ABSTRACT

Abuja, the federal capital of Nigeria was created when Lagos failed function as the Federal Capital due to the resultant urban problems as a result of land availability. Currently, the rate of implementation of the master plan and urban development is outpaced by the rate of urban growth due to urbanization, as a result exerting a lot of strain on the urban facilities of the city which affects the life of the residents. This study is aimed at identifying suitable site for future sustainable development.

The study evaluates urban growth policies namely; social equity, compact growth and environmental protection into spatial layers as the framework for multi criteria evaluation using geographical information system. The spatial layers are distance to road, distance to central area, distance to educational facilities, distance to green/open spaces, soil, slope, vegetation, natural features, and pollution sites were evaluated and prioritized as per judgement of relevant experts. The influencing weights among the layers were computed using Analytical Hierarchy Process. The overall Consistency Ratio (CR) of the module was (0.04) and fulfilled the tolerable threshold ($CR \leq 0.1$). The Weighted Linear Combination (WLC) function of ArcGIS model builder has been applied to generate suitability map.

The map clearly presents the areas that are suitable for future sustainable urban development and also areas that are not, reducing the possibility of future disaster.

Keywords: Multi criteria evaluation; sustainable urban growth; Abuja; analytical hierarchy process; land suitability analysis; geographical information system.

ÖZET

Nijerya'nın federal başkentiolan Abuja, Lagos'unarazimevcudiyetininsonucuolarakortayaçıkankentselsorunlardandolayı Federal Sermayeolarakişlevgörmediğindeyaratıldı. Halihazırda, anaplanınuygulanmasıvekentselgelişim, kentleşmedenkaynaklanankentselbüyümeoranıylageridekalmaktadır; bununsonucuolarak, kentinkentseltesislerine, sakinlerinyaşamınıetkileyenbirçokzorlamauygulanmaktadır.Bu çalışma, gelecektekisürdürülebilirkalkınmaiçinuygunbiralanınbelirlenmesiniamaçlamaktadır. Çalışmakentselbüyümepolitikalarınıdeğerlendirmektedir; Coğrafibilgisisteminikullanarakçokkriterlideğerlendirmeçerçevesiolaraksosyaladalet, kompaktbüyümevemekânsalkatmanlaraçevreselkoruma.Mekansaltabakalaryollarauzaklık, merkezialanauzaklık, eğitimtesislerineuzaklık, yeşil / açıkalanlarauzaklık, toprak, eğim, bitkiörtüsü, doğalözelliklervekirlilikalanlarıdeğerlendirilmişveilgiliuzmanlarınkararınagöreönceliklendirilmiştir. KatmanlararasındakietkilemeağırlıklarıAnalitikHiyerarşiSürecikullanılarakhesaplanmıştır.ModülüntoplamTutarlılıkOranı (CR) (0.04) idivetolereedilebilireşiği (CR ≤ 0.1) karşıladı. ArcGIS model üreticisininAğırlıklıLineerKombinasyonu (WLC) fonksiyonuuygunlukharitasıoluşturmakiçinuygulanmıştır. Harita, gelecektesürdürülebilirkentselgelişimiçinuygunolanalanlarıvegelecektekifelaketolasılığınıazaltmayanalanlarıaçıkçaortayakoymaktadır.

AnahtarKelimeler:Çokkriterlideğerlendirme; sürdürülebilirkentselbüyüme; Abuja; analitikhiyerarşisüreci; araziuygunluğuanalizi; coğrafiBilgiSistemi.

EVALUATING THE URBAN GROWTH OF ABUJA, NIGERIA USING MCE AND GIS.

A THESIS SUBMITTED TO THE GRADUATE SCHOOL OF APPLIED SCIENCES OF NEAR EAST UNIVERSITY

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Approval of Director of Graduate School of Applied Sciences

Prof. Dr. Nadire Cavus

We certify this thesis is satisfactory for the award of the degree of Masters of Science in Architecture

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Assist.Prof. Dr. Kozan Uzunoglu	Committee Member, Department of Architecture, NEU
Dr. Can Kara	Supervisor, Committee Member Department of Architecture, NEU

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Date:

ACKNOWLEDGEMENTS

I would like to take this opportunity to acknowledge my parents. My mother (Hajiya Zainab Umar Shuaibu) for her never ending love and patience. My father (Alhaji Abdullahi Dattijo Shuaibu) for his unshakable support and guidance. As well as my extended family for their prayers and encouragement throughout my study.

I will also like to acknowledge my beloved fiancée Halima Kabir Doro for the extra ordinary understanding she has shown throughout my study. Not forgetting my dear friend Sadiq Abdu Ali for all the help he rendered throughout the duration of the thesis.

This thesis would not have been possible without the help, support and patience of my principal supervisor, my deepest gratitude goes to Dr. Can Kara, for his constant guidance and encouragement. He has guided me through all the stages of the writing of my thesis. Without his consistent and illuminating instruction, this thesis could not have reached its present form.

Thank you all…

To my family…

ABSTRACT

Abuja, the federal capital of Nigeria was created when Lagos failed function as the Federal Capital due to the resultant urban problems as a result of land availability. Currently, the rate of implementation of the master plan and urban development is outpaced by the rate of urban growth due to urbanization, as a result exerting a lot of strain on the urban facilities of the city which affects the life of the residents. This study is aimed at identifying suitable site for future sustainable development.

The study evaluates urban growth policies namely; social equity, compact growth and environmental protection into spatial layers as the framework for multi criteria evaluation using geographical information system. The spatial layers are distance to road, distance to central area, distance to educational facilities, distance to green/open spaces, soil, slope, vegetation, natural features, and pollution sites were evaluated and prioritized as per judgement of relevant experts. The influencing weights among the layers were computed using Analytical Hierarchy Process. The overall Consistency Ratio (CR) of the module was (0.04) and fulfilled the tolerable threshold ($CR \leq 0.1$). The Weighted Linear Combination (WLC) function of ArcGIS model builder has been applied to generate suitability map.

The map clearly presents the areas that are suitable for future sustainable urban development and also areas that are not, reducing the possibility of future disaster.

Keywords: Multi criteria evaluation; sustainable urban growth; Abuja; analytical hierarchy process; land suitability analysis; geographical information system.

ÖZET

Nijerya'nın federal başkenti olan Abuja, Lagos'un arazi mevcudiyetinin sonucu olarak ortaya çıkan kentsel sorunlardan dolayı Federal Sermaye olarak işlev görmediğinde yaratıldı. Halihazırda, ana planın uygulanması ve kentsel gelişim, kentleşmeden kaynaklanan kentsel büyüme oranıyla geride kalmaktadır; bunun sonucu olarak, kentin kentsel tesislerine, sakinlerin yaşamını etkileyen bir çok zorlama uygulanmaktadır. Bu çalışma, gelecekteki sürdürülebilir kalkınma için uygun bir alanın belirlenmesini amaçlamaktadır.

Çalışma kentsel büyüme politikalarını değerlendirmektedir; Coğrafi bilgi sistemini kullanarak çok kriterli değerlendirme çerçevesi olarak sosyal adalet, kompakt büyüme ve mekânsal katmanlara çevresel koruma. Mekansal tabakalar yollara uzaklık, merkezi alana uzaklık, eğitim tesislerine uzaklık, yeşil / açık alanlara uzaklık, toprak, eğim, bitki örtüsü, doğal özellikler ve kirlilik alanları değerlendirilmiş ve ilgili uzmanların kararına göre önceliklendirilmiştir. Katmanlar arasındaki etkileme ağırlıkları Analitik Hiyerarşi Süreci kullanılarak hesaplanmıştır. Modülün toplam Tutarlılık Oranı (CR) (0.04) idi ve tolere edilebilir eşiği (CR $\leq$ 0.1) karşıladı. ArcGIS model üreticisinin Ağırlıklı Lineer Kombinasyonu (WLC) fonksiyonu uygunluk haritası oluşturmak için uygulanmıştır.

Harita, gelecekte sürdürülebilir kentsel gelişim için uygun olan alanları ve gelecekteki felaket olasılığını azaltmayan alanları açıkça ortaya koymaktadır.

Anahtar Kelimeler: Çok kriterli değerlendirme; sürdürülebilir kentsel büyüme; Abuja; analitik hiyerarşi süreci; arazi uygunluğu analizi; coğrafi Bilgi Sistemi.

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LIST OF ABBREVIATIONS

AGIS: Abuja Geographical Information System

AHP: Analytical Hierarchy Process

AMAC: Abuja Municipal Area Council

ARCGIS: Aeronautical Reconnaissance Coverage Geographical Information System

CGIA: Center for Geographical Information and Analysis

CI: Consistency Index

COHRE: Center on Housing Rights and Eviction

CR: Consistency Ratio

DEM: Digital Elevation Model

ESDC: European Soil Data Center

FCDA: Federal Capital Development Authority

FCT: Federal Capital Territory

FCTA: Federal Capital Territory Administration

GIS: Geographical Information System

IPA: International Planning Associates

LAS: Land Suitability Analysis

LRT: Light Rail Transit

LULC: Land Use Land Cover

MCE: Multi Criteria Evaluation

NPC: National Population Commission

PCM: Pair-wise Comparison Matrix

SERAC: Social and Economic Rights Action Center

SUG: Sustainable Urban Growth

WLC: Weighted Linear Combination

CHAPTER ONE

INTRODUCTION

The inception and building of Abuja occurred mainly in the 80's, replacing Lagos as the Federal Capital Territory of Nigeria afterwards. The main motivation for its creation is the rapid urban growth that made the previous capital (Lagos) overcrowded and congested, the unity of the nation as the country consist of various ethnic and religious groups, and the need for a neutral central symbol (Figure 1.1) for the country (COHRE & SERAC, 2008). Abuja was designed for a population of a little over three million people, similar to many capital cities; the population of people in Abuja is on a tremendous increase. In the 1991 census, the city had a population of about 317,673 people and in 2006 census, the city had a population of about 1,406,2398 people (NPC, 2006). The rapid increase in population, leads to higher rate of urbanization and increased demand for basic amenities and infrastructures. Majority of the main cities in Nigeria like Abuja are experiencing rapid urban and environmental degradation, as there is lack of sufficient infrastructure(s), good maintenance of the existing infrastructures and environmental destructions.

This thesis focuses on identifying suitable sites for sustainable urban growth of Abuja. This entails the integration of GIS and MCE tools to handle site suitability analysis aimed at identifying environmentally safe and economically feasible sites for urban development. This study can further be used as guideline for the development of other states in Nigeria.

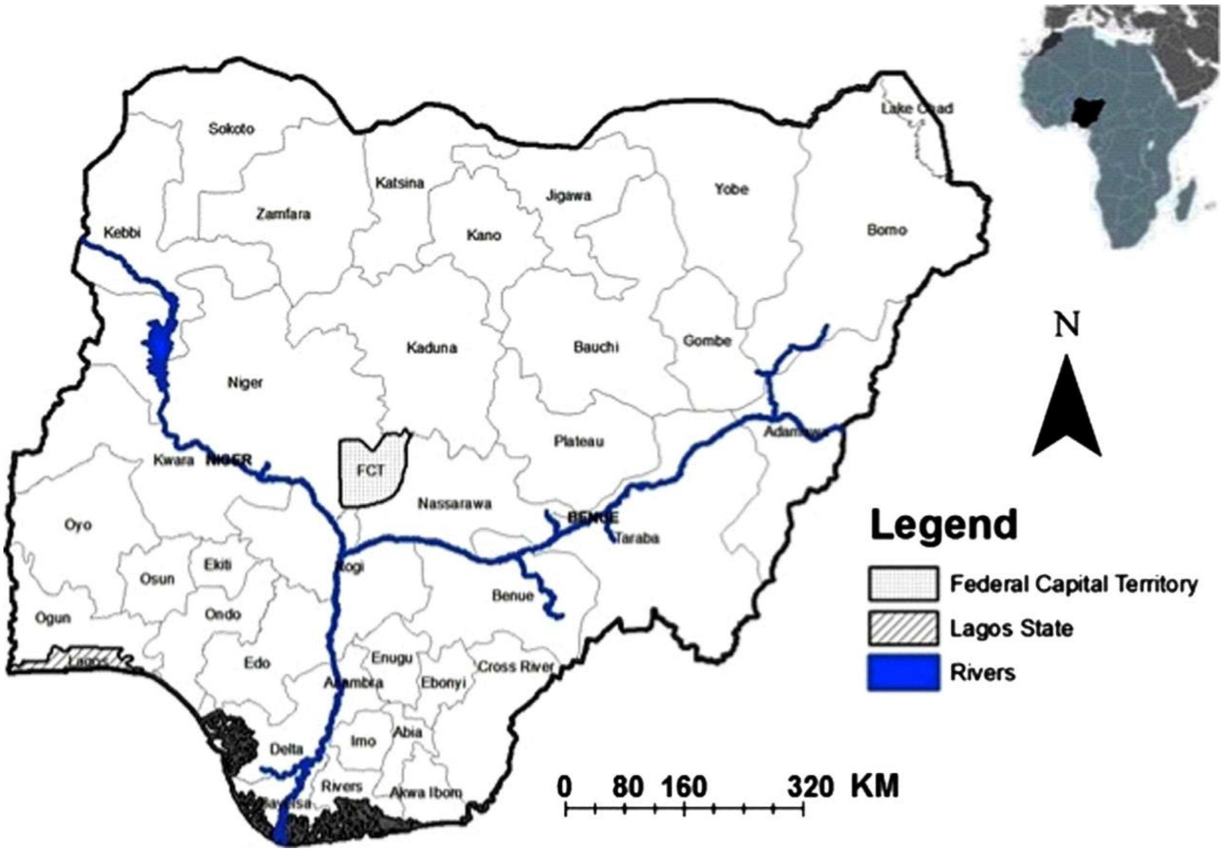

Figure 1.1: Position of Abuja at the center of Nigeria (Abubakar, 2016)

1.1 Thesis Problem Statement

Abuja being the Federal Capital Territory of Nigeria is facing massive urbanization due to the movement of people to the city in search of jobs and better lives. This rapid urban growth is causing major socio-economic and environmental problems that affect the urban life of the people in Abuja. The inappropriate execution of the Abuja master plan resulted in the rapid expansion and increase in the number of settlements.

The rapid increase in urban growth of Abuja caused a massive stress on the city's infrastructure, particularly housing. The massive housing deficit from the influx of people gave rise to rapidly increasing rents, overcrowding, traffic congestion, growth of squatter settlements and homelessness.

1.2 The Aim and Objectives of the Thesis

This study purposes to analyze the urban growth of Abuja using an integrated GIS with MCE. It will help to give better insight into the sustainability of Abuja. The main aim of this research is;

- To assess land use suitability in order to determine the most suitable site for future land use development for sustainable urban growth in Abuja.

The objectives of this research are:

- To evaluate urban growth of Abuja.
- To promote sustainable urban growth in Abuja for better urban management and planning practices in the future.

1.3 The Research Questions

This research proposes to response to the below mentioned queries:

- Which sites are the most suitable for sustainable urban growth in Abuja
- What are the main negative impacts of uncontrolled urban growth?
- What is the relationship between urban growth and sustainability, and the criteria for sustainable urban growth in a city?
- How urban growth modelling tools such as GIS and MCE are used to assess land suitability for urban growth?

1.4 Significance of the Thesis

The lack of strict adherence to the Abuja master plan resulted in the rapid urban growth and expansion of the city, affecting the urban life of the people. The outcome of this study will provide decision makers and town planners in Abuja with information that'll make future spatial planning easier for them. The study will provide a more realistic result for the choices related to urban growth and development. The research findings can also be used as a model for other Nigerian cities and possibly beyond, particularly considering those with similar socio-political and economic environments.

1.5 Scope and Limitations of Thesis

The scope of the research is restricted to evaluating the urban growth pattern of Abuja in order to identify the most suitable alternative for future sustainable development. The research achieves this through the use of GIS and MCE tools to develop and analyze growth models. Therefore sustainability studies as well as urban studies are used to fortify the study.

This study is limited to the Municipal area of Abuja, to serve as the model of sustainable urban growth and development to other cities in the country. But due to the limited documentation of Nigeria as a whole in regards to GIS data, some of the data required for the analysis were mapped out by the author using the base map in ArcGIS.

CHAPTER TWO

THEORETICAL BACKGROUND

This chapter elucidates on sustainable urban growth (SUG) and land suitability analysis. The meaning as well as components of SUG is explained. It also discusses on the meaning of land suitability analysis and how GIS is used for land suitability analysis. Selections of case study examples are used for more clarification.

2.1 Sustainable Urban Growth

Sustainable urban growth consist of two root words; sustainable and urban growth. In order to properly understand the meaning of sustainable urban growth, I'll first define the root words. UN define sustainability; "as any development that meets the needs of the present without compromising the ability of the future generation to meet their needs" (UN, 1987). On the other hand urban growth is defined by UNICEF as "the increase in the number of people who live in towns and cities" (UNICEF, 2012). Therefore, by extension sustainable urban growth is any change in the urban demographics that suits the present without having impact on the resources in a manner that it'll affect the forthcoming generation negatively. As more people move into the urban areas, the need for the development of building, structures and infrastructures to cater for the growing population becomes imminent, thereby resulting in urban development.

Sustainable urban growth is derived from sustainable development; Atay (2009) explained that it "refers to the urban growth in which human needs are met equally and efficiently and also ensures the maintenance of this situation and environment for current and future generations living in the urban boundaries". This consists of all-round environmental, economic, social and institutional principles. European environment agency (EEA, 1995) recommends the following principles for a sustainable urban development:

- “Environmental capacity”: development in accordance with the environmental capacity.
- “Resilience”: development with ability to withstand or recover from external stress.
- “Reversibility”: development plans should be made in such a way they can be overturned.
- “Efficiency”: maximizing all the land resources and economic benefits.
- “Equity”: equal access to resources and services by all (Kara, 2013).

2.1.1 Components of sustainable urban growth

Sustainable urban growth comprises of three major dimensions namely; environmental, economic and socio-demographic.

- Environmental; this deal with the effect the population exert on the available natural resources including water, food and energy. Therefore, environmental sustainable growth is the measure of the percentage change in population and the use of resources (Turner, 1993).
- Economic; this dimension of sustainable urban growth deals with economic development that can endure for long duration. As defined by Goodland & Ledec (1986) “a pattern of development which optimizes the economic and other societal benefits in the present without jeopardizing the likely potential for similar benefits in the future”. This will encompass the efficient utilization of capital, natural resources and labour.
- Socio-demographic; this dimension of sustainable urban growth covers the optimal size and the balance between the rural and urban area (Portnov & Pearlmutter, 1999).

Spatial planning for sustainable urban growth ensures socio-economic improvement, protection of natural and cultural environment, and promotes even distribution of resources. The development policies to achieve this are reliant on the following:

- Compact development; controls the physical expansion of the urban areas and promotes re-use of old urban sites (brown field). Compact development prevents the use of new land for development, which in turn ensures energy conservation as well as savings in infrastructure cost and dependence on car transportation over long distances. Re-use of old urban sites allows for the integration of varying urban functions with minimal environmental impact.
- Better accessibility; and social equity promotes use of efficient and environmentally friendly transport system, especially public transport. This helps in strengthening compact development and embraces an integrated approach to transport planning. Dependence on car for movement will be greatly reduces while public transport and cycling is promoted.
- Environmental protection; strives to attain the balance between protection and development. It ensures the preservation of areas of sensitive biodiversity as well as environmental resources. This can be achieved through wise and prudent management of environmental resources for the longevity of the ecosystem (Kara, 2013).

2.2 Land Suitability Analysis

"Suitability is a measure of how well the qualities of a land unit match the requirements of a particular form of land use". Therefore, land suitability is appropriateness of piece of site for specified purpose, i.e. when a piece of land fits right with the use it is intended for (FAO, 1976).

Misra & Sharma (2015) defined site suitability as a "method of understanding existing site qualities and factors that will determine the location for a particular activity". This entails a thorough evaluation of the environmental resources as well as the features that characterized the site through the use of mapping methods. The end-product of a site suitability analysis is a comprehensive result showing the most suitable to least suitable sites for a specified activity (Misra & Sharma, 2015).

Land suitability analysis is based upon a selection of criteria to analyze how the land will be suitable for specified use (Jain & Subbaiah 2007). For a sustainable urban development, some key factors; LULC, accessibility to transportation network, flood extent and ground water condition are critical for modelling suitability site (Sunil, 1998). Ranatunga (2001) Table 2.2 further highlights other suitability factors.

Table 2.1: Important suitability factors for sustainable urban development (Ramatunga, 2001)

Location (physical); suitability, stability and constrain	**Infrastructure; availability, adequacy, quality and consistency**	**Socio-economic factors**
Land availability	Distance from city center and employment	Affordability of housing and services
Soil suitability for development	Accessibility and transport facilities	Land values, land owners and development costs
Environmental conditions (natural hazards such as flooding, land slide, erosion etc.)	Water supply, power and communication	Density, ethnic diversity and socio-economic classes
Topography	Local services such as schools, shopping, market places, administrative and recreational facilities	Development policy

2.2.1 Land suitability analysis with GIS

GIS is a system created with the ability to process; receive, save and analyze all kinds of spatial and geographical data. GIS contain variety of tools that enables the production of interactive queries, evaluation of spatial data, editing of maps and presentation of the final output from these operations (Heywood et al., 2006).

LSA involves the use of criteria of the site to ascertain the area that is most and least suitable for development. Back in the day, such analysis is carried out using a series of transparent maps overlaid so that each map fits over the other in such a way that all shadings and labeling are visible. Such method of analysis is associated with several a shortcoming among which is the limitation in the number of layers that the eye can interpret at once (CGIA, 2005).

The competency of GIS for spatial analysis mitigates the earlier shortcomings of the map overlay method. GIS offers new approach to suitability analysis which allows for easy remodeling with changes in siting criteria, and produces result maps appropriate for presentation. The steps in GIS suitability analysis consist of;

- Determine criteria for analysis
- Define required data
- Decide what GIS operation to be carried out
- Organize the data
- Develop a model
- Run the model
- Evaluate results
- Improve the model where necessary (CGIS, 2005).

2.2.2 Case study examples

The explanation of some case study examples where land suitability analysis using GIS was carried out will be given;

Weldu & Deribew (2016): in this case study, the authors tried to identify the potential sites suitable to fulfill the housing demand in the city of Dire Dawa, Ethiopia. One of the reasons for the selection of this case study is that, both the city of Abuja, Nigeria and Dire Dawa, Ethiopia share the same African geography.

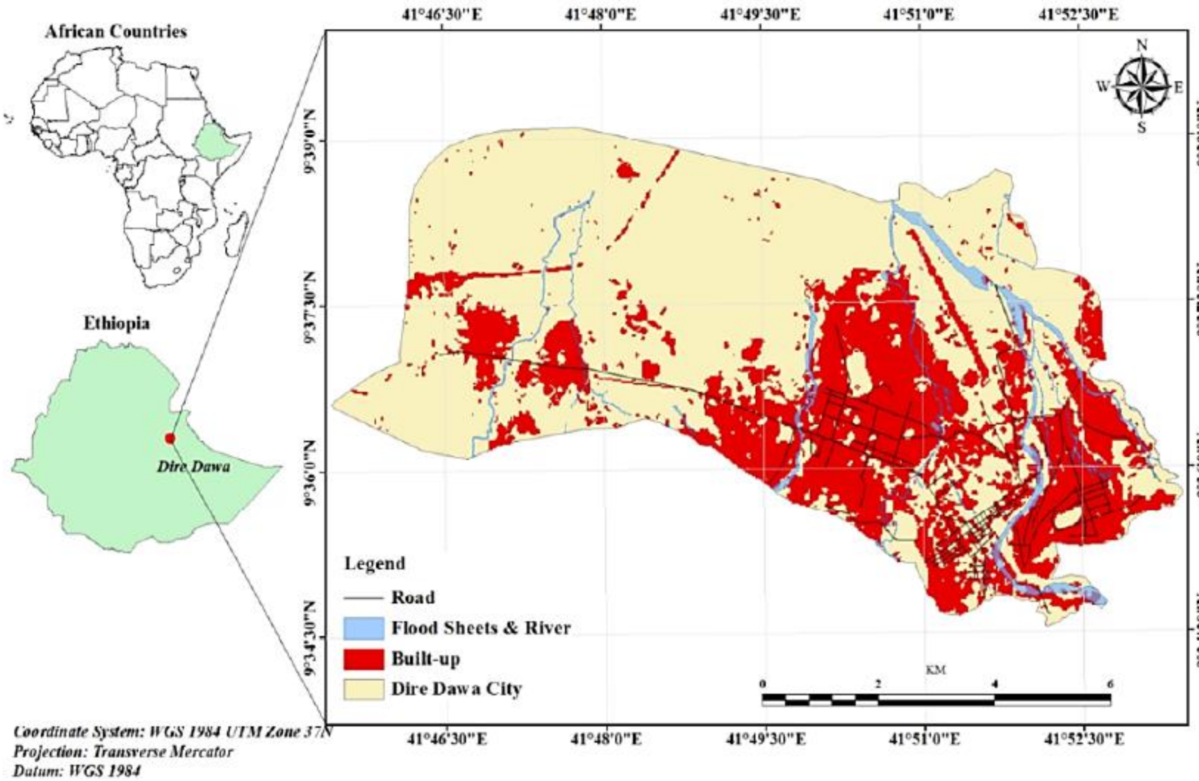

Figure 2.1: Location map of Dire Dawa (Weldu & Deribew, 2016)

Much like Abuja, Dire Dawa is experiencing similar population growth caused by unprecedented urbanization due to the immigration of people to the city for better economic returns. Consequently, this has strained the infrastructure of the city and caused illegal settlements to be built in different corridors of the city, even ignoring topographical factors such as steeper slopes and flood prone areas. The sustainable growth policies used in this case study are environmental protection and socio-economic development.

