EROSION MODELING IN NORTHERN MAKURDI, BENUE STATE, NIGERIA

BY

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DECLARATION

I declare that the work in this Thesis entitled "Erosion Modeling in Northern Makurdi, Benue State, Nigeria" is a record of my own research work under the supervision of Dr. B.A. Sawa and Dr. B. Akpu. The information derived from the literatures has been duly acknowledged in the text and a list of references provided. No part of this work has been submitted for the award of degree in any other University.

William Ogbale AGI _____ _____

Signature Date

CERTIFICATION

This thesis entitled "EROSION MODELING IN NORTHERN MAKURDI, MAKURDI, BENUE STATE, NIGERIA" by William Ogbale AGI , meets the regulations governing the award of the degree of Master of Science of Ahmadu Bello University and is approved for its contribution to knowledge and literary presentation.

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DEDICATION

This research work is dedicated to my wife Dinah Ngem Agi, thanks for your amazing patience.

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A work of this nature can hardly be completed without the contributions of people who knowingly or unknowingly helped in making the work a success.

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ABSTRACT

Erosion is one of the major problems in Nigeria and Benue State in particular. Uncontrolled deforestation, unhealthy agricultural practices, indiscriminate land clearing due to urbanization resulted in widespread soil erosion over the land surface of Northern Makurdi. The aim of the study was to apply Remote Sensing and GIS techniques in erosion modeling in Northern Makurdi. The objectives of this thesis were to determine the major causes of soil erosion in the study area, estimation of the average amount of annual soil loss using the Revised Universal Soil Loss Equation (RUSLE) model and to map and analyze the distribution of soil erosion sites within Northern Makurdi for the years 2003 to 2012. Data on rainfall Data, soil erodibility, topography, cover management and support practice were utilized. The sediment yield of the study was estimated to be between 0 to 48ton/ha/yr. This number is expected to increase with time as agricultural activities and deforestation continue to take place. The major causes of soil erosion within the study are the erosivity of the rainfall, low cover management and support practice. The estimated soil losses were higher at Utagudu, parts of Agan, North Bank, Ajoraku and Ihyev settlements, Akondonyou, some parts of North bank and Kwabo areas recorded low losses. Land use mostly affected by very high and severe erosion are the bare soils and the crop lands. About 62% of the study area suffered low erosion, less than 15% of the study with moderate and high erosion and 34% of the study suffered severe erosion. Land use mostly affected by very high and severe erosion are the bare soils and the crop lands. The urban areas also showed traces of severe erosion which may be due to forms of urbanization and development. A soil loss map of study was produced showing areas of various risks. In the immediate and medium term, it is expected that a halt in deforestation, bush burning and indiscriminate land clearing so as to protect the land and as well serve as an effective strategy for management of the sediments. In the longer term, the agricultural practices such as stripcropping, terracing, cover cropping, mulching as a strategy should be implemented, based on modifications to the current land use practices, to encourage soil conservation and minimize soil loss from the contributing settlements.

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CHAPTER ONE: INTRODUCTION

1.1 BACKGROUND TO THE STUDY

Soil erosion is a persistent problem which threatens the fragile economies of many developing nations, especially those countries where the density of the population is high and the carrying capacity of the land is being stretched to its limits (Bee, 1983). Soil erosion is a hazard traditionally associated with agriculture in tropical and semi-arid areas and is important for its long-term effects on soil productivity and sustainable agriculture (Morgan, 1995). Since the soil renews itself, although slowly, some erosion is permissible as long as no more soil is eroded than is formed. However, if the soil is removed faster, the quality of the soil as a crop-growing medium decreases, production costs will rise and at a certain stage economic crop production will no longer be feasible (FAO, 1977). According to FAO (1977), soil erosion is a major global environmental problem, having widespread and serious negative effects on water quality and biodiversity and promoting the emission of climate changing greenhouse gases.

Soil erosion is one of the most critical environmental hazards of modern times throughout the world. Vast areas of land now being cultivated may be rendered economically unproductive if the erosion of soil continues unabated (Asiabaka and Boers, 1988). According to Asiabaka and Boers (1988), soil erosion is described as an accelerated process under which soil is bodily displaced and transported away faster than it can be formed; the agents of soil erosion are principally running water, glaciers, waves and wind.

Erosion usually transports rocky materials or soil particles after the processes of weathering have broken them down into smaller pieces which are moveable. Information on the factors leading to soil erosion can be used as a perspective for the development of appropriate land use plan (Tripath and Singh, 1993; Manyatsi, 1999). Factors that influence

soil erosion are: rainfall erosivity, soil erodibility, slope length and steepness, crop management and conservation practices (Barrow, 1991).

The major variables affecting soil erosion comprise climate, soil properties, topography, vegetation and other related factors (Tripath and Singh, 1993; Manyatsi, 1999). Climatic variables affecting erosion are precipitation, wind velocity, temperature, humidity and radiation receipts (Tripath and Singh, 1993). Precipitation is the most forceful factor causing erosion through splash and surface runoff. The erosivity of rain is affected by the total amount of rain as well as its rainfall intensity. Climate affects the erosion conditions of an area directly as well as through the vegetation that occurs (Manyatsi, 1999).

Slope accelerates erosion as it increases the velocity of the flowing water. Different characteristics of slope such as steepness of slope, length of slope, slope angle, configuration, variation in steepness, micro-topography and aspect of slope, affect soil erosion (Tripath and Singh, 1993). Soil erosion becomes severe when nature's balance is disturbed by human activities of growing crops and meeting other necessities (Manyatsi, 1999). The presence of vegetation acts as an erosion-retarding factor. Vegetation acts as a protective layer or buffer between the atmosphere and the soil. Plant cover can play an important role in reducing erosion provided that they extend over a sufficient proportion of the soil surface (Morgan, 1995).

Thus the reliability of estimated soil loss is based on how accurately the different factors were estimated or prepared because the earth surface differs from one area to another (Brown, 1984; Lal, 1994; Bahadur, 2008) and by knowing the factors controlling soil erosion, information on erosion risk can be extrapolated. Often it is the interaction of more than one of these factors that results in erosion. However, one causative variable can be taken at a time and used to infer a map of erosion risk. These include climatic erosivity indices, soil erodibility factors, etc. (Pallaris, 2010).

In Nigeria, many lives and properties have been lost to perennial erosion problems in many communities. This is exacerbated by the increased rainfall and flood events and the increasing rate of unplanned urbanization (Ibitoye and Eludoyin, 2010). Enabor and Sagua (1988) estimated that 30 million tonnes of soil were lost on annual basis from both rural and urban environments due to erosion. Akanigbo (1984) stated that soil erosion in its various forms had long been recognized as a major impediment to agricultural production in many parts of the world and Nigeria in particular. Soil erosion reduces soil quality and it is a long time problem: globally soil erosion's most serious impact may be its threat to the long term sustainability of agricultural productivity.

Apparently, soil erosion has been recognized not only within the rural but also in the urban environments in Nigeria and in many other parts of the world. In urban areas like Makurdi, population explosion, rapid urbanization, climate change, increased rainfall, poor agricultural practices etc. are factors that contribute to soil erosion, it is also of universal importance as man's activities, directly or indirectly, depend on the soil. Soil erosion thus constitutes a national hazard, which containment is a prerequisite to national development. (Isikwue, Abutu and Onoja, 2012).

The Universal Soil Loss Equation (USLE) model was suggested first based on the concept of the separation and transport of particles from rainfall in order to calculate the amount of soil eroded in agricultural areas (Wischmeier and Smith, 1965). According to Wischmeier and Smith (1965), it is the most widely used and accepted empirical soil erosion model developed for sheet and rill erosion based on a large set of experimental data from agricultural plots. The USLE has been enhanced during the past 30 years by a number of researchers to Modified Universal Soil Loss Equation (MUSLE) and Revised Universal Soil Loss Equation RUSLE (Williams, 1975, Renard, Foster, Weesies, McCool and Yoder, 1997). The USLE was originally developed for soil erosion estimation in croplands on gently

sloping topography (Wischmeier and Smith, 1978). The use of the USLE and its derivatives is limited to the estimation of gross erosion, and lacks the capability to compute deposition along hill slopes, depressions, valleys or in channels (Beasley, 1989).In 1996, the U.S. Department of Agriculture (USDA) developed a method for calculating the amount of soil erosion under soil conditions besides pilot sites such as pastures or forests. RUSLE added many factors such as the revision of the weather factor, the development of the soil erosion factor depending on seasonal changes, the development of a new calculation procedure to calculate the cover vegetation factor, and the revision of the length and gradient of slope (Renard *et al*., 1997).The RUSLE has broadened its application to different situations, including forest, rangeland, and disturbed areas (Renard *et al.*, 1997). Traditionally, these models were used for local conservation planning at an individual property level. The factors used in these models were usually estimated or calculated from field measurements.

Remote sensing (RS) is the science of obtaining data/information about the earth's surface without directly being in contact with it, this is done by sensing and recording reflected and emitted energy and processing, analyzing, and applying that information (Sabins, 1997). Geographic Information System (GIS) is an arrangement of computer hardware, software, and geographic data that people interact with to integrate, analyze, and visualize data; identify relationships, patterns, and trends; and find solutions to problems. The system is designed to capture, store, update, manipulate, analyze, and display studied data and used to perform analyses (ESRI, 2005).

The methods of quantifying soil loss based on erosion plots possess many limitations in terms of cost, representativeness, and reliability of the resulting data. They cannot provide spatial distribution of soil erosion loss due to the constraint of limited samples in complex environments (Wang, Gertner, Fang, and Anderson, 2003). So, mapping soil erosion in large areas is often very difficult using these traditional methods. The use of Remote Sensing and

Geographical Information System (GIS) techniques makes soil erosion estimation and its spatial distribution feasible with reasonable costs and better accuracy in larger areas (Millward and Mersey, 1999; Wang *et al*., 2003). While conventional methods yield point-based information, Remote Sensing (RS) technique makes it possible to measure hydrologic parameters on spatial scales while Geographic Information Systems (GIS) integrates the spatial analytical functionality for spatially distributed data (Alejandra and Rojas-González, 2008). In most hydrological applications, statistical methods and image processing have proved to be most effective. These techniques do not ask for complex physical measurements which can usually be carried out only for very small areas. Statistical methods are, therefore, applicable over larger areas whereas physically-based methods are preferred in basic research. Visual interpretations are still a meaningful technique for analyzing remote sensing data and may even be preferred to digital analysis techniques in certain situations (e.g. in field campaigns in remote regions or in projects where no or only limited computer equipment is available). The most common applications of remote sensing data in hydrology are related to the investigation of cloud cover, impervious surfaces, floods, land use, radiation, rainfall, snow cover, soil moisture and surface temperature to name a few important applications for monitoring and forecasting (Baumgartner, 1996).

Remote sensing and GIS technologies do not replace conventional maps but facilitate processing, management and interpretation of all the available data. Remote sensing data coupled to conventional data (e.g. hydrological, climatological, topographical etc.) within a GIS give a digital representation of the temporal and spatial variations of selected variables and can serve as input into hydrological models. Due to the digital character of these data, quantitative analyses can be carried out and data can easily be updated and specific selections of data can be displayed or printed as a conventional map. Remote sensing and GIS can be used separately or in combination with hydrological models (whereas selected hydrological

modelling can be done within the GIS). In the case of a combined application, an efficient, even though more complex, approach is the integration of remote sensing data processing, GIS analyses, database manipulations and models into a single analysis system. Such an integrated analysis, monitoring or forecasting system (based on remote sensing, GIS and DBMS technologies) requires the researcher to understand not only the problem but also the available technologies yet without being a computer expert. Such an integrated analysis system enables the hydrologist to focus on solving the problem rather than spend time on technical difficulties. Solving a hydrological problem with such an integrated system may be summarized as follows (Baumgartner, 1996);

i. recognition of a specific hydrological problem
ii. measuring the necessary variables by means of remote sensors and conventional, terrestrial methods
iii. design of a GIS including data layers, attribute information, etc.
iv. building up a database for managing all the data
v. processing the data using techniques such as image processing, GIS analyses, regression and correlation analyses, etc. for deriving model-relevant variables.
vi. selection or design of an appropriate hydrological model
vii. input of variables into the model, model computations and error analysis
viii. comparison of the results from model computations with actual remote sensing and ground data (determination of accuracy, updating the model computations, model calibration, etc.).

Hence, the need to apply Remote Sensing and GIS in erosion modeling in northern Makurdi.

1.2 STATEMENT OF THE RESEARCH PROBLEM

Issues associated with soil erosion, movement and deposition of sediment in rivers, lakes and estuaries persist through the geologic ages around the world. The general situation is aggravated in recent times with the increasing human interventions in the environment (Alejandra and Rojas-González, 2008). Cultivation without using specific control techniques, unplanned land use, such as establishing industrial facilities or constructing houses on agricultural land, uncontrolled urban development and also destroying forests are fundamental factors of soil erosion (Biard and Baret, 1997).

It has been reported in a study carried out by Ibitoye and Eludoyin (2010) on land exposure and soil erosion in part of humid region of Southwest Nigeria that soil erosion appears to be an urban phenomenon and has been occurring at unprecedented rates, creating numerous problems and resulting in heavy economic, human and social losses in many cities in Nigeria and if it is allowed to continue unchecked it has the potential to impact on food security, water resources, biodiversity and climate change .

Erosion occurs in Makurdi and this affects land that can be used for different purposes such as infrastructural development, farming and also pose a serious risk to human lives. If control measures are not taken to tackle this problem, it will serve as a recipe for an environmental disaster. The increasing amounts of erosion in Makurdi has caused several environmental problems such as damage to infrastructure, degrading land, clogging of drains, increased pollution and sedimentation (Agada, 2014).

Bahadur (2008) mapped soil erosion susceptibility using Remote Sensing and GIS in the Upper Nam Wa Watershed, Nan Province Thailand and the estimated erosion rates ranged from 0 to 619.29 tons/ha/year. In Nigeria, researches on erosion have been carried out but there is little work on the application of GIS in erosion modeling particularly in North Central Nigeria. Adediji, Tukur and Adepoju (2010), assessed the Revised Universal Soil

Loss Equation (RUSLE) in Katsina area, Katsina state of Nigeria using Remote Sensing (RS) and Geographic Information System (GIS). The research revealed an estimated potential mean annual soil loss of 17.35 ton/ac/yr. Also, the potential erosion rates from the erosion classes identified ranged from 0 to 4185.12 ton/ac/yr.

Igbokwe *et al.,* (2005) mapped the impact of gully erosion in southeastern Nigeria using satellite Remote Sensing and Geographic Information System. The results revealed 9.93 and 45.71 tons/ ha/ yr. of soil loss from low lying areas and hilly areas respectively. Ibitoye (2006) assessed the accelerated erosion in Irele LGA, Ondo State, Nigeria. The results revealed that the volume of soil loss for Lipanu, LA. Primary School area, Idogun Quarters, Ajagba and Ado Quarters Akotogbo was 47522.13 m^3. Isikwue, Abutu and Onoja. (2012) researched on the erodibility of soils in South West Benue State and discovered that the soil loss in Adumoko, Otukpa, Orokam, Idabi, Owukpa, Ugbokolo, Ajide, Idobe, Ichama, Okpoga, Ochobo, Liami, Awulewu, Ogwanoku and Onyangede areas was 431.98 tons/ha/yr.

Makurdi is an urban centre with diverse land use pattern. The increasing rate of urbanization has led to serious disruption in the landscape which made the area susceptible to various forms of erosion. A cursory visit to Makurdi reveals that some areas are seriously eroded, particularly farmland are been rendered unusable. Conventional techniques have their limitation on the size of coverage, spatial scope of area which can be investigated with the use of Remote Sensing and GIS techniques. This is the gap this research seeks to fill. Hence the need to apply Remote Sensing and GIS techniques in erosion modeling in Makurdi.

This study attempted to answer the following research questions

i. What are the major causes of soil erosion?

ii. What is the amount of soil loss?

iii. How is erosion distributed in the area?

1.3 AIM AND OBJECTIVES

The aim of this study is to apply Remote Sensing and GIS techniques in erosion modeling in Makurdi. The stated aim was achieved through the following objectives which are to;

i. determine the major causes of soil erosion in the study area.

ii. estimate the average amount of soil loss using the Revised Universal Soil Loss Equation (RUSLE).

iii. map and analyze the distribution of soil erosion sites in the area.

