degradation Indicators (Local Names in Parenthesis) and Perceived Causes for Their Development

Soil degradation indicators	Observation of indicators (%)	Description	Perceived Causes
Rills *(Kwaranyar zaizaya)*	72	Rills are seen as shallow linear depressions or channels in soil that carry water after recent rainfall. They form a network of branching channels, depending on amount of rain and roughness of the ground surface. They are observed to develop immediately after a rainfall event.	Rainfall, runoff, steep slopes
Gully *(Kwazazzabo)*	69	This refers to a deep depression, channel or ravine in a landscape, looking like a recent and very active extension to natural drainage channels.	Rainfall, steep slopes, compound/road/roof runoff
Sheetwash (*Zaizayar kasa*)	55	This is observed as a flow path or sheet of runoff that flows over the soil surface, leaving smoothed surface and has sediment cover that shows the lines of the flow.	Rainfall, loose soils, steep slopes
Pedestals	31	A pedestal is a column of soil standing out from the general eroded surface, protected by a cap of resistant material (such as a stone or root). Bunch grasses can also protect the soil immediately under them and give a pedestal-like feature.	Rainfall, loose soils, tall tress
Armour Layer	15	An armour layer is the concentration, at the soil surface, of coarser soil particles that would ordinarily be randomly distributed throughout the topsoil.	Rainfall,, runoff
Tree Root Exposure ***(****Zaizayar jijiyoyin bishiyoyi****)***	47	Plant or tree root exposure describes a situation where the base of the tree trunk or lateral roots are partially exposed above the present soil surface.	Runoff
Exposure of Below Ground Portions of Structures	48	Sheet erosion, resulting in a reduction in the general ground level, can be identified where the below ground portions or foundations of man-made structures, such as fences posts, other poles, old tracks and roads, bridges and buildings, are exposed.	Runoff
Rock Exposure	61	Rock exposure describes the situation where underlying rock has because of erosion, been exposed at the ground surface. Lands with rock exposure cover impair tillage and crop cultivation.	Runoff, shallow soil-depth
Build up Against Barriers	17	Where the transport of eroded material is halted by an obstruction, the particles suspended in the runoff may be deposited against the obstruction as the water slows. This results in a build up of sediment against the barrier.	Runoff, soil wash
Soil and Plant Rooting Depth	38	Soil depth is simply the vertical depth of soil from the surface down to weathered rock, or other impermeable barrier such as a stone-line or hardpan.	
Plant Root Exposure (*Zaizayar tsirrai*)	75	Literally meaning seeing roots. This happens when the soil around the stem of the plant has been removed.	Sheetwash, steep slopes, loose soils
Loose Sandy Surface Soils (*Yashi*)	74	This describes loose topsoil material that can be lifted by runoff water or wind easily. This soil condition is observed when in situ topsoil has been removed by runoff-induced erosion.	Raindrops, sheetwash,
Stoniness (*Marmara*)	69	The stoniness are exposed on soil surface after the dark top-soil and the red sub-soil layers have been eroded. Areas with stoniness impair root penetration of shallow-rooted legume crops and cannot support mechanization.	Runoff, shallow soil-depth

Sedimentation (*Dallakir /Turai*)	9	This literally means covering or burying by sand and other sediments. It describes the effect the surface runoff water, through sheetwash or rill features, leaves when it comes against a barrier, depression or lacks transport capacity. Farmers describe these as fertile soils.	Rainfall, runoff, steep slopes
Red soils (*Jar-kasa*)	38	Farmers describe these as barren soils which occur when the ‘’sweetness’’ of soils have been washed away by rainfall.	Soil wash, steep slopes
parasitic angiosperms, *Striga hermonthica* and *S. gesnerioides, (wuta wuta)*	67	The farmers describe ‘Harkiya’, ‘Aya-aya’ and’ kiri-kiri as ‘dangerous’ weeds which cause soil nutrient depletion and result in ‘death’ of plants.	Soil nutrient depletion, overcropping

Adopted from Stocking and Murnagham (2000); Okoba and Sterk (2006).