The authors selected eleven criteria namely slope, land use land cover, accessibility to roads, accessibility to railway, distance from built-up area, proximity to urban center, population density, distance from airport, flood area, aspect (topography) and soil for the evaluation. These criteria were developed into thematic layers using ArcGIS software. With the aid of GIS based AHP, a decision support tool, the thematic layers are computed and attributed weights. The authors performed GIS analysis techniques including buffer, overlay, classification and reclassification for the evaluation. The result was added-up, creating site suitability map in fig 2.2.

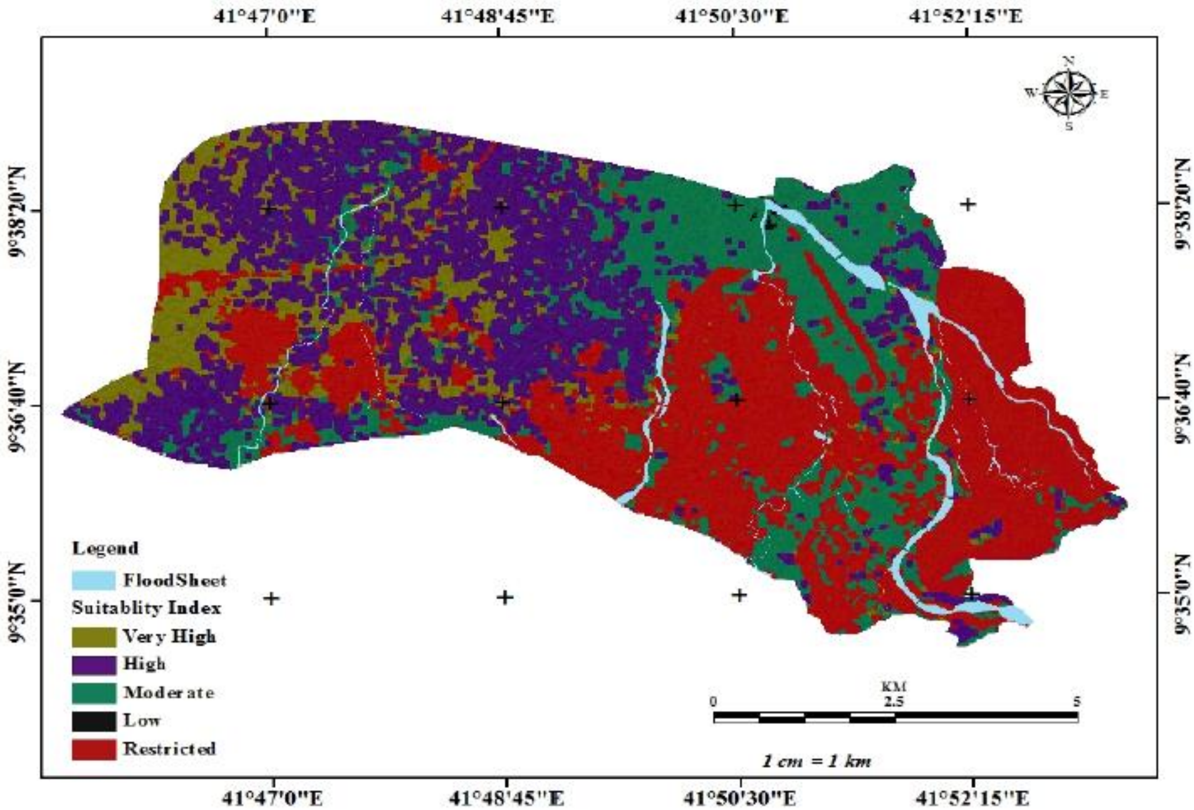

Figure 2.2: Suitability map for housing development in Dire Dawa city (Weldu & Deribew, 2016)

Abura et al (2017): in this case study, the authors used GIS and AHP to determine suitable location for urban growth in Seremban, Malaysia that'll ensure the protection of the ecosystem in the city. One of the reasons for selecting this case study is that, both Abuja and Seremban city are the states capital with similar land area and the economic point of the state.

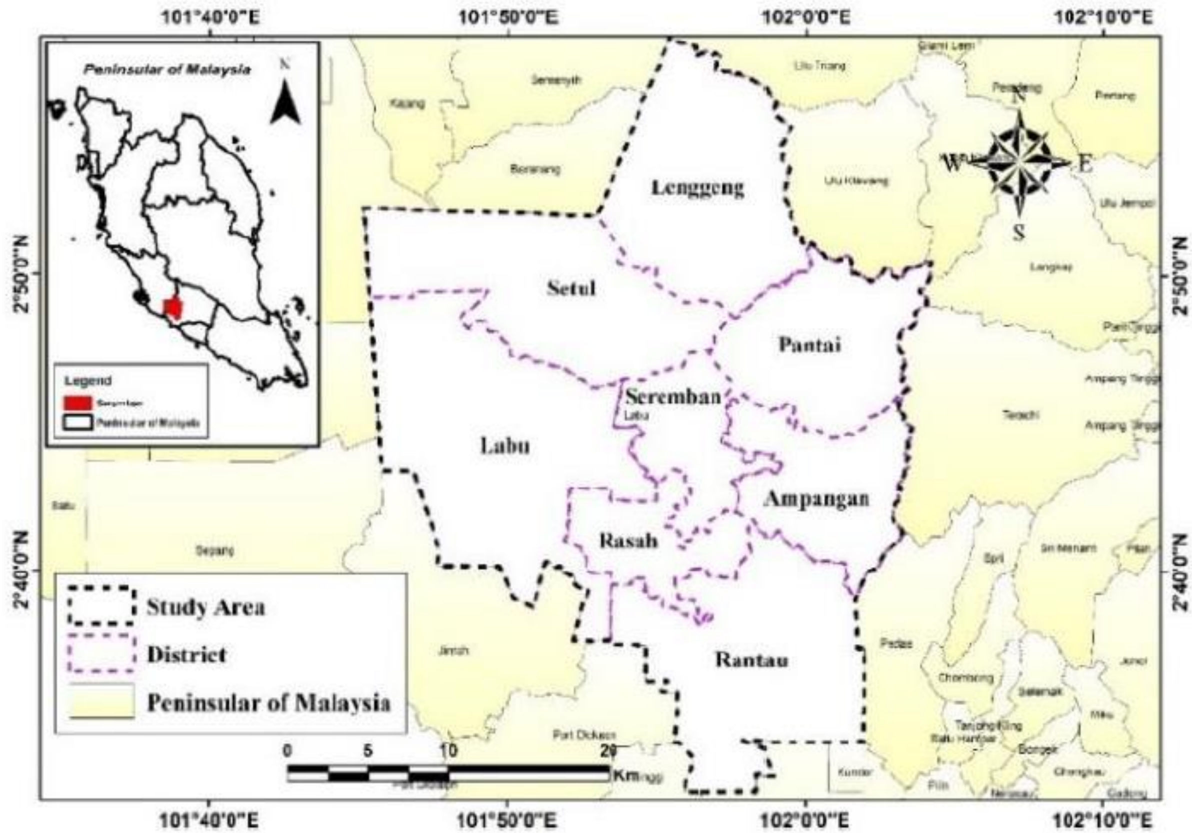

Figure 2.3: Location map of Seremban city (Abura et al, 2017)

Same with Abuja, besides being the largest city in the state, Seremban city is the economic hub of the state and is projected to be the future focal point for development. As a result, the population of the city is projected to double its number in the near future, like the case with Abuja. Furthermore, the city is experiencing a surge of immigrating people from nearby states due to the city's economic prospect and affordability. The authors chose four sustainable growth policies to reach the objective of the study namely; physical factors, environmental factors, utility factors and socio-economic factors.

The authors selected fourteen criteria namely population density, soil, land cover, distance from stream, proximity to roads, slope, distance from highway, proximity to railway, distance from power line, proximity to commercial center, elevation, proximity to educational facilities, proximity to residential houses and distance to industrial areas for the evaluation.

These criteria were computed and assigned scores according to their suitability for urban growth. With the aid of GIS-AHP analysis, the most ideal sites for urban growth in the city of Seremban were identified (Figure 2.4), and the authors utilized GIS tools; union, Euclidean distance, raster calculator, conversion, raster calculator, reclassification and model builder for the research.

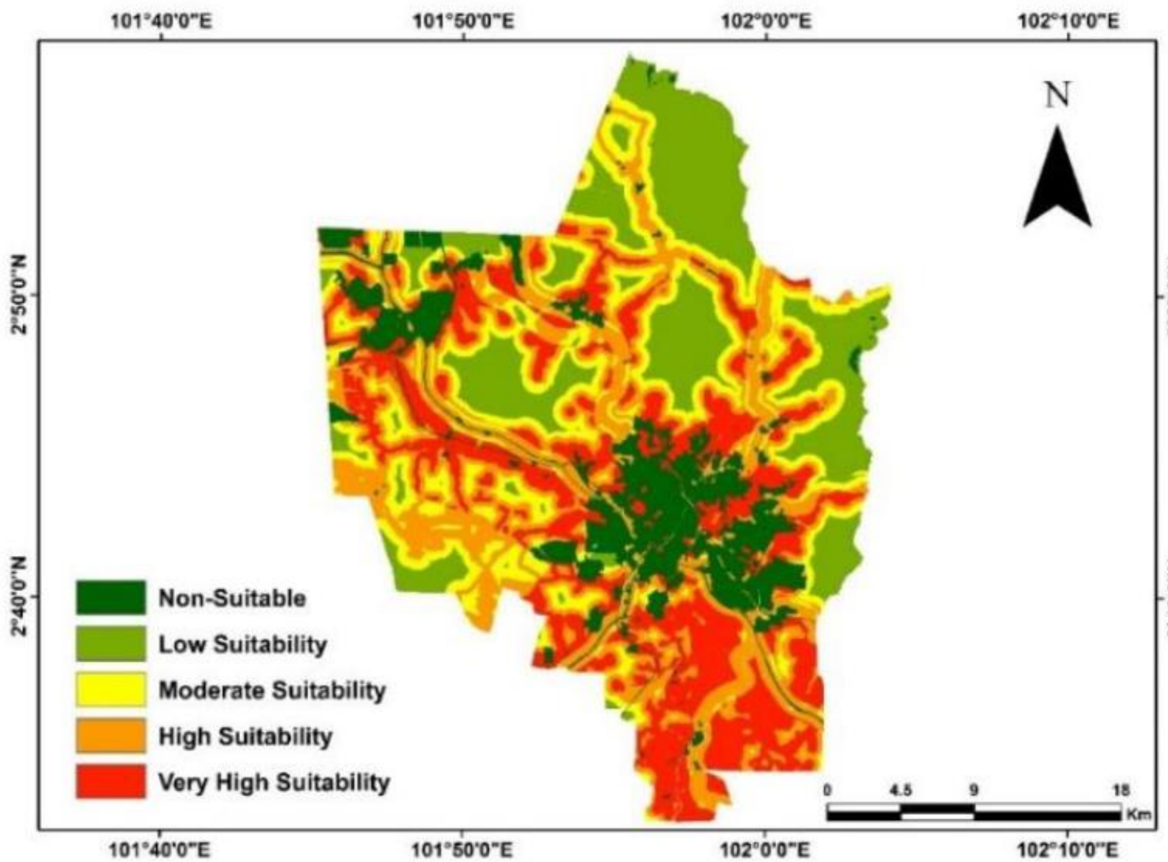

Figure 2.4: Suitability map for urban growth of Seremban city (Abura et al, 2017)

Kara & Akcit (2018): in this case study, the authors used GIS and MCE to generate suitability map for sustainable urban growth and to mitigate possible future disaster in Kyrenia. The reason for selecting this case study is the similarity in sustainable growth approached shared between this case study and Abuja; a development growth that encompasses social equity, environmental protection and compact development.

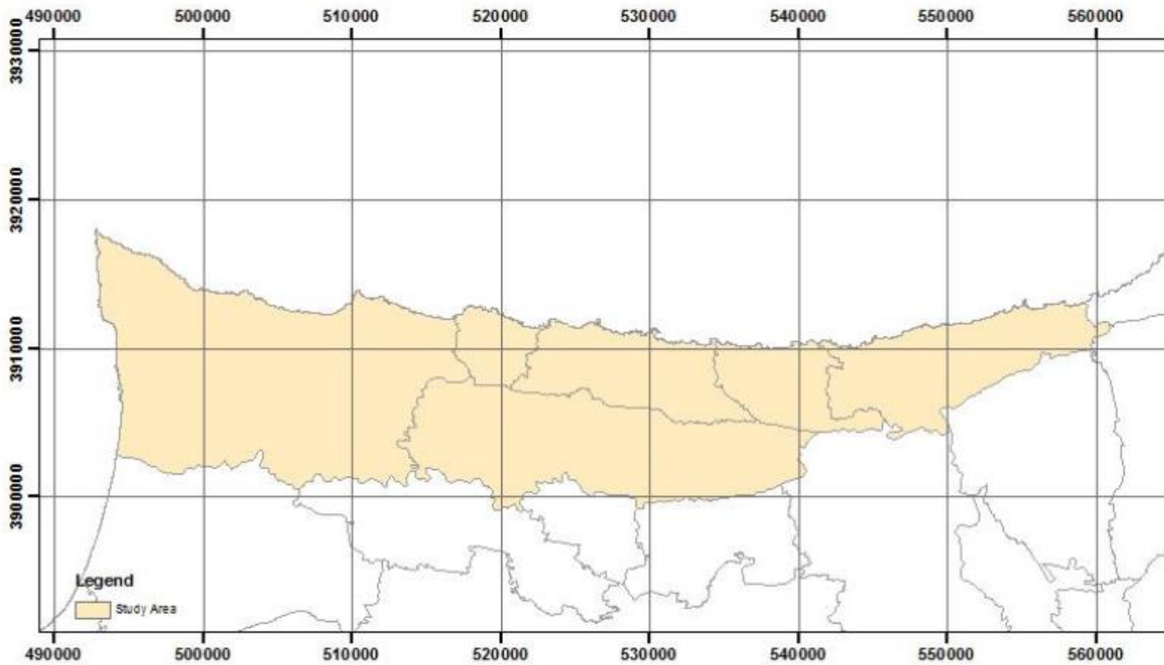

Figure 2.5: Location map of Kyrenia, North Cyprus (Kara & Akcit, 2018)

Much like Abuja, Kyrenia in the past decade has experienced a rapid urbanization resulting in the loss of primary soil, vegetation, haphazard housing, and decline in ease of access to social services and green spaces. The authors evaluated urban growth policies namely; environmental protection, compact growth, and equality to services, to developed suitability map (Figure 2.6) using MCE in GIS. The spatial layers are proximity to roads, proximity to city center, slope, soil productivity, vegetation, distance from environmental protected areas (NATURA 2000 sites), and proximity to green/open and distance to educational facilities. The layers are transformed into raster maps assigned with cell value, which was later multiplied with criteria weight. The constrain map was computed with suitability raster maps to obtain the final suitability map.

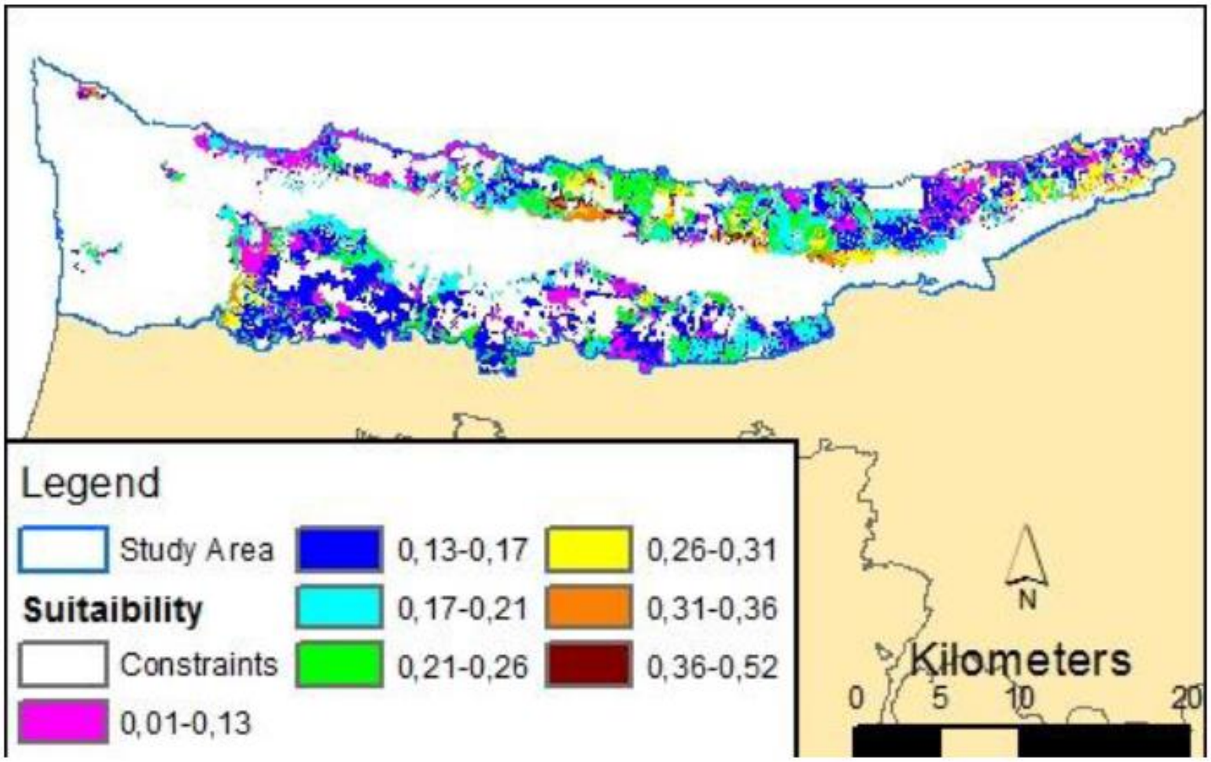

Figure 2.6: Suitability map of Kyrenia, North Cyprus (Kara & Akcit, 2018)

There is great potential in using GIS for evaluating land suitability for sustainable growth. It provides planners with valuable tool for land use planning and future evaluation of rural and urban planning. These case studies show how GIS with AHP can be a significant method for spatial analysis and urban planning.

2.3 Chapter Summary

Sustainable urban growth is to ensure an effective utilization of available resources at the same time while conserving it for the coming generation. This will encompass the economic, environmental and social-demographic aspect. In order to achieve this, effective growth policies such as Compact growth, Social equity and Environmental protection become invaluable. Through these policies, environmental safety, economic feasibility and equal social accessibility can be achieved.

Land suitability analysis is an important aspect of urban planning and land-use management. It provided the bases for the future planning of cities through the process of decision-making in order to prevent spatial disaster. GIS is a computerized solution to the previous map overlay method been used for land suitability analysis. It has modernized the method and eradicated all the errors and shortcomings associated with the method. Therefore, using GIS for land suitability analysis is the most effective way to ensure accurate result and outcome, as shown in the case study examples.

Based off this chapter, it is deduced that those effective growth policies; compact growth, social equity and environmental protection, will be translated into spatial layers – distance to center, distance to roads, slope, distance to education, distance to green/open, distance from pollution sites, soil, vegetation and natural features – in order to carry out the land suitability analysis using the GIS application. The end-product of the land suitability analysis will be a comprehensive map indicating locations that are the most suitable for future sustainable urban growth of Abuja.

CHAPTER THREE

METHODOLOGY

This chapter explains the approach and the Data used for the analysis. GIS as well as the urban growth modeling tools are expounded. Also the data, its use as well as the source are stated.

3.1 Methodological Tools

The methodological tools are the various software tools that are used for the suitability analysis of the sites ideal for sustainable urban growth. Each of the tools are used different part of the analysis. They are explained as follows;

3.1.1 Geographical information system

There has been different description about GIS, but basically it's a computer based tool for organizing, communicating and understanding the science of our world through visualization, mapping and analyzing events on earth. Furthermore, GIS generates information in form of 2D thematic maps, 3D visualization scenes, tables, graphics, diagrams etc. (Kara, 2013).

GIS is powerful application that provides decision-makers with a variety of tools for management and evaluation of spatial data. It can be described as a box with equipment for management of geographic data and to solve multitude of spatial problems. GIS also contains analytical tools intended to help with multi-criteria problems, providing the user with extra useful functionality (Carver, 1991).

Jankowski (1995) cited from McKenna (1980) that there are four steps appropriate for a structured method to decision-making. The use of GIS is most important at the second stage of the decision-making;

- *Problem definition:* problem is identified urging the need for a solution.
- *Search for alternatives and selection criteria:* potential solutions and criteria for evaluating them are established.
- *Evaluation of alternatives:* the impacts of each alternate solution are assessed
- *Selection of alternatives:* alternate solutions are classed from most desirable to least desirable

GIS technology utilizes geographical science with tools for better understanding. It helps people to obtain actionable information from all types of data. Example of the desktop-based GIS software is ArcGIS, which will be used for this study.

3.1.2 Multi criteria evaluation

Malczewski (1999) defined MCE as "a procedure that typically multiplies conflicting and corresponding criteria that are essential to be evaluated in decision-making". It involves choosing an alternative from a group of many options. The selection is dependent on the characteristics of the alternatives, which in most cases are either contradictory or corresponding, called criteria.

Basically, MCE is aimed at analyzing the amount of possibilities to choose from in a multiple of criteria. A big advantage about using MCE is the possibility to evaluate numerous complex factors at different scales to produce a composite suitability map for the intended project. GIS and MCE has been acknowledged worldwide for their outstanding capacity in spatial decision support system in site suitability analysis (Carver, 1991).

The first step in MCE analysis is making an evaluation matrix with elements representing the attributes for the set of alternate choices base on the specified group of criteria. The criteria are combined using weighted linear combination, i.e. each criterion is multiplied with weight value and the result is added-up to obtain a multi-criteria solution, using the equation below (Eastman, 1999).

$$S = \sum_{j=1}^{n} WjXij \tag{3.1}$$

S = suitability

Wj = relative value of criterion j

Xij = normalizing weight of area i relative to criterion j

n = criteria number.

MCE methods used for evaluation of multi-choice solutions are many and varied. Within the frame of this research, AHP is chosen for the analysis.

3.1.3 Analytical hierarchy process

AHP is kind of technique for the evaluation of multiple criteria developed in 1980 by Prof. T.L. Saaty. Saaty (2008) referred it as theory of measurement by means of pair wise comparison that is relative to the decision of professionals obtained by the scale. AHP has become a prominent technique used for evaluating land suitability and has helped planners and decision-makers to scrutinize all necessary data before arriving at a final solution for future land-use (Aburas, 2015).