1.4 SCOPE OF THE STUDY

The study involves the application of Remote Sensing and Geographic Information System in erosion modeling in Northern Makurdi, Makurdi, Benue state, Nigeria. The study area is the northern part of Makurdi which is divided by river Benue is made up of the following wards; Northbank 1, Northbank 2, Agan, Mbalagh and settlements: Ihyev, Kwabo, Ajoraku, Utagudu and Akondonyou respectively. The temporal scope covers between 2003-2012 because a 10 year duration is a criteria for the study as stated in the RUSLE handbook and also the need to highlight the present conditions.

1.5 SIGNIFICANCE OF THE STUDY

Soil degradation is a serious problem in Nigeria affecting about 50 million people and leads to the greatest loss of Gross National Product (GNP) (US $3000 million per year) relative to other environmental problems (World Bank, 1990). Enabor (1988) estimated that 30 million tonnes of soil were lost on annual basis from both rural and urban environments.

A stakeholders' meeting held at Abuja in 2004 showed that all the states of the Federation were being confronted with one aspect of erosion or the other (Ibitoye, 2006).

Apparently, soil erosion has been recognized not only within the rural but also in urban environment in Nigeria (Jeje, 1988, 2005; Ibitoye, 2006). Therefore there is a need to draw up efficient measures to tackle erosion in Makurdi North. The benefits such as improved agricultural output, less cost in terms of construction and reduced downtime and construction delays, effective environmental protection, reduction in water treatment costs, improvements and protection of the aesthetic and recreational values etc. cannot be overemphasized.

The information gathered from this research can serve as data for the Benue state government in planning, development and control purposes. By knowing the areas with their various levels of vulnerability in terms of erosion, the government can draw up an action plan to address this risk based on their assessments.

CHAPTER TWO

CONCEPTUAL, THEORETICAL FRAMEWORK AND LITERATURE REVIEW

2.1 INTRODUCTION

This chapter discussed various concepts of soil erosion, factors that control soil erosion, soil erosion models, modeling soil erosion using the Revised Universal Soil Loss Equation (RUSLE), Geographical Information System (GIS) and Remote Sensing (RS) and the review of relevant literature.

2.2 CONCEPTUAL FRAMEWORK

2.2.1 Soil Erosion

Soil erosion by water involves the processes of detachment, transportation, and deposition of sediment by raindrop impact and flowing water (Forster and Meyer, 1977, Wischmeier and Smith, 1978; Julien, 1998). Erosion is a two -phase process consisting of detachment of individual particles from the soil mass and their transportation by erosive agents such as running water. When insufficient energy is no longer available to transport the particles, a third phase deposition occurs (Julien, 1998).

2.2.3 Remote Sensing and Geographic Information System (GIS)

Remote sensing (RS) is the science of obtaining data/information about the earth's surface without directly being in contact with it, this is done by sensing and recording reflected and emitted energy and processing, analyzing, and applying that information (Sabins,1997). Remote sensing is presently in transition from a descriptive phase to a quantitative technology. Measurements may be carried out from the ground (field measurements) but the advantages of remote sensing applications in hydrology as a source of spatial information (in opposition to point measurements) becomes more obvious if sensors on air- or spaceborne platforms are used. The sensors measure the spectral characteristics of

interest and their variations in time over large areas, providing data input into various hydrological models. Additionally, remote sensing data represent an important input into algorithms which allow the derivation of hydrological parameters. Remote sensing - especially using spaceborne sensors - offers the advantage of long term (years to decades) temporal and spectral data sets over relatively large regions (local to global scale) and, therefore, of monitoring the (temporal, spectral and spatial) variations of objects at the Earth's surface.

Processing remotely sensed data is focused primarily on data recorded in the optical range (0.4-12.5 /xm) of the electromagnetic spectrum. Generally, two major processing groups may be distinguished: physically-based and statistically-based methods, both in combination with image processing techniques.

Geographic Information System (GIS) is an arrangement of computer hardware, software, and geographic data that people interact with to integrate, analyze, and visualize data; identify relationships, patterns, and trends; and find solutions to problems. The system is designed to capture, store, update, manipulate, analyze, and display studied data and used to perform analyses (ESRI, 2005). Geographic Information Systems (GIS) in addition to remote sensing have contributed significantly to applied hydrology in state and government monitoring and forecasting projects. GIS technology can provide resource managers and decision makers with tools for effective and efficient storage and manipulation of remotely sensed information and other spatial and non-spatial information (Estes, 1992). Remotely sensed data, effectively integrated within a GIS, can be used to facilitate measurements, mapping, monitoring and modelling activities. Designing and building a GIS database may be an expensive enterprise since it includes the import and entry of data from many different sources (this means that very often data have to be digitized from source documents). Data

themes can range from hydrological (e.g. runoff) and climatological (e.g. temperature, precipitation) to data from both point and areal measurements.

2.3 Erosion Models and Soil Loss Estimations

Soil erosion is the outcome of a large number of causative factors of varying importance, which interact in a complex manner (Elwell, 1981). A model is a representation of reality; it never claims to be reality but attempts to mimic reality as much as possible (Breetzke, 2004). In the dynamic and ever expanding science of soil erosion, models are the closest and only aspects that are useful to predict soil loss. Researchers have developed soil erosion models to describe how an erosion system functions and how the system responds to change. These models can then be used for farm planning, site-specific assessments, project evaluation and planning, policy decisions or as research tools to study processes and the behavior of hydrologic and erosion systems (Foster, 1990; De Roo, 1993).

There are two kinds of erosion models, namely, process based models and mathematically/empirically based ones (Agada, 2014). Empirically/mathematically and process based models are available for predicting soil erosion and sediment transport. Empirically based technology means regression or lumped mathematical models, which were developed using the experimental data of plot studies on erosion by water. Universal Soil Loss Equation, USLE, later revised as Revised USLE or RUSLE is one such model developed in the USA with more than 10,000 plot years of research data and experience of soil scientists (Renard, Foster, Weesies, Mc Cool and Yoder, 1996). It is the most widely used model for soil erosion estimation because of the simplicity. It is based on the set of mathematical equations that estimate average annual soil loss from inter-rill and rill erosion. In addition, the equation combines interrelated physical and management parameters such as soil type, rainfall pattern, and topography that influence the rate of erosion. Erosion Productivity Impact calculator (EPIC) model (Williams, Jones and Dyke, 1984) which was

developed to assess the effect of soil erosion on soil productivity, also uses USLE and Modified USLE (MUSLE) model (Williams and Berndt, 1977) to simulate erosion process. Chemical, Runoff and Erosion from Agricultural Management Systems (CREAMS) model (Kinsel, 1980), Agriculture Non-point Source Pollution model (AGNPS) model (Young, Onstad, Bosch and Anderson, 1987), and Soil and Water Assessment Tool (SWAT) model (Arnold, Srinivasan, Muttiah and Williams, 1998) are the examples of hybrid models which are based on USLE/MUSLE/RUSLE for the erosion estimation but use the sediment transport approach on the basis of continuity equation for sediment yield estimation.

Physical or process based models are intended to represent the essential mechanisms controlling erosion and sediment transport process. These models are the synthesis of individual component that affect the erosion and transport process. Aerial Non-point Source Watershed Environmental Response Simulation (ANSWERS) model (Beasley, Huggins and Monke, 1980), Kinematic Runoff and Erosion model (KINEROS) model (Woolhiser, Smith, and Goodrich, 1990), European Soil Erosion model (EUROSEM) model (Morgan, Quinton, Smith, Govers, Poesen, Auerswald, Chisci, Torri, and Styczen, 1998) and Water Erosion Prediction Program (WEPP) (Nearing, Foster, Lane, and Flinkener, 1989), are examples of process based models. Although physically based models try to emulate the physical processes involved in soil erosion and sediment transport, the weakness of these models is numerous parameters they need for calibration and also suffer from the problem of equifinality (Beven, and Freer, 2001).

2.3.1 The Revised Universal Soil Loss Equation (RUSLE)

The extent of erosion, specific degradation, and sediment yield from farmlands, abandoned mine sites, hill slopes, open lands and watersheds are related to a complex interaction between topography, geology, climate, soil, vegetation, land use, and man-made developments (Shen and Julien, 1993). The USLE is the method most widely used around the

world to predict long-term rates of interill and rill erosion from field or farm size units subject to different management practices. Wischmeier and Smith (1965) developed the USLE based on many years of data from about 10,000 small test plots throughout the U.S. Each test plot had about 22m flow lengths and they were all operated in a similar manner, allowing the soil loss measurements to be combined into a predictive tool. RUSLE was developed to incorporate new research since the earlier USLE publication in 1978 (Wischmeier and Smith, 1978). Agriculture Handbook 703 (Renard *et al.,* 1997) is a guide to conservation planning with the RUSLE. According to Smith (1999), RUSLE can best be described as a software version of a greatly improved USLE, which draws heavily on USLE data and documentation. The main differences being that RUSLE incorporates more data than USLE, it corrects errors in the USLE analysis and fills gaps in the original data and, most importantly, RUSLE is much more flexible than USLE and allows for the modelling of a greater variety of systems and alternatives (Smith, 1999). According to RUSLE user guide (1995), soil loss values computed by RUSLE should be used as a guide rather than being as considered absolute values and that soil loss values computed for a profile is representative of an area to the degree that the profile represents the area (Mughogho, 1998).

Wise use of prediction technology like the USLE/RUSLE requires that the user be aware of a procedure's limitations. The USLE/RUSLE is an equation that estimates average annual soil loss by sheet and rill erosion on those portions of landscape profiles where erosion, but not deposition, is occurring. It does not estimate deposition like that at the toe of concave slopes, and it does not estimate sediment yield at a downstream location. Also, it does not include ephemeral gully erosion. Furthermore, the USLE/RUSLE does not provide information on sediment characteristics, such as those needed in many water quality initiatives. An important scientific limitation of the USLE/RUSLE as an empirically based equation is that it does not represent fundamental hydrologic and erosion processes explicitly.

For example, the effect of runoff, as might be reflected in a hydrologic model, is not represented directly in the USLE/RUSLE. Fundamental erosion processes and their interactions are not represented explicitly. An example where the USLE does not give the proper result is the deposition of sediment in furrows on flat grades. Analysis of any single data set may show significant differences between estimates with the USLE/RUSLE and observed data. Such limited comparisons are not at all an indication of the overall performance of the USLE/RUSLE. As an empirical equation derived from experimental data, the USLE/RUSLE adequately represents the first-order effects of the factors that affect sheet and rill erosion (Renard *et al*., 1991).

The underlying assumption in the RUSLE is that detachment and deposition are controlled by the sediment content of the flow. The erosion material is not source limited but the erosion is limited by the carrying capacity of the flow. When the sediment load reaches the carrying capacity of the flow, detachment can no longer occur.

Sedimentation must also occur during the receding portion of the hydrograph as the flow rate decreases. The basic form of the RUSLE equation has remained the same, but modifications in several of the factors have changed. Both USLE and RUSLE compute the average annual erosion expected on field slopes and are shown in equation 3.1

$A = R \times K \times L \times S \times C \times P$---------- (Eq 1)

Where:

A = computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units selected for K and for the period selected for R. In practice, these are usually selected so that A is expressed in ton× $acre^{-1}$× yr^{-1}, but other units can be selected (that is, ton× $ha^{-}1$× $yr^{-}1$);

R = rainfall-runoff erosivity factor—the rainfall erosion index plus a factor for any significant runoff from snowmelt (100ft×tonf×$acre^{-1}$×yr^{-1});

K = soil erodibility factor – the soil-loss rate per erosion index unit for a specified soil as measured on a standard plot, which is defined as a 72.6-ft (22.1m) length of uniform 9% slope in continuous clean-tilled fallow;

L = slope length factor – the ratio of soil loss from the field slope length to soil loss from a 72.6-ft length under identical conditions;

S = slope steepness factor – the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions.

C = cover management factor – the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow.

P = support practice factor – the ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to soil loss with straight-row farming up and down the slope.

L and S factors stand for the dimensionless impact of slope length and steepness, and C and P represent the dimensionless impacts of cropping and management systems and of erosion control practices. All dimensionless parameters are normalized relative to the Unit Plot conditions, as described in Agriculture Handbook 703. Over the years, the USLE and RUSLE became the standard tool for predicting soil erosion not only in the U.S., but also throughout the world (Meyer, 1984). Widespread use has substantiated the usefulness and validity of RUSLE for this purpose.

2.3.1.1 Rainfall-Runoff erosivity factor **(*R*)**

The R factor represents the input that drives the sheet and rill erosion process, and differences in R values represent differences in erosivity of the climate. The erosivity of rains is not distributed uniformly throughout the year. Many of the most erosive rains occur in the spring when row-cropped land is bare and ready for planting, so the soil is most susceptible to erosion when the most erosive rains occur. Thus, in assessing erosion, the magnitude of the

R factor and its seasonal distribution must be addressed in relation to the cropping system. Of the RUSLE factors, R is one of the most exactly computed from input data: rainfall amounts and intensities.

However, these data are not always available, especially in isolated areas of foreign countries (Renard *et al*., 1991).

2.3.1.2 Soil erodibility factor **(*K*)**

Ideally, soil erodibility is a measure of a soil resistance to the erosive powers of rainfall energy and runoff. K factor reflects the susceptibility of a soil type to erosion i.e. it is the reciprocal of soil resistance to erosion (FAO, 1993). The K factor is a measure of the inherent credibility of a given soil under the standard condition of the unit RUSLE plot maintained in continuous fallow. Values for K typically range from about 0.10 to 0.4S (customary English units), with high-sand and high-clay content soils having the lower values and high-silt content soils having the higher values. Because of its great range in possible values, the K factor may be of slightly greater importance, from a sensitivity point of view, than is the R factor (Renard *et al*., 1991). In RUSLE, K is assumed to be constant throughout the year. In the absence of published data, nomographs are widely used for predicting erodibility where K values are predicted as a function of five soil profile parameters: %silt, %very fine sand, %sand, %organic matter, soil structure and permeability. K values vary with texture, aggregate stability, shear strength, infiltration capacity and organic matter and chemical content. Some researchers have shown that K also varies with antecedent moisture and with freezing and thawing (Mughogho, 1998).

Rainfall simulation studies are less accurate, and predictive relationships are the least accurate (Romkens, 1985). For satisfactory direct measurement of soil erodibility, erosion from field plots needs to be studied for periods generally well in excess of 5 years (Loch *et*

al., 1998). Therefore, considerable attention has been paid to estimating soil erodibility from soil attributes such as particle size distribution, organic matter content and density of eroded soil (Wischmeier *et al.,* 1971).

2.3.1.3 Slope length and steepness Factor **(*LS*)**

The L and S factors represent the effects of slope length (L) and slope steepness (S) on the erosion of a slope. In general RUSLE model calculation, the L and S factor are calculated by different equations. The L factor (slope length factor) is the ratio of soil loss from a slope length relative to the standard erosion plot length of 22.1m. The actual slope length is the horizontal distance (excludes slopes) of the plot being modeled and is converted to the slope length factor. The S factor (slope steepness factor) is the ratio of soil loss relative to a 9% slope, which is the standard slope that experiment plots use. The slope steepness factor is calculated as a function of slope (Kim, 2014).

2.3.1.4 Cover management factor (*C*)

The land-cover management factor is a ratio comparing the soil loss from a specific type of vegetation cover. It is used to determine the effectiveness a crop/vegetation management system has on preventing soil loss (Kim, 2014).

2.3.1.5 Support practice factor **(*P*)**

The Support Practice Factor (P) in RUSLE is defined as the ratio of soil loss with a specific support practice to the corresponding soil loss with straight row upslope and downslope tillage. The P factor accounts for control practices that reduce the erosion potential of the runoff by their influence on drainage patterns, runoff concentration, runoff

velocity, and hydraulic forces exerted by runoff on soil. The supporting mechanical practices include the effects of contouring, stripcropping, or terracing.

2.4 REVIEW OF LITERATURE

2.4.1 Types of Erosion

Momoh, (2005) defined sheet erosion as the uniform removal of soil in thin layers from sloping land, resulting from sheet and overland flow. Raindrops detach the soil particles and the detached sediment can reduce the infiltration rate by sealing the soil pores. When the rate of rainfall exceeds the rate of infiltration of water into the soil, water starts to flow over the soil of the sloping land. At this point erosion commences and picks up the rain drop-detached particles and carries them along. The eroding and transporting power of sheet flow is a function of the rainfall intensity, infiltration rate and field slope for a given size, shape, density of soil particles and erodibility potential of the soil.