It is significant to note that over the present study area, the other forms of soil indicators, which obviously were present but were less obvious to the farmers, were rarely described or correlated to soil degradation damage. Such indicators include crusting, compaction and loss of organic matter .

5.3.12.2 Classification of erosion indicators

Farmers were asked during the focus group discussions to classify the listed indicators based on which they considered most important. The outcome of their classification shows two major classification systems: soil related and plant/crop related indicators; past and present indicators (Table 5.21). Most of the indicators described are soil related, while only a few are crop/plant related. It is clear from the discussion of the farmers that of the plant related indicators, the parasitic angiosperms, *Striga,* and uncontrolled weed infestation are the most widely recognized. Although most of the respondents are aware of plant coloration and stunted growth, only few farmers related soil degradation to them.

Within the two-broad groups of soil and plant related indicator, the farmers distinguished between past and current indicators. This distinction is based on the duration the indicators take before they could be clearly manifested and therefore detected (Stocking and Murnaghan, 2000; Okoba and Sterk, 2006).

Table 5.21: Farmers' Classification of Soil Degradation Indicators

SOIL RELATED INDICATOR	PRODUCTION/PLANT RELATED INDICATOR
Current erosion indicators (reversible)	
■ Rills	■ Coloration of plants
■ Splash pedestals	
■ Sedimentation	
■ Sheetwash	
■ Root exposure (in food crops)	
Past erosion indicators (non-reversible)	
■ Rock exposure	■ Low crop yield
■ Root exposure (in trees)	■ parasitic angiosperms, *Striga hermonthica/ S. gesnerioides*
■ Stoniness/gravelly surface layer	■ Stunted plant growth
■ Red soils	■ Uncontrollable weeds
■ Gullies	
■ Loose/sandy surface soils	
■ Low organic activities (eg earthworms, ants, etc	

Similarly, the findings from the survey agrees with other studies (Stocking and Murnaghan, 2000; Okoba and Sterk, 2006) which have found that past indicators were observed only after several cycles of erosion events that lasted at least for one rainy season or several years of rainfall events, while current erosion indicators such as rills and small gullies may evolve into past erosion indicators if proper erosion control measures were not applied to halt their development. These findings suggest that farmers are aware of both the short (current indicators) and long-term (past indicators) impact of soil erosion on their land, as have been found by previous studies (Wenner, 1989; Lal and Elliot, 1994;Okoba and Sterk, 2006). The result of the survey and group discussions show that farmers are often not worried by the existance of current erosion indicators. For example, sedimentation represents areas of high soil fertility and is hardly observed as a problem to most farmers. This agrees with similar findings

by Okoba and Sterk (2006). Farmers regard current erosion indicators as reversible because they are easily obliterated through ploughing and weeding (Okoba and Sterk, 2006). Because of that, they hardly relate these indicators to the decreasing crop yields and therefore not given priority among their production problems (Wenner, 1989). Lal and Elliot (1994) observed that current indicators were easy to permanently reverse by change of land use and land management practices that improved soil structural stability and organic matter content. Farmers who did not take permanent remedial action on current erosion indicators, more permanent, spatially distinct and irreversible forms of erosion indicators tended to develop and remain exposed on the soil surface (Okoba and Sterk, 2006). Splash pedestals are clear indicators of high sheet erosion rates of orders of 50t /ha/1 per year or more (Stocking and Murnaghan, 2001). Several years of temporal ‘‘removal or destruction’’ of the less recognised pedestals could lead to drastic lowering of the soil’s productive capacity, resulting in reduced yields or need for higher inputs (Okoba and Sterk, 2006).