AHP is a structured approach ideal for use in complex cases of decision making involving competing criteria. It is an effective tool that helps enumerate both the subjective and objective parts of a decision by simplifying the complex choices into a chain of pair-wise comparison for producing the output. It also has a valuable method for testing to make sure the evaluation done by the decision-maker is constant, thereby curbing partiality in the process of decision-making (Mocenni, 2017).

In AHP, complex problems are simplified within a hierarchy arrangement consisting of three levels (Figure 3.1). The top level is main objective, which in this study is sustainable urban growth. The second level presents the main criteria (compact growth, social equity & environmental protection) and the third level presents the alternate solution (the aim of this study) (Kara, 2013).

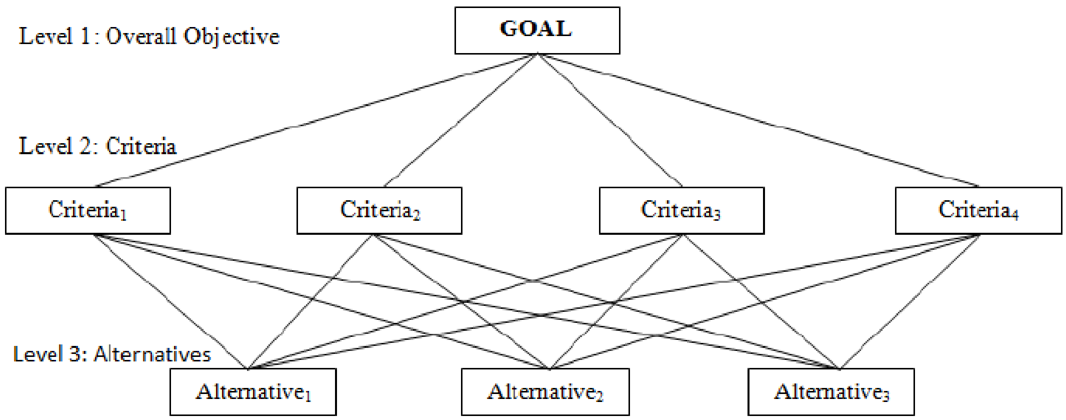

Figure 3.1: AHP hierarchy structure (Agarwal et. al., 2014)

Mocenni (2017) indicates that implementation of AHP is in three following stages:

- *Computing the criteria weights;* PCM is used for computing the values of the different criteria. It is the ways of comparing the relevance of two criteria with respect to each other, helping decision-makers gauge the contribution of every criterion to the overall objective (Appendix 1). As proposed by Saaty, pair-wise comparison is carried out using the scale with numbers 1 to 9 to assign comparative importance (Table 3.1) (Saaty, 2008).

Table 3.1: Pair-wise comparison values (Saaty, 2008)

Level for importance	Translation	Description
1	Exact importance	Criteria are the same in the
2	Slight importance	
3	Moderate importance	A criterion is a little more
4	More reasonable importance	
5	Essential importance	A criterion strongly favored
6	More essential	
7	Demonstrated important	A criterion is preferred more
8	Really essential	
9	Absolutely important	A criterion is completely

Each criterion is compared with others to determine its weight. Therefore, the number of criteria will determine how many comparisons to be made using the formula (3.2) below;

$$\frac{\boldsymbol{n(n-1)}}{\boldsymbol{2}} \tag{3.2}$$

n = number of criteria

- *Computing the matrix of option scores:* after the pair-wise comparison, the Eigen Value and Eigen Vector need to be computed. This is done through normalizing each of the columns of the matrix, after which every column of the matrix is added-up. The numbers from the summation are used to divide each element of the matrix. The normalized Eigen Vector is derived by averaging across the rows of the matrix. The values of the summation from the column of the matrix multiplied with Eigen Vector gives Eigen Value. Summation of all Eigen values is λmax = the greatest Eigen value of preference matrix.
- *Checking the consistency:* this is to check how reliable the decisions have been comparative to the other samples of random decisions. This is done by calculating the CI and CR with the equations 3.3 & 3.4 below;

$$\boldsymbol{CI} = \frac{\boldsymbol{\lambda \max - n}}{\boldsymbol{n-1}} \tag{3.3}$$

CI = Consistency Index

n = criteria number or order of matrix

λmax = greatest Eigen value

$$\mathbf{CR} = \frac{\boldsymbol{CI}}{\boldsymbol{RI}} \tag{3.4}$$

CR = Consistency Ratio

RI = Random Consistency Index

CI = Consistency Index

Table 3.2: *Values of random consistency index (Kara, 2013 cited from Saaty, 1980)*

N	1	2	3	4	5	6	7	8	9	10	11…
RI	0	0	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49	1.51

n = criteria number or order of the matrix

When value of CR is ≤ 0.1 (10%), the inconsistency is satisfactory. But if value of CR is > 0.1 (10%), the inconsistency is non-satisfactory and the expert decision needs to be looked over. Further explanation on the use of AHP is in Appendix 2.

3.1.4 Weighted linear combination

WLC technique is among the most utilized decision model in GIS for obtaining composite maps. WLC is commonly used in suitability analysis, resource evaluation problems and land use selection. The main reason for its popularity is its ease of implementation in GIS with its algebra operations plus cartographic modeling (Malczewski, 2000).

WLC allows for evaluation and combination of criterion to a common numeric range in order to produce a fused output map layer using the equation (3.5) below (Weldu & Deribew, 2016);

$$S = \left(\sum_{j=1}^{n} \boldsymbol{Wi} \times \boldsymbol{Xi}\right) \times \pi \boldsymbol{cj} \tag{3.5}$$

S = suitability index

n = number of criteria

Wi = weight of each criteria i

Xi = Score of the criteria

Cj = constrains

Π = product of constrains (1-suitable, 0-unsuitable)

For this study, the final suitability map will be the result of weights and rated suitability scores of each criterion analyzed in ArcGIS spatial analysis model builder tool.

3.2 Data and Layers

The data needed for the development of the layers used for the evaluation are itemized in the Table 3.3 below, along with the source of the data.

Table 3.3: Data and their sources used for the analysis

Data	Source	Layer
Soil class map	ESDC https://esdac.jrc.ec.europa.eu/content/soils-map-nigeria	Soil
Digital Elevation Model (DEM)	Office of the Surveyor General of the Federation Abuja, Nigeria	Slope
Satellite images	https://remotepixel.ca/projects/index.html#L8ba	Vegetation
Road network, natural features points, educational facilities, green/open spaces, pollution sites, center	The author by means of screen digitization technique	Distance to roads, distance from natural features, distance to education, distance to green/open, distance from pollution sites, distance to center

3.3 Methodological Approach

From literary works, the significant factors that affect the suitability of a site for urban growth were determined. In order to carry out the suitability analysis with GIS-AHP, scores must be assigned to every single factor in accordance to their relevant suitability for urban growth. Therefore, pair-wise comparison matrix using Saaty's nine-level scale was used (Appendix 1), based off expert opinions (Appendix 4). After the formation of the PCM, the factor weights are calculated and CR was used to assess the constancy of expert's opinions (Appendix 3). Consistency ration should be less than 0.1 is acceptable, signifying a rational degree of constancy in the pair-wise comparisons. Using GIS tools, final suitability map was produced.

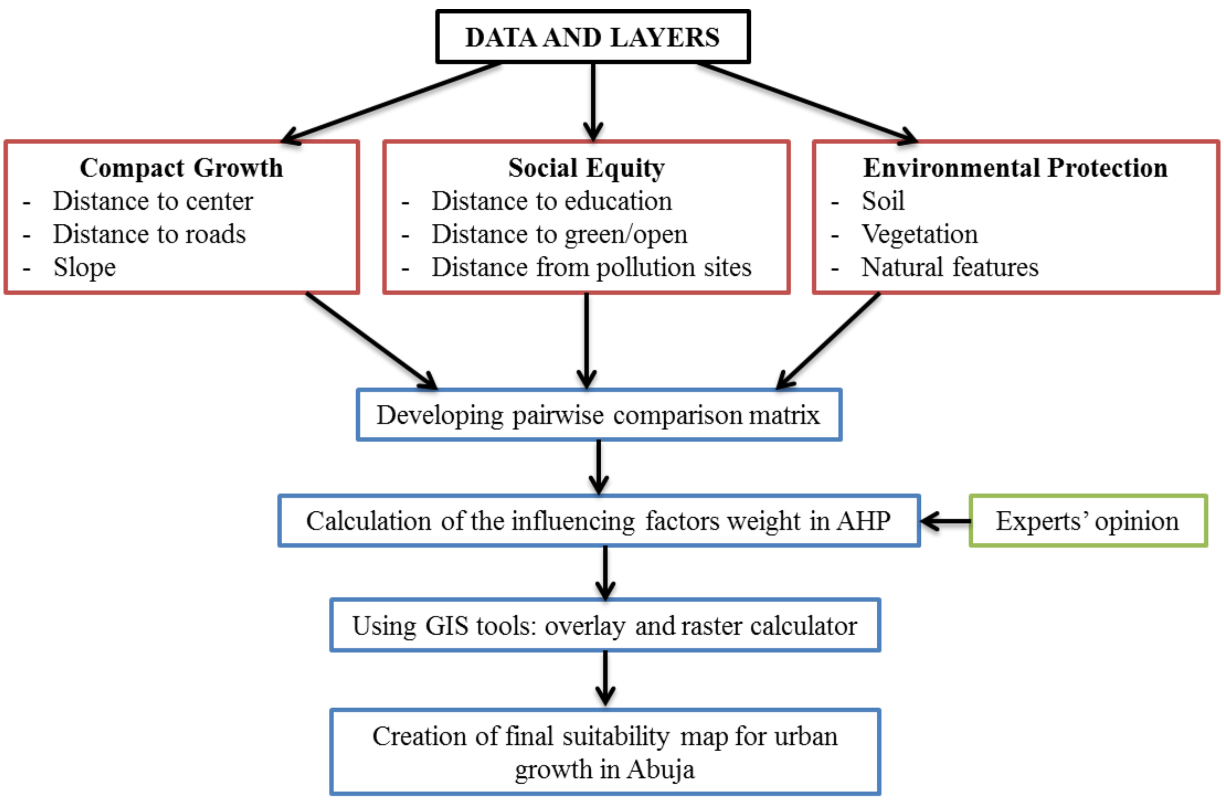

Figure 3.2: Methodological framework for developing land suitability map (Author)

3.4 Chapter Summary

GIS is a modernized solution to problems of spatial analysis which helped to get rid of the errors encountered before. While MCE is a technique that helps a decision maker to overcome any form of uncertainty in the process of decision-making. Therefore, by combining GIS with MCE, the decision-maker will have a solid support system to back him up when carrying out a decision such as site selection or land use allocation

AHP is an example of MCE and it’s used for this study. This is because AHP helps to simplify complex spatial decision process into a series of hierarchy using comparison matrix based off the opinions of experts who have professional or academic knowledge, in such a way that all the criteria are compared with each other in order to determine their level of priority. For this study, using the questionnaire sample in Appendix 1, the input of 12 experts (architect 1, architect 2, environmental engineer, AMAC housing manager, project manager, planning and development surveyor, economist, quantity surveyor, landscape architect, building contractor, transport engineer and town planner) were utilized in the AHP computation.

Based off this chapter, after effective growth policies from chapter two have been translated into spatial layers, AHP technique will be utilized to compute their priority hierarchy which in the end determined how they conclude the final suitability map.

CHAPTER FOUR

STUDY AREA AND APPLICATION OF METHOD

This chapter gives an overview of Abuja and its urban context. Location and master plan of Abuja are explained, as well as the transport network, land use and cost. The issues of rapid urbanization and resultant vegetation loss are explained.

It also explained how the data are analyzed using the stated methodology to arrive at the final suitability map.

4.1 Geographical Background and Location of Study

Abuja is located at the center of Nigeria, northern of the converging point by the country's major rivers; river Niger and river Benue (Figure 1.1). Abuja falls within latitude 9.07^0N and longitude 7.48^0E with a land area of 8,000km^2. Abuja has the savannah vegetation, giving it a rich soil for agriculture and a favorable climate that is neither too hot nor too cold all year round. Abuja also experiences two weather condition; the rainy season (March – October) characterized by prevalent rainfall and the dry season (October – March) characterized by bright sunshine (FCDA, 2018).

Abuja is divided into six area councils; Kuje, Abaji, Bwari, Gwagwalada, Kwali and Municial Area Council (AMAC). The focus of this study is the Municapal Area Council (AMAC) (Figure 4.1). AMAC with land area of 1,769hm^2 is the administrative center with high concentration of secondary and tertiary economic activities. Consequently, the rate of urbanization is high.

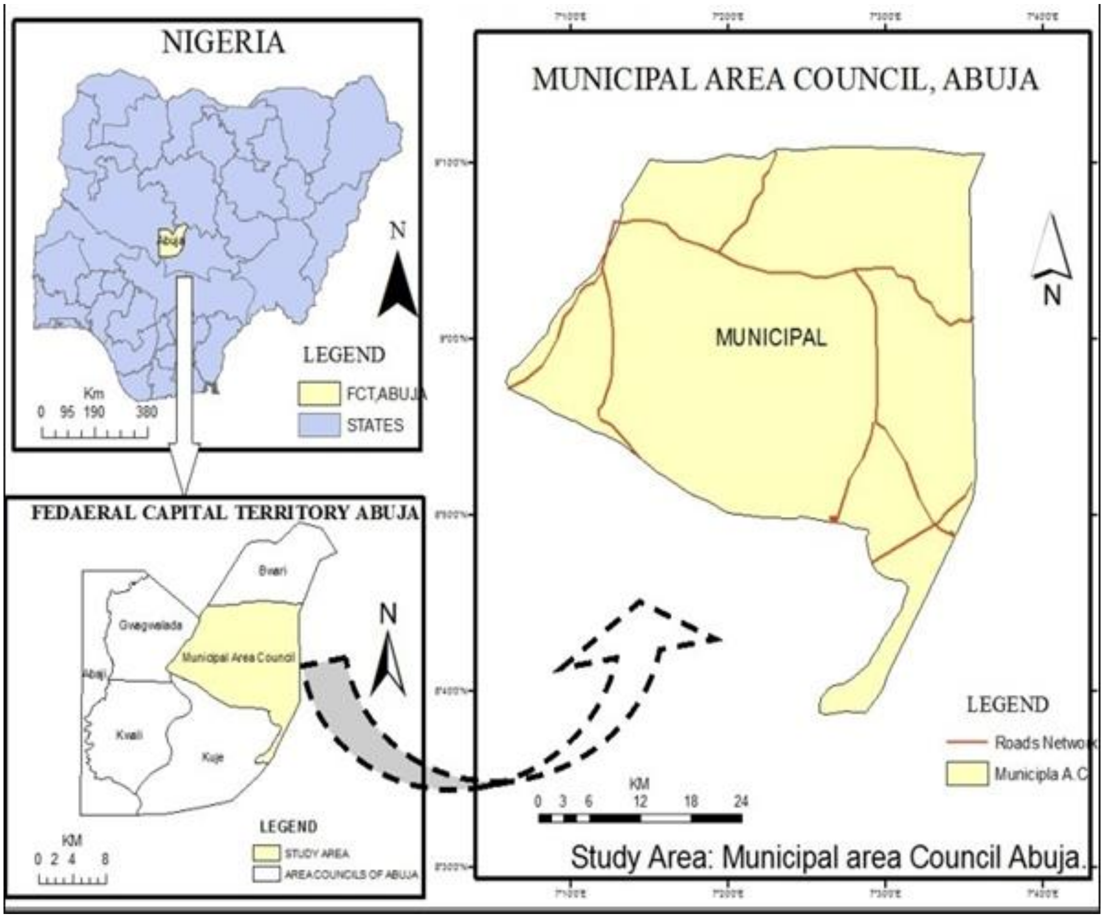

Figure 4.1: Abuja showing the boundary of the study area (Author)

4.2 Master Plan of Abuja

Abuja was designed by IPA (International Planning Associates) a collaboration of design companies from USA namely; Archisystems, Wallace McHarg Roberts & Todd, and Planning Research Corporation (Elleh, 2001). The design was "to offer a long-term direction for the systematic implementation of the Capital City" (Ikoku, 2004). The design was located at the north-eastern part of Abuja (Figure 4.2); it is considered to be the most convenient place for human habitation and development (Fannan et al., 2010). The city was designed to be environmentally smart and well organized for intended population of 1.7 million by 2000 and 3.2 million upon completion (Todd, 1984).

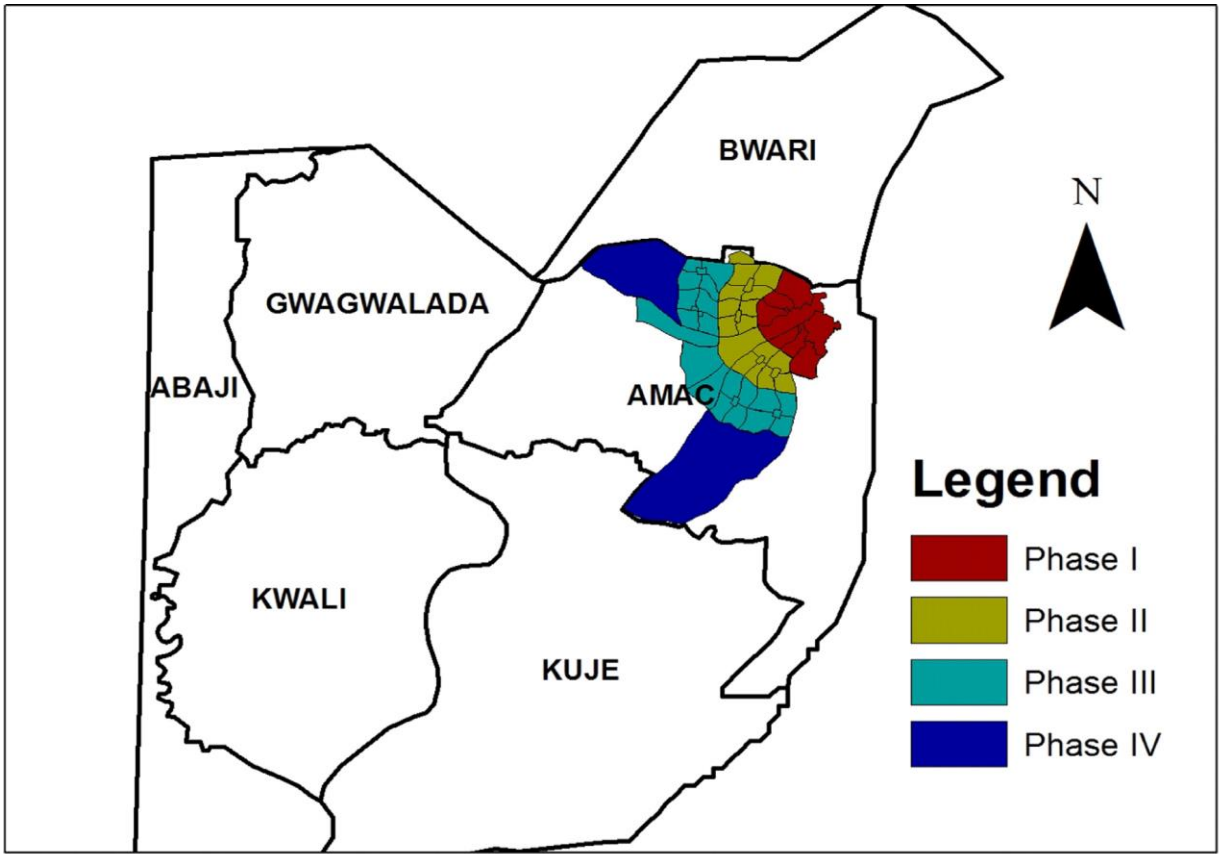

Figure 4.2: The Abuja master plan showing the development phases (Abubakar, 2016)

The master plan proposes the construction of Abuja in four phases, in an urban form shaped like a crescent that radiates outwards from the center. The first phase and some part of the second phase were constructed concurrently at the inception of the city, with the first phase of the plan being completed and contains some vital government agencies such as Presidency, Central Business District, Supreme Court, National Assembly and Cultural Center (which contains Conference Center, National Ecumenical Center, National Library, National Mosque and National Theatre). Also residential areas such as Garki, Asokoro, Wuse, Maitama and Guzape are also in the first phase, while Dururmi, Gudu, Katampe, Utako, Mabushi and Wuye were in phase two. The remaining phases constitute the framework for the systematic development of the satellite towns around the main city (Abubakar, 2016).

The plan presented a development outline for numerous schemes and sectors; housing services, transport network, land use and other infrastructural facilities. Ango (2001) expressed that should diligence be used in the implementation of the Master Plan, it'll produce a city that is environmentally safe, free of congestion, pollution, diseases, social vices and anything that'll affect the quality of life of the people (Ango, 2001).

4.2.1 Abuja transportation network

As a strategy to control traffic congestion, the design of the Master Plan consist of high ways, aerial roads, LRT, and transit buses that link-up the city as well as the satellite settlements (Figure 4.3). However, as a result of rapid urbanization, the City has become congested and driving through or commuting from the satellite towns is such a nightmare. This is especially during the peak hours (early morning & evenings after work) on the express ways towards the city; Abuja-Lafiya Expressway, Umaru Musa Yaradua Expressway (Airport Road) and Kaduna-Abuja Expressway (Usman, 2013).

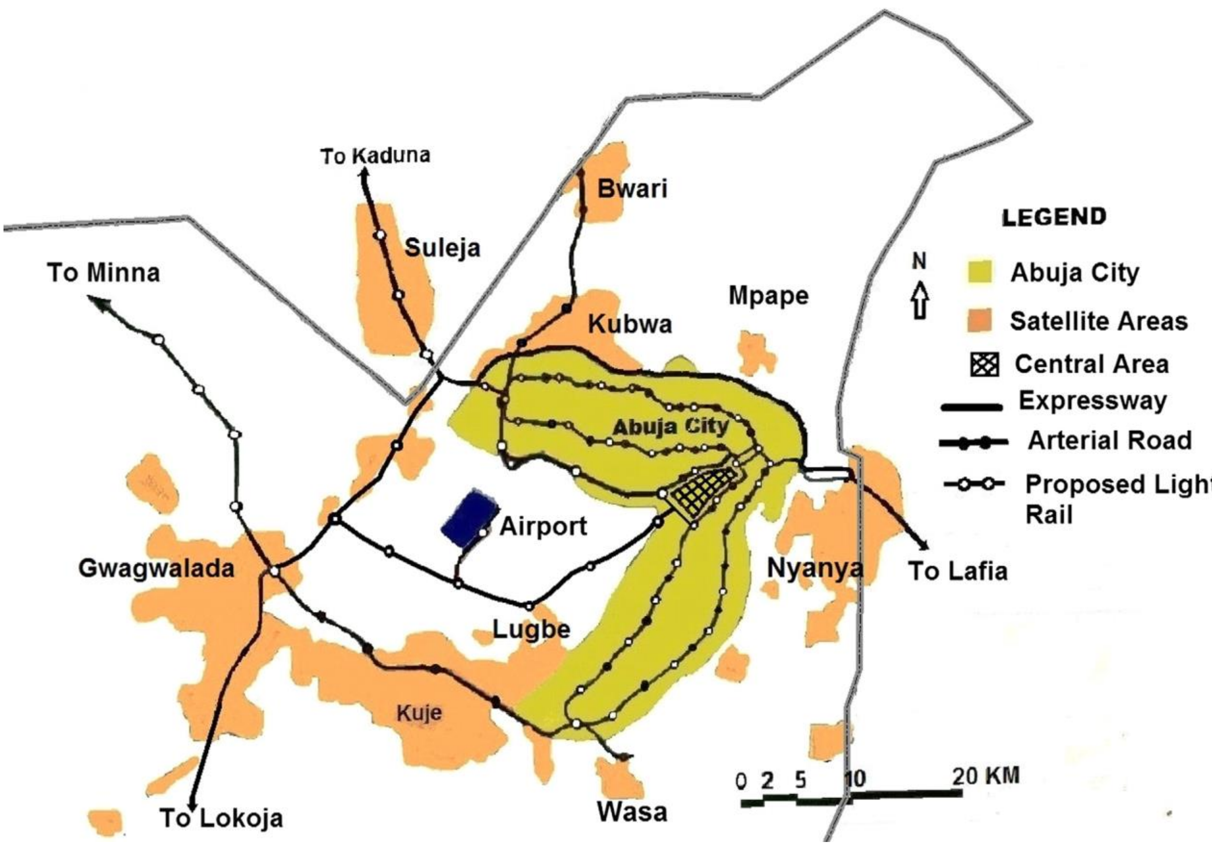

Figure 4.3: Abuja public transport system (Abubakar, 2014)

4.2.2 Abuja land use

The Federal Capital Terriroty Act (FCT Act) was passed on in 1976 by the legislative arm of the government to manage the design and development of Abuja. This Act resulted in the creation of FCDA, to over-see implementation of the Master Plan (FCTA, 2016). Based off the Master Plan, a land budget allocation (Table 4.1) was drawn up as a guideline for the development of the systems and sectors.