Rill erosion is the detachment and transport of soil by a concentrated flow of water in a minute channel. Rill erosion the predominant form of erosion under most conditions. It is most serious where intense storm occurs on soil with high runoff producing characteristics and high erodible top soil (Momoh, 2005). According to (Momoh 2005), gully erosion produces channels larger than rills. These channels carry water during and after rains. The amount of sediment from the gully depends primarily on the run-off producing characteristics of watershed, and the drainage areas; soil characteristics, alignment, size and shape of the gully and slope in the channel.

2.4.2. Factors Controlling Soil Erosion

Erosion by water is known to be directly controlled by a number of factors; climate, vegetation, soil properties and topography. Each factor is itself complex, and the various factors interact with one another.

A. Climate

The climatic term needs to be appropriately summed over the frequency distribution of storm rainfalls, but it can be seen that this approach provides a rationale for combining the effects of topography, soils and climate into a single integrated erosion forecast. Both low frequency and high frequency components of the climate are important for erosion. Low frequency events determine the seasonal cycle of the soil water balance, which provides the environment for growth of crops or natural vegetation. It may be appropriate to run a vegetation growth model (natural or crop), which then contains the potential to give a dynamic response to changed land use or climate conditions. High frequency rainfall events are clearly crucial for generating overland flow. The simplest effective tool for estimating runoff is the notion of a threshold storm size. Beneath the threshold there is little or no runoff; above it all or a high proportion of the additional rainfall generates overland flow. The runoff threshold and proportion of subsequent runoff are simplifications of cumulative infiltration and runoff curves. Runoff Threshold is estimated from the crown cover, soil organic matter and soil texture/ structure characteristics. The threshold represents the effects of surface storage in random roughness and plough furrows, the dynamic evolution of soil crusting and moisture storage within the upper soil layers (Mike, 2003)

B. Vegetation

Vegetation acts on several ways, which may be dominant under different conditions, first by protecting the soil from rainsplash impact and crusting, second by intercepting rainfall which is lost to evaporation and third by building up organic matter in the soil which greatly enhances the short-term dynamic storage and release of soil moisture. The combined effect of these processes is to decrease the runoff and soil erodibility. Vegetation also resists erosion by adding to surface roughness which reduces overland flow velocity, and binds the

soil together with shallow root mats, particularly in grasses. However, it is recognised that vegetation is strongly influenced by land use, agricultural activity, both in cropland and by grazing, fire management etc. (Mike, 2003).

C. Soil Properties

The most important soil property is the erodibility. Erodibility is seen as primarily a property of the soil texture, with highest values for fine sand and silt soils with low clay content. Wischmeier and Mannering (1969), reported factors that influenced soil erodibility are its texture, organic matter content, pH, structure, bulk density of plough layer and subsoil, aeration, porosity, parent materials aggregation and various interaction of these variables (Mike, 2003).

D. Topography

It is important to correctly allocate topographic and soil classes, since there is a strong correlation between high relief areas and strong rocks/soils. After a period of adjustment through erosion, erodible areas are reduced to lowlands while less erodible areas form highlands. High erosion is partly associated with the anomalies from such equilibrium landscape which are associated with recent tectonics or sea level change. More generally, the erosion of an uplifted highland area produces marginal piedmont areas where dis-equilibrium conditions of high erosion rates tend to persist longest in the landscape (Mike, 2003).

2.5. Soil Erosion Modelling: RUSLE, Remote Sensing and GIS Applications

Soil erosion is a persistent problem which threatens the fragile economies of many developing nations, especially those countries where the density of the population is high and the carrying capacity of the land is being stretched to its limits (Bee, 1983). Soil erosion is a

hazard traditionally associated with agriculture in tropical and semi-arid areas and is important for its long-term effects on soil productivity and sustainable agriculture.

In Nigeria, many lives and properties have been lost to perennial erosion problems in many communities. This is exacerbated by the increased rainfall and flood events and the increasing rate of unplanned urbanization (Ibitoye and Eludoyin, 2010).

Chansheng (2003) integrated Geographic Information Systems (GIS) and Agricultural Nonpoint Source Pollution model (AGNPS) to analyze the effect of land use change on nonpoint source pollution to simulate the impact of land use change on runoff, sediment, and nutrient yields based on a 25-year, 24-h period of single storm event of 114 mm. ArcView nonpoint source pollution modeling (AVNPSM), an interface between ArcView GIS and AGNPS is developed to facilitate agricultural watershed modeling. The simulation results show that expansion of urban land is likely to lead to an increase in surface runoff, peak flow, and soil erosion.

Li, Lu, Valladares, and Batistella (2004) applied the Revised Universal Soil Loss Equation (RUSLE), Remote Sensing, and Geographical Information System (GIS) to the mapping of soil erosion risk in Brazilian Amazonia. Soil map and soil survey data were used to develop the soil erodibility factor (K), and a digital elevation model image was used to generate the topographic factor (LS). The cover management factor (C) was developed based on vegetation, shade, and soil fraction images derived from spectral mixture analysis of a Landsat Enhanced Thematic Mapper Plus image. A soil erosion risk map with five classes (very low, low, medium, medium-high, and high) was produced based on the simplified RUSLE within the GIS environment. The results indicate that most successional and mature forests are in very low and low erosion risk areas, while agroforestry and pasture are usually associated with medium to high risk areas.

Singh, Aggarwal, Turdukulov and Hariprasad (2002) carried out a study on Prioritization of Bata river basin using Remote Sensing and GIS Techniques. Assessment of soil erosion and analysis of soil loss based on sub-watershed within a watershed is required for evolving appropriate conservation practices. Soil erosion assessment in this study has been done using Morgan Morgan and Finney model (1984). The model encompasses some of the recent advances in understanding of soil erosion processes. By using this model, it was found that the average annual soil loss in the watershed is 17.22 t/ha. Detailed analysis shows that detachment limited soil erosion is higher in the agricultural & barren land, while transport limited erosion is higher in the forestland.

Ouyang and Bartholic (2001) developed an interactive web based approach to use RUSLE and Geographical Information System (GIS) to predict soil erosion. The on-line RUSLE web site has a user-friendly interface. Users can get access to the website and use the drop-down menus to define the inputs and get the calculated results quickly. A user can run different "what-if scenarios and compare the impacts of different terrain, crops, soils and management on soil erosion. The web site has capability to generate an erosion index map. The map is generated from Arc/Info GIS and can be displayed on the web browser. It also allows users to inquiry the terrain information for the study area through the Internet Map Server. The on-line RUSLE web site provides a good tool for soil conservationists, crop consultants, extension agents as well as environmental educators.

Adinarayana (1999) formulated a set of knowledge-based rules, for assessing the soil erosion of the heterogeneous hilly catchment, from the knowledge of the multi-disciplinary resource-experts and the knowledge of the local catchment resources, in addition to the field observations. This rule-based model which is hopefully fast and cost-effective and without effect of the individual bias, helped in inferring the erosion intensity units that most likely to occur at any given pixel in the system. Finally, the catchment was grouped into four different

erosion intensity units namely very severe, severe, moderate to severe and slight to moderate. The quantitative soil loss (t ha^{-1} $year^{-1}$) ranges, estimated by USLE model by a spatial information analysis approach (GIS), were also computed: (a) Very severe (>50): (b) Severe (40–50); (c) Moderate to severe (20–40); and (d) Slight to moderate (<20).

De Jong, Paracchini, Bertolo, Folving, Megier, and de Roo. (1999) demonstrated the integrated use of (1) multi-temporal Landsat Thematic Mapper (TM) images to account for vegetation properties, (2) a digital terrain model in a GIS to account for topographical properties and to assess the transport capacity of overland flow, (3) a digital soil map to assess the spatial distribution of soil properties, and (4) a limited amount of soil physical field data. They found that SEMMED (soil erosion model for Mediterranean regions) model is most sensitive to the initial soil moisture storage capacity and the soil detachability index. The main advantages of SEMMED are that it simulates processes at a regional scale and, where possible, it uses available data sources such as remote sensing imagery, digital elevation models (DEM) and (digital) soil databases, which usually are not available for smaller catchment areas.

Shrestha (1997) ran a soil erosion assessment model using (Morgan *et al.*, 1984) in a GIS environment and showed that annual soil loss rates are the highest (up to 56 tonnes/ha/yr.) in the areas with rain-fed cultivation, which is directly related to the sloping nature of the terraces. The lowest soil losses (less than 1 ton/ha/yr.) are recorded under dense forest. In the degraded forest, the soil loss varies from 1 to 9 tonnes/ha/yr. and in the grazing lands it is estimated at 8 tonnes/ha/yr. The study shows that soil erosion can be modelled in the mountainous region and that the results confirm the soil loss data obtained by means of experimental erosion field plots in the area, and the study of suspended sediment delivery from small catchments.

Garg and Harrison (1992) demonstrated the use of a Geographic Information System (GIS) for monitoring land use change, land degradation and erosion risk in the Albudeite catchment, South East. Spain. Digital Elevation model (DEM) derived from elevation contours was used to calculate terrain parameters, such as slope and aspect. The land use data were analyzed together with DEM, slope, and aspect using a GIS to study the distribution of land use and land degradation features, and to monitor land use changes. An erosion risk map of the area was also produced by combining land use, gully density and slope data using the GIS. It was found that nearly 50% of the total area is susceptible to erosion risks, ranging from moderate to very severe, and that 56% of the cultivated land is threatened by these risks. Slopes of between 2–8° were found to be critical as both land use changes and erosion risks were greatest at these gradients.

Khan (2001) studied Guhiya basin (with an area of 1614 km^2) for priority watershed delineation with the objective of selecting watersheds to undertake soil and water conservation measures using remote sensing and Geographical Information System (GIS) techniques. Using the terrain information derived from geocoded satellite data and 1:50,000 topographic maps, 68 watersheds were assessed on the basis of their erosivity and sediment yield index values. On the basis of sediment yield index values the watersheds were grouped into very high, high, moderate and low priorities. High priority watersheds with very high SYI value (>150) need immediate attention for soil and water conservation whereas, low priority watershed having good vegetative cover and low SYI value (<50) may not need immediate attention for such treatments.

Babu, Chandra, and Khybri (1983) analyzed the existing soil loss data and concluded that soil erosion was taking place at an average rate of 16.35 tonnes per ha per year totaling 5334 million tonnes per year. Nearly 29% of the total eroded soil was permanently lost to the sea, and nearly 10% was deposited in reservoirs, resulting in the reduction of their storage

capacity by 1 to 2% annually. The remaining 61% of the eroded soil were transferred from one place to another. The annual water erosion rate values ranged from less than 5 tonnes per hectare per year to more than 80 tonnes per hectare per year in shiwalik hills.

Bahadur (2008) mapped soil erosion susceptibility using Remote Sensing and GIS in the Upper Nam Wa Watershed, Nan Province Thailand and the estimated erosion rates ranged from 0 to 619.29 tons/ha/year.

Bhaware (2006) evaluated the effect of Soil Erosion in Sitla-rao watershed using remote sensing and GIS in Dehradun district of Uttaranchal state. It revealed that about 36 percent of total area of watershed was found under very low risk of erosion. Around 26 percent of watershed lies in moderate risk of erosion, while about 20 percent of area shows high to severe risk of soil erosion. Vulnerability to soil erosion risk in the watershed revealed that 42.47 percent area of cropland (mainly maize) was in high soil erosion risk class within open forest cover, 46 percent of the area is under moderate to high risk of erosion and more than 47 percent of open scrub observed to be contributing to moderate to severe class of erosion risk.

Soo (2011) modelled soil erosion using RUSLE and GIS on Cameron highlands, Malaysia for hydropower development for the years 1997 and 2006, the sediment yield of the Ringlet Reservoir was predicted to be 282,465.5 m^3/ year for 1997 and 334,853.5 m^3/ year for 2006.

Kumar (2013) integrated a RUSLE-3D (Revised Universal Soil Loss Equation-3D) model and geographic information system (GIS) for predicting the soil loss and the spatial patterns of soil erosion risk in the Shivalik region, average soil loss was predicted to be 35.47 t $ha^{-1}yr^{-1}$. Very dense forest cover had lowest soil erosion rate (8.50 t $ha^{-1}yr^{-1}$) whereas highest erosion rate (134.9 t $ha^{-1}yr^{-1}$) was under open forest in the hilly landform. Soil loss was predicted to be lowest in very dense forest and highest in the open forest in the hilly

landform. Agricultural land-1 and agriculture land-2 to have moderately high and low soil erosion risk, respectively. The study predicted that 15% area has 'moderate' to 'moderately high' and 26% area has high to very high risk of soil erosion in the sub-watershed.

Bobe (2004) predicted soil loss using SLEMSA and USLE soil erosion models in Ethiopia, the estimated soil losses for the study sites in eastern Ethiopia ranged from 1.07 t ha^{-1} yr^{-1} for Diredawa to 98.84 t ha^{-1} yr^{-1} for Gelemso. The estimated soil losses for these areas are attributed to the combined effects of the various factors affecting erosion at each site. In some areas, a single factor may have an overwhelming effect than others leading to large differences in the estimated soil loss among the research site. For instance, the highest soil loss estimated at Gelemso is mainly due to its highest K value which is a function of rainfall erosivity and soil erodibility factors.

In Nigeria, researches on erosion have been carried out Adediji, Tukur and Adepoju (2010), assessed the Revised Universal Soil Loss Equation (RUSLE) in Katsina area, Katsina state of Nigeria using Remote Sensing (RS) and Geographic Information System (GIS). The research revealed an estimated potential mean annual soil loss of 17.35 ton/ac/yr. Also, the potential erosion rates from the erosion classes identified ranged from 0 to 4185.12 ton/ac/yr.

Igbokwe *et al.,* (2005) mapped the impact of gully erosion in southeastern Nigeria using satellite Remote Sensing and Geographic Information System. The results revealed 9.93 and 45.71 tons/ ha/ yr. of soil for low areas and high areas respectively.

2.5.1 Soil Erosion Analysis: The Use of Conventional Techniques

Ibitoye (2006) assessed the accelerated erosion in Irele LGA, Ondo State, Nigeria. The results revealed that the volume of soil loss for Lipanu, LA. Primary School area, Idogun Quarters, Ajagba and Ado Quarters Akotogbo was 47522.13 m^3.

Isikwue, Abutu and Onoja. (2012) researched on the erodibility of soils in South West Benue State and discovered that the soil loss in Adumoko, Otukpa, Orokam, Idabi, Owukpa, Ugbokolo, Ajide, Idobe, Ichama, Okpoga, Ochobo, Liami, Awulewu, Ogwanoku and Onyangede areas was 431.98 tons/ha/yr.

CHAPTER THREE: THE STUDY AREA AND METHODOLOGY

3.1 INTRODUCTION

This chapter discussed the study area in terms of the location, climate, rainfall, economic activities, population, soil, vegetation and landuse. It also describes the data sources, method of data collection and the techniques used for data analysis. In order to meet objectives of the study, the methodology followed and the materials used are discussed in this chapter.

3.2 THE STUDY AREA

3.2.1 Location and Size

The location of the study area is the northern part of Makurdi Local Government Area, Benue state which lies between latitudes 7°35□ 01□ N and 7°52□ 36□ N and longitudes 8°20□ 28□ E and 8°40□ 05□ E of the Greenwich meridian (Omale, 1994) see Fig 3.1. Northern Makurdi has an area coverage of about 8 square kilometer radius. It has eleven council wards with a total population of 578, 664 people (Agada, 2011). Figure 1 shows the study area.

3.2.2 Climate

Northern Makurdi experiences a warm tropical climate characterized by wet and dry seasons. Temperatures are high throughout the year. The mean annual maximum temperature range is from 22°C to 32°C. The relative humidity ranges from 50% to 80% being lowest in the dry season months of December to February and highest during the rainy season months of June to September. The elevation is 106.4m above sea-level (Idoga, 2005). The amount and type of rainfall experienced in Makurdi at any location and time of the year depends on its position in relation to the inter-tropical convergence zone (Monanu, 1975). There is generally a wet season that lasts from April to October and a dry season from November to

March. The mean annual rainfall is about 1131mm.The duration of rainfall is normally between 200 and 300 days (Idoga, 2005). A rainfall pattern of this characteristics indicates a fairly heavy rainfall which can increase the rate of erosion potential in the area with less vegetation cover.