5.3.13 Community versus scientific perceptions

5.3.13.1 Severity of soil degradation

The result of field survey carried out clearly shows that soil degradation in the study area is severe, and certainly affects the quality of life of residents. This agreed with the community view. The respondent farmers, however, appear not to have recognized the existence and effects of sheet erosion and other forms of soil degradation, in particular, loss of soil structure and organic matter. Yet these are important forms of soil degradation in the study area. Although community opinion is not unanimous, most residents believe soil loss has worsened over the years. The result of the field survey carried out also point to this fact that soil loss is continuing at quite a high rate, but lack of baseline data makes this inconclusive.

5.3.13.2 Causes of soil degradation

Both scientists and residents agreed that climatic element is the prime cause of most degradation processes in the study area, and that poor vegetation cover exacerbate the problem. However, there is less agreement on land use factors affecting vegetal cover and runoff generation. Rainfall, paths, roads and tracks, and to a lesser degree overgrazing, feature in community and scientific perceptions of causes, but only the scientific view holds that the naturally high erodibility of soils of the study area and improper cropping practices are soil degradation-encouraging factors.



Plate X: Focus group discussion with farmers in Saye (above) and one-on-one interview with *sarkin noma*, Mallam Yau in Dambo (below).

CHAPTER SIX: SUMMARY, CONCLUSION AND RECOMMENDATION

6.1 Summary

This study aimed at an assessment of soil degradation in the Zaria area. The first part of the study employed remote sensing/ GIS techniques in the assessment of general land use/land cover with a view to showing the extent of land degradation in the study area. The results of the analysis showed that landuse cover in the study area, between 1990-2009 is dominated by scrubland and cultivated land. This is followed by the built-up and fadama areas. The water bodies and bare surfaces consistently ranked the lowest. The considerable fluctuations in the trend of some of the land use within the examined period is partly ascribed to climatic factors (rainfall) and the period of acquisition of the satellite imageries. The results showed that land use changes/ exchanges are occurring at rates not lower than 1.6% per annum.

The results also show an upward trend for built up area. The upward trend in built up area is a reflection of population growth and conversion of other land uses to built up areas. The downward trend in cultivated land use may be as a result of conversion of cultivated areas to other land uses such as built up area (due to urban expansion) and bare surfaces (due to soil degradation). Land use/cover changes for bare surfaces and scrubland showed concave patterns with decrease in spatial coverage in 1999 and increase in 2009, while plantation/forest and water bodies showed convex patterns of change within the period under study.

In general, the analysis of data on land use/land cover change showed that both spatial and temporal changes in the LULC of the Zaria area over the examined period are significant. Result of Chi-square analysis carried out to determine the level of significant changes in the areal coverage of the different land use and land cover types for the periods studied showed statistical

significance at $p < 0.01$, with a calculated X^2 value of 612.09 and a table value of 26.2. This indicates significant changes in the different land use/cover types in the area studied.

The second part of the research entailed field assessment of the physico–chemical status of the surface soils of the area with a view to demonstrating its degradation. Twenty five composite soil samples comprising of four sub-samples were taken from five different land uses (plantation, badland, fadama, cultivated and scrubland land uses) and analysed for soil physico-chemical properties. The results show all soils are sandy, rarely heavier than a sandy clay loam due to the loss of the finer fractions in surface wash and/or translocation into the sub-soil. This may also be partly due to the granitic nature of soil parent material over the study area. Soil texture influences soil quality characteristics such as infiltration, water and nutrient retention capacity, etc

The soil bulk density shows statistically significant differences amongst the various landuses. The lowest value is recorded over the plantation ($1.45 g/cm^3$). The highest values of $1.52 g/cm^3$ and 1.64 are recorded over the badland site and the cultivated land, respectively. Overall, all soils are very high in bulk density value (above $1.25 g/cm^3$, the value for normal mineral soil). Bulk density values over the cultivated, fadama and badlands are higher than the recommended value for tropical soils. The high bulk density and low porosity over the different land uses, especially the cultivated and badlands, indicate deterioration of the soil properties due partly to the effects of over grazing and cultivation.