Table 4.1: Land budget plan for Abuja city (Ikoku, 2004)

	Land Use type	Allocated Land (ha)	Allocation Percentage (%)
1	Residential	12486	48.97
2	Small industries	920	3.61
3	Infrastructure	1840	7.22
4	Commercial and Services	1952	7.65
5	Green spaces and Recreational Facilities	8300	32.55
	Total	**25498**	**100%**

From table 4.1, is it evident that the highest portion of the land is allocated for residential use, followed by green spaces and recreational facilities.

4.2.3 Abuja land cost

The price of land in Abuja is generally higher than any other part of Nigeria because it's the Federal Capital Territory. It became the subject of all kinds of speculation as many serviced and un-serviced plots of land that were assigned to individuals by the government at a cheap price are sold and re-sold on the open market for outrageous profit. For people with low salary, land in Abuja is completely beyond them. Since getting a plot of land requires making a nonrefundable payment for application fee of about ₦100, 000 or $650 (exchange rate of $1 = ₦160), after which an expensive land premium comes after the allocation of the land (AGIS, 2017).

4.3 Abuja Population Growth

Buildings and structures are the profound modification of the natural environment by human urban activities (Ifatimehin et al, 2006) such as; commercial, industrial, residential, institutional and recreational land use. Population is a major factor that affects the development and quality of life in terms of its size and composition. Increase in population is caused by high fertility rate, low mortality rate and migration rates; in the case of Abuja migration is believed to be the main reason for the population growth. Abuja is experiencing rapid urbanization as a result of migration of people not only from the rural areas, but also from other states of the country in search of a better wage and salary (Okoye, 2013).

From the 1991 census, the city had a population of about 317,673 people. The 2006 census showed that the city had a population of 1,406,239 (NPC, 2016). Based on the projection by World Bank, the population of the city by 2015 is at 2.44 million (Figure 4.4). This rapid urbanization as a result of population increase is putting a lot of strain on the amenities and infrastructures of the city. Consequently, the city is experiencing urban degradation, due to lack of sufficient infrastructures, good maintenance of the existing infrastructures and environmental destructions (Gbadegesin cited in Aluko, 2010).

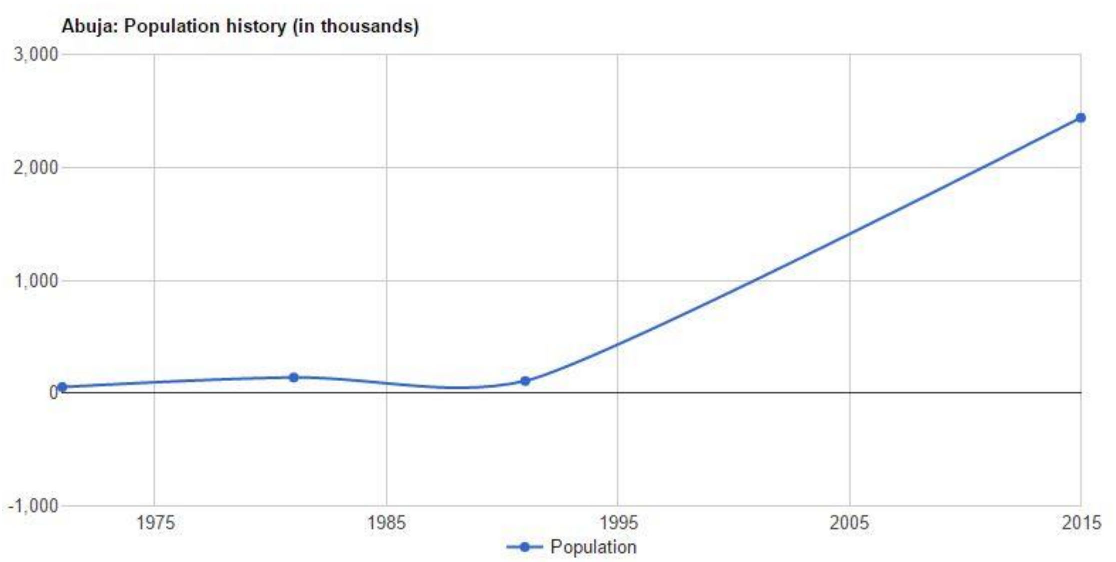

Figure 4.4: Abuja population histories (World bank.org 2018)

4.4 Abuja Land Use Land Cover Change

Studies on urban expansion have become critical factors as strategies for handling land as a resource and monitoring environmental changes. One of such studies is the Land Use Land Cover (LULC). This study provides accurate evaluation of the increase or decrease as well as condition of forests, grasslands, water and at the same time indicates how land resources have become a priority (Mengistu et al, 2007).

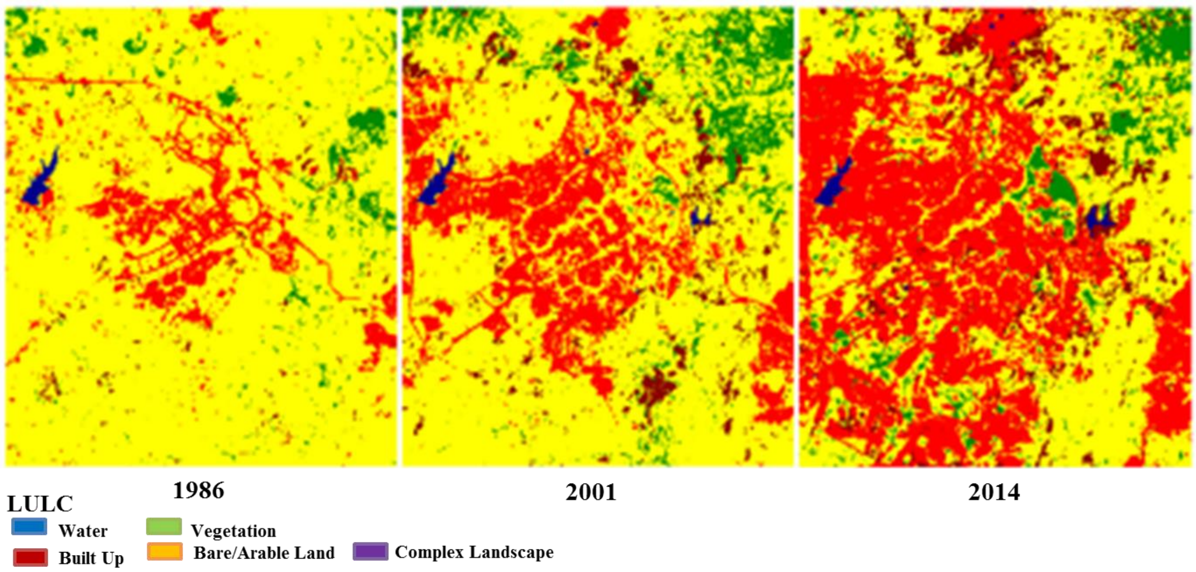

Figure 4.5: LULC maps of Abuja (Mahmoud et al, 2016).

The rapid urbanization due to population growth in Abuja has seen a swift change in the LULC of the city. From Figure 4.5 above, the urban expansion has been rapid within the city, at the expense of vegetal cover. The importance of vegetation in the environment is highlighted by its role as a carbon sink. The urban expansion is observed to be in a radial pattern similar to the capital cities of Beijing and Tokyo (Sorensen, 2000).

4.5 Abuja Urbanization and Loss of Green

The design of the city of Abuja, like most modern cities, is influenced by the concept of Garden City, with adequate landscaping infused with low density development. From the Master Plan, 32% of land is allocated for open space and parks (Figure 4.6) (Alkali, 2005).

The open space and parks consist of recreational facilities, gardens, parks; children play grounds, outdoor games, sports centers, neighborhood parks, district parks and national parks.

Figure 4.6: Overview of the green and open spaces of the city of Abuja (Jibril, 2010)

However, as the city grew and rapid urbanization, the areas marked out as “Green Areas” became the subject of abuse and were allocated to developers who converted them to other land uses (Figure 4.7 & Figure 4.8). This causes alteration of the initial design and development of the City. Since 2003, several attempts have been made at the reclamation and restoration of the “Green Areas”, but the success recorded isn’t that much (Jibril, 2010).

Figure 4.7: How Asokoro District Park was converted to commercial development (Jibril, 2010)

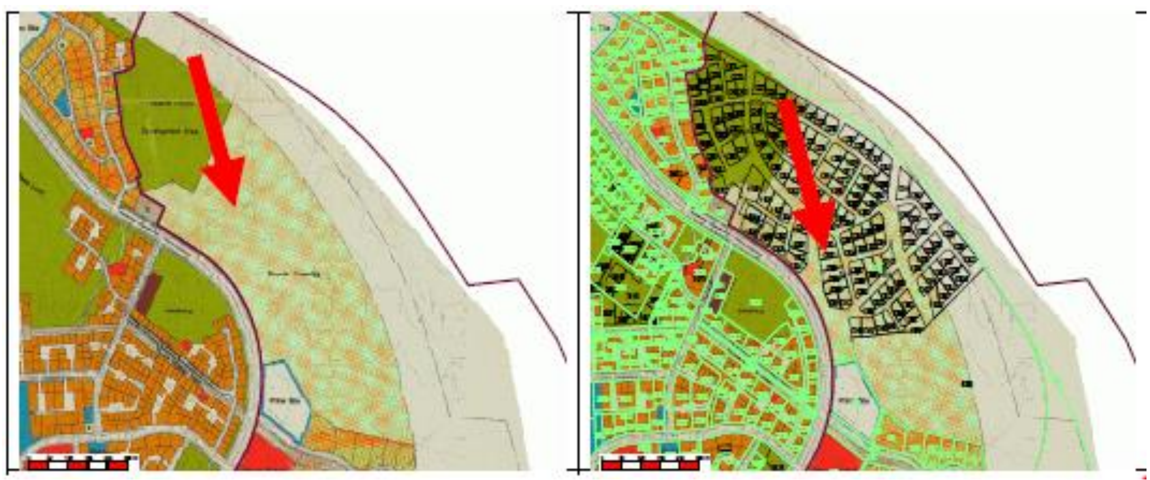

Figure 4.8: How Maitama Sport Complex was converted to residential development (Jibril 2010)

4.6 Application of Methodology

In this part of the study, the results of the analyzed data using the stated methodology are presented. The layers (criteria and sub-criteria) used to determine the suitable sites for sustainable urban growth in Abuja are explained;

4.6.1 Distance to roads

Urban growth should be accessible to existing road network for effective mobility of the people. Therefore, areas within 0 – 250m, 250 – 500m, 500 – 1km and 1km+ distance were determined for evaluation (Figure 4.9).

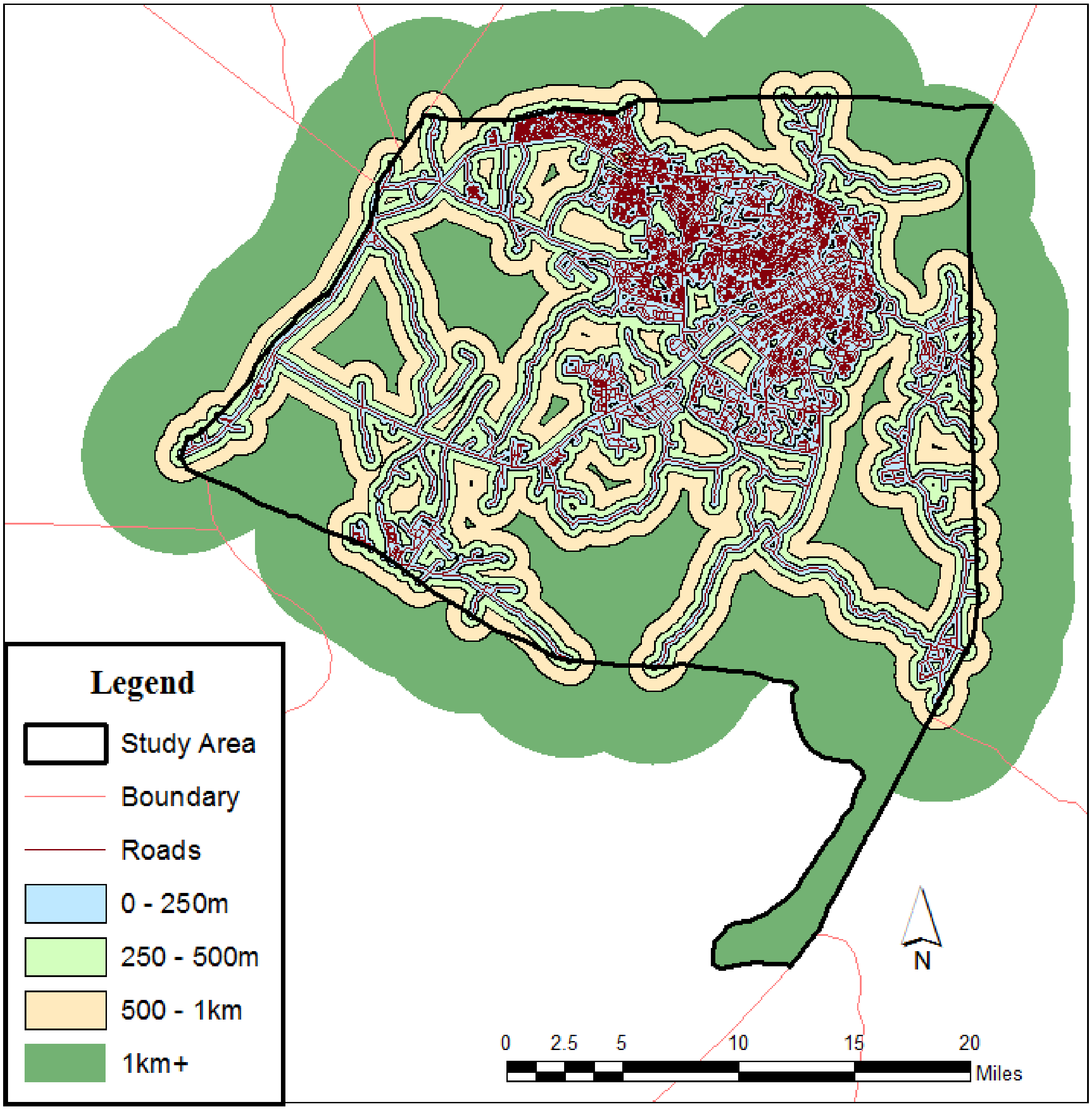

Figure 4.9: Distance to roads criteria map (Author)

4.6.2 Distance to education

For a sustainable urban development, integration of educational facilities (primary and secondary schools) at close proximity for easy access by the people is vital. Therefore, areas within 0 – 250m, 250 – 500m, 500 – 1km and 1km+ distance are determined for evaluation (Figure 4.10).

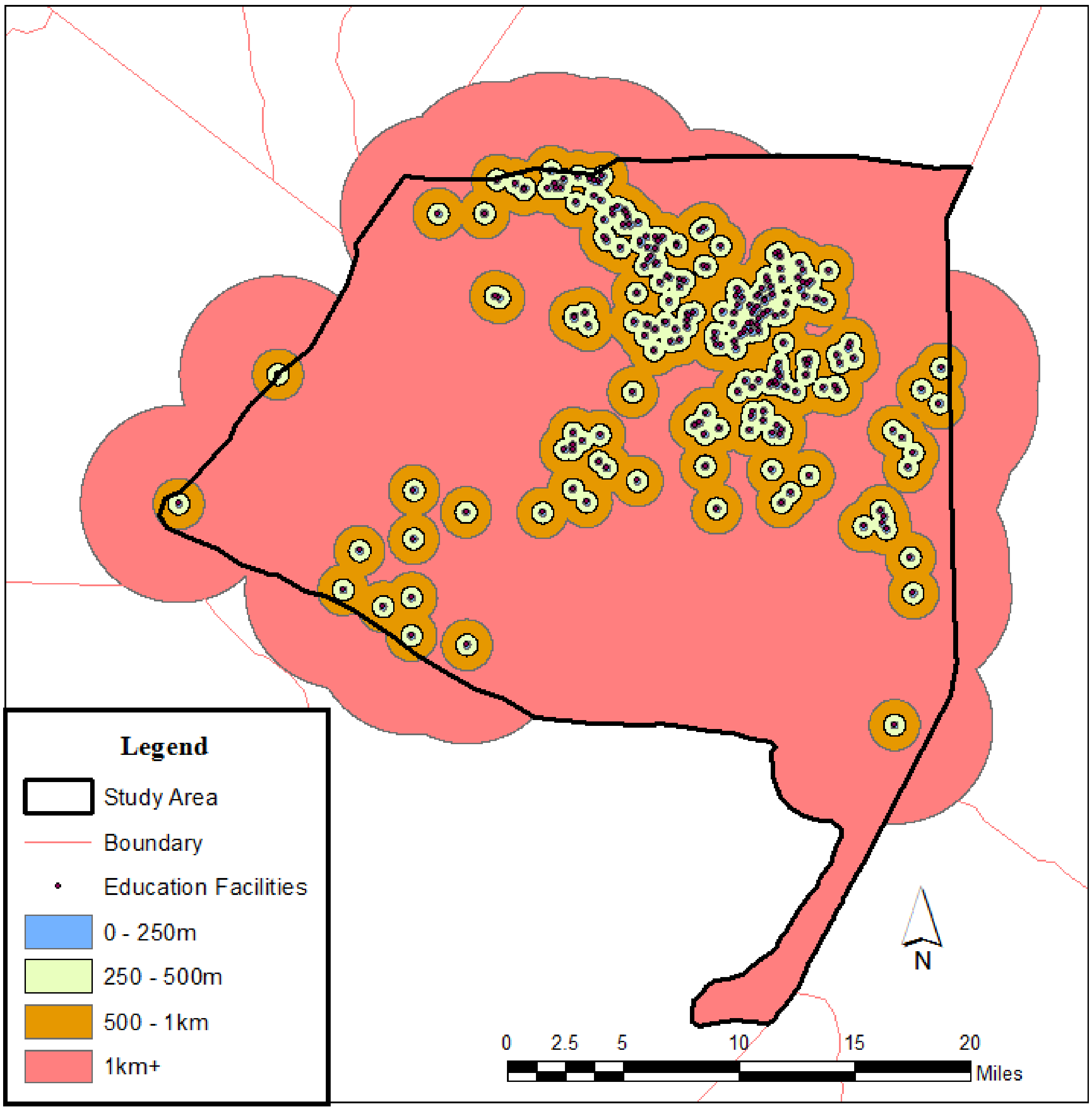

Figure 4.10: Distance to education criteria map (Author)

4.6.3 Slope

From an economic point, sites that have fairly gentle slopes or flat terrain are more suitable because steep slope areas results in increase in the construction cost. Therefore sites with lower slope are most ideal for urban growth. For the analysis, areas with 0 – 2%, 2 – 5%, 5 – 10% and 10%+ slope are determined for evaluation (Figure 4.11).

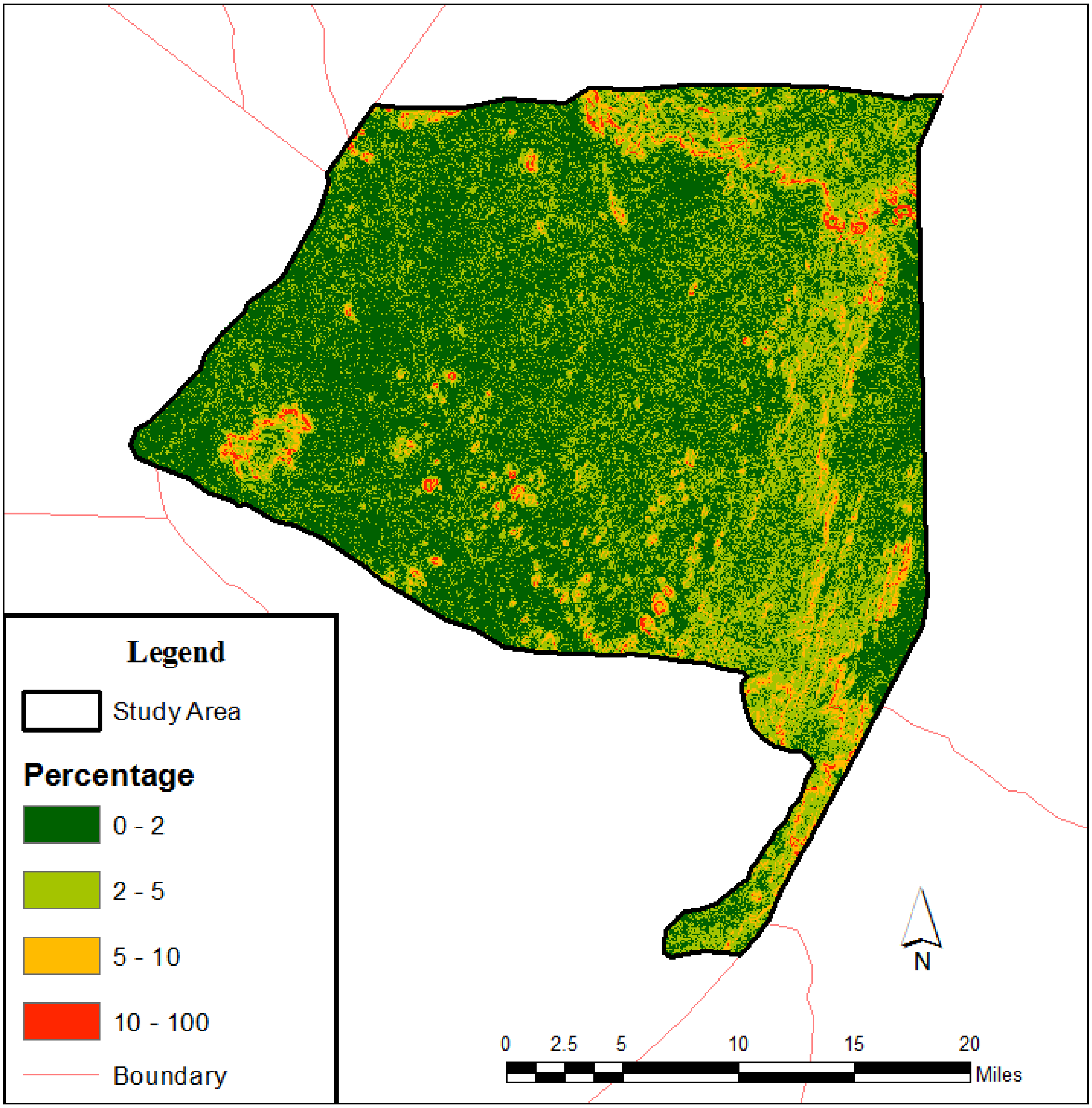

Figure 4.11: Slope criteria map (Author)

4.6.4 Distance to green/open

Green and open spaces such as parks, sports and recreational should be easily accessed by the people within an urban environment. As such, areas within 0 – 250m, 250 – 500m, 500 – 1km and 1km+ distance are determined for evaluation (Figure 4.12).