3.2.3 Population and economic activities

Northern Makurdi is inhabited by many tribes with a population of 148,966 consisting of about 78,648 males and 70,052 females (FGN, 2007). These tribes include the Tivs, Idomas, Etilos, Jukuns, Igedes, Hausas, Yorubas and Ibos. The Tivs are the dominant tribe. Northern Makurdi is made up largely of people who engage in commercial activities, farming and agrarian peasantry. Northern Makurdi is a sub-urban area with the highest concentration of people in north bank. Dense population also exist in some low-lying parts of the study such as Agan, ihyev and Utagudu. Arable cropping is based on local staple food crops, under subsistent production. The farming systems, crops priorities or options and combinations as well as intensity of cultivation vary with the natives and the soil condition in the state. (Abah, 2013).

3.2.4 Soil, Geology and Vegetation

Benue State is about 80% underlain by sedimentary rock materials, with a little bit of basaltic extrusion in the Benue River trough of Makurdi Local Government Area (Bennette, Blair Rains, Gosden, Hill, Howard, Hutcheon, Kerr, Mansfield, Rackman and Wood, 1979), an area underlain mostly by consolidated shales, Eze -Aku, Nkopro and Awgu with frequent out - crops of Makurdi sandstone in the south and Keana sandstone in the north bank of the river Benue. The dominant parent material produce deep well drained sandy soil in the inter-fluvial slope. (Adaikwu, 2010). The soils are generally coarse textured especially in the surface horizons and are well drained to moderately well drained (Fagbemi, 2000; Akamigbo,

1988).The vegetation consists of trees, shrubs and grasses. Dominant trees include *Acacia spp*, *Mangifera spp*, *Citrus spp*, while grasses include *Imperata cylindrical*, *Oryza spp*, and *Pennisetum spp* and *Hyperrheni spp*. With the nature of the geology, soils and vegetation there is an indication that these parameters help in reducing runoff and limiting the impact of eroding agents.

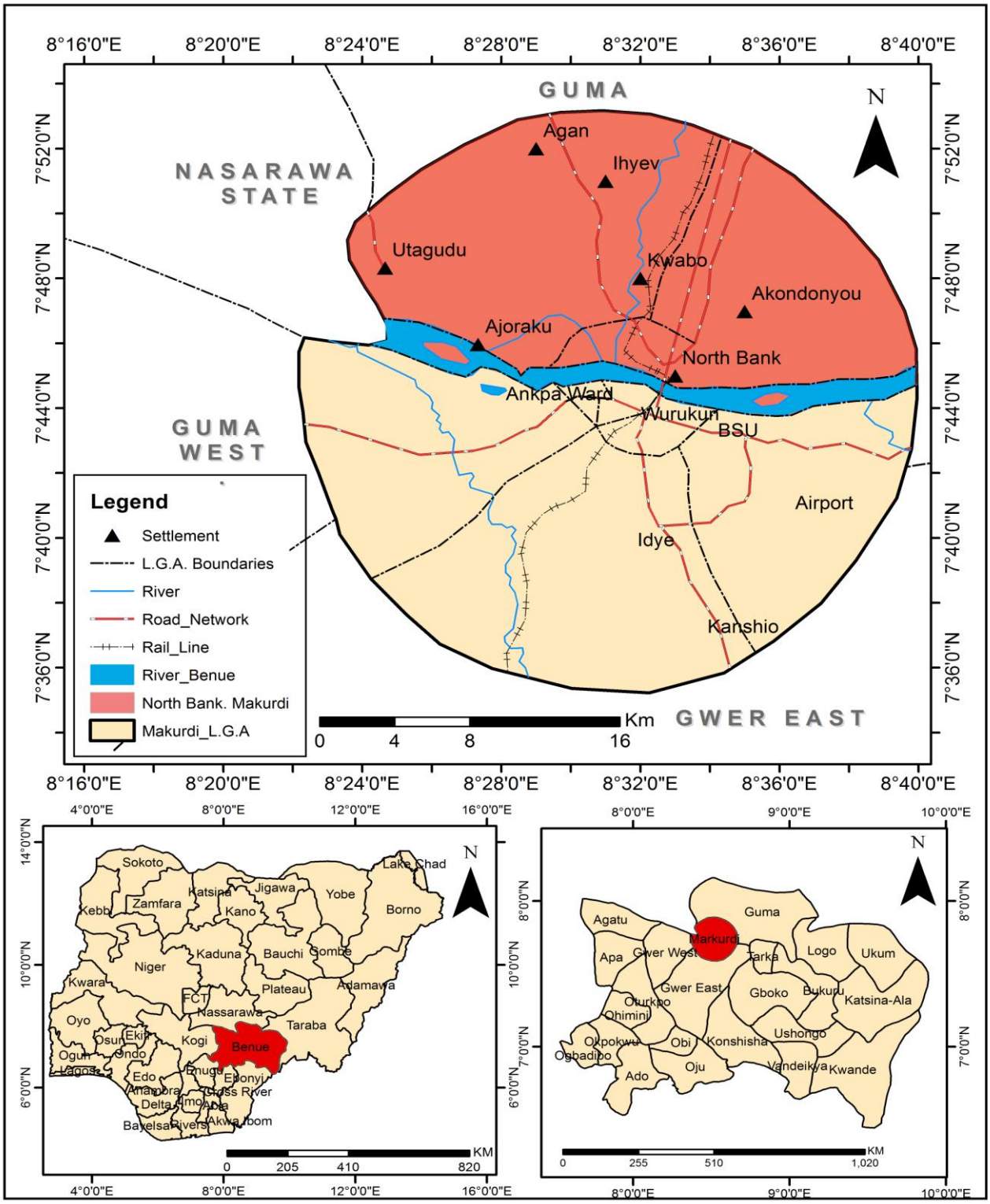

Figure 3.1: Northern Makurdi
Source: Modified from Administrative Map of Benue State

3.3 METHODOLOGY

This section describes the data, tools and procedures adopted for the study. This section discussed the methodology employed for the study, and is arranged in four segments:

i .Types of data required for the study.

ii. Sources of data

iii. Data processing

iv. Data analysis

3.3.1 Reconnaissance Survey

A reconnaissance survey was carried out by the researcher in order to get acquainted with the study area. The Benue State Ministry of Agriculture, the Federal Geological Survey Makurdi and the Soil Science Department of the Federal University of Agriculture Makurdi Benue State were contacted for relevant information concerning the study. From the reconnaissance it revealed that certain data such as the geology map, soil map and data on cover management and support practice of the study area were not available. Data acquired from the survey was the soil erodibility factor for input into the erosion model.

3.3.2 Types of Data Required

The types of data required for this study are as follows:

i. A Shuttle Radar Topographic Mission (SRTM) data for producing a digital elevation model (DEM).

ii. A 30m resolution LANDSAT ETM+ multispectral satellite imagery of the year 2012 of the study area for the extraction of the cover management factor (C) and support practice factor (P).

iii. Hydrological data from 2003 – 2012 for calculating rainfall-runoff erosivity factor (R).

iv. Soil data were used to calculate the soil erodibility factor (K).

3.3.2.1 Sources of Data

The data for this study was obtained from the following sources:

i. DEM of study area

The SRTM of the study area was sourced from the Benue State Ministry of Lands and Survey.

ii. Satellite Imagery

A 30m resolution LANDSAT ETM+ multispectral satellite imagery of the year 2012 of the study area was be obtained from www.usgs.gov

iii. Hydrological data

Rainfall data of the study area was sourced from the National Metrological Agency (NIMET)

iv. Soil Data

Soil data on the erodibility of soils within the study showing the different soil classes in the study area was adapted from a research carried out by Agada (2015) from the Federal University of Agriculture Makurdi.

The rainfall and soil maps of northern Makurdi were produced from the rainfall and soil data respectively. Other secondary information required were obtained from dissertations, journals textbooks, past projects, etc.

3.3.3 Data Processing and Analysis

i. The SRTM was used to generate a digital elevation model (DEM), where the slope and thus the slope length (LS) were generated. This is one of the parameters used in estimating the average amount of soil loss in the study area.

ii. The rainfall data were used to calculate the rainfall factor R. This was achieved by applying the Roose (1977) rainfall equation R = (0.55×Pa), where Pa is the mean

annual rainfall, which is also another parameter used in the RULSE equation for estimating the average amount of soil loss.

iii. The soil data was processed using the spatial analyst tool in ArcGIS 10.1 to produce a soil map and the soil factor (K) extracted which is also another parameter used in the RULSE equation for estimating the average amount of soil loss.

iv. The 30m resolution LANDSAT ETM+ multispectral satellite imagery covering Makurdi was downloaded and extracted from full scene. The sub-setting of the imagery was done. A supervised classification was carried out and thus a land use/cover management and support practice maps was produced and then the cover management factor (C) and support practice factor (P) were estimated.

After data have been captured they were analyzed to achieve the stated objectives.

The determination of the major causes of soil erosion in the study area was achieved by analyzing the classified map of the study area, the hydrological (rainfall) data, and the soil data. This was achieved by applying Bobe's (2004) technique where ±20 is added to each factor to determine what factor(s) contribute fundamentally to soil erosion or are the major cause(s) of soil erosion in the study area.

The estimation of the average amount of soil loss using the Revised Universal Soil Loss Equation (RUSLE). Using Revised Universal Soil Loss Equation (RULSE) the estimated amount of soil loss was obtained.

The RULSE equation is defined by the following parameters (Wischmeier and Smith, 1978)

$A = R \times K \times L \times S \times C \times P$ ---------- (Eq. 1)

Where:

A = computed spatial average soil loss and temporal average soil loss per unit of area, expressed in the units selected for K and for the period selected for R. In practice,

these are usually selected so that A is expressed in ton× $acre^{-1}$× yr^{-1}, but other units can be selected (that is, ton× ha^{-1}× yr^{-1});

R = rainfall-runoff erosivity factor—the rainfall erosion index plus a factor for any significant runoff from snowmelt (100ft×tonf×$acre^{-1}$×yr^{-1}); this factor was obtained from the rainfall data of the study area.

K = soil erodibility factor – the soil-loss rate per erosion index unit for specified soil as measured on a standard plot, which is defined as a 72.6-ft (22.1-m) length of uniform 9% slope in continuous clean-tilled fallow;

L = slope length factor – the ratio of soil loss from the field slope length to soil loss from a 72.6-t length under identical conditions;

S = slope steepness factor – the ratio of soil loss from the field slope gradient to soil loss from a 9% slope under otherwise identical conditions.

C = cover management factor – the ratio of soil loss from an area with specified cover and management to soil loss from an identical area in tilled continuous fallow

P = support practice factor – the ratio of soil loss with a support practice like contouring, strip-cropping, or terracing to soil loss with straight-row farming up and down the slope. These factors were derived from the classified land use map of the study area. These factors as defined above are the inputs of the RUSLE model used in estimating the average amount of soil loss as modeled by Wischmeier and Smith (1965). When all these factors as defined are obtained and then multiplied as shown in the equation above the estimated amount of soil loss were calculated.

Map and analyze the distribution of soil erosion sites. A map of each factor that has been imputed was overlayed to produce a soil erosion map of the study area and this was used to carry out a vulnerability assessment depending on the level of severity. This was achieved by using the weighted overlay in the spatial analyst function of the ArcGIS 10.1

software where the map of each variable was inputted to produce a soil erosion map of Northern Makurdi.

The methodology flow chart of this study is shown in Figure 3.2

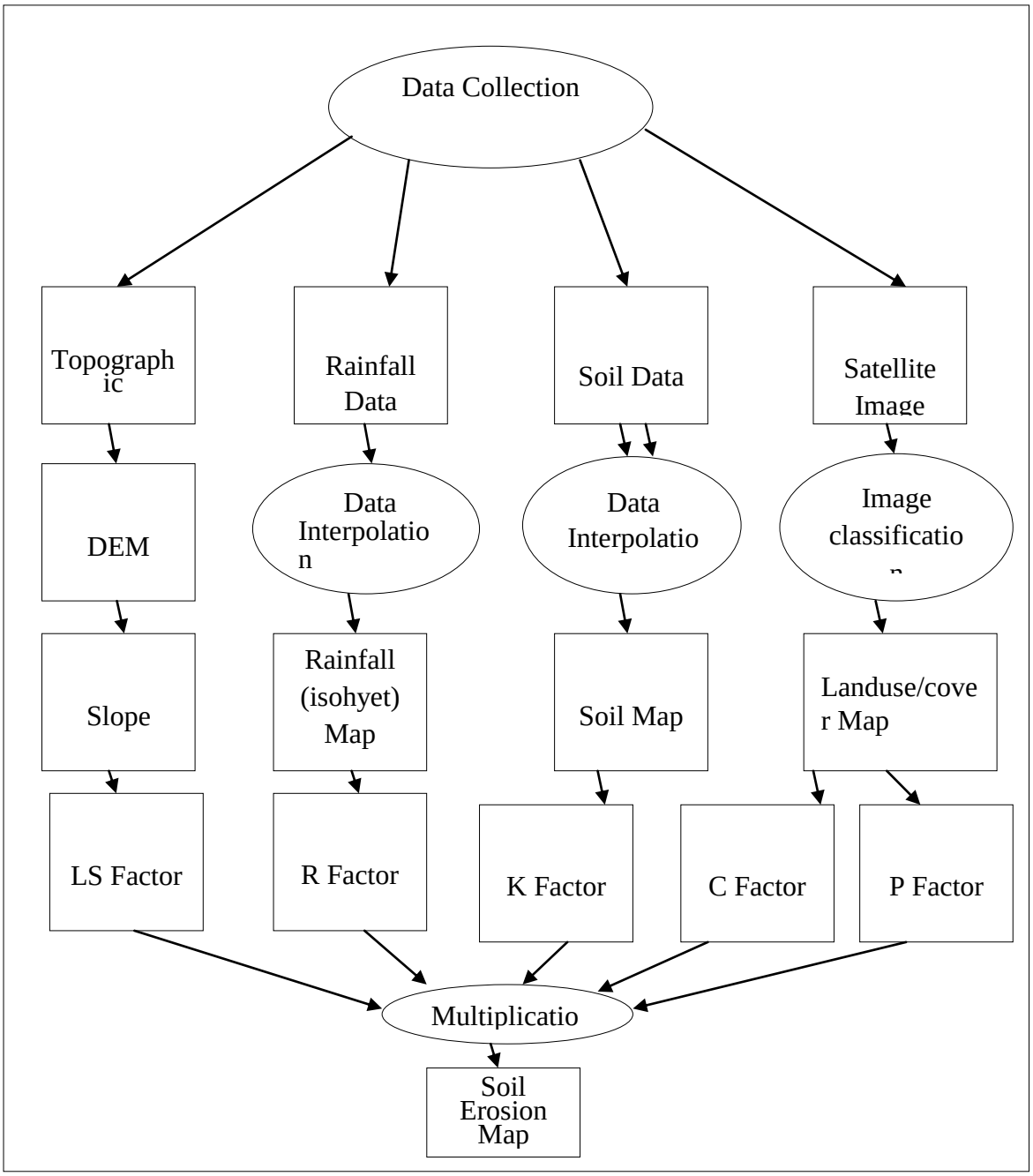

Figure 3.2: Flow Chart of Study Methodology
Source: Adapted from Adediji, Tukur and Adepoju (2010)

3.3.4 Rainfall-Runoff Erosivity Factor (R) Estimation

Wischmeier and Smith (1958) derived the rainfall and runoff erosivity factor from research data from many sources. The rainfall – runoff erosivity factor is defined as the mean annual sum of individual storm erosion index values, EI_{30}, where E is the total storm kinetic energy and I_{30} is the maximum rainfall intensity in 30 minutes. To compute storm EI_{30}, continuous rainfall intensity data are needed. Wischmeier and Smith (1978) recommended that at least 20 years of rainfall data be used to accommodate natural climatic variation.

Renard *et al*. (1997) states that the numerical value used for R in RUSLE must quantify the effect of raindrop impact and must also reflect the amount and rate of runoff likely to be associated with the rain. The rainfall runoff erosivity factor (R) derived by Wischmeier appears to meet these requirements better than any of the many other rainfall parameters and groups of parameters tested against the plot data.