Mean values of moisture content range between 14.88-25.02%. Fadama land use has the highest mean gravimetric moisture content (25.2%), followed by plantation (17.6%), shrubland (16.9%), degraded land (16.8%), while cultivated land had the least (14.9%). The higher mean values of soil moisture content of the fadama land use may be attributed to the loamy nature of the soils.

Result of t-test show significant difference in moisture content between fadama and badland land uses and between cultivated and fadama land uses. The high soil moisture over the plantation land use may be attributed to the high organic content of the soils because higher organic content encourages higher moisture retention by soils and less evaporation from soil surface because the soils are protected by tree canopies. However, the low moisture content in cultivated and degraded lands may be attributed to high bulk densities, low organic matter and high evaporation rates from the soil surfaces due to exposure to solar radiation.

In productive soils exchangeable bases in the soil are in the order of Ca>Mg>Na>K. The dominance of Ca and Mg in soils of the savannah have been stressed by Jones and Wild (1978) and Jaiyeoba (1995) and Madaki (2011). The exchangeable Ca reveals significantly different amount amongst the various landuses. The value is highest over the fadama land (3.00 cmol/kg^{-1}) while the badland recorded the lowest amount (0.65 cmol/kg^{-1} respectively). Similar, to the exchangeable Ca, the soil exchangeable Mg is highest over the fadama land (0.82 cmol/kg^{-1}) and lowest over the badland (0.15 cmol/kg^{-1}), while values over the remaining land uses are intermediate. The differences amongst the various land uses are also highly significant, statistically. The mean value of exchangeable K also shows significant differences amongst the landuse categories. Unlike both Ca and Mg, however, the value over the plantation site (0.35 cmol/kg^{-1}) and the cultivated land (0.24 cmol/kg^{-1}) are greater than those of the shrubland (0.11 cmol/kg^{-1}) and badland (0.10 cmol/kg^{-1}). The exchangeable Na did not reveal statistically significant differences amongst the landuses. The value ranged between 0.12 cmol/kg^{-1} over the badland and 0.66 cmol/kg^{-1} over the plantation. Overall, all soil are low in exchangeable cations. This may be attributed to the high level of leaching that has taken place in the soils. However, the soils in the area generally have high base saturation ranging from 54% over the badland,

through 56% over shrubland, 64% over the plantation land and 67% over cultivated land, to 71% over the fadama land.

The CEC revealed significantly different amounts amongst the various landuses. It is highest over the plantation (6.76 cmol/kg^{-1}) and least over the badland (4.31cmol/kg^{-1} respectively). Overall, all soils are low in CEC, a reflection presumably of the sandy texture and or low organic matter content of the soils. Ratings of CEC results for top soils considers CEC values under 7 Cmol/kg to be low for tropical soils (Landon, 1991; Moukam and Ngakanou,1997; Malgwi, 2007). However, CEC values equal or greater than 8 cmol/kg^{-1} have been found to be suitable for cultivation (Raji et al., 2005). The low CEC values over cultivated and badlands show that soils under these land uses have been degraded.

The mean value of the soil pH is highest over the plantation site (6.54) and lowest over the badland site (5.44). The soil exchangeable H+Al is lowest over the shrubland (0.08 cmol/kg^{-1}) and highest over the badland site (0.30 cmol/kg^{-1}). The values over the remaining landuse types are the same (0.09 cmol/kg^{-1}). Analysis of variance reveals significantly different value amongst the various landuses. The pH rating for tropical soils is between 5.6 - 6.5and 5 -8.0. However, the range of the pH values over the different landuses show that the soils are slightly acidic (Akogun,1986 and Abubakar,1995) and reflects the humid tropic's strong leaching regime (Jim, 2003).