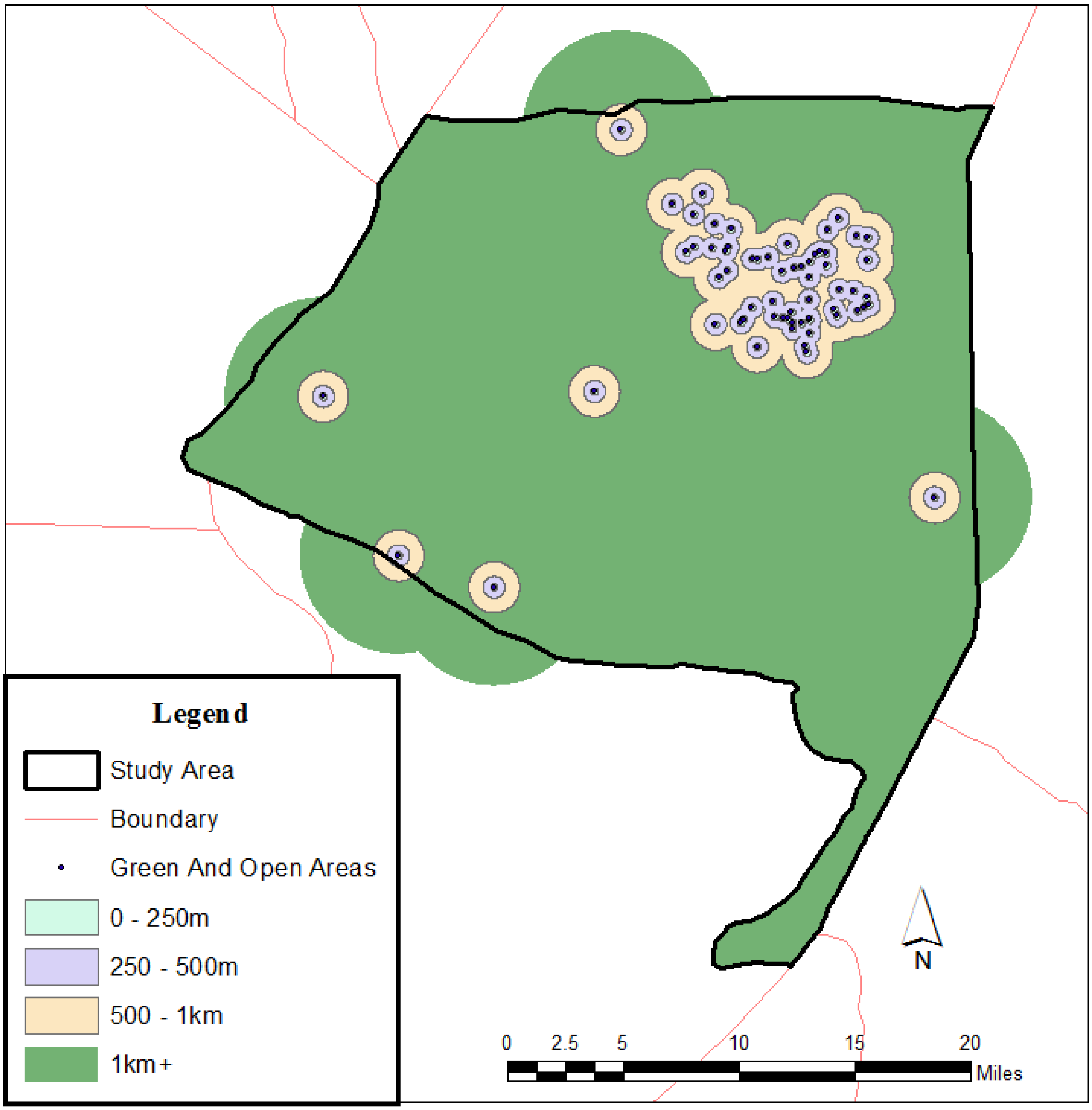

Figure 4.12: Distance to green/open criteria map (Author)

4.6.5 Soil

The soil class of Abuja municipality has geology of Undifferentiated Basement Complex and a relief of Undulating plains with scattered rock outcrops and hills. The soil is described as shallow to moderately deep with well drained to some-what poorly drained soils of loamy sand to sand loamy. The soil is suitable for both agriculture and construction. Therefore, areas with arable soil should not be used for urban growth (Figure 4.13).

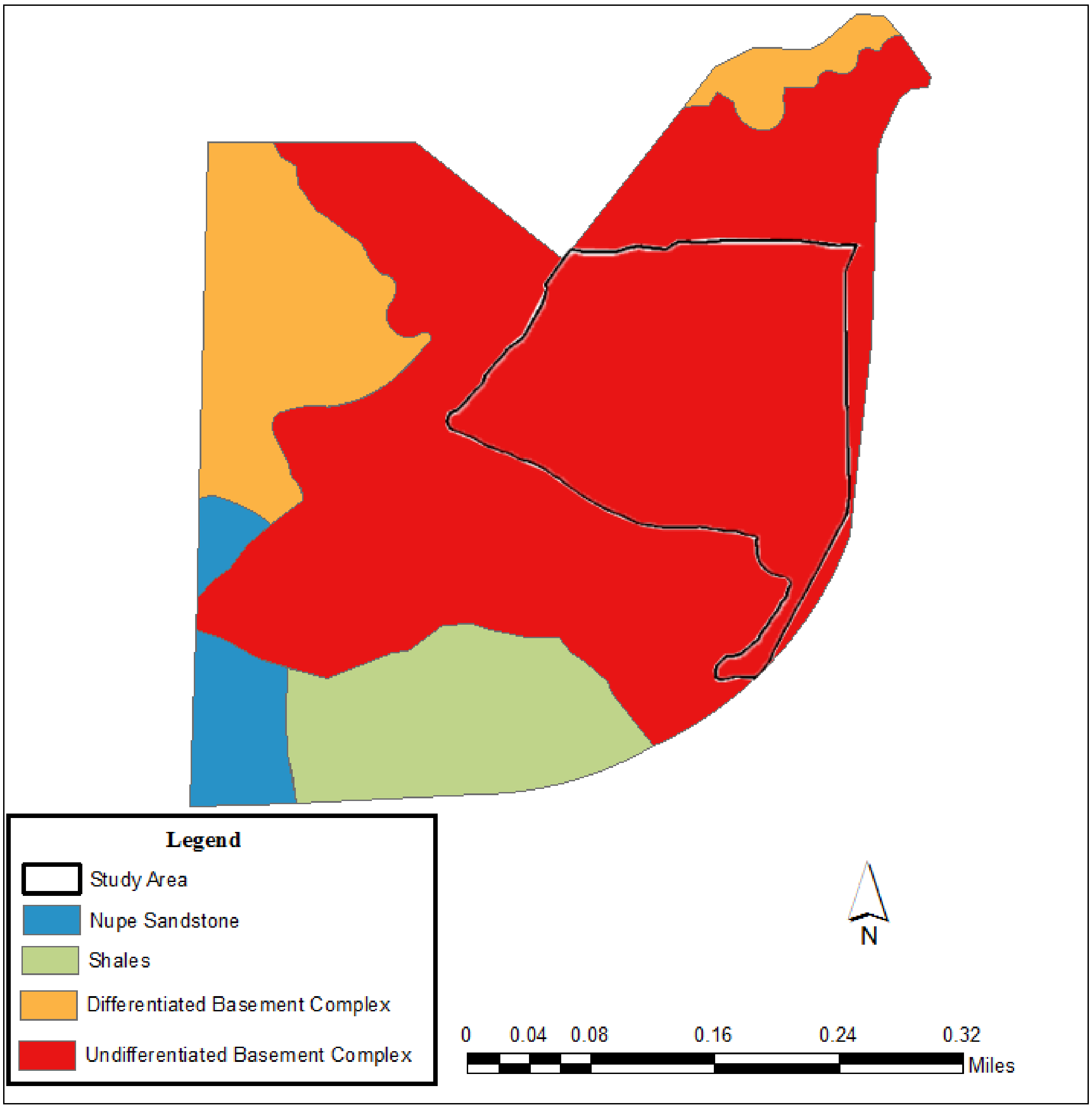

Figure 4.13: Soil criteria map (Author)

4.6.6 Vegetation

Vegetation is also important to the ecological uniqueness of a place; as such need to be preserved. Forest and wetland vegetation are not to be cleared and used for urban growth, therefore, will be selected as constrains and subtracted from assessment process (Figure 4.14).

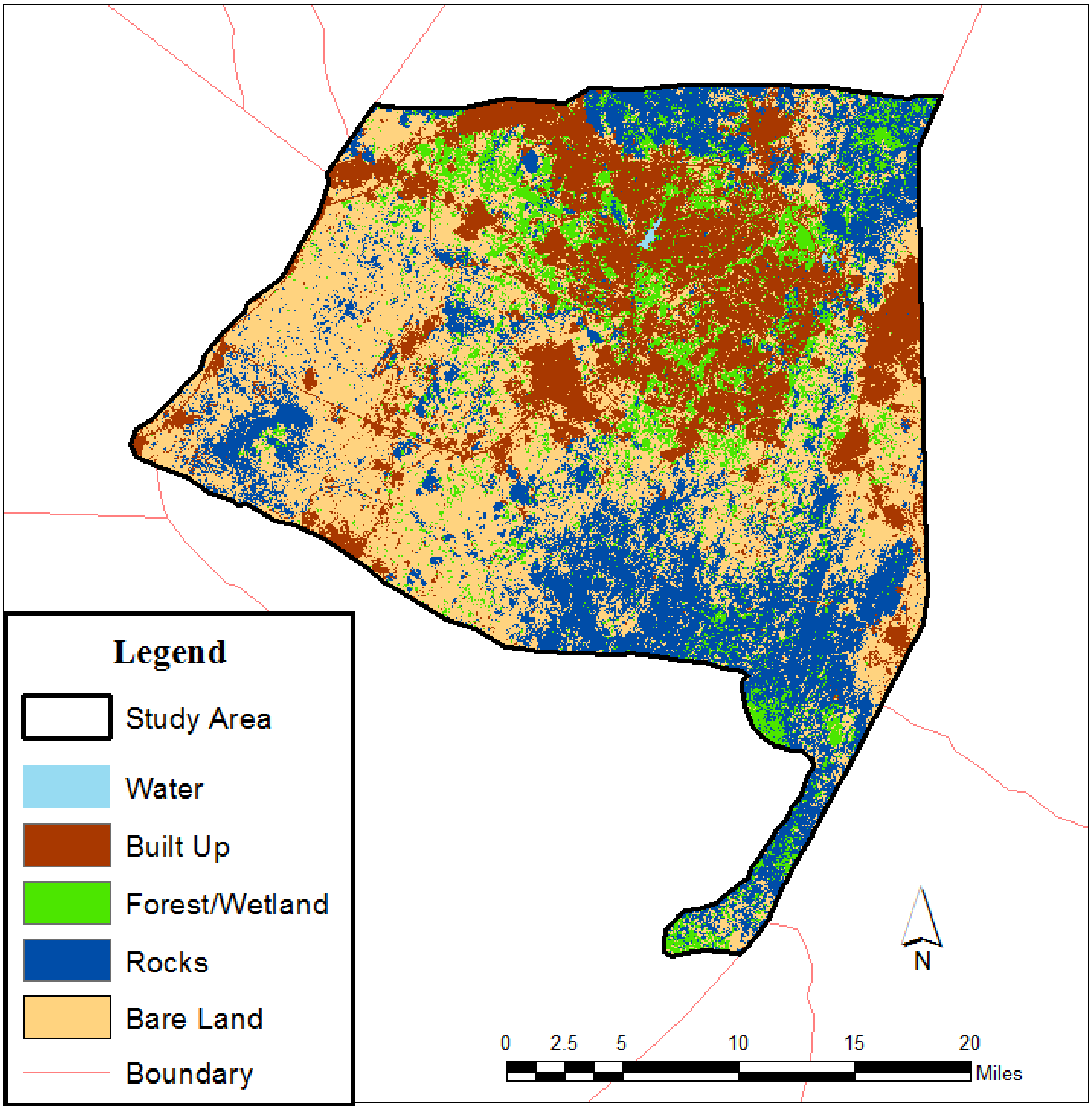

Figure 4.14: Vegetation criteria map (Author)

4.6.7 Distance from pollution sites

Sites such as quarries, treatment plant and airport causes noise and air pollution making them undesirable for living. Therefore, sustainable urban growth should be away from such sites. For this analysis, areas within 0 – 1km, 1 – 5km and 5km+ distance are determined for evaluation (Figure 4.15).

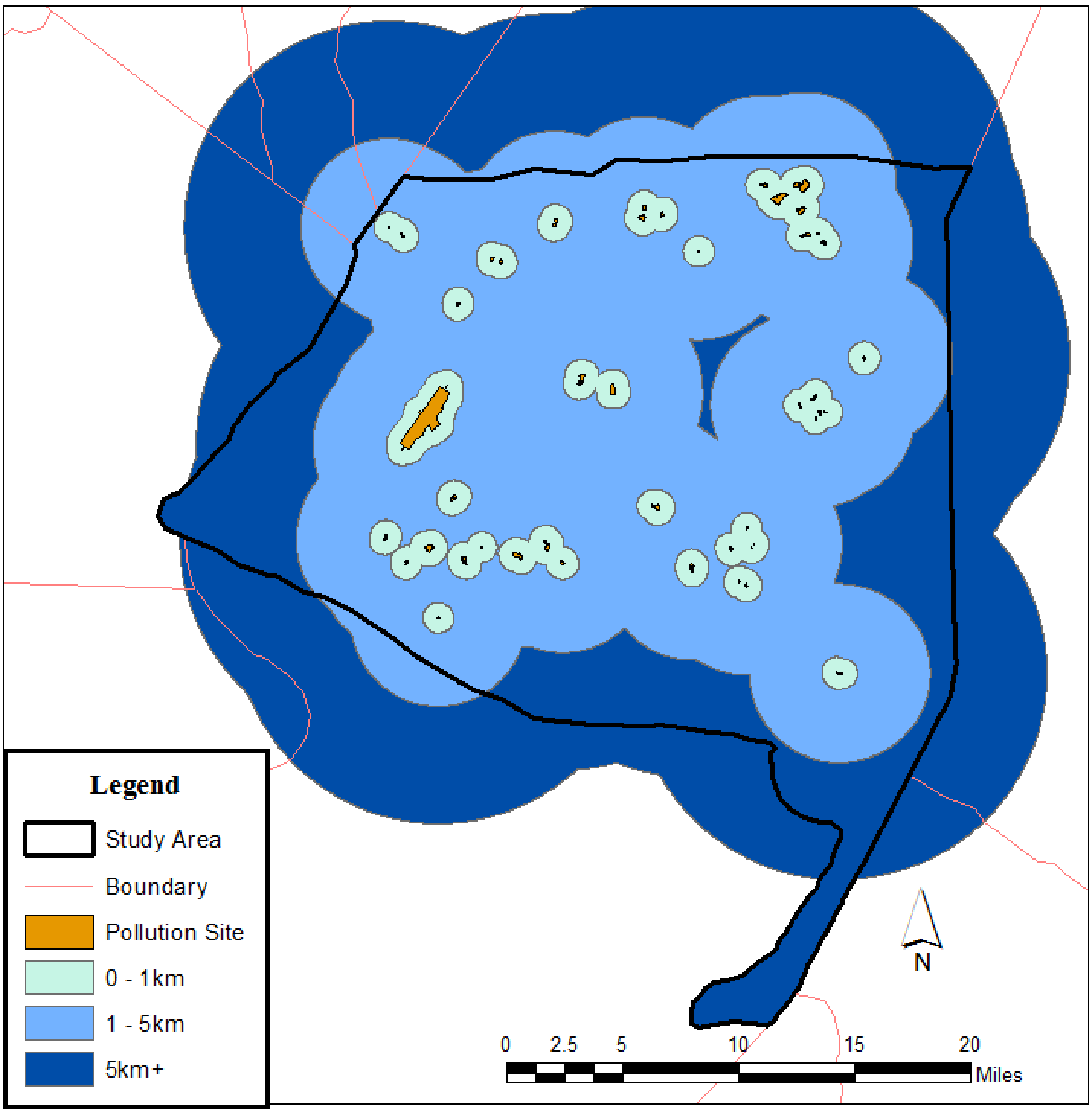

Figure 4.15: Distance from pollution sites criteria map (Author)

4.6.8 Distance to center

Central business district is the center of Abuja municipality, containing structures for the administrative, economic and expatriate activities. For a sustainable urban growth, development should be closer to the center to curb the need for longer commute. Therefore, areas within 0 – 1km, 1 – 5km and 5km+ distance were determined for evaluation (Figure 4.16).

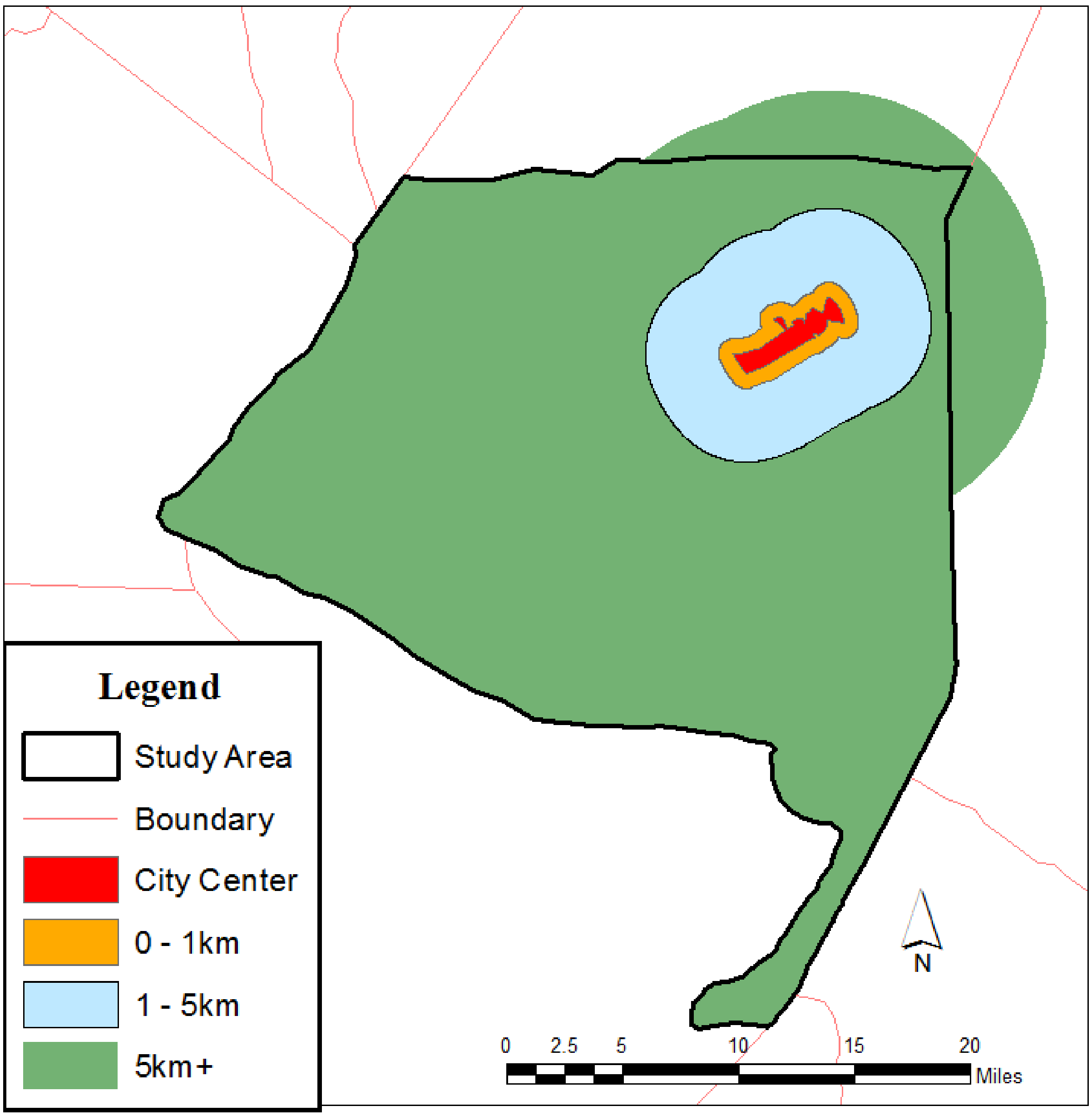

Figure 4.16: Distance to center criteria map (Author)

4.6.9 Distance from natural features

Natural features such as the lakes and river streams are delicate sites and vital to the eco-system and need protecting. Therefore, should be encroached upon through urban growth so as not to destroy them. For the analysis, such sites are added to constraints for evaluation and areas within 0 – 500m, 500 – 1km and 1km+ is determined for evaluation (Figure 4.17).

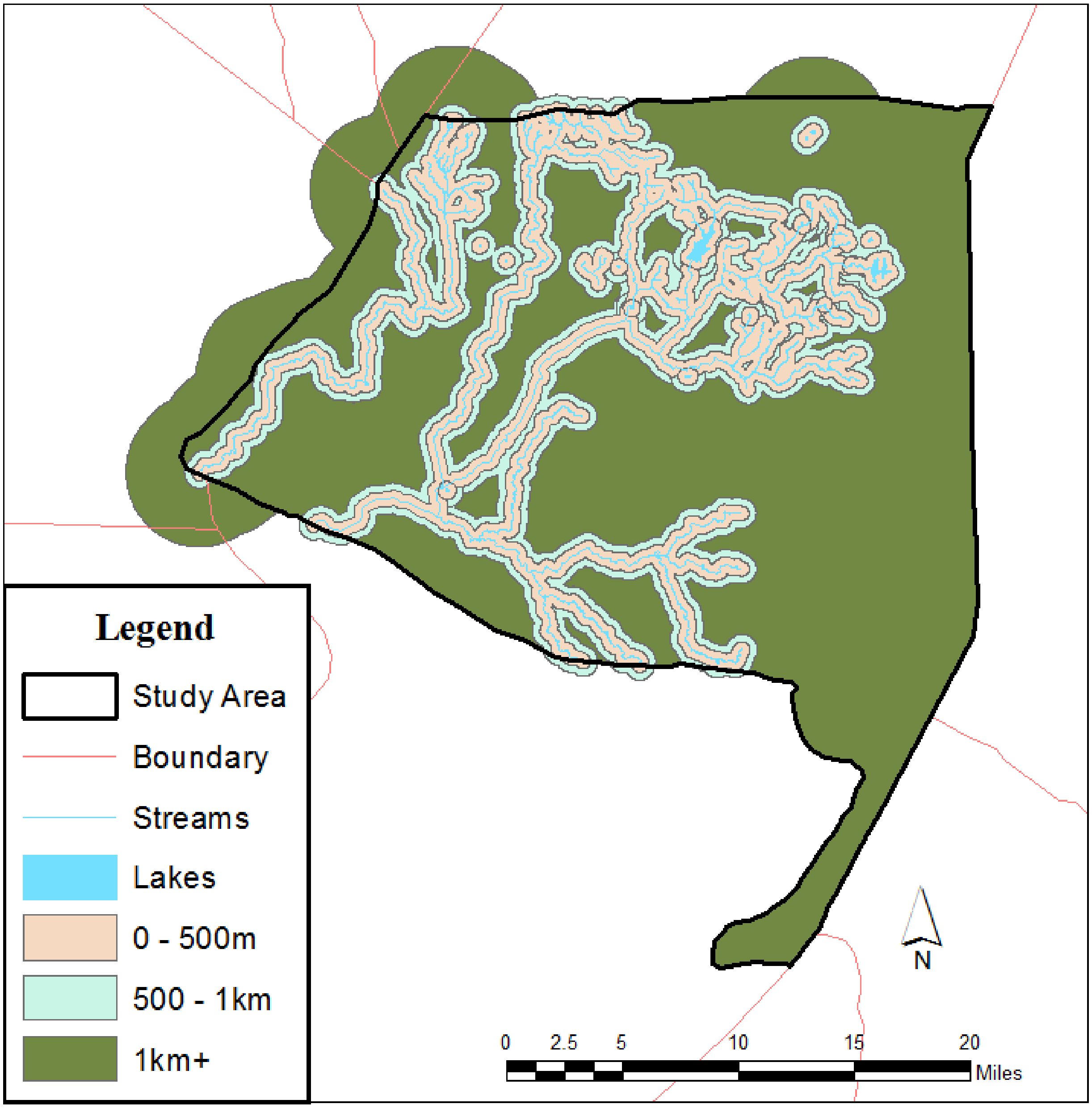

Figure 4.17: Distance from natural features criteria map (Author)

4.7 Pair-Wise Comparison and Weight Table

The result of the AHP calculation for the main policies and criteria are explained in the Tables 4.2 & 4.3 below:

Table 4.2: Weights and CR values for main and sub-criteria

Main Policy	Weights	CR	Criteria	Weights	CR
Compact Growth	0.318	0.04	Distance to Center	0.306	0.02
			Distance to Roads	0.404	
			Slope	0.29	
Social Equity	0.32		Distance to Education	0.333	0.03
			Distance to Green/Open	0.44	
			Distance from Pollution sites	0.227	
Environmental Protection	0.363		Soil	0.205	0.03
			Vegetation	0.171	
			Natural Features	0.624	

Table 4.3: Evaluation values and priority for the sub-criteria

Criteria	Sub-Criteria	Priority (1, 3, 5, 7, 9)
Distance to Center	0 – 1km	9
	1 – 5km	7
	5km+	5
Distance to Roads	0 – 250m	9
	250 – 500m	7
	500 – 1km	5
	1km+	3
Slope	0 – 2%	9
	2 – 5%	7
	5 – 10%	5
	10 – 100%	3
Distance to Education	0 – 250m	9
	250 – 500m	7
	500 – 1km	5
	1km+	3
Distance to Green/Open	0 – 250m	9
	250 – 500m	7
	500 – 1km	5
	1km+	3
Distance from Pollution sites	0 – 1km	3
	1 – 5km	7
	5km+	9
Soil	Nupe Sandstone	1
	Shales	1
	Differentiated	1
	Undifferentiated	9
Vegetation	Water	1
	Built Up	3
	Forest/Wetland	5
	Rocks	7
	Bare Land	9
Natural Features	0 – 500m	5
	500 – 1km	7
	1km+	9

The priority values is to gauge the importance of the evaluation value with 1 = least important and 9 = highly important

4.8 Final Suitability Map

The final suitability map is the outcome of the combination and overlay of all the criteria maps using the suitability index formula; S = ∑ [Policy Weight * Criteria map * Criteria Weight] (Figure 4.18). Therefore; suitability map = [(0.318*distance to center*0.306) + (0.318*distance to roads*0.404) + (0.318*slope*0.29)) + (0.32*distance to education*0.333) + (0.32*distance to green/open*0.44) + (0.32*distance from pollution sites*0.227)) + (0.363*soil*0.205) + (0.362*vegetation*0.171) + (0.363*natural features*0.624)].