Wischmeier and Smith (1965) found that the best predictor of rainfall erosivity factor (R) was:

$$R = \frac{1}{n}\sum_{j=1}^{n}\left[\sum_{k=1}^{m}(E)(I_{30})_k\right] \quad \text{---------- (Eq 2)}$$

Where:

R = rainfall-runoff erosivity factor—the rainfall erosion index plus a factor for any significant runoff from snowmelt ($100ft \times tonf \times acre^{-1} \times yr^{-1}$);

E = the total storm kinetic energy in hundreds of ft. per tons per acre;

I_{30} = the maximum 30-minute rainfall intensity;

j= the counter for each year used to produce the average;

k= the counter for the number of storms in a year;

m= the number of storms n each year;

n= the number of years used to obtain the average R.

The calculated erosion potential for an individual storm is usually designated EI.

The total annual R is therefore the sum of the individual EI values for each rainfall storm event. The energy of a rainfall storm is a function of the amount of rain and of all the storm's intensity components. The median raindrop size generally increases with greater rain intensity (Wischmeier *et al*., 1958), and the terminal velocity of free-falling water drops increases with larger drop size (Gunn and Kinzer, 1949). Wischmeier (1978) also found that the rain kinetic energy (E) relationship, based on the data of Laws and Parsons (1943), is expressed by the equation;

$E = 916 + (331)\log_{10} I$ $I \leq 3.0$ in/hr. ---------- (Eq3)

I = the average rain intensity;

E= the kinetic energy in ft. /tons per acre inch of rain

Roose (1977) model for estimating values of rainfall erosivity from rainfall amounts for West African climates was adopted. The equation is given as

R = (0.55×Pa) ---------- (Eq 4)

Where R is the rainfall erosivity factor [MJ mm $ha^{-1}h^{-1}yr^{-1}$],

Pa is the Annual average rainfall amount (mm).

Rainfall data using non recording rain guage was sourced at the Nigerian Meteorological Service Agency (NIMET) Makurdi located at the Nigerian Tactical Air Command Makurdi. The long-term non recording rain guage data (2003 – 2012) were used to

compute long – term averages for the study area. Wischmeier and Smith (1978) recommended that at least 20 years of rainfall data should be used to accommodate natural climatic variation but a 10 years rainfall data can also be used as stated in the RUSLE handbook (Renard *et al.,* 1997). Each of the rainfall charts was analyzed by summing up the monthly averages to the yearly averages. To obtain rainfall amount in mm, the rainfall from January – December averages for the 10 years. Related to the rainfall runoff erosivity factor, the values of the rainfall records in the study area was used to generate the rainfall map. But due to the unavailability of other rainfall stations in the study area besides the NIMET station in Makurdi, surrounding rainfall stations and their averages was used and hence the rainfall map of the study area extracted.

Table 3.1 shows the surrounding rainfall stations and their annual averages

Table 3.1: Surrounding Rainfall Stations

No	Stations	Latitude	Longitude	Annual Average	R Factor
1	Abuja	9.08226	7.31312	1451	798.05
2	Lokoja	7.80888	6.73737	1105	607.75
3	Ibi	8.17829	9.73475	984	541.20
4	Ogoja	6.65806	8.79644	1812	996.60
5	Makurdi	7.68333	8.61666	1151	635.28
6	Enugu	6.44520	7.49113	1766	971.30
7	Jos	9.91808	8.85086	1151	684.20

Source; Nigeria Hydrological Services Agency (2013)

Each data point needs to be interpolated spatially to make the same grid cell size as the other thematic maps: Rainfall map, DEM, Soil Map and Land use map.

After data collection, R factor was determined for the selected rainfall gauging stations using the equations earlier listed as shown in Table 3.2. Isohyet maps for R factor were generated using ArcGIS10.1. All the data points were interpolated spatially using the Ordinary Kriging method found in the ArcGIS 10.1 Spatial Analyst tool to make the same

resolution or grid cell size as the other maps inserted in the ArcGIS. The parameters used for Kriging method are shown in Table 3.2 Kriging is based on statistical models that include autocorrelation – that is, the statistical relationships among the measured points. Because of this, not only do geostatistical techniques have the capability of producing a prediction surface, they also provide some measure of certainty or accuracy of predictions.

Table 3.2: Kriging Method

Parameter	**Values**
Value to be interpolated	R factor
Semivariograms Properties	
A. Kriging Method	Ordinary Kriging
B. Semivariogram Model	Spherical
Interpolation cell size	5 x 5 km
Kriging Parameter	
A. Search Type	Fixed
B. Number of Points	15
C. Maximum Search Distance	150 km

3.3.5 Evaluation of Soil Erodibility Factor (K)

Soil erodibility (K) represents the susceptibility of soil or surface material to erosion, transportability of the sediment, and the amount and rate of runoff given a particular rainfall input, as measured under a standard condition. The standard condition is the unit plot, 22.1m long with a 9 percent gradient, maintained in continuous fallow, tilled up and down the hillslope (Weesies, 1998). K values reflect the rate of soil loss per rainfall-runoff erosivity (R) index. Soil erodibility factors (K) are best obtained from direct measurements on natural runoff plots. For the universal soil loss equation (USLE) (Wischmeier and Smith, 1978) and RUSLE (Renard *et al.,* 1997), the concept of soil erodibility was introduced as the K factor, which was defined as the average rate of soil loss per unit of rainfall erosion index from a

cultivated continuous fallow plot of a 9 percent slope and 22.1m long. For a standard plot as earlier defined, soil erodibility factor, K, is calculated from the equation

K =A/R---------- (Eq 5)

Where A is amount of soil loss and R is rainfall erosivity factor in the USLE (Wischmeier and Smith, 1965; 1978).

Soil samples of various horizons from selected soil profiles in the study area were collected to carry out soil analysis, namely: SIWES FARM and NEW AGRONOMY FARM NORTHCORE from the University of Agriculture North Bank Makurdi. These soil samples were assessed using the Wischmeier, Johnson, and Cross (1971) nomograph. The nomograph relates the K factor to five soil profile parameter (Zhang, Li, Peng and Yu, 2012). The soil properties – percentage of silt (0.002- 0.05mm) plus percentage of very fine sand (0.05 – 0.01mm) and the percentage of sand (0.1-2mm) needed for the estimation of K using the nomograph were adopted from Agada (2015). The soils used in this study were formed on shale and sandstone parent material respectively.

Characteristics of landscape were considered for soil mapping. Relief information associated with various landforms existing in the study area such as hills, rivers, etc. was extracted from the satellite imagery. This information was utilized to delineate various soil units from satellite imagery. To discriminate different units, various image elements associated with terrain elements such as landform, topography, relief, slope, land use/land cover, drainage network, etc. were used for the soil mapping. For this study, K factor shape file was added as a layer into ArcGIS 10.1, the soil map attribute table was edited by adding a new field of K values under the Edit menu at attribute view before K factor were produced. The K factor for the various soil classes were added. The theme was in vector form and was converted to grid form with cell size of 20m.

3.3.6 Slope Length and Steepness Factor (LS) Derivation

The effect of topography on soil erosion is accounted for by the LS factor in RUSLE, which combines the effects of a slope length factor, L, and a slope steepness factor, S. In general, as slope length (L) increases, total soil erosion and soil erosion per unit area increase due to the progressive accumulation of runoff in the downslope direction. As the slope steepness (S) increases, the velocity and erosivity of runoff increase.

Slope length (L) is defined as the ratio of soil loss from the field slope length to that from a 22.1 m length under otherwise identical conditions. The L and S factors are usually considered as single topographical factor and can be estimated using the equation.

$LS = \left(\frac{x}{22.13m}\right)^{m} [(0.065 + 0.045(s) + 0.0065(s^2)]$ ---------- (Eq 6)

Where;

LS is topographical factor and is dimensionless,

x is slope length (meter)

m is an exponent whose value depends on slope gradient and

s is slope gradient (percent)

Current recommendations (Wischmeier and Smith, 1978) for the exponent m are as follows:

m = 0.5 if slope ≥ 5 percent

m = 0.4 if slope < 5 percent and > 3 percent

m = 0.3 if slope ≤ 3 percent and ≥ 1 percent

m= 0.2 if slope < 1 percent

x = (flow accumulation × cell value) ---------- (Eq 7)

By substituting *x* value, LS equation will be:

$$LS = \left(\frac{\text{Flow Accumulation} \times \text{Cell Value}}{22.13}\right)^{m} [(0.065 + 0.045(s) + 0.0065(s^2)] \text{ ---------- (Eq 8)}$$

The DEM of the study area was extracted from shuttle radar topographic mission data. This was achieved by using the extraction by mask Spatial Analyst tool of ArcGIS. DEM represents the surface terrain of the study area and permits to retrieve geographical information. Slopes of DEM in percentage were also generated using Surface Analysis under the Spatial Analyst function. Surfacing function was used to generate a DEM and to represent as a surface or one-band image file where the value of each pixel was a specific elevation value. A gray scale was used to differentiate variations in terrain. The Slope map was generated in ArcGIS 10.1 software by using DEM. Slope map was classified based on USDA criteria given in the Table 3.3

Table 3.3: Slope classes

Class	Slope Range (%)	Slope Class
A	0-1	Nearly Level
B	1-3	Very Gentle Sloping
C	3-5	Gentle Sloping
D	5-10	Moderately Sloping
E	10-15	Strongly Sloping
F	15-25	Moderately steep to steep Sloping
G	25-33	Steep Sloping
H	33-50	Very steep
I	>50	Extremely steep slope

Source: Soil Survey Manual (Bhaware, 2006)

As the first step, the elevation value was modified by filling the sinks in the grid. This is done to avoid the problem of discontinuous flow when water is trapped in a cell, which is

surrounded by cells with higher elevation. This was done by using the Fill tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS 10.1. Then, Flow direction was generated from the Fill grid. The Flow direction tool takes a terrain surface and identifies the down-slope direction for each cell. This grid shows the on surface water flow direction from one cell to one of the eight neighbouring cells. This was done by using the Flow direction tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS. Based on the Flow direction, Flow accumulation was calculated. Flow accumulation tool identifies how much surface flow accumulates in each cell; cells with high accumulation values are usually stream or river channels. It also identifies local topographic highs (areas of zero flow accumulation) such as mountain peaks and ridgelines. This was done by using the Flow accumulation tool under Hydrology section found under Spatial Analyst Tool Function in ArcGIS 10.1.

Finally, the Raster calculator function under Spatial Analyst feature (Map Algebra) was used to input the equation 6 to compute LS factor. Themes of slope of DEM in percentage and flow accumulation were activated to run the process as shown in equation 7 and 8. Cell value of 20m was utilized in equation 7. The m value of 0.5 was selected for equation 6 because about 80% of the terrain of the study was steeper than 20º. LS values ranged from 0 to 42.

3.3.7 Cover Management Factor (C) Estimation

The cover management factor (C) represents the effects of vegetation, management, and erosion control practices on soil loss. As with other RUSLE factors, the C value is a ratio comparing the existing surface conditions at a site to the standard conditions of the unit plot. RUSLE uses a sub factor method to compute soil loss ratios (SLR), which are the ratios of soil loss at any given time in the cover management sequence to soil loss from the standard

condition. The sub factors used to compute a soil loss ratio value are prior land use, canopy cover, surface cover, surface roughness, and soil moisture.

In RUSLE model, estimation of *C* factor takes into account a series of sub-factors that include prior land use, canopy cover, surface cover and surface roughness (Renard, Foster, Weesies, McDool, and Yoder, 1991). C value is equal to 1 when the land has continuous bare fallow and have no coverage. C value is lower when there is more coverage of a crop for the soil surface resulting in less soil erosion (Soo, 2011). A satellite image of the study was interpreted for the detailed information about land cover and land use activities. To generate the scenario of land use land cover, a 30m LANDSAT ETM+ multispectral image of Makurdi was downloaded from www.usgs.gov website and the image bands from 1-10 were stacked and subsetted for the study area using the ERDAS IMAGINE 9.2 software. The satellite image was interpreted making use of the interpretation keys such as tone, texture, pattern, shape, size, shadow, site and association to derive thematic information. Characteristics of the land surface, including natural and artificial cover were considered. Existing land use practices were investigated through field survey and training sites for different land uses were marked to derive information about land use activities and land cover for plotting land use land (LULC) cover map. A maximum likelihood supervised classification was then applied to the imagery using the ArcGIS 10.1 software with the following training sites namely; Urban, water body, Forest. Crop land and wasteland. From the LULC map derived C factor values were assigned for the various classes based on the literature (Roose 1977; Singh, Ram and Chandra, 1981; Narain, Khybri, Tomar and Sindhwal, 1994). This is shown in table 3.4

Table 3.4: The vegetal cover factor (C Factor) for different crops in West Africa.

Bare continuously fallowed		1
Forest or dense shrub, high mulched crops		0.001
Savannah, prairie in good condition		0.01
Over-grazed savannah or prairie		0.1
Crop cover of slow development or late planting--first year		0.3 to 0.8
Crop cover of rapid development or early planting-first year		0.01 to 0.1
Crop cover of slow development or late planting-second year		0.01 to 0.1
Com, sorghum, millet (as a function of yield)		0.4 to 0.9
Rice (intensive fertilization)		0.1 to 0.2
Cotton, tobacco (second cycle)		0.5 to 0.7
Peanuts (as a function of yield and the date of planting		0.4 to 0.8
1st year cassava and yam (as a function of the date of planting)		0.2 to 0.8
Palm tree, rubber-tree, coffee, cocoa with cover crop		0.1 to 0.3
	burned- residue	0.2 to 0.5
Pineapple on contour (as a function of slope)	buried residue	0.1 to 0.3
	surface residue	0.01
Pineapple and tied-ridging (slope 7%)		0.1

Source; Roose (1977)

The study area's land use classification map was used in the estimation of Cover management and support practice factors. The cover management factor (C) of the study was calculated based on (Roose 1977; Singh, Ram and Chandra, 1981; Narain, Khybri, Tomar and Sindhwal, 1994) in Table 3.6

3.3.8 Support Practice Factor (P) Estimation

Conservation practice factor (P) in the RUSLE model expresses the effect of conservation practices that reduce the amount and rate of water runoff, which reduce erosion. It includes different types of agricultural management practices such as: strip-cropping, contouring and terracing (Farhan, Zregat and Farhan, 2013). The P value range is between 0 to 1 where 0 represents very good manmade erosion resistance facility and 1 represents no manmade erosion resistance facility. P value is lower and less than 1 when the adopted conservation practice reduces soil erosion. Each value of P was assigned according to the cultivation method, land use and slope (Shin, 1999) shown in Tables 3.7 and 3.8

Table 3.5: Support practices factor (P) based on Slope and Cultivation Method.

Slope (%)	Contouring	Strip Cropping	Terracing
0.0 -7.0	0.55	0.27	0.10
7.0 - 11.3	0.60	0.30	0.12
11.3 - 17.6	0.80	0.40	0.16
17.6 - 26.8	0.90	0.45	0.18
>26.8	1.00	0.50	0.20

Source; Kim (2006)

Table 3.6: Support practices factor (P) based on different Land Use (Troeh, Hobbs, & Donahue, 1999)

Land Use	P factor
Agricultural Stations	0.40
Coconut	0.50
Diversified Crops	0.45
Estate Buildings and Associated Areas	0.40
Fish and Hyacinth Ponds	0.50
Forest	0.10
Mixed Horticulture	0.40
Newly Cleared Land	0.70
Orchards	0.40
Other Mining Areas	1.00
Paddy	0.50
Reclaimed Area	0.70
Recreational Area	0.60
Rubber	0.40
Scrub	0.20
Swamps	0.50
Unused Land	0.45
Urban Associated Areas	1.00
Water	0.50
Dipterocarp Forest	0.10
Lowland Forest	0.10

Source; Soo (2011)

The LULC map was used to produce the C and P factor maps. To produce C and P factor maps, the land use shape file was added to ArcGIS. C and P factors were generated the same way as K factor by editing the attribute table. The land use attribute table was edited

with adding a new field of C and P values under the Edit menu at attribute view before the C and P factor was produced. The values of C were adopted from the Table 3.6; the vegetal cover factor (C Factor) for different crops in West Africa.

CHAPTER FOUR: RESULTS AND DISCUSSION

4.1 Introduction

This chapter presents and discusses the results of the study.