The differences in the soil organic matter content amongst the different landuses, by analysis of variance are statistically significant at the 0.01 level. The value is lowest over the badland (0.25g/kg^{-1}) and highest over the plantation (1.77g/kg^{-1}) while values over the remaining land uses are intermediate. The comparatively higher organic matter content over plantation land use

may be attributed to continuous litter deposition and minimum disturbance, while the lower organic matter content over cultivated land and badland may be attributed to continuous and persistent cultivation (Agboola and Corey,1973). There is predominance of upland and lowland (fadama) cultivation in the study area. Cropping and tillage practices destroy soil aggregate matterial and make such soils susceptible to erosion, leaching and compaction. Loss of organic matter accelerates soil compaction and loss of soil moisture.

The third part of this research involved a farm-level survey of farmers perception of soil degradation problem and coping strategies through the use of structured questionnaires and focus group discussions. Results show that across the study area, all categories of age groups are engaged in farming, with medium to large family sizes. Results from the study showed that farmers' perception of soil degradation are strongly associated with declining yields. A Likert-type scale was used to assess farmers' identification of, extent of use and attitudes to land management practices.

A high proportion of the respondents are married, with large family sizes. This indirectly reduces income per head. Where households depend on less productive agricultural land, this has implications on land use and soil degradation because the level of soil degradation by farmers is often influenced by factors such as poverty (Bridges and VanBarren, 1997).

Chi-square analysis between farmers adaptation strategies and specific socio-demographic characteristics show that while results show no statistical significance between respondents' age, house hold sizes and coping strategies, there is a relationship between level of education, income, landownership and length of farming and actual coping strategies employed by respondents in the study area.

Most respondents cite financial constraints as reasons why they adopt certain soil management practices and not others. Similarly, there is significant relationship between level of education and farmers' adoption of sustainable soil management practices. However, studies have also shown that farmers often have knowledge and ability accumulated through years of experience and passed down through generations (Saidu, *et al*., 2004; Mikkelson and Langohr, 2004). A major effect of illiteracy is that if a sizeable number of the population can not find employment in the formal sectors because they are illiterate or not educated enough, they have to rely on agriculture to feed their families and earn an income. This means more lands must be acquired or existing ones cultivated year after year (Aminu, 2011).

Similarly, land ownership may have implications for adoption of soil conservation measures because studies have shown that farmers are unlikely to make long term soil fertility and soil erosion control investments in farms which do not belong to them for fear of losing the land (Mai angwa *et al*., 2007) and cost of rents on land may also encourage excessive use of lands by tenants and result in degradation. Levels of use or adoption of sustainable soil management practices are directly influence by incomes and farmers willingness to take risks.

Results from the study show that most respondents have cultivated their lands for more than ten years. The basic cultivation practice in the study area is mixed farming on upland and lowland areas. Fallow periods are rarely observed due mainly to land scarcity and competition. Thus rejuvenating the soil fertility status is through application of organic and inorganic fertilizers, compost. Intensive cropping practices in the study area have been identified as an important factor in soil fertility decline and other forms of soil degradation (Akogun, 1986; Abubakar, 1995).

Results show a general high level of awareness of soil degradation across the studied villages, as perceived by the individual farmer respondents and the participants at the focus group discussions. The most commonly observed soil degradation indicators are erosion-based and include rills, stoniness, loose soils, sheetwash, infestation by parasitic angiosperms, root exposure and red soil. However, it is significant to note that over the study area, the other forms of soil degradation indicators such as crusting, compaction, loss of organic matter, which were present but were less obvious to the farmers, were rarely described or correlated to soil degradation damage. The findings show that though farmers are aware of both the short (current indicators) and long-term (past indicators) of soil degradation, they are less worried by the presence of the current erosion indicators such as rills or their impacts because these are easily obliterated by ploughing (Okoba and Sterk, 2006). However, observation showed that the most commonly recognised soil degradation indicators are plant/production related. This is because farmers tend to be production/ output oriented rather than environmentally oriented (Wilkinson, 1996; Townsley *et al*., 1997). Yellowing plant leaves and reduced yields will likely worry the farmer more than the presence of rills or sheet erosion.