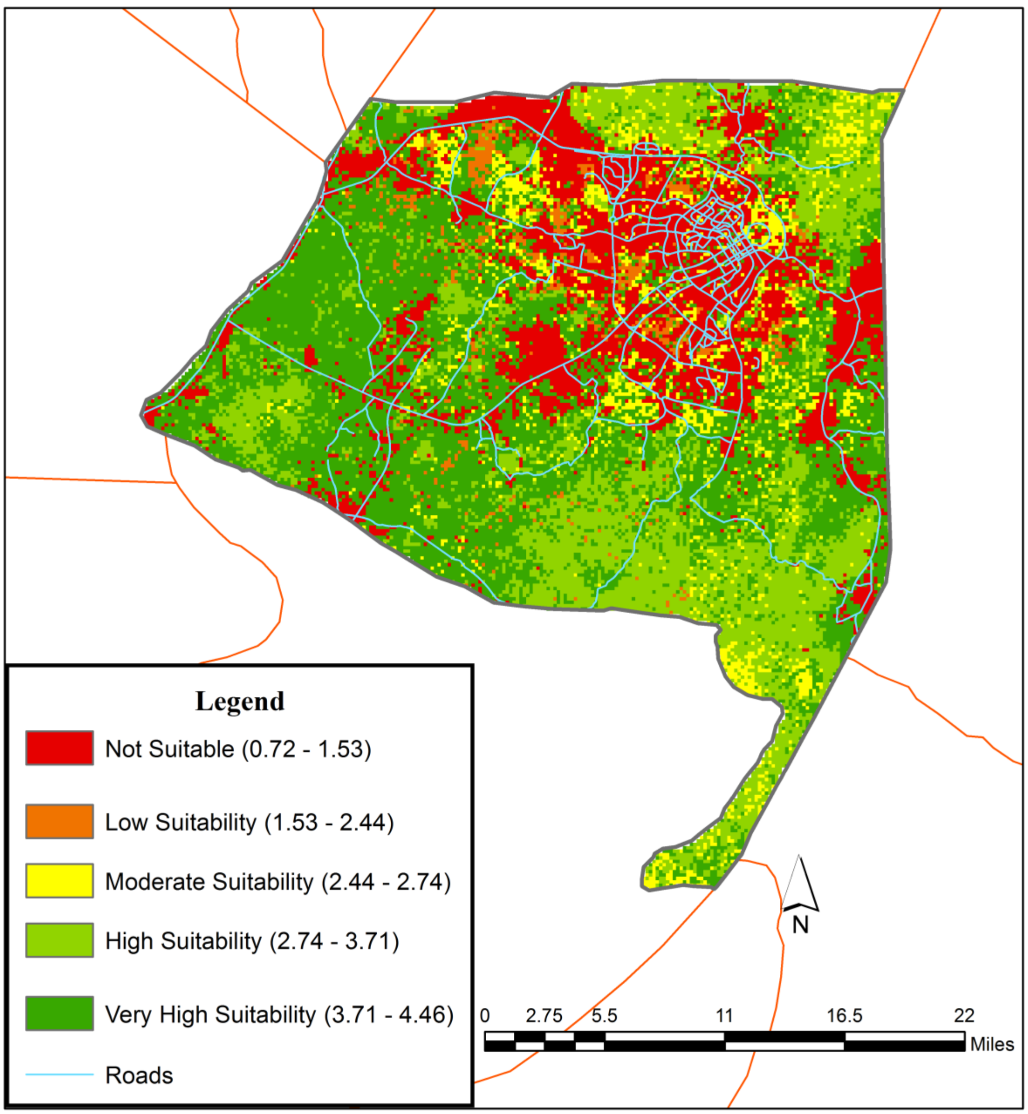

Figure 4.18: Suitability map for sustainable urban growth (Author)

CHAPTER FIVE

DISCUSSION, CONCLUSION AND RECOMMENDATION

This chapter discusses the output of the suitability map in terms of the size of area that is suitable for sustainable urban growth. Also possible growth and development strategies are recommended and concluded base off the assessment of the suitability map.

5.1 Discussion

The final suitability map (Figure 4.18) indicates that the suitability of Abuja for a sustainable urban growth is classed into five categories. Table 5.1 enumerates the output from the suitability map;

Table 5.1: Suitability categories and area size coverage

Suitability Category	Area (km^2)	Coverage (%)
Not suitable	187.05	10.57
Low suitability	372.35	21.05
Moderate suitability	161.85	9.15
High suitability	547.70	30.96
Very high suitability	500.05	28.27
Total	**1769**	**100**

From the table 5.1 above, its shows that 59.23% of the total land area in Abuja Municipality falls under high suitability and very high suitability, while 31.62% falls under the unsuitable and low suitability. The result directs attention to the fact that areas around the center of the Abuja municipality fall within the range of moderate to very high suitability. Therefore future urban growth model can be planned to radiate outwards towards the edge of the municipality from the center.

The growth and development plans should be in accordance with the suitability of the site. Areas of very high suitability should be developed first descending down the suitability rank. Areas of moderate and low suitability can be developed as recreational centers and facilities to make-up for the green areas that were re-appropriated and developed for a different land use.

Any future urban planning in Abuja will require strict implementation strategies that will necessitate for protection of the ecosystem, conservation of resources, maintain safe and comfortable way of life as well as equal distribution of wealth and services in the future.

5.2 Conclusion

This study is a step towards finding solution to the looming urban problems in the city of Abuja. The study focuses on identifying suitable sites for sustainable urban growth of the city. To that end, the study implored the spatial analysis tools; GIS with MCE to handle the suitability analysis so that environmentally safe and economically feasible sites for urban growth can be identified. Abuja is an important city in Nigeria. Being the Federal Capital, it became susceptible to rapid urbanization and influx of people for the economic advantage the city offers. It is imperative that the city thrives and not fail as Lagos did, so as to serve as a model for the development of other cities.

The research questions proposed as a way to achieve the main aim of the study have been answered. The first question is about the main negative effect of uncontrolled urban growth. Well the main negative effects of uncontrolled urban growth as can be seen with the case of Abuja are environmental degradation, congestion and growth of squatter settlements. In the case of Abuja, the slow rate and improper implementation of the master plan of the city is causing the slow urban decay of the city. These effects have contributed to the drastic reduction of the livability and quality of life in the city.

Moreover, this study answered the second research question about the relationship between urban growth and sustainability. This study clearly shows that urban growth must be guided by sustainability and must be in accordance with sustainable principles. This will ensure a long-term utilization and conservation of available resources. The criteria for a sustainable urban growth in a city are the effective growth policies of compact development, social equity and environmental protection. Proper implementation of these policies will ensure even and effective distribution of resources, protection of delicate ecosystem and socio-economic improvement of the people.

This study further answers the third research question about the use of GIS and MCE for land suitability analysis. The study highlights the effectiveness of GIS based MCE technique as a decision support system, serving as a guideline to overcome future environmental hazards. GIS based MCE provides planners with support tool for effective urban planning and land-use management. Its simplicity in understanding and application made it a widely used technique for spatial analysis.

This pilot study can further be used by planners or researchers as guideline for future research and development of other cities in Nigeria.

5.3 Recommendation

The city of Abuja has the potential to develop into a sustainable urban community. Its administrative structures coupled with its geographical delineation further reiterate the feasibility. In order to achieve that, all stakeholders including the Federal Government and the Area Councils must stringently comply with the principles of sustainable community design and development.

This study recommends that for the future sustainable urban planning of the city, the Compact City model should be adopted. The Compact City model offers solution to the current urban problems in Abuja; environmental, economic and social. The model will bring about dense and proximate development patterns, public transport systems that link-up the urban areas and equal accessibility to local services and jobs.

Compact Cities reduce the impact on the environment, with short travel distance within the urban area and little reliance on automobile. They also play an integral role in the economy by increasing the efficiency of the infrastructure giving the urban dwellers easier access to services, jobs and social networking.

Furthermore, this study recommends that a bottom-up approach will be the best strategy for the implementation of any future sustainable urban planning, which will result in the creation of an environmentally safe, socially fit and economically viable city.

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APPENDICES

APPENDIX 1

QUESTIONNAIRE SAMPLE

EVALUATING THE URBAN GROWTH OF ABUJA, NIGERIA USING MCE AND GIS

Dear respondent,

This questionnaire is part of an on-going study titled above, aimed at identifying suitable site for sustainable urban growth of Abuja. Abuja is the federal capital of Nigeria; a country in the western part of Africa. The outcome of this questionnaire will further solidify the bases for the overall analysis

Multi Criteria Evaluation (MCE) and Geographical Information System (GIS) based support tools will be used for the analysis, according to sustainability criteria; compact growth, social equity and environmental protection. In this questionnaire, your expert opinion is required by grading a criterion in terms of which is more important relative to the other using numbers 1-9.

1	Equal importance
3	Moderately more important
5	Strongly more important
7	Very strongly more important
9	Extremely more important
2,4,6,8	Intermediate values

A scale containing the numbers will be presented with the criteria at both ends of the scale and you are to indicate which you think is more important than the other. You can mark the number towards the direction of the criteria you think is more important.

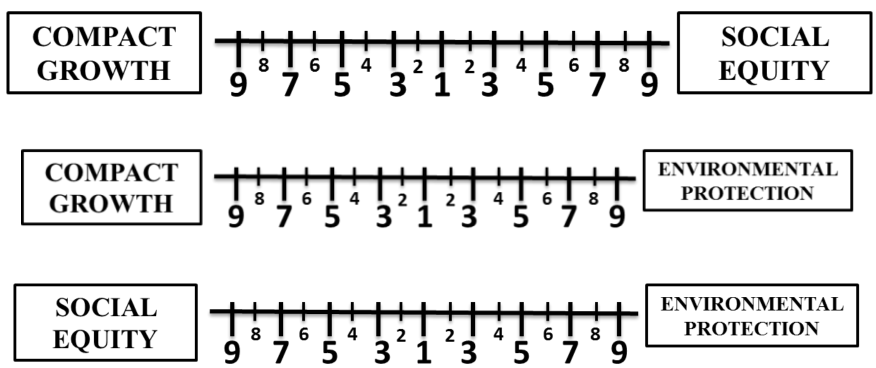
Name:

Profession:

1- **Main criteria:**

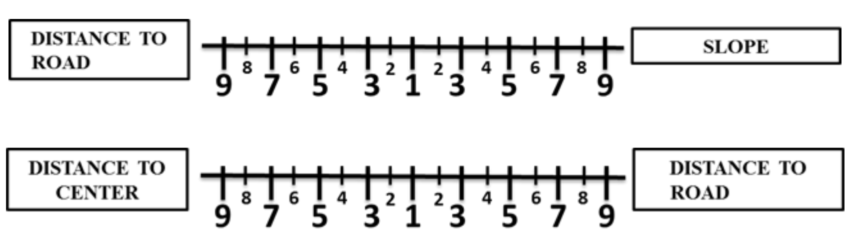
- Compact Growth; urban development for the effective utilization of resources by having the facilities and infrastructure compacted together. This reduces the usage of new land for development in favor of reusing old urban site in order to conserve resources.

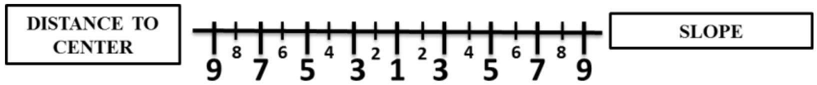
- Social Equity; urban development where every person has equal access to all the amenities. This promotes integration of such amenities within close proximity thereby deregulating mobility.
- Environmental Protection; urban development that places emphasis on the preservation of natural resources for the betterment of the environment.



2- Sub criteria (Compact Growth):

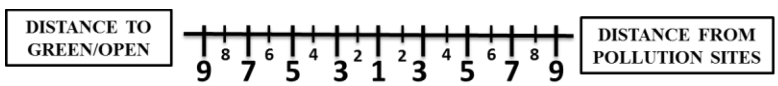
- Distance to center; Central Business District is the center of Abuja municipality, containing structures used for the administrative, economic and expatriate activities. Therefore, urban development should be closer to the center in order to reduce the need to commute long distances.
- Distance to road; urban development should be accessible to the road network and rail for effective mobility of the people.
- Slope; areas with suitable slope of about $0\text{-}12^0$ should be effective utilized for urban development than areas with higher slope.

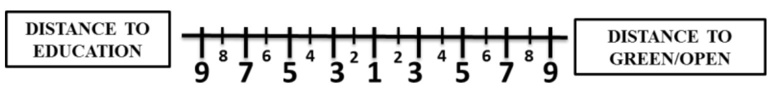


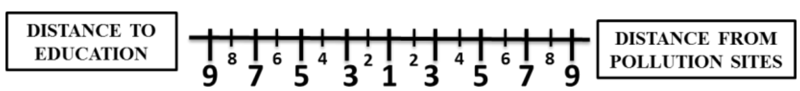


3- Sub criteria (Social Equity):

- Distance to education; urban development should integrate primary and secondary schools at close proximity for easy access.
- Distance to green/open; green spaces such as parks, sports and recreational facilities should be easily accessed by the people.
- Distance from pollution sites (quarries, treatment plants & airport); urban development should be away from noise and air pollution sites.

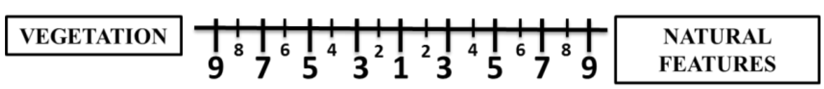


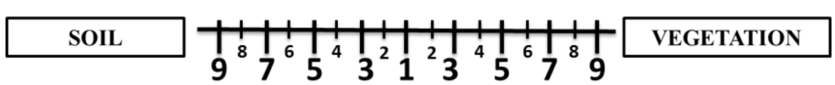


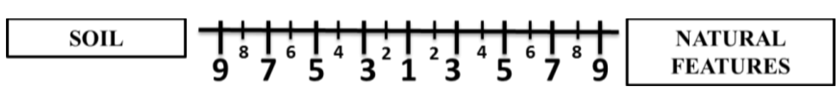


4- Sub criteria (Environmental Protection):

- Soil; areas with arable soil should not be used for urban development.
- Vegetation; forest and wetland vegetation should not be cleared and used for urban development.
- Natural features (lakes & water streams); urban development should not encroach on such natural features so as not to destroy them.







APPENDIX 2

APPROVAL LETTER FROM ETHICS COMMITTEE

YAKIN DOĞU ÜNİVERSİTESİ

BİLİMSEL ARAŞTIRMALAR ETİK KURULU

10.05.2018

Dear Jaarfar Abdullahi Shuaibu

Your application titled **"Evaluatıng The Urban Growth of Abuja Using MCE nad GIS"** with the application number YDÜ/FB/2018/27 has been evaluated by the Scientific Research Ethics Committee and granted approval. You can start your research on the condition that you will abide by the information provided in your application form.

Assoc. Prof. Dr. Direnç Kanol

Rapporteur of the Scientific Research Ethics Committee

Direnc Kanol

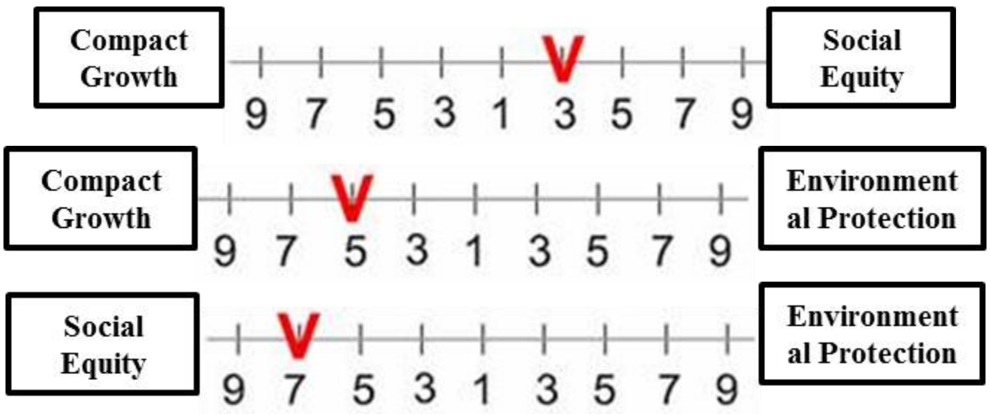
Note: If you need to provide an official letter to an institution with the signature of the Head of NEU Scientific Research Ethics Committee, please apply to the secretariat of the ethics committee by showing this documen

APPENDIX 3

AHP CALCULATION

Step one:

- Obtain expert opinion base off Saaty's 1-9 scale



- Compute pairwise comparison matrix

If the expert's opinion value is on the *left-side* of 1, the *actual-value* is used but if it's on the *right-side* of 1, then the *reciprocal-value* is used.

$$\begin{array}{l c}
 & \begin{array}{ccc} \text{Compact Growth} & \text{Social Equity} & \text{Environmental Protection} \end{array} \\
\begin{array}{l} \text{Compact Growth} \\ \text{Social Equity} \\ \text{Environmental Protection} \end{array} & \left[\begin{array}{ccc} 1 & \frac{1}{3} & 5 \\ & 1 & 7 \\ & & 1 \end{array}\right]
\end{array}$$

- Completing the matrix table

The rest of the table is completed as reciprocal values of the upper entries

$$\begin{array}{l c}
 & \begin{array}{ccc} \text{Compact Growth} & \text{Social Equity} & \text{Environmental Protection} \end{array} \\
\begin{array}{l} \text{Compact Growth} \\ \text{Social Equity} \\ \text{Environmental Protection} \end{array} & \left[\begin{array}{ccc} 1 & \frac{1}{3} & 5 \\ 3 & 1 & 7 \\ \frac{1}{5} & \frac{1}{7} & 1 \end{array}\right]
\end{array}$$

Step two:

- Normalized the matrix entries

  The values of the columns of the matrix are summed up and each of the entry value in a column is divided by the sum total from the column

$$\begin{array}{rc} & \begin{array}{ccc}\text{Compact Growth} & \text{Social Equity} & \text{Environmental Protection}\end{array} \\ \begin{array}{r}\text{Compact Growth}\\ \text{Social Equity}\\ \text{Environmental Protection}\end{array} & \begin{bmatrix}1 & \frac{1}{3} & 5\\ 3 & 1 & 7\\ \frac{1}{5} & \frac{1}{7} & 1\end{bmatrix} \\ \text{Sum} & \begin{array}{ccc}\frac{21}{5} & \frac{31}{21} & 13\end{array}\end{array} \xrightarrow{\text{Dividing each entry with sum of the column}} \begin{array}{c}\begin{bmatrix}\frac{5}{21} & \frac{7}{31} & \frac{5}{13}\\ \frac{15}{21} & \frac{21}{31} & \frac{7}{13}\\ \frac{1}{21} & \frac{3}{31} & \frac{1}{13}\end{bmatrix} \\ \begin{array}{ccc}1 & 1 & 1\end{array}\end{array}$$

- Compute weight of criteria (Eigen Vector X)

  The Eigen Vector is gotten by averaging across the rows

$$X = \frac{1}{3}\begin{bmatrix}\frac{5}{21}+\frac{7}{31}+\frac{5}{13}\\ \frac{15}{21}+\frac{21}{31}+\frac{7}{13}\\ \frac{1}{21}+\frac{3}{31}+\frac{1}{13}\end{bmatrix} = \begin{bmatrix}0.2828\\ 0.6434\\ 0.0738\end{bmatrix}$$

- Compute Eigen Value (λ_{max})

  The Eigen Value is gotten by summing up the product between Eigen Vector and sum of the column matrix

$$\lambda_{max} = \frac{21}{5}(0.2828) + \frac{31}{21}(0.6434) + 13(0.0738) = 3.0967$$

Step three:

- Check for consistency

  Checking for consistency is to ensure that the values from the expert's opinion are rational, i.e., if X is more significant than Y and Y is more significant than Z, then X is more important than Z.

- Compute Consistency Index (CI)

  This is obtained using the equation below, where n = number of criteria, which is 3

$$CI = \frac{\lambda_{max} - n}{n - 1} = \frac{3.0967 - 3}{2} = 0.0484$$

- Compute Consistency Ratio (CR)

  This is obtained with the equation below, RI = 0.58 (Table 3.2, n = 3)

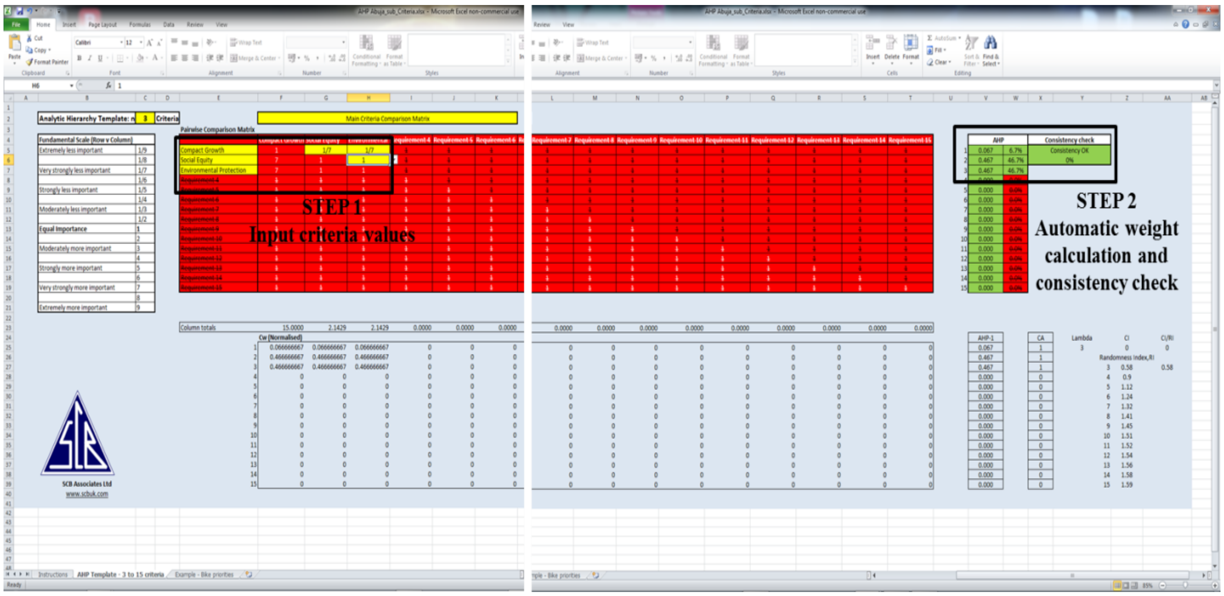
$$CR = \frac{CI}{RI} = \frac{0.0484}{0.58} = 0.083$$

When the value of CR ≤ 0.1 then the expert's opinion is acceptable, otherwise, it'll have to be revised.