4.2 Causes of Soil Erosion in Northern Makurdi

In an attempt to identify the major factors causing soil erosion in the study area Bobe's (2004) technique was applied where each factor is increased and decreased by 20% while the other factors are kept constant in order to see the effect of each of the variables on the soil loss within the area. This was used as an indicator of the amount of soil loss reduction by an improvement in a certain management practice (Bobe, 2004). The estimated soil loss due to changes in one of its input variables while keeping the others constant and the percentage change as compared to the original estimated soil loss is presented in Table 4.1

Table 4.1: Response to Soil Loss by RUSLE due to changes in some input variables

Soil Loss(SL) ton/ha/ yr.	SL due to 20% increase in Rainfall Factor (R)		SL due to 20% increase in soil factor (K)		SL due to 20% increase in topographic factor (LS)		SL due to 20% increase in Cover factor (C)		SL due to 20% increase in management practice factor (P)	
	Increase	20% Decrease	Increase	20% Decrease	Increase	20% Decrease	Increase	20% Decrease	Increase	20% Decrease
	Amount ton/ha/ yr.		Amount ton/ha/ yr.		Amount ton/ha/ yr.		Amount ton/ha/ yr.		Amount ton/ha/ yr.	
48.21	54.49	30.23	50.41	33.61	50.41	33.61	51.01	33.61	50.41	33.61

Source: Authors Analysis (2015)

Soil loss responded highly to change in rainfall erosivity factor R in the area. A 20% increase in the value of R led to an 11.53% increase in the estimated soil loss. Though a 20% decrease led to a 37.29% decrease of soil loss.

The change in soil loss due to 20% increase in soil erodibility factor K indicated a 4.36% increase in soil loss and a 20% decrease in K led to a 30.28% decrease in average soil loss. This is directly proportional to the values of the slope factor LS, the support practice factor P.

The effect on the increase in the slope factor and support practice factor (LS and P) showed a 4.36% increase and 30.28% decrease in average soil loss. However there was a 5.49% increase in soil loss for a 20% increase in the cover management C factor though a 30.28% decrease in soil loss was estimated for a 20% decrease in C which is the same for the K, LS and P factors.

In general, RUSLE model applied to study is more sensitive to changes in rainfall and surface cover. This is shown by the increase in soil loss for these factors compared to others. The implication is that, a small deviation in estimating or measuring the R factor and cover factor C may lead to large errors in estimating the actual soil loss for a given area. Though there were increases in soil loss due to the percentage increase in other factors but the results showed the same results for the other factors, which meant the factors had the same effect on each other.

From this results, it indicates that the estimated soil loss was relatively higher where all erosion parameters are proportionally high. Higher rainfall R and cover management factor C have a more pronounced effect on increasing estimated soil loss. Thus rainfall R and cover management factor C are major causes of erosion in the study area. This can be explained by the high erosivity values recorded for the study though this is due to nature of the rains experienced in the guinea savannah. This result is similar to that of Arnoldus (1980) on rainfall aggresivity

index (RAI), which showed that regions with erosivity of above 160 is very high. FAO (1979) rainfall erosivity ratings showed that rainfall greater than 1000mm were classed as very high in erosivity ratings in which the study area erosivity falls. For this study average annual rainfall for the 10 year study is 1150.60mm. These results are similar with findings of Bobe (2004), where there is a relationship between rainfall (erosivity factor R) to high soil loss. Due to activities such as uncontrolled logging, bush burning has left the land surface exposed and thereby increasing the susceptibility to run off and subsequently sedimentation. However, since the effect of any single factor on the predicted soil loss is dependent on the values of the other factors, separate evaluation of each factor is not reasonable.

4.3 The Annual Average Soil Loss Rate

The occurrence of soil erosion has a close relationship with the status of land use and the situation of farmland management along with topographical characteristics such as slope length and steepness (Kim, 2006). The RUSLE equation (equation 1) was used to calculate the annual average soil loss rate (A) in ton/ha/year and the resulting soil loss map generated. For ease of interpretation, the values of erosion potential were divided into 5 classes by shown in Table 4.2

Table 4.2: Derivation of the ordinal categories of soil erosion potential

Erosion Class	Numeric Range (ton/ha/yr.)	Erosion Potential
1	0 - 10	Low
2	10 - 20	Moderate
3	20 - 29	High
4	29 - 39	Very High
5	39 - 48	Severe

Source: Adapted from Soo, (2011)

4.3.1 Rainfall - Runoff Erosivity Factor (*R*)

The rainfall distribution in northern Makurdi during the period 2003-2012 is presented in Table 4.3 The average annual rainfall in the study area varied between 762 mm to 1493.mm. The annual rainfall data and rainfall average for seven surrounding rainfall stations were used to generate the rainfall distribution map of the study area. Rainfall erosivity factor map (R) was developed. The rainfall and erosivity factor maps (Figures 4.1 and 4.2) were generated.

Table 4.3: Annual Precipitation Records (mm)

Yr./Mon.	Jan.	Feb.	Mar.	Apr.	May	Jun.	Jul.	Aug.	Sept.	Oct.	Nov.	Dec.	Ann. Sum
2003	0.0	0.0	0.0	56.4	30.7	200.0	119.2	145.3	136.4	39.8	33.7	0.0	761.52
2004	0.0	0.0	7.8	61.0	73.3	164.5	169.8	185.1	162.9	147.5	0.7	0.0	972.60
2005	0.0	0.0	22.0	42.9	90.5	209.8	142.4	112.7	159.4	91.6	0.0	0.0	871.32
2006	46.9	0.0	13.3	26.1	276.1	109.9	322.7	215.1	229.3	103.6	0.0	0.0	1343.04
2007	0.0	0.0	8.7	124.8	170.5	210.0	114.5	272.7	217.9	219.2	1.6	0.0	1339.92
2008	3.0	0.0	0.0	186.1	147.4	186.1	81.6	330.2	83.0	81.5	0.0	1.6	1100.52
2009	2.3	0.0	3.0	180.1	190.3	239.6	86.1	275.3	140.5	284.1	1.2	0.0	1402.56
2010	0.0	0.0	12.6	31.4	134.7	119.4	192.7	178.1	305.6	116.8	24.0	0.0	1115.28
2011	0.0	0.0	0.0	78.0	142.8	60.4	87.0	217.4	272.0	293.4	0.0	0.0	1151.04
2012	0.0	0.5	0.0	143.2	145.2	160.6	351.9	174.3	290.7	199.1	27.3	0.0	1492.80

Annual average Precipitation (Pa) = $\sum$ annual Sum = 11550.60/10=1150.60

Inputting variables into equation 4

R = (0.55×Pa)

R = 635.28

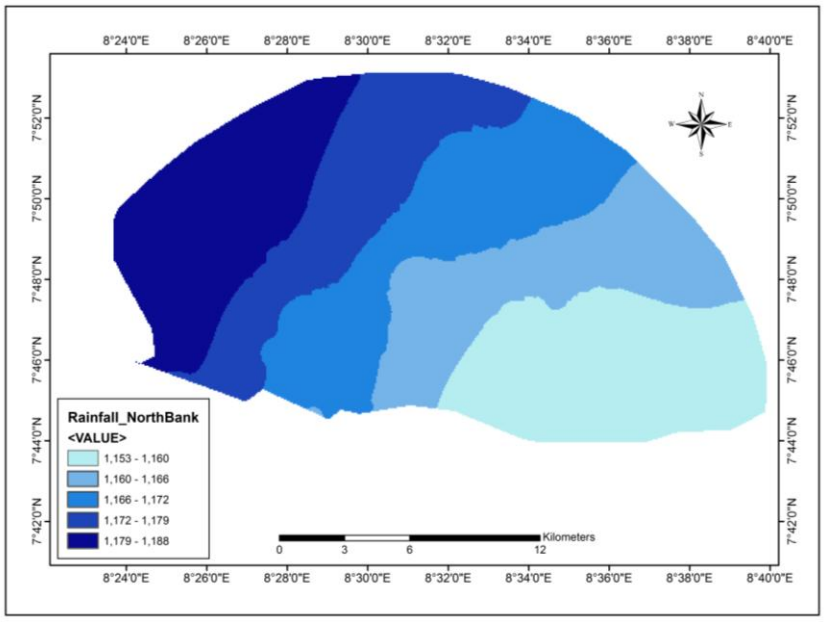

Fig 4.1: Rainfall Map

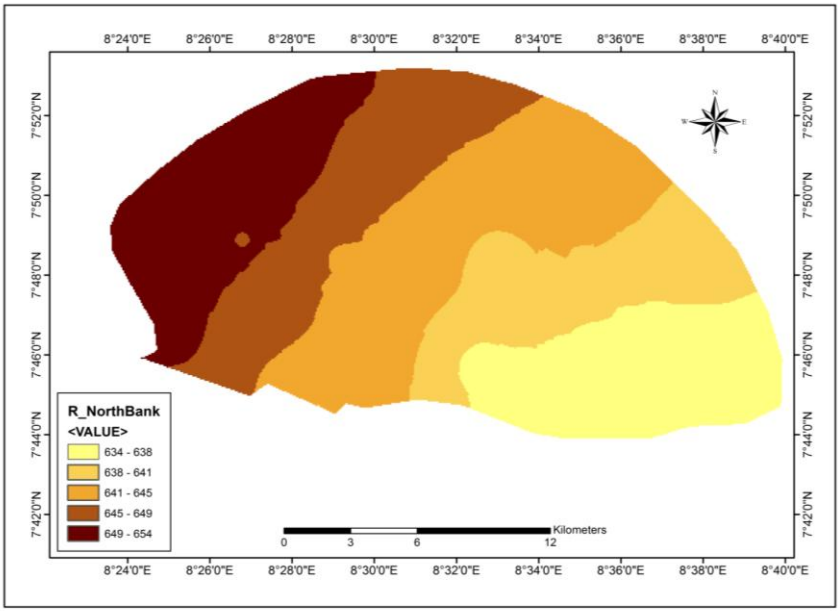

Fig 4.2: R – Factor Map

4.3.2 Soil Erodibility Factor (K)

Based on Table 4.4 the Soil Erodibility Factor (K) of the study area was determined. Estimated soil erodibility ranged from 0.041 to 0.061 for the soils used in this study. The soil distribution in the study area and derived erodibility factor is given in Table 4.4. Soil erodibility map for K factor was adopted from Agada (2015) using the method described in section 3.3.5. The theme produced is shown in Figure 4.3.

Table 4.4: Soil Erodibility classes

Study Sites	% Sand	% Fine Sand	% Silt	Erodibility ($Mg.ha.h.ha^{-1}.MJ^{-1}mm^{-1}$)
SIWES FARM PLOT 1	25.2	45	30	0.061
SIWES FARM PLOT 2	19.5	34	11	0.051
NORTHCORE PLOT 1	20.8	54	5	0.044
NORTHCORE PLOT 2	29.6	45	5	0.041

Source; Agada, (2015)

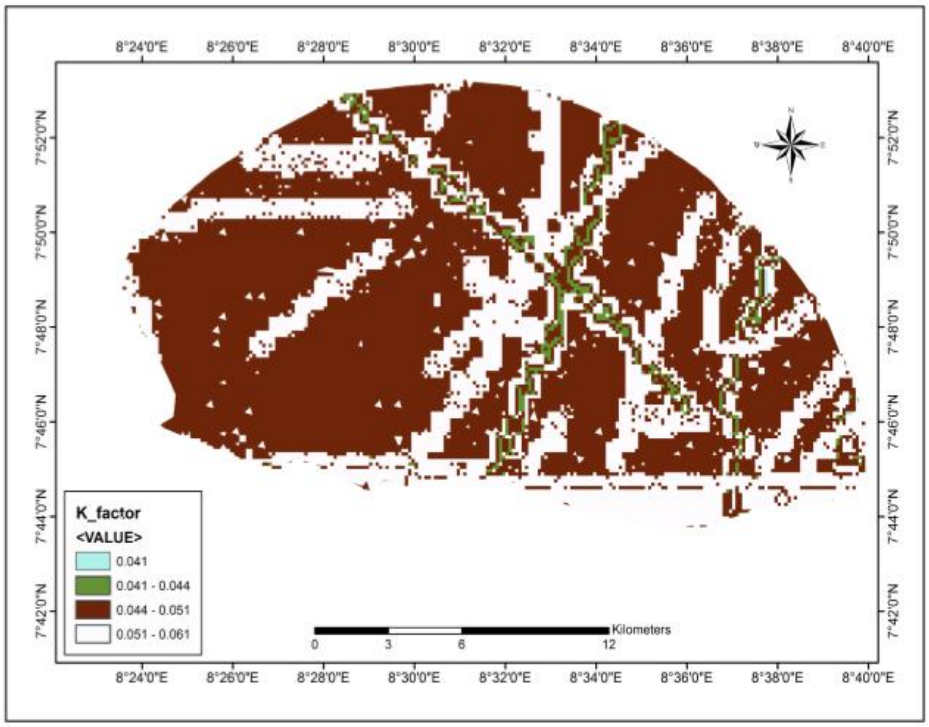

Fig 4.3: K factor Map

4.3.3. Slope Length and Steepness Factor (LS)

Slope length and steepness (LS) was predicted using the DEM, slope, fill, flow direction and flow accumulation maps (Figures 4.4 - 4.9) respectively. LS values ranged between 0 to 42. LS factor map was developed and shown in Figure 4.9.