6.2 Conclusion

It is clear from this study that across the study area, various land use practices are exacerbating the problem of soil degradation. The assessment of land use/ land cover changes between 1990 to 2009 showed very significant changes in the various land uses in the Zaria area. The study showed that changes in land uses were responsible for land/soil degradation in the study area. For example, while there was considerable expansion in the degraded, built-up and fadama (wetlands) land uses, the study showed significant decrease in shrub land, cultivated and forest

plantation land uses. Soil degradation is often a function of the socio-economic characteristics of the population. For example, natural vegetation clearance is attributed to land shortages for built-up uses and cultivation. Forest plantation clearance and continuous cropping practices in both upland and low land (fadama or wetlands) areas destroy soil properties and lead to widespread degradation of soils in the area.

Results from this study have demonstrated the need for an all-inclusive methodology in assessing soil degradation. For example, land use/land cover assessments using remotely sensed data permits soil degradation assessments on a temporal and spatial scale. Similarly, actual soil survey and field assessments of the nature and severity of soil degradation carried out in this study, combine to give a holistic view of the problem of soil degradation in the Zaria area.

6.3 Recommendations

This study affirms that land use/land cover exchanges in the study area are not sustainable and have adverse environmental and economic consequences and pose serious threats to food security and land resources. A move towards globally sustainable soil management needs to be coupled with solutions to other related environmental problems and socio-economic/ political issues such as poverty, food security and over population. A good way of tackling the menace of soil degradation in Africa in general and Nigeria in particular, is to provide adequate, accurate and relevant information on the forms, extent and severity of soil degradation. This can be achieved by incorporating farmers' knowledge and perceptions of soil degradation phenomena into science based methods (quantification and analysis) of soil degradation assessment.

It is rational to assume that more lands will be cleared for cultivation or converted to built-up areas as the population and urbanization in the study area increase. Therefore, there is need to implement urgent practical and sustainable land management policies which include;

1. Improved and affordable land management techniques for land users
2. Improved information systems for land management
3. Provision of incentives for rehabilitation of degraded lands
4. Incorporate land degradation studies into school curriculums.
5. Systematic testing of technology performance and adoption across a wide range of biophysical and socio-economic conditions.
6. Development of secure land tenure system which assures long-term access to lands.

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APPENDIX I: LOCATION OF SAMPLE POINTS BY CO-ORDINATES

S/N	LULC	Sample points	Co-ordinates	
			Latitude (N)	(Longitude)
	Bare surfaces			
1.		1	11^0 09' 40.37''	7^0 49' 08.95''
2		2	11^0 12' 20.39''	7^0 35' 59.62''
3		3	11^0 16' 44.05''	7^0 39' 16.37''
4		4	11^0 05' 34.33''	7^0 32' 12.97''
	Built up areas			
5		1	11^0 07' 09.45''	7^0 42' 46.89''
6		2	11^0 10' 49.51''	7^0 40' 23.70''
7		3	11^0 04' 45.19''	7^0 40' 55.81''
8		4	11^0 11' 08.07''	7^0 47' 40.47''
	Cultivated area			
9		1	11^0 09' 32.99''	7^0 34' 38 .73''
10		2	11^0 04' 94.18''	7^0 46' 46.2''
11		3	$11^0$16' 97.04''	7^0 38' 27.51''
12		4	11^0 06' 59.10''	7^0 45' 15.42''
	Scrubland			
13		1	$11^0$03' 35.15''	7^0 46' 35.27''
14		2	11^0 12' 32.41''	7^0 39' 46.19''
15		3	11^0 06' 39.33''	7^0 45' 56.30''
16		4	11^0 09' 33.15''	7^0 34' 48.45''
	Plantation/forest			
17		1	11^0 04' 16.35''	7^0 45' 09.97''
18		2	11^0 16' 06.12''	7^0 39' 31.24''
19		3	11^0 07' 36.98''	7^0 45' 17.84''
20		4	11^0 10' 44.51''	7^0 36' 57.41''
	Fadama			
21		1	11^0 04' 29.81''	7^0 47' 20.15''
22		2	11^0 17' 15.26''	7^0 18' 57.35''
23		3	11^0 07' 15.76''	7^0 45' 40.40''
24		4	11^0 09' 32.82''	7^0 34' 52.23''
	Water bodies			
25		1	11^0 06' 26.70''	7^0.43'25.80''
26		2	11^0 03' 07.63''	7^0.41'52.59''
27		3	11^0 08' 11.37''	7^0.39'18.74''
28		4	11^0 08' 13.02''	7^0 45' 41.62''