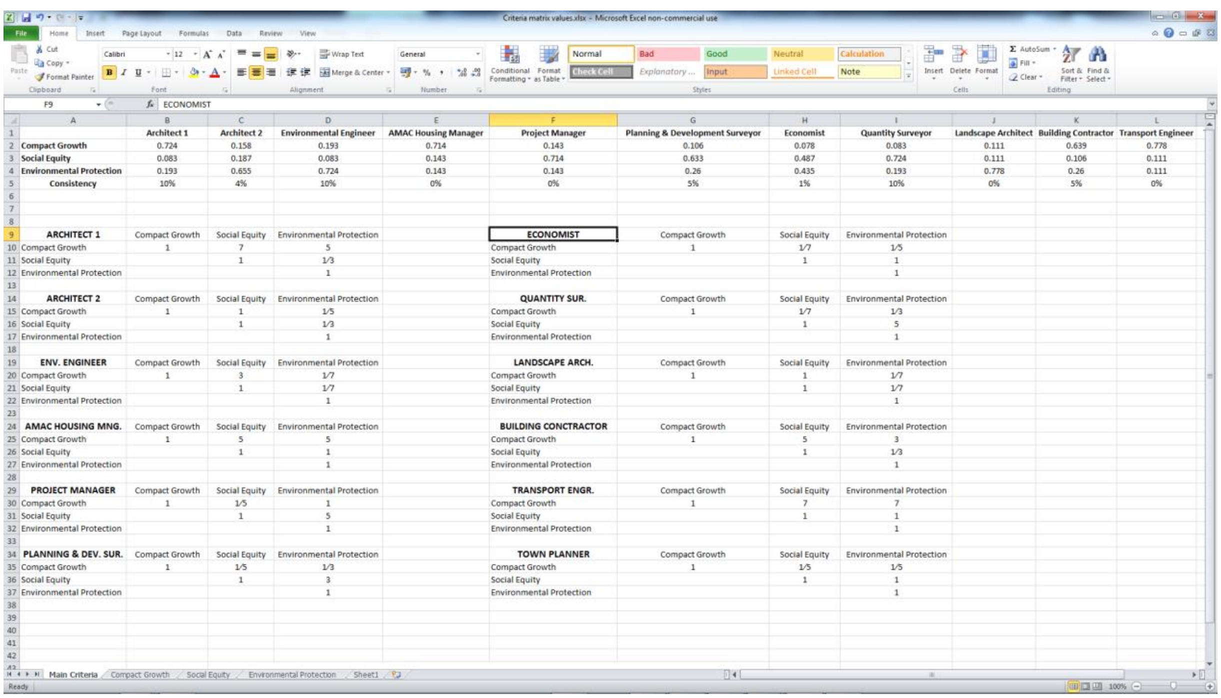
APPENDIX 4

AHP EXCEL SHEET CALCULATION

Screenshot of AHP comparison matrix excel computation



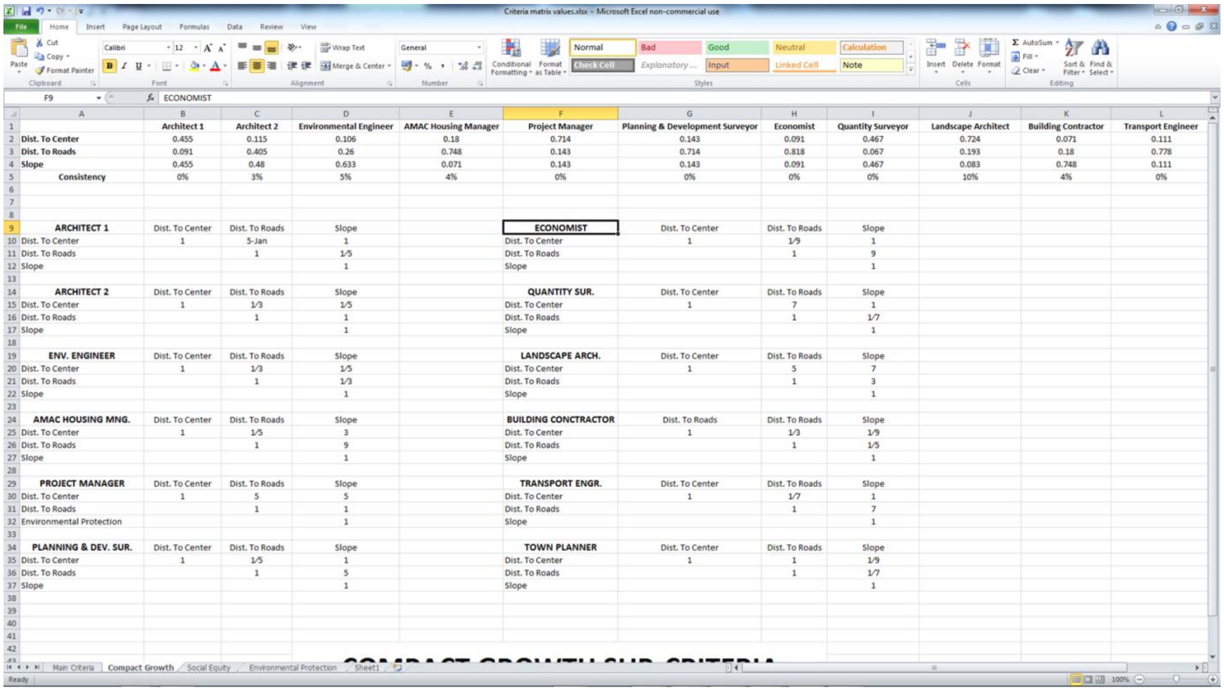
Screenshot of main criteria comparison matrix by professionals



	Architect 1	Architect 2	Environmental Engineer	AMAC Housing Manager	Project Manager	Planning & Development Surveyor	Economist	Quantity Surveyor	Landscape Architect	Building Contractor	Transport Engineer
Compact Growth	0.724	0.158	0.193	0.714	0.143	0.106	0.078	0.083	0.111	0.639	0.778
Social Equity	0.083	0.187	0.083	0.143	0.714	0.633	0.487	0.724	0.111	0.106	0.111
Environmental Protection	0.193	0.655	0.724	0.143	0.143	0.26	0.435	0.193	0.778	0.26	0.111
Consistency	10%	4%	10%	0%	0%	5%	1%	10%	0%	5%	0%

ARCHITECT 1	Compact Growth	Social Equity	Environmental Protection	ECONOMIST	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	7	5	Compact Growth	1	1/7	1/5
Social Equity		1	1/3	Social Equity		1	1
Environmental Protection			1	Environmental Protection			1
ARCHITECT 2	Compact Growth	Social Equity	Environmental Protection	QUANTITY SUR.	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	1	1/5	Compact Growth	1	1/7	1/3
Social Equity		1	1/3	Social Equity		1	5
Environmental Protection			1	Environmental Protection			1
ENV. ENGINEER	Compact Growth	Social Equity	Environmental Protection	LANDSCAPE ARCH.	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	3	1/7	Compact Growth	1	1	1/7
Social Equity		1	1/7	Social Equity		1	1/7
Environmental Protection			1	Environmental Protection			1
AMAC HOUSING MNG.	Compact Growth	Social Equity	Environmental Protection	BUILDING CONCTRACTOR	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	5	5	Compact Growth	1	5	3
Social Equity		1	1	Social Equity		1	1/3
Environmental Protection			1	Environmental Protection			1
PROJECT MANAGER	Compact Growth	Social Equity	Environmental Protection	TRANSPORT ENGR.	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	1/5	1	Compact Growth	1	7	7
Social Equity		1	5	Social Equity		1	1
Environmental Protection			1	Environmental Protection			1
PLANNING & DEV. SUR.	Compact Growth	Social Equity	Environmental Protection	TOWN PLANNER	Compact Growth	Social Equity	Environmental Protection
Compact Growth	1	1/5	1/3	Compact Growth	1	1/5	1/5
Social Equity		1	3	Social Equity		1	1
Environmental Protection			1	Environmental Protection			1

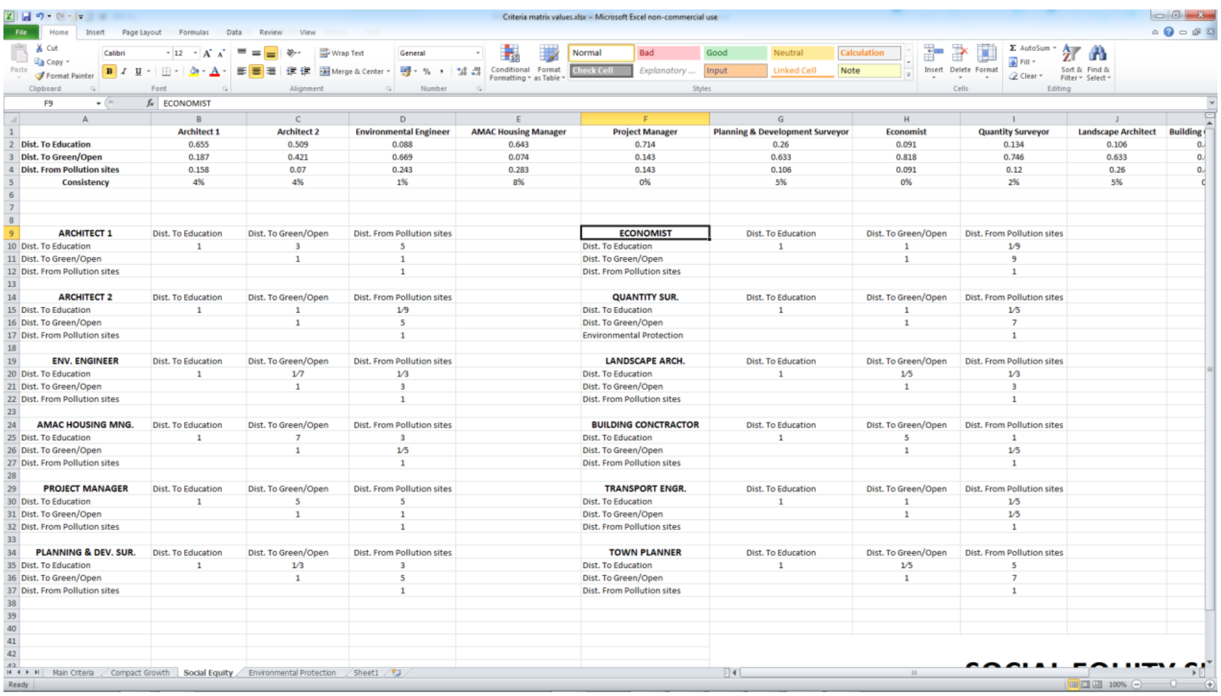
Screenshot of compact growth sub-criteria comparison matrix by professionals



	Architect 1	Architect 2	Environmental Engineer	AMAC Housing Manager	Project Manager	Planning & Development Surveyor	Economist	Quantity Surveyor	Landscape Architect	Building Contractor	Transport Engineer
Dist. To Center	0.455	0.115	0.106	0.18	0.714	0.143	0.091	0.467	0.724	0.071	0.111
Dist. To Roads	0.091	0.405	0.26	0.748	0.143	0.714	0.818	0.067	0.193	0.18	0.778
Slope	0.455	0.48	0.633	0.071	0.143	0.143	0.091	0.467	0.083	0.748	0.111
Consistency	0%	3%	5%	4%	0%	0%	0%	0%	10%	4%	0%

ARCHITECT 1	Dist. To Center	Dist. To Roads	Slope		**ECONOMIST**	Dist. To Center	Dist. To Roads	Slope
Dist. To Center	1	5-Jan	1		Dist. To Center	1	1/9	1
Dist. To Roads		1	1/5		Dist. To Roads		1	9
Slope			1		Slope			1
ARCHITECT 2	Dist. To Center	Dist. To Roads	Slope		**QUANTITY SUR.**	Dist. To Center	Dist. To Roads	Slope
Dist. To Center	1	1/3	1/5		Dist. To Center	1	7	1
Dist. To Roads		1	1		Dist. To Roads		1	1/7
Slope			1		Slope			1
ENV. ENGINEER	Dist. To Center	Dist. To Roads	Slope		**LANDSCAPE ARCH.**	Dist. To Center	Dist. To Roads	Slope
Dist. To Center	1	1/3	1/5		Dist. To Center	1	5	7
Dist. To Roads		1	1/3		Dist. To Roads		1	3
Slope			1		Slope			1
AMAC HOUSING MNG.	Dist. To Center	Dist. To Roads	Slope		**BUILDING CONCTRACTOR**	Dist. To Roads	Dist. To Roads	Slope
Dist. To Center	1	1/5	3		Dist. To Center	1	1/3	1/9
Dist. To Roads		1	9		Dist. To Roads		1	1/5
Slope			1		Slope			1
PROJECT MANAGER	Dist. To Center	Dist. To Roads	Slope		**TRANSPORT ENGR.**	Dist. To Center	Dist. To Roads	Slope
Dist. To Center	1	5	5		Dist. To Center	1	1/7	1
Dist. To Roads		1	1		Dist. To Roads		1	7
Environmental Protection			1		Slope			1
PLANNING & DEV. SUR.	Dist. To Center	Dist. To Roads	Slope		**TOWN PLANNER**	Dist. To Center	Dist. To Roads	Slope
Dist. To Center	1	1/5	1		Dist. To Center	1	1	1/9
Dist. To Roads		1	5		Dist. To Roads		1	1/7
Slope			1		Slope			1

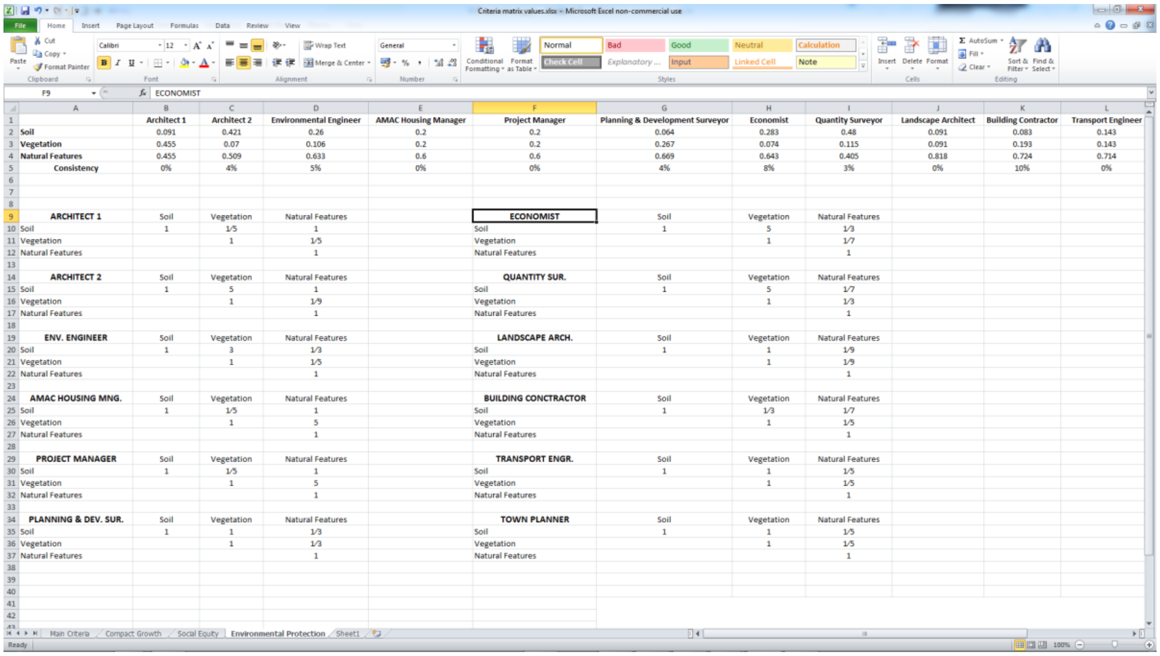
Screenshot of social equity sub-criteria comparison matrix by professionals



	Architect 1	Architect 2	Environmental Engineer	AMAC Housing Manager	Project Manager	Planning & Development Surveyor	Economist	Quantity Surveyor	Landscape Architect	Building
Dist. To Education	0.655	0.509	0.088	0.643	0.714	0.26	0.091	0.134	0.106	0.
Dist. To Green/Open	0.187	0.421	0.669	0.074	0.143	0.633	0.818	0.746	0.633	0.
Dist. From Pollution sites	0.158	0.07	0.243	0.283	0.143	0.106	0.091	0.12	0.26	0.
Consistency	4%	4%	1%	8%	0%	5%	0%	2%	5%	[illegible]

ARCHITECT 1	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**ECONOMIST**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	3	5		Dist. To Education	1	1	1/9
Dist. To Green/Open		1	1		Dist. To Green/Open		1	9
Dist. From Pollution sites			1		Dist. From Pollution sites			1
ARCHITECT 2	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**QUANTITY SUR.**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	1	1/9		Dist. To Education	1	1	1/5
Dist. To Green/Open		1	5		Dist. To Green/Open		1	7
Dist. From Pollution sites			1		Environmental Protection			1
ENV. ENGINEER	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**LANDSCAPE ARCH.**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	1/7	1/3		Dist. To Education	1	1/5	1/3
Dist. To Green/Open		1	3		Dist. To Green/Open		1	3
Dist. From Pollution sites			1		Dist. From Pollution sites			1
AMAC HOUSING MNG.	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**BUILDING CONCTRACTOR**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	7	3		Dist. To Education	1	5	1
Dist. To Green/Open		1	1/5		Dist. To Green/Open		1	1/5
Dist. From Pollution sites			1		Dist. From Pollution sites			1
PROJECT MANAGER	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**TRANSPORT ENGR.**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	5	5		Dist. To Education	1	1	1/5
Dist. To Green/Open		1	1		Dist. To Green/Open		1	1/5
Dist. From Pollution sites			1		Dist. From Pollution sites			1
PLANNING & DEV. SUR.	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites		**TOWN PLANNER**	Dist. To Education	Dist. To Green/Open	Dist. From Pollution sites
Dist. To Education	1	1/3	3		Dist. To Education	1	1/5	5
Dist. To Green/Open		1	5		Dist. To Green/Open		1	7
Dist. From Pollution sites			1		Dist. From Pollution sites			1

Screenshot of environmental protection sub-criteria comparison matrix by professionals



	Architect 1	Architect 2	Environmental Engineer	AMAC Housing Manager	Project Manager	Planning & Development Surveyor	Economist	Quantity Surveyor	Landscape Architect	Building Contractor	Transport Engineer
Soil	0.091	0.421	0.26	0.2	0.2	0.064	0.283	0.48	0.091	0.083	0.143
Vegetation	0.455	0.07	0.106	0.2	0.2	0.267	0.074	0.115	0.091	0.193	0.143
Natural Features	0.455	0.509	0.633	0.6	0.6	0.669	0.643	0.405	0.818	0.724	0.714
Consistency	0%	4%	5%	0%	0%	4%	8%	3%	0%	10%	0%

ARCHITECT 1	Soil	Vegetation	Natural Features		ECONOMIST	Soil	Vegetation	Natural Features
Soil	1	1/5	1		Soil	1	5	1/3
Vegetation		1	1/5		Vegetation		1	1/7
Natural Features			1		Natural Features			1
ARCHITECT 2	Soil	Vegetation	Natural Features		QUANTITY SUR.	Soil	Vegetation	Natural Features
Soil	1	5	1		Soil	1	5	1/7
Vegetation		1	1/9		Vegetation		1	1/3
Natural Features			1		Natural Features			1
ENV. ENGINEER	Soil	Vegetation	Natural Features		LANDSCAPE ARCH.	Soil	Vegetation	Natural Features
Soil	1	3	1/3		Soil	1	1	1/9
Vegetation		1	1/5		Vegetation		1	1/9
Natural Features			1		Natural Features			1
AMAC HOUSING MNG.	Soil	Vegetation	Natural Features		BUILDING CONCTRACTOR	Soil	Vegetation	Natural Features
Soil	1	1/5	1		Soil	1	1/3	1/7
Vegetation		1	5		Vegetation		1	1/5
Natural Features			1		Natural Features			1
PROJECT MANAGER	Soil	Vegetation	Natural Features		TRANSPORT ENGR.	Soil	Vegetation	Natural Features
Soil	1	1/5	1		Soil	1	1	1/5
Vegetation		1	5		Vegetation		1	1/5
Natural Features			1		Natural Features			1
PLANNING & DEV. SUR.	Soil	Vegetation	Natural Features		TOWN PLANNER	Soil	Vegetation	Natural Features
Soil	1	1	1/3		Soil	1	1	1/5
Vegetation		1	1/3		Vegetation		1	1/5
Natural Features			1		Natural Features			1

AHP main criteria comparison input by professionals

PROFESSIONALS	GRWOTH POLICY			
	Compact Growth	Social Equity	Environment Protection	Consistency
Architect 1	0.724	0.083	0.193	10%
Architect 2	0.158	0.187	0.655	4%
Environmental Engineer	0.193	0.083	0.724	10%
AMAC Housing Manager	0.714	0.143	0.143	0%
Project Manager	0.143	0.714	0.143	0%
Planning and Development Surveyor	0.106	0.633	0.26	5%
Economist	0.078	0.487	0.435	1%
Quantity Surveyor	0.083	0.724	0.193	10%
Landscape Architect	0.111	0.111	0.778	0%
Building Contractor	0.639	0.106	0.26	5%
Transport Engineer	0.778	0.111	0.111	0%
Town Planner	0.091	0.455	0.455	0%
Average	0.318166667	0.31975	0.3625	4%

AHP compact growth comparison input by professionals

PROFESSIONALS	COMPACT GROWTH			
	Distance to Center	Distance to Roads	Slope	Consistency
Architect 1	0.455	0.091	0.455	0%
Architect 2	0.115	0.405	0.48	3%
Environmental Engineer	0.106	0.26	0.633	5%
AMAC Housing Manager	0.18	0.748	0.071	4%
Project Manager	0.714	0.143	0.143	0%
Planning and Development Surveyor	0.143	0.714	0.143	0%
Economist	0.091	0.818	0.091	0%
Quantity Surveyor	0.467	0.067	0.467	0%
Landscape Architect	0.724	0.193	0.083	10%
Building Contractor	0.071	0.18	0.748	4%
Transport Engineer	0.111	0.778	0.111	0%
Town Planner	0.49	0.451	0.059	1%
Average	0.305583333	0.404	0.290333333	2%

AHP Social Equity comparison input by professionals

PROFESSIONALS	SOCIAL EQUITY			
	Distance to Education	Distance to Green/Open	Distance from Pollution	Consistency
Architect 1	0.655	0.187	0.158	4%
Architect 2	0.509	0.421	0.07	4%
Environmental Engineer	0.088	0.669	0.243	1%
AMAC Housing Manager	0.643	0.074	0.283	8%
Project Manager	0.714	0.143	0.143	0%
Planning and Development Surveyor	0.26	0.633	0.106	5%
Economist	0.091	0.818	0.091	0%

Quantity Surveyor	0.134	0.746	0.12	2%
Landscape Architect	0.106	0.633	0.26	5%
Building Contractor	0.455	0.091	0.455	0%
Transport Engineer	0.143	0.143	0.714	0%
Town Planner	0.193	0.724	0.083	10%
Average	0.332583333	0.440166667	0.227166667	3%

AHP environmental protection comparison input by professionals

PROFESSIONALS	**ENVIRONMENTAL PROTECTION**			
	Soil	Vegetation	Natural Features	Consistency
Architect 1	0.091	0.455	0.455	0%
Architect 2	0.421	0.07	0.509	4%
Environmental Engineer	0.26	0.106	0.633	5%
AMAC Housing Manager	0.2	0.2	0.6	0%
Project Manager	0.2	0.2	0.6	0%
Planning and Development Surveyor	0.064	0.267	0.669	4%
Economist	0.283	0.074	0.643	8%
Quantity Surveyor	0.48	0.115	0.405	3%
Landscape Architect	0.091	0.091	0.818	0%
Building Contractor	0.083	0.193	0.724	10%
Transport Engineer	0.143	0.143	0.714	0%
Town Planner	0.143	0.143	0.714	0%
Average	0.204916667	0.171416667	0.623666667	3%

APPENDIX 5

SPATIAL ANALYSIS OF THE CRITERIA TO GENERATE LAYER MAPS

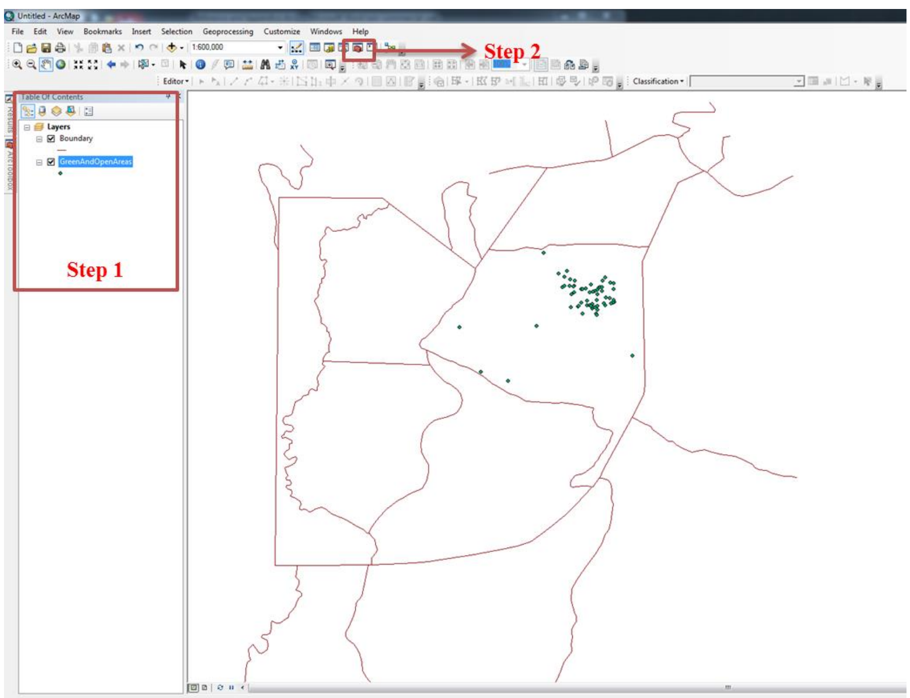
Four spatial analyses were carried out in GIS to generate the layer maps, namely; buffer, slope classification and digitizing.