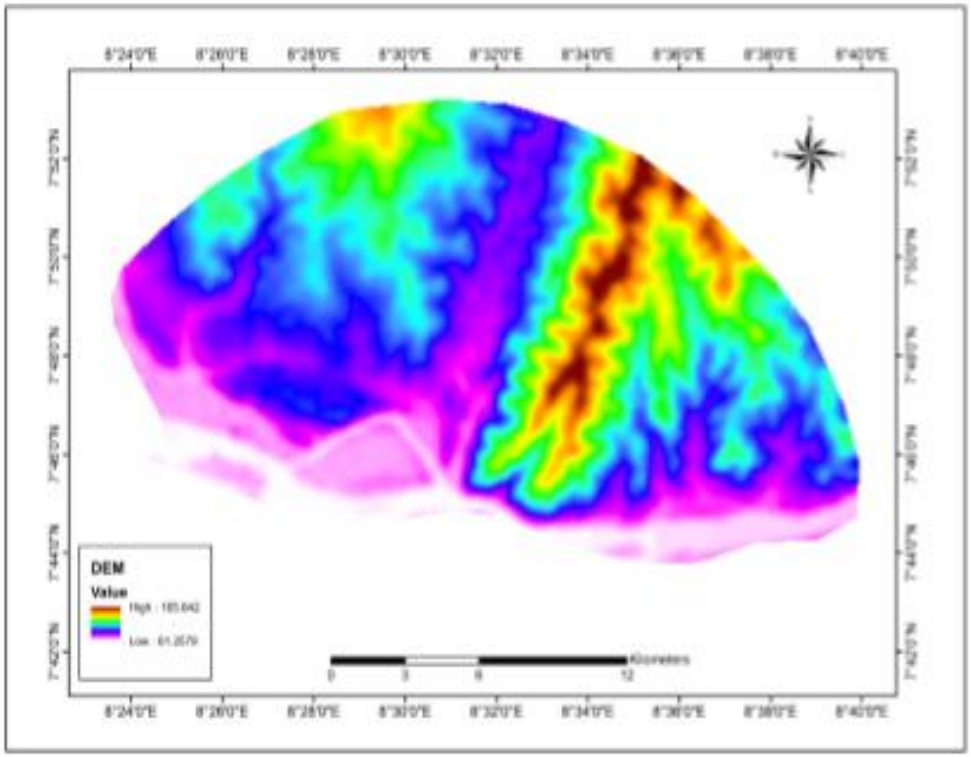

Fig 4.4: DEM

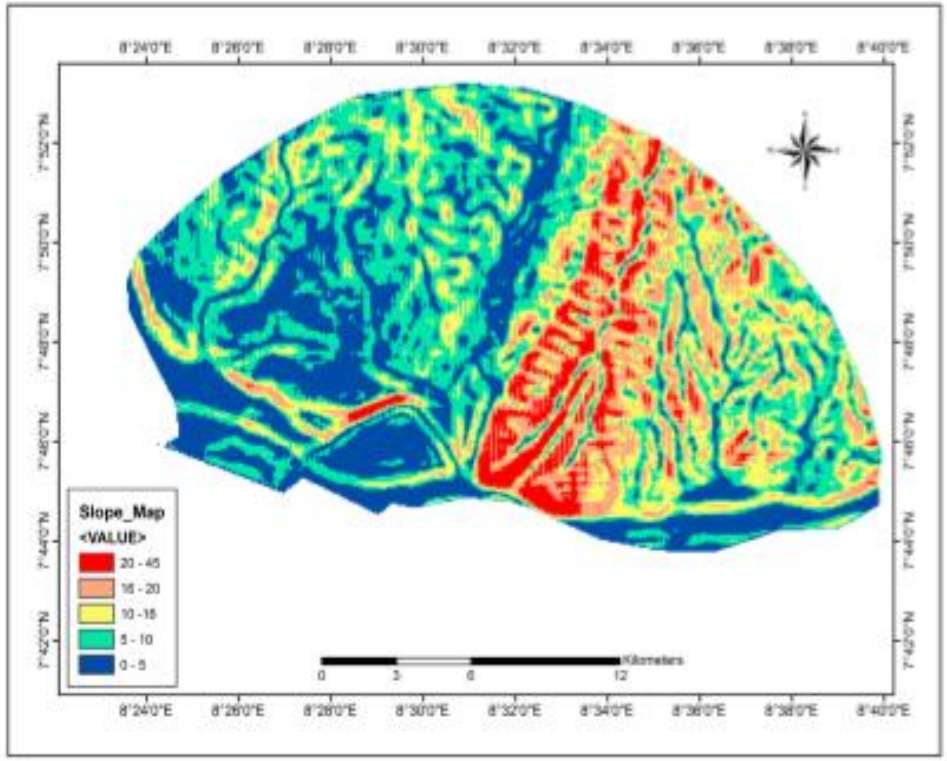

Fig 4.5.: Slope Map

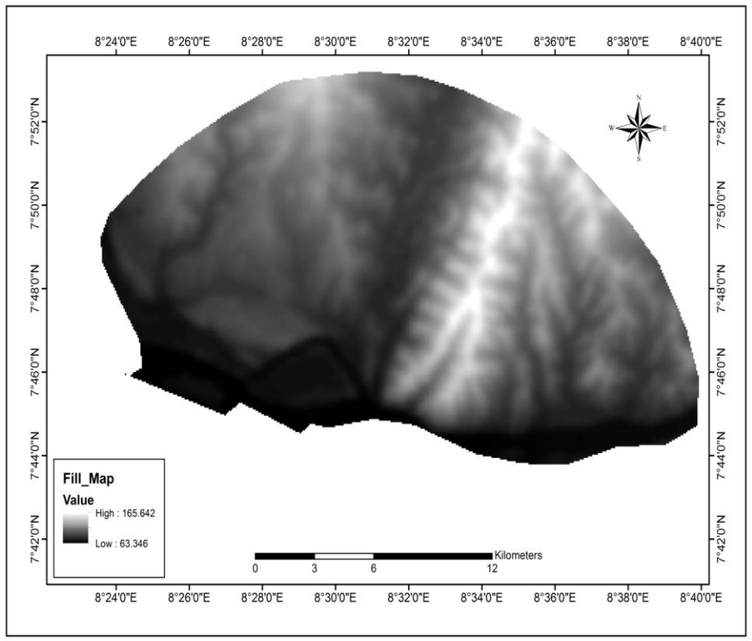

Fig 4.6.: Fill Map

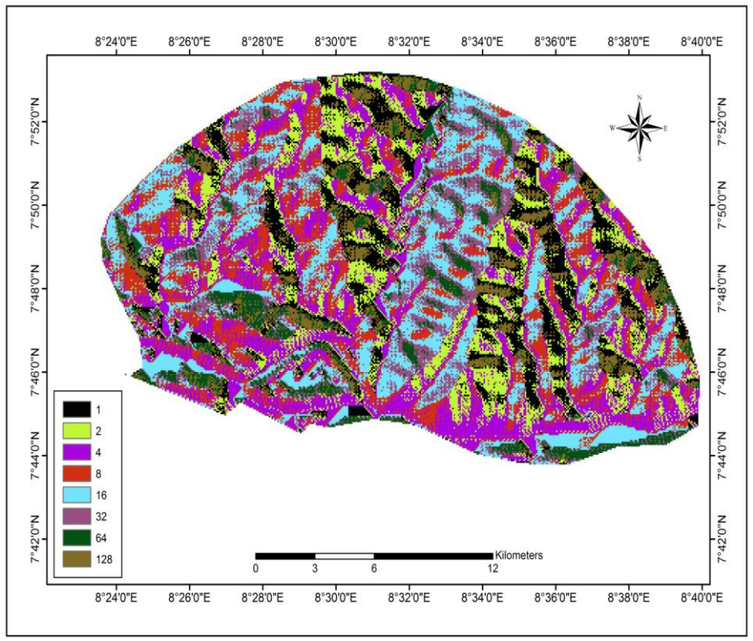

Fig 4.7: Flow Direction

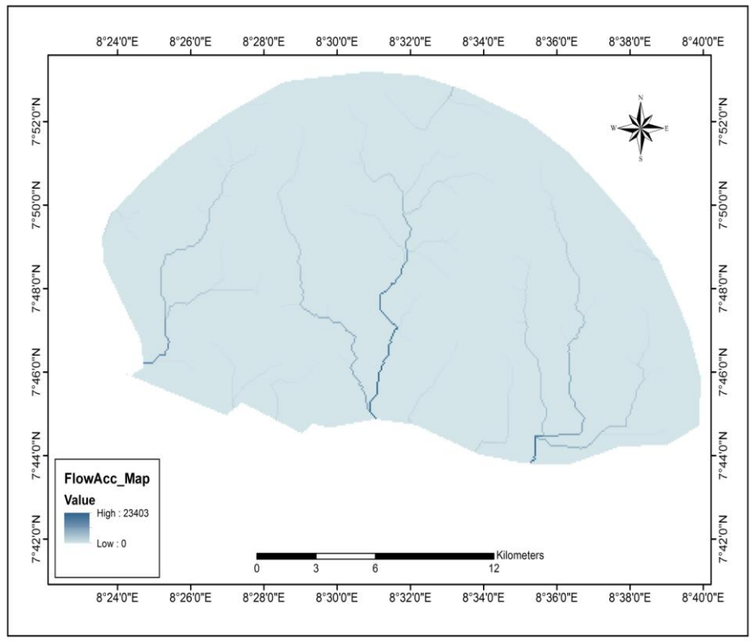

Fig 4.8: Flow Accumulation

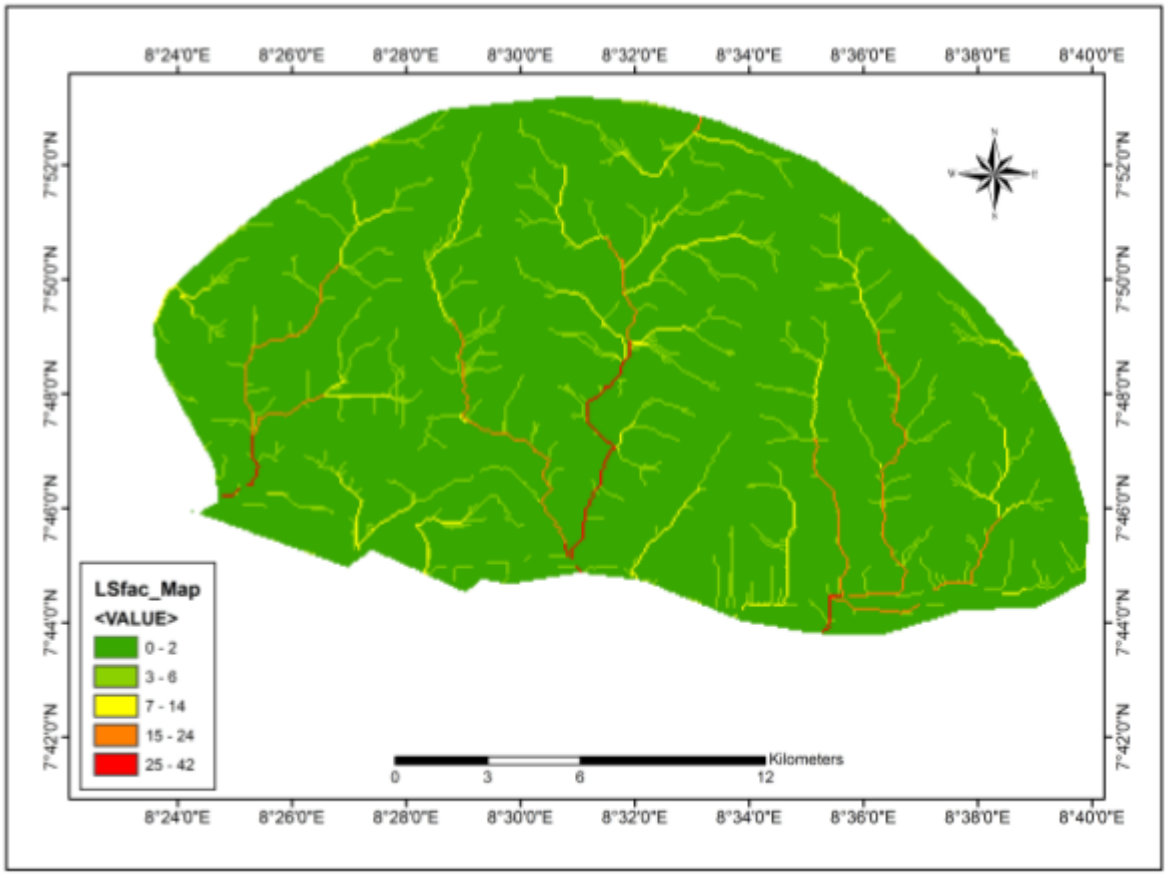

Fig. 4.9: LS factor Map

4.3.4 Cover Management Factor (C)

The Land use classification map of the study area was used in the estimation of Cover management and support practice factors as described in sections 3.3.7 and 3.3.8 of the previous chapter. Table 4.5 shows the classes of land use for northern Makurdi and their area covered in hectares and square kilometers.

Table 4.5: **Land Cover Class and Area covered for Northern Makurdi**

Land Cover Type	Area (hectares)	Area (km^2)
Water Body	1657.62	16.58
Urban	4082.31	40.82
Forest/Vegetated area	7349	73.49
Crop Land	14310.96	143.11
Waste Land	10225.24	102.25
Total	37625.13	376.25

Source; Authors Analysis, (2015)

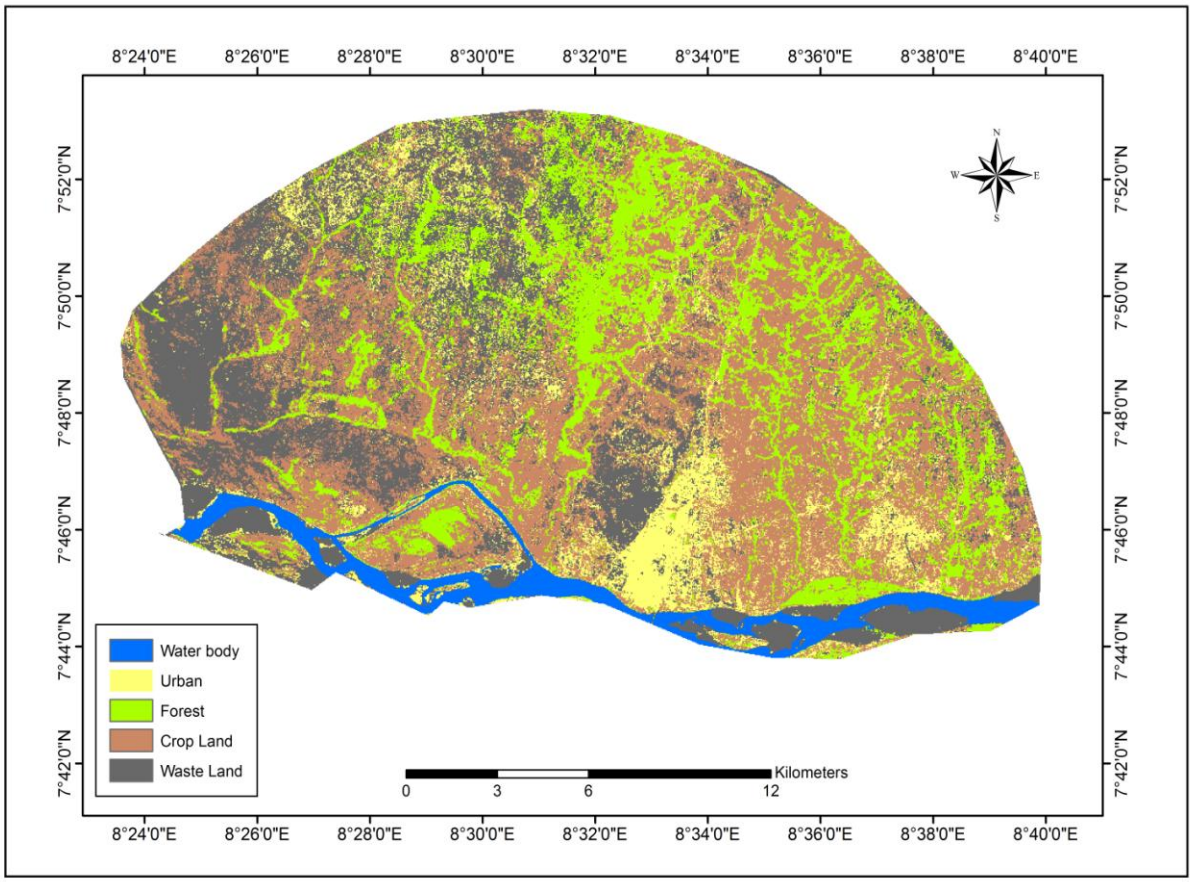

Fig. 4.10: Land Use Classification Map

The cover management factor (C) of the study was calculated based on (Roose 1977; Singh, Ram and Chandra, 1981; Narain, Khybri, Tomar and Sindhwal, 1994) described in section 3.3.7 and Table 3.6 of the previous chapter. This is shown in Table 4.6

Table 4.6: C factor for Northern Makurdi, Makurdi

Land Use	C Factor
Urban	0.05
Water Body	0.00
Forest	0.003
Crop Land	0.4
Wasteland	0.7

Source; Authors Analysis, (2015)

The C factor map of the study was developed as shown in figure 4.11

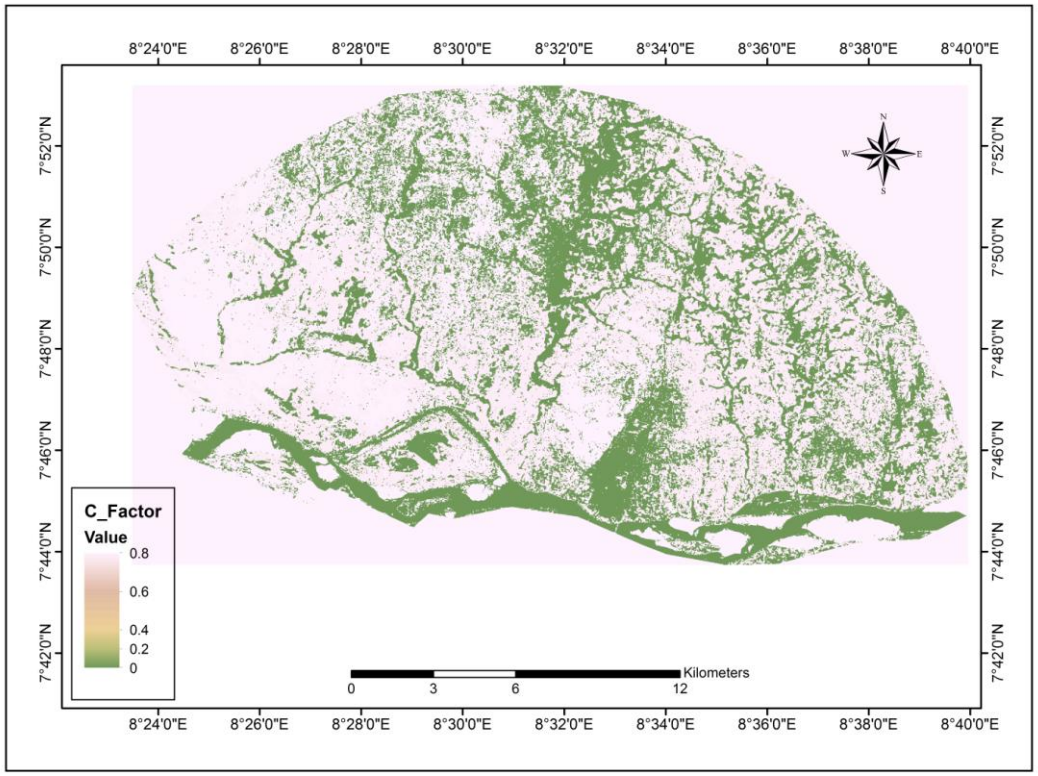

Fig. 4.11: C Factor Map

4.3.5 Support Practice Factor (P)

The support practice factor (P) of the study was estimated based on the (Troeh, Hobbs, & Donahue, 1999) described in section 3.3.8 and Table 3.7 of the previous chapter. For this study, P values were chosen based on the land use instead of slope and cultivation method and is depicted in Table 4.7. The theme was converted from vector form to grid form with the cell size of 20m. The map generated is shown in Figure 4.12.