APPENDIX II: RATINGS FOR TROPICAL SOILS AND DATA INTERPRETATION

1. Soil Depth				
Very shallow	<25cm			
Shallow	25-50cm			
Moderately deep	50-100cm			
Deep	100-150cm			
Very Deep	>150cm			
2. Soil pH Reaction				
Extremely acid	<4.5			
Very strongly acid	4.5-5.0			
Strongly acid	5.1-5.5			
Moderately acid	5.6-6.0			
Slightly acid	6.1-6.5			
Neutral	6.6-7.3			
Slightly alkaline	7.4-7.8			
Moderately alkaline	7.9-8.4			
Strongly alkaline	8.5-9.0			
Very strongly alkaline	>9.0			
3. Organic Carbon (%)				
Low	<1%			
Medium	1-1.5%			
High	>1.5%			
4. Exchangeable Cation (mol (+)	Ca	Mg	K	Na
kg^{-1}	0-2	0-0.3	0-0.15	0-0.1
Low	2-5	0.3	0.15-0.3	0.1-0.3
Medium	>5	1.0	>0.3	>0.3
High		>1.0		
5. Cation Exchange Capacity (cmol(+) kg^{-1})	NH_4Oac	ECEC		
Low	>6	>4		
Medium	6-12	4-10		
High	>12	<10		
6. Base Saturation (%)	NH_4Oac			
Low	<50			
Medium	50-80			
High	>80			

Source: Soil survey staff, 1975.

APPENDIX III: QUESTIONNAIRE FOR RESIDENTS ON AN ASSESSMENT OF SOIL DEGRADATION IN THE ZARIA AREA.

Dear Sir/ Madam,

The questionnaire below is designed for a survey on **an assessment of soil degradation in the Zaria area**. The survey is a research work being undertaken as a requirement for the award of PhD degree in Geography by the Ahmadu Bello University, Zaria. The information you provide in answering the questions in the survey will be treated confidentially and used purely for academic purposes.

Thank you for your consent.

Researcher

Aminu Zuni

PART ONE: SOCIO-DEMOGRAPHIC CHARACTERISTICS

1. Location:

Village:……..

GPS: Latitude……. Longitude…… Elevation…….

2. Demographic data:

i. Age ……..

ii. Sex …….

iii. Marital status …….

iv. House hold size(number of people) ……

v. Average monthly income(N) …….

vii. Level of education

(a) Qur'anic education ☐ (b) Adult education ☐ (c) Primary ☐ (d) Secondary ☐ (e) Tertiary ☐ (f)None☐

viii. Land ownership:

Owned ……..

Rented …….. If rented, from whom? ……..

ix. Length of farming on land (yrs) ……

x. Membership of any agricultural association/ CBO?

(a) No……

(b) Yes ……

(c) …….