Table 4.7: P Factor for Northern Makurdi, Makurdi

Land Use	P Factor
Urban	0.9
Water Body	0.01
Forest	0.1
Crop Land	0.4
Wasteland	1

Source; Authors Analysis, (2015)

The P factor map of the study was developed as shown in figure 4.12

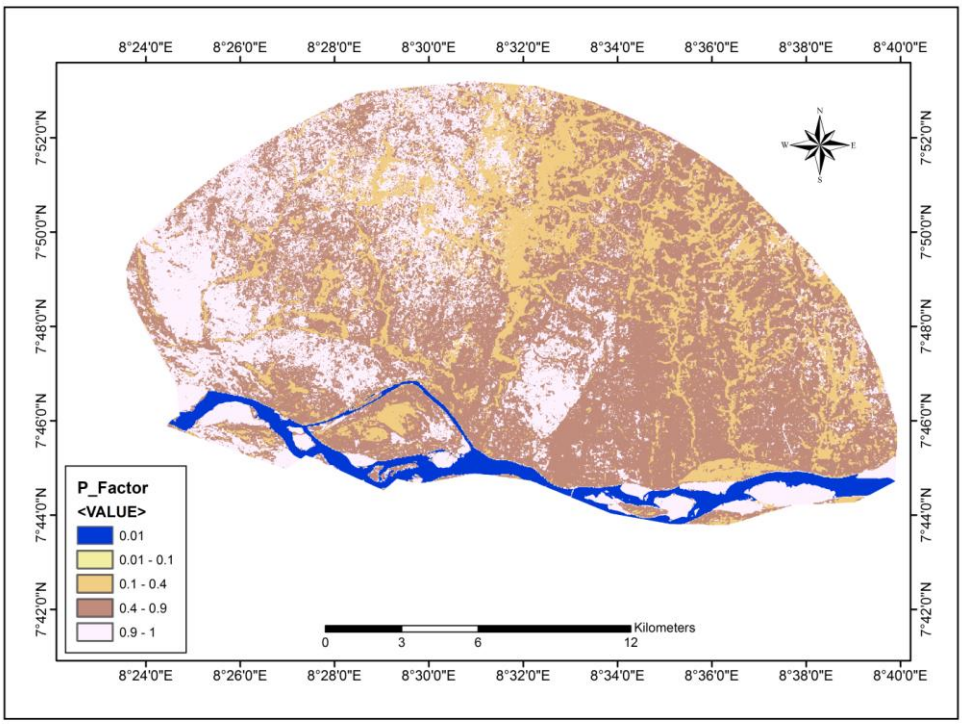

Fig. 4.12: P Factor Map

All the computed factors were substituted in equation 1 to produce the soil erosion map of Makurdi North shown in Figure 4.13.

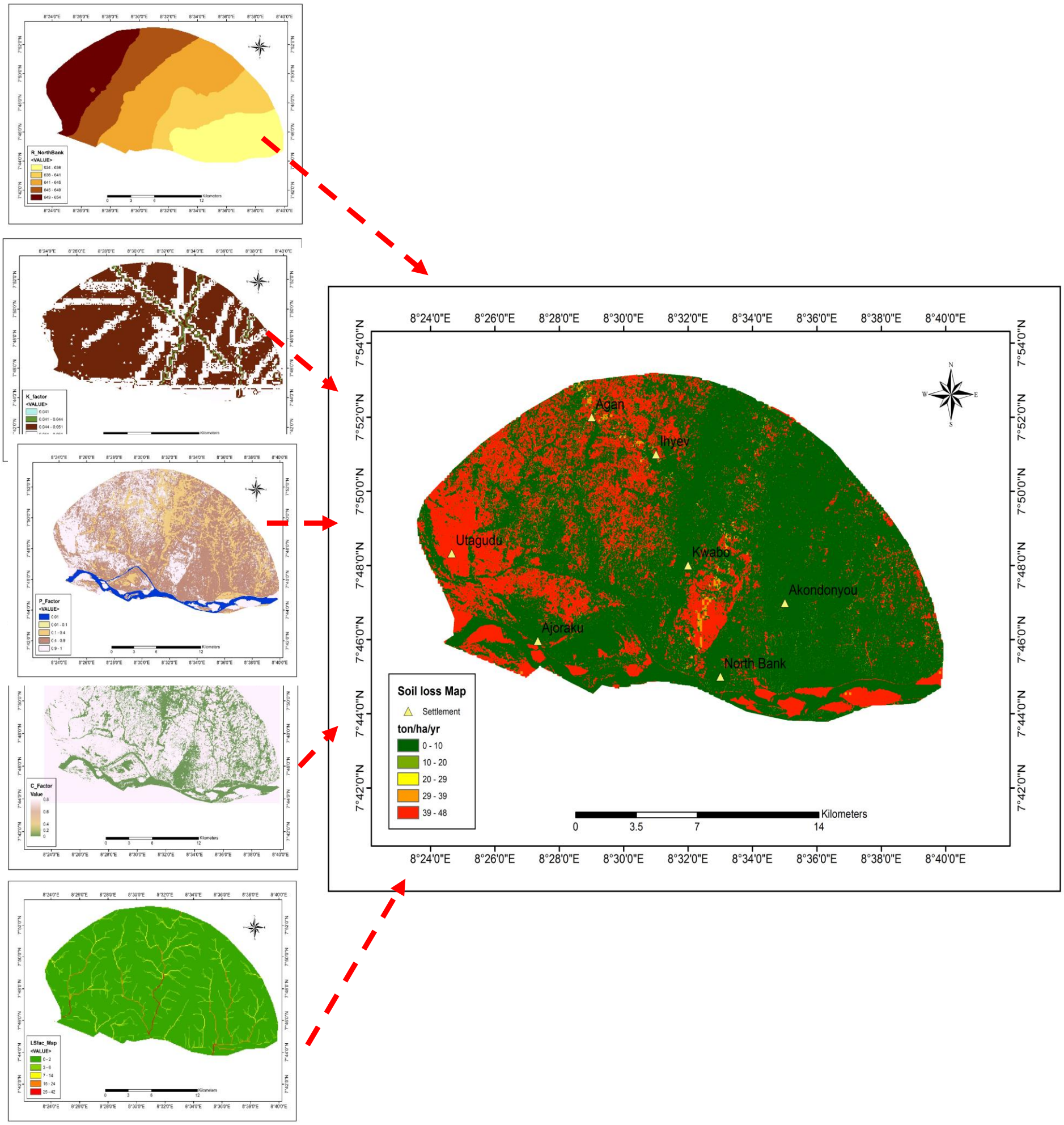

Fig 4.13: Soil Loss Map

The Soil erosion Map (Fig 4.13) of Northern Makurdi showed flashes of yellow, orange and red, which indicate high, very high and severe erosion sites. Annual average soil loss rate using the RUSLE model ranged between 0 to 48 ton/ha/yr. as generated by the multiplication of the input factors.

From Fig 4.13, it can be seen that the waste land and crop lands were mostly eroded. This can be attributed to the high rainfall and less vegetation cover to protect the soil. Also there were traces of erosion within forested/vegetated areas but due to the cover of vegetation it halted the spread of erosion within these areas. There are signs of erosion within the urban areas and sites close to the water body. The soil loss in the vegetated areas can be attributed to logging activities. When the area is deforested, leaving the land exposed and bare, the C and P (Tables 4.6 and 4.7) value become high posing huge erosion risks. A histogram of the Soil loss Map generated shown in Fig 4.14.

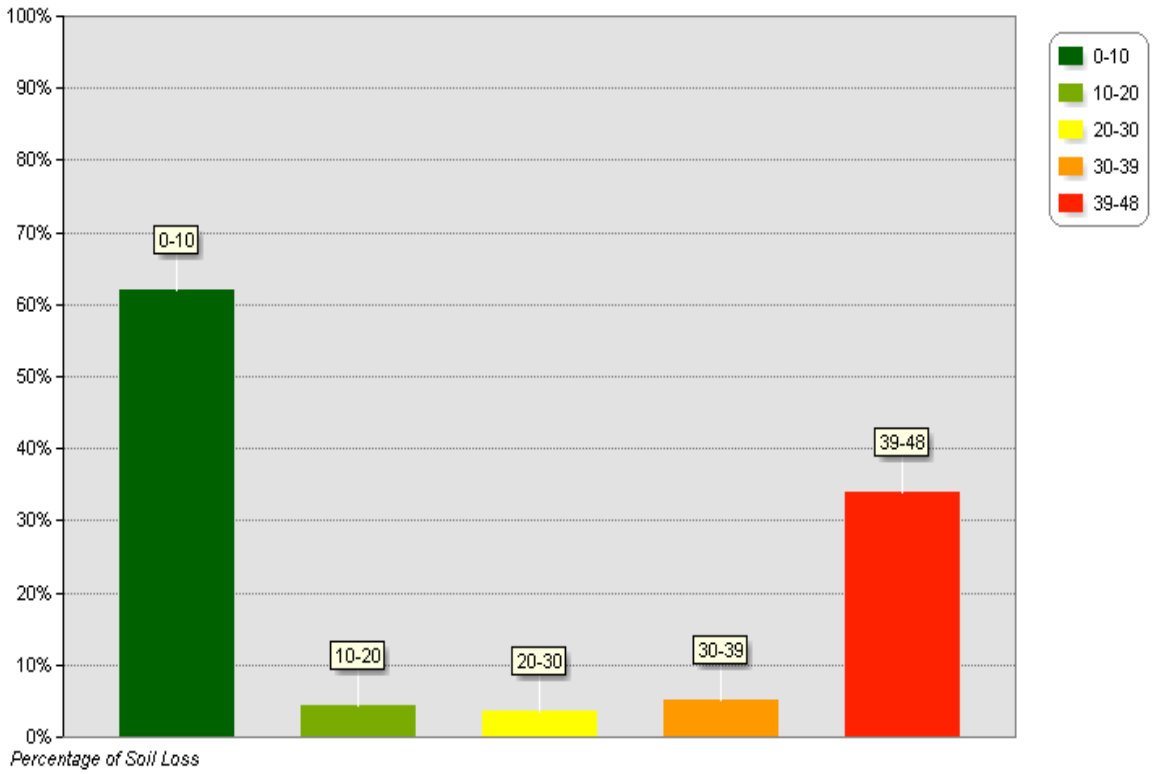

Fig 4.14: Histogram of Soil Loss Rate
Source; Authors Analysis, (2015)

From the Figure 4.14 the area covered by 0-10 ton/ha/yr. of estimated soil loss falls in an erosion class 1 of erosion potential category low (Table 4.2) makes up 62% of the study area, the area covered by 10-20 ton/ha/yr of estimated soil loss with an erosion class 2 falls within an erosion potential category (Moderate) makes up less than 5% of the study area. Areas covered by 20-30 and 30-39 ton/ha/yr. of estimated soil lost cover about 10% of the study. The area with the highest erosion potential (39-48 ton/ha/yr) category 5 classed as severe this implies high rate of soil erosion for about 34% of the study area.

4.4 Distribution of Erosion Sites Within the Study Area

The estimated soil losses were higher at Utagudu, parts of Agan, North Bank, Ajoraku and Ihyev settlements as seen in the Soil Loss Map of the study area (Fig 4.13). It is depicted by the Red Colour. The high soil loss values for these areas are attributed to the combined effects of the various factors affecting erosion at each settlement especially the high R factor values recorded at Utagudu. Other categories of erosion (moderate, high and very high) can be found in some parts of Agan. In Ajoraku and North Bank, the LS factor may have had an overwhelming effect than others. At Akondonyou, some parts of North bank and Kwabo areas seemed to record low losses which was largely due to the evenness of the topography, crop cover C and support practice factor P. This can be attributed to more surface cover from developed urban environments, less logging, less open spaces and the urban factor. Areas with a vegetal cover or some form of covering which could be infrastrsucture, buildings etc. can reduce the impact of erosion on the surface soil. This notwithstanding does not exclude the urban areas from any of the types of erosion especially gullies.

CHAPTER FIVE: SUMMARY, CONCLUSION AND RECOMMENDATIONS

5.1 Introduction

This chapter highlights the summary of the study. The general objective of the study was to determine the major causes of soil erosion within northern Makurdi and the distribution of erosion within the study. In attaining this objective the findings of the study have specifically described the causes of soil erosion in a period of 2003 to 2012 and the amount of soil lost within the temporal scope.

5.2 Summary of Findings

This research applied Remote Sensing and GIS techniques in erosion risk modeling in Northern Makurdi. The study was carried out in order to determine the major factors causing soil erosion the study area. The annual average soil loss for the study was estimated using the Revised Universal Soil Loss Equation (RUSLE) model. Furthermore places with severe, very high, high and low soil loss were mapped and analyzed. The findings from the analysis include:

i. The major causes of soil erosion within the study area are the erosivity of the rainfall, low cover management and support practice. This may be adduced to the high rainfall within the study (1150.60mm), forms of agricultural practices which leaves the surface open and rapid urbanization within the study.

ii. The estimated average annual soil loss for the study area ranged from 0 to 48 ton/ha/yr. The estimated soil losses were higher at Utagudu, parts of Agan, North Bank, Ajoraku and Ihyev settlements, Akondonyou, some parts of North bank and Kwabo areas recorded low losses.

iii. About 62% of the study area suffered low erosion, less than 15% of the study with moderate and high erosion and 34% of the study suffered severe erosion.

iv. Land use mostly affected by very high and severe erosion are the waste land and the crop lands. The urban and vegetated/forested areas were least eroded or had low to moderate erosion though there are signs that the vegetated areas may be experiencing high erosion.

5.3 Conclusion

Highly erosive rainfall, poor cover management and support practices, deforestation and land clearing in Northern Makurdi for agricultural, urbanization and infrastructure development have resulted in widespread soil erosion over the land surface. The extent of soil erosion occurring in the area is still increasing and is now a major cause for concern. The RUSLE model was combined with RS and GIS techniques to analyze the annual average soil loss rates caused by the various factors which influence soil erosion: rainfall, soil erodibility, topographical factors and the cover and support practices within the study and to evaluate the spatial distribution of soil loss rates under different land uses. From the results of the study, it can be concluded that combination of rainfall, lack of cover for the surface soil, were the major causes of soil loss in the study area.

5.4 Recommendations

Based on the findings of this research, the following recommendations are proffered:

i. Agricultural practices like strip cropping, contouring, terracing, cover cropping and mulching can be employed by the farmers so as to protect bare land and agricultural land, also environmental degrading practices such as deforestation, bush-burning and clearing land for urbanization should be controlled. The Benue State Ministry of

agriculture should establish a land conservation unit to handle issues relating to deforestation and to educate farmers on proper agricultural practices to embark on and also for the state government to place checks on uncontrolled urbanization

ii. Accurate prediction of certain RUSLE input factors can be complemented by the Benue State Ministry of Agriculture by accumulating more accurate input data. For example, the values C and P factors were estimated based on landuse. More accurate methods can be developed to arrive at more precise values for these factors especially when employing the RUSLE model at spatial scales. More researches should also be carried out in erosion studies in order to validate input data such that results give a near true expression of the present situation on ground. Also NIMET should establish more rainfall stations to enhance the accuracy of recorded data particularly in the study area.

iii. The Benue State Government should employ immediate erosion controlling measures for areas that suffered severe erosion (Utagudu, parts of Agan, North Bank, Ajoraku and Ihyev settlements respectively). Control measures such as land filling, immediate planting of some of trees and vegetal cover should be taken to stem the spread especially at Utagudu settlement. Also other less forms of erosion should be checked preventing further degeneration.

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