3. Multipurpose trees on farm (list in order of dominance)

Tree	Uses	Habitat

4. Cropping system (Rank in order of dominance)

Crop grown	Grown as		Grown under		Comment
	primary	secondary	Rain-fed	irrigation	
Yam					
Maize					
Sorghum					
Millet					
Sweet potatoes					
Groundnut					
Vegetable					

PART TWO: AWARENESS TEST

5. Awareness of the causes of soil degradation

Causes	Aware		Not Aware	
Soil Erosion				
Deforestation Overgrazing Poor farming practices Over cultivation Over population poverty Lack of fertilizers Lack of incentives from Government				

6. Awareness of the consequence of soil degradation

Consequences	Aware		Not Aware	
Low crop yield Stunted plant growth Presence of pests Presence of particular weeds Plant coloration Soil colour change Low soil organic activities Rill erosion Gully erosion Sheet erosion Poverty and economic backwardness				

7. Awareness of land management practices

Practices	Aware		Not Aware	
Mixed cropping Chemical fertilizer application Organic manure application Animal dung application Ash application Compost Terracing Crop rotation Mono cropping Mulching Tree planting Contour plowing Bush fallowing				

8. Information sources about land management practices

Sources	**Frequencies**	**Percentage**
Friends and relatives Extension agents Radio Trainings Schools Print media		

9. Identification of land management practices in the study area and their extent of use of these practices

Practices	Very often		Often		Rarely		Never	
Mixed cropping Organic manure Making water ways Rotational grazing Tree planting Closure of grazing land Mulching Crop rotation Contour plowing Terracing Fallowing								

10. Attitude towards land management practices

Code	Attitude statements	Agree	Undecided	Disagree
A_1	Mixed cropping reduces soil degradation			
A_2	Crop residues protect soils from erosion			
A_3	Terracing reduces soil erosion and helps to conserve soil			
A_4	Crop rotation maintains soil structure and conserve soil moisture			
A_5	Close growing crops are more effective for erosion control than inter tilled crops			
A_6	It is unnecessary to use compost and animal dung if inorganic fertilizer are used			
A_7	Shortened length of growing period minimizes soil loss			
A_8	Grazing on farm lands by livestock destroys soil structure			
A_9	Land fallowing is an effective way of maintaining soil fertility			
A_{10}	Tree planting improves soil fertility			
A_{11}	Controlled grazing minimizes soil degradation			
A_{12}	Keeping lands permanently under forest cover is the best way to conserve lands			
A_{13}	Deforestation, over cultivation and overgrazing are major causes of land degradation			
A_{14}	There is need for stricter restrictions against deforestation			

11. Signs of fertility decline generally

S/N	Soil related	S/N	Production/plant related
1	Color change	1	Low crop yield
2	Stony/gravelly surface	2	Presence of particular weeds (name them)
3	Sandy surface	3	Coloration of plants
4	Gully erosion	4	Stunted plant growth
5	Rill erosion	5	Uncontrollable weeds
6	Low organic activities (e.g earthworm, ants etc)	6	

12. Forms of soil degradation in community (to be assessed on the field, farmland built up areas)

Nature	**Area most affected (built-up area, farmlands, rangeland etc.)**	**Severity (mild, moderate, severe, very severe)**	**Trigger factors**
Sheet erosion			
Rill erosion			
Gully erosion			
compaction			
crusting			
material			
Deposition			
Wind erosion			
Waterlogging			

PART THREE: PERCEPTIONS AND COPING STRATEGIES

13. **Farmers' perceived adaptations**.

Perceived Adaptations	
Different crops Change variety Crop diversification Different planting dates Reduced length of growing season Abandon land Mixed cropping Mixed farming Increase irrigation Change use of fertilizers, chemicals and pesticides Increase prayers Increase family size Plant trees Use insurance No adaptation	

12. **Actual adaptation measures used by farmers**.

Actual Adaptations	
Specialized crop under dry land Specialized crop under irrigation Multiple crops under irrigation Mixed multiple crops/livestock under dry land Improved variety of crops Farm more Change crop	

PART FOUR: BARRIERS TO ADOPTION OF SOIL CONSERVATION MEASURES

13. What are the various constraints you encounter in adopting modern soil conservation measures? (To be rated in order of importance; state underlying causes)

Problem	**Rating**	**Causes**
Insufficient labor		
lack of capital		
low farm input		
High cost of transportation		
Obsolete farm tools		
Lack of Government incentives		
Low prices of farm produce		