Buffer

The buffer analysis is to create a range of specified distance from the criteria, kind of like a ring around the criteria. This analysis was carried out for all the criteria except for soil, slope and vegetation.

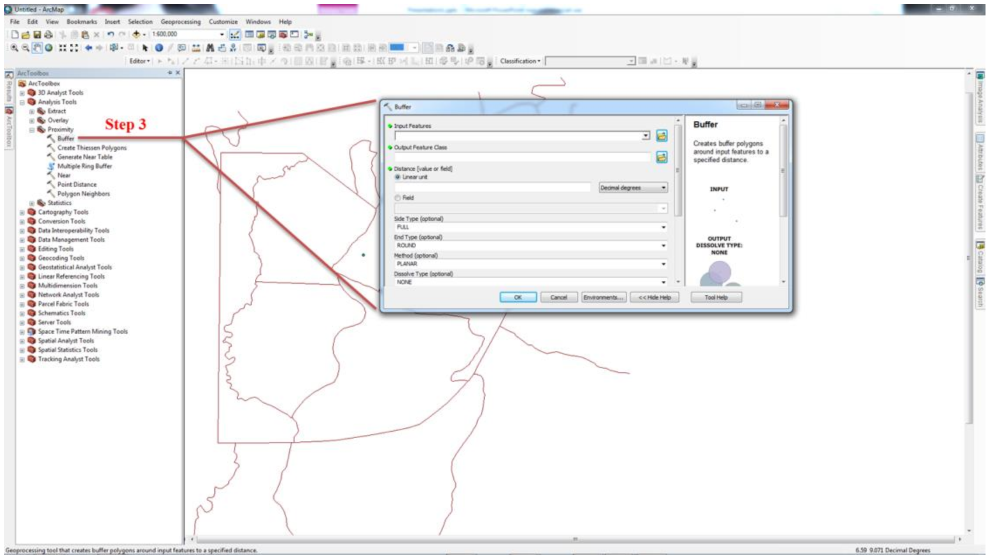
Steps:

1- Open ArcMap with the layer file to be analyzed included in the table of content



2- Open Arc Toolbox – Analysis tools – Proximity – Buffer (double click on buffer)

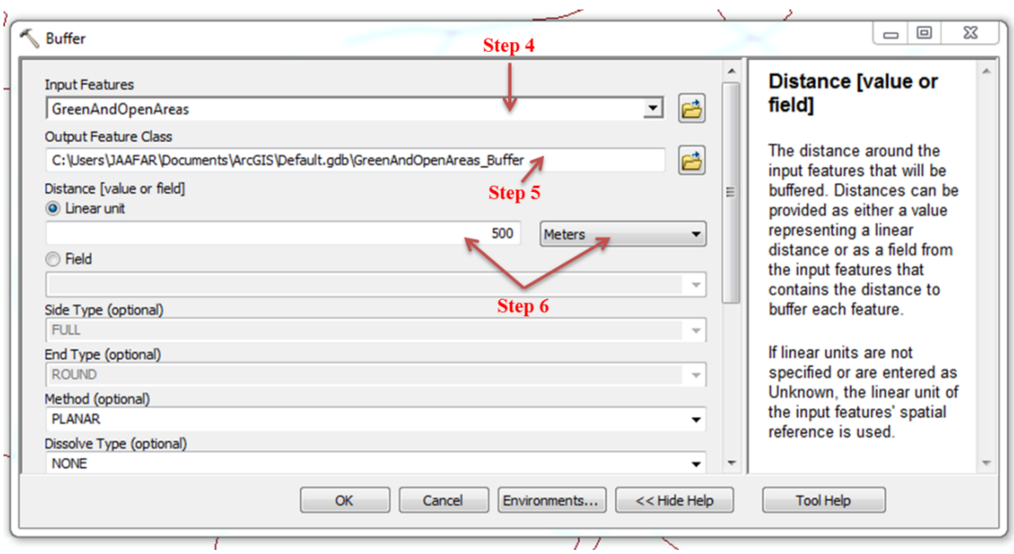
3- The Buffer analysis windows panel will open



4- Drag and drop the layer file from the table of content at the input features pane

5- Specify name and where the output will be saved at output feature class pane.

6- Specify the buffer distance and unit at the distance pane and click ok to carry out analysis



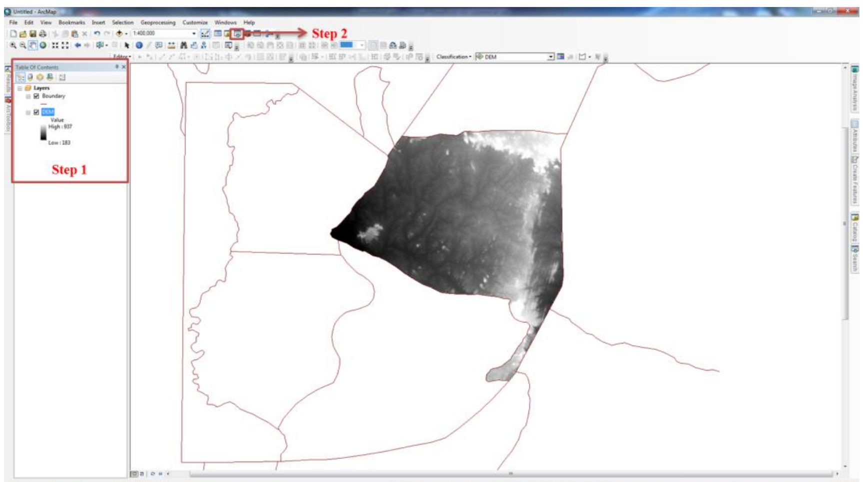
7- The result will appear. Repeat same procedure with varying distance for the buffer.

Slope

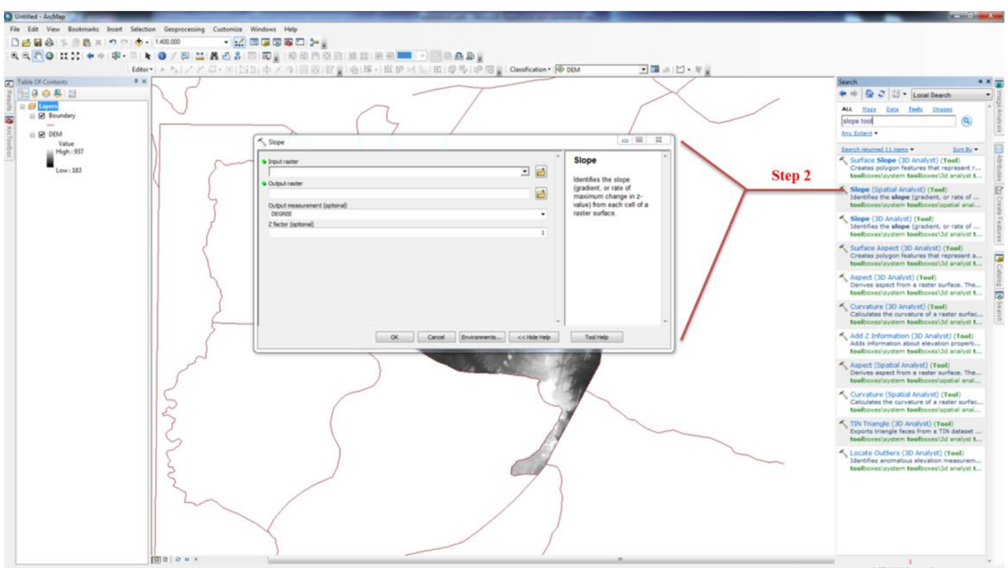
This spatial analysis was carried out using the DEM to determine the slope percentage of the study area.

Steps:

1- Open ArcMap with the layer file to be analyzed (DEM) included in the table of content



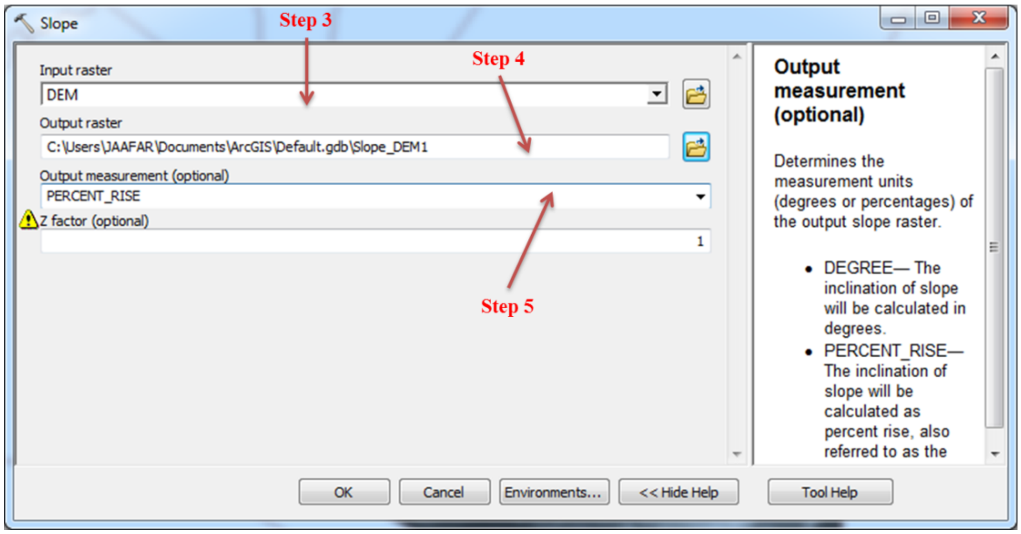
2- Click on Search icon – type 'slope tool' and the slope analysis windows will open



3- Drag and drop the layer file from table of content into the input raster pane

4- Specify name and location where the analysis result will be save at output raster pane

5- Specify the kind of slope whether degrees or percentage at the output measurement pane and click ok.

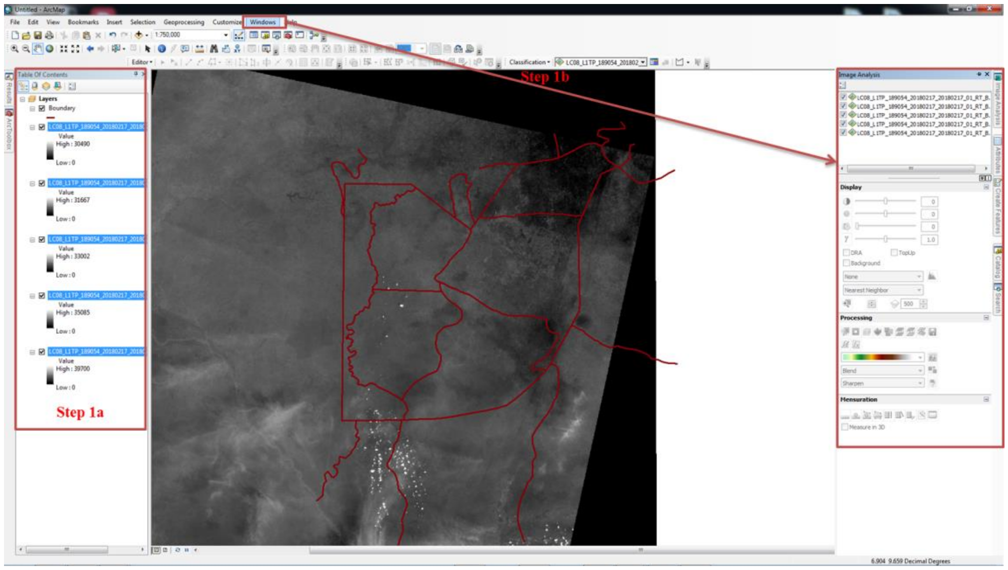


Classification

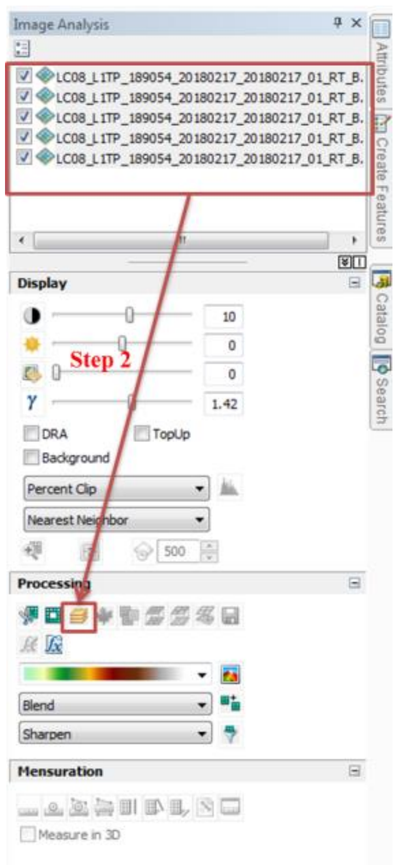
This is a spatial analysis carried out on Landsat Images to mark out the different features on the map, such as built up, bare land, vegetation etc. this analysis was carried out on the vegetation criteria.

Steps:

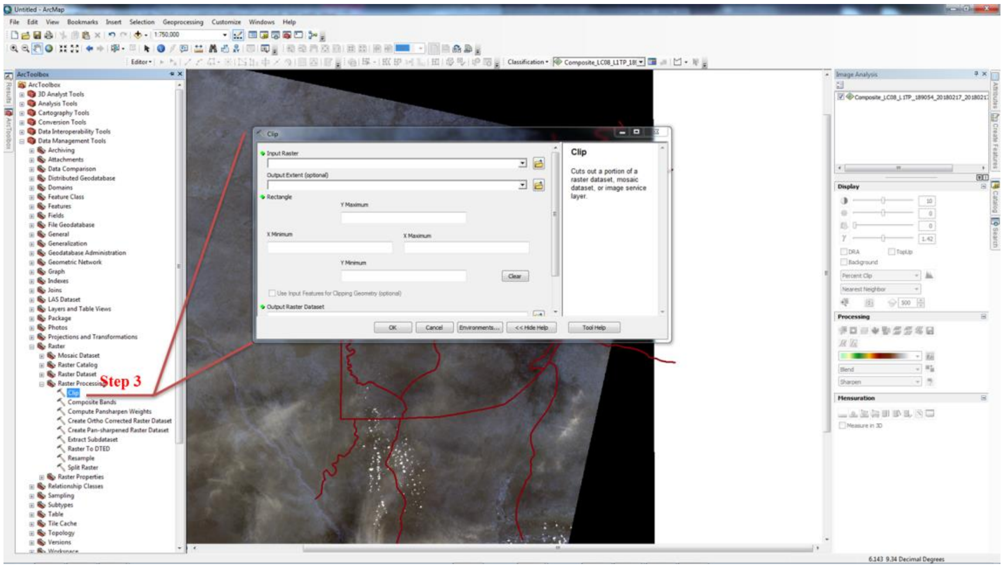
1- Insert the Landsat images in the table of content pane and open ‘image analysis’ from windows tab menu.



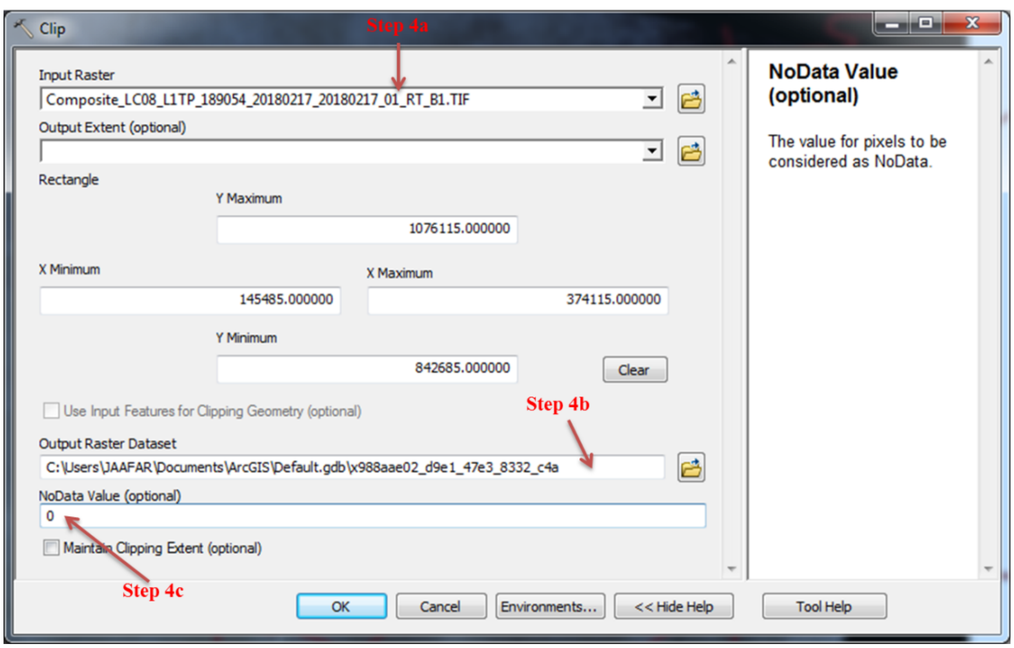
2- Merge the Landsat images into one using the 'composite band' icon on the image analysis pane.



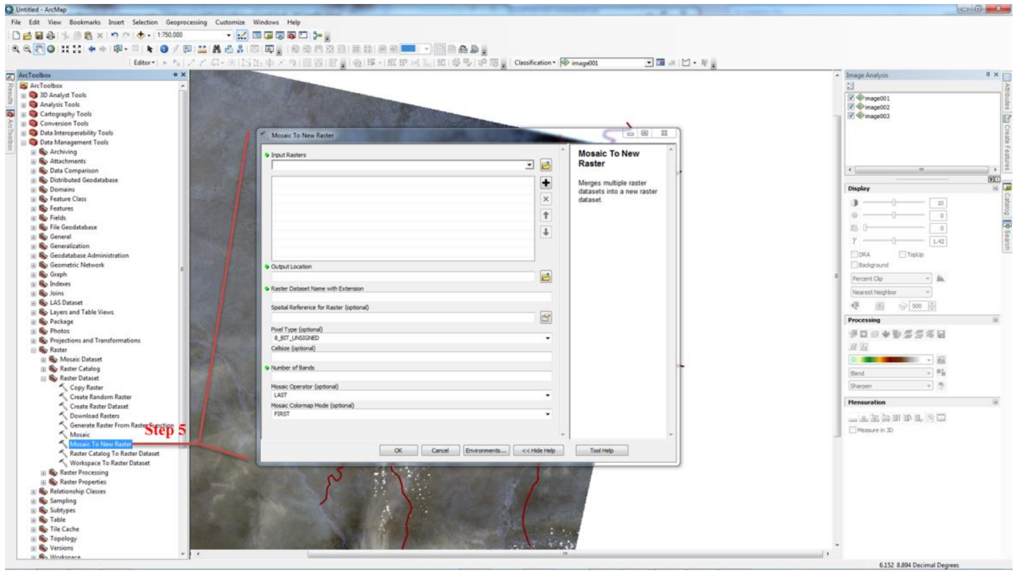
3- Open Arc Toolbox – Data management tool – Raster – Raster processing – Clip (double click) and the clip analysis window appears.



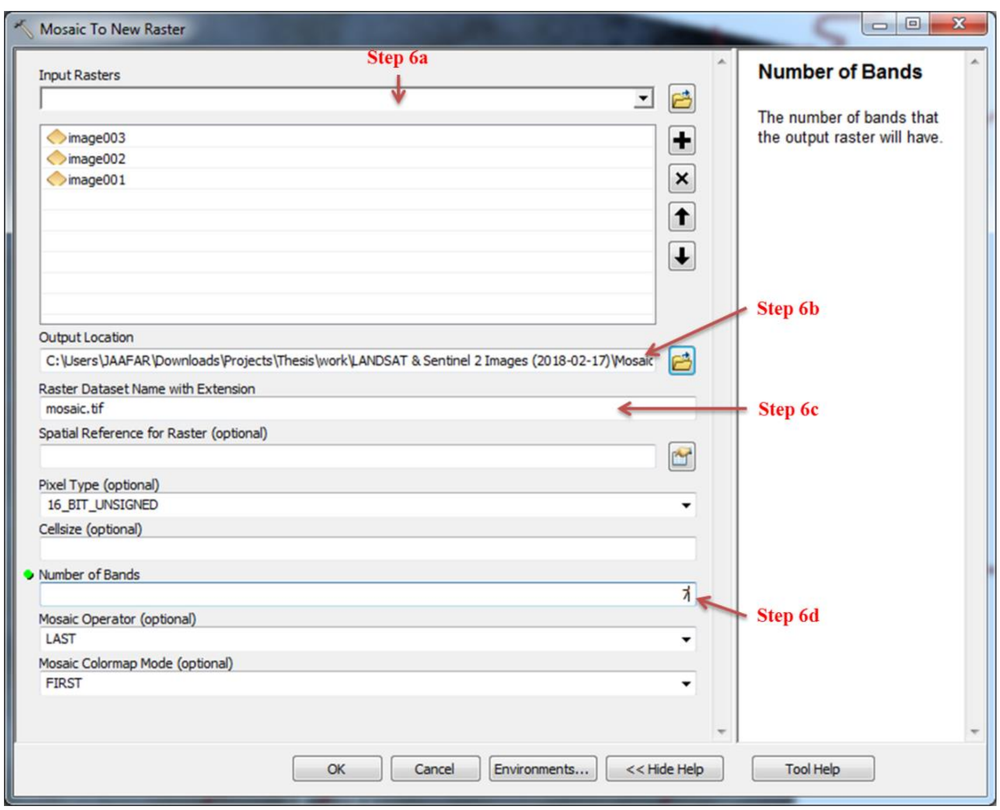
4- Drag and drop the composite raster file from the table of content and drop on the ‘input raster’ pane. Specify name and where the output will be saved. At ‘NoData value’ pane, set the value at 0 and click ok. Repeat the process two more times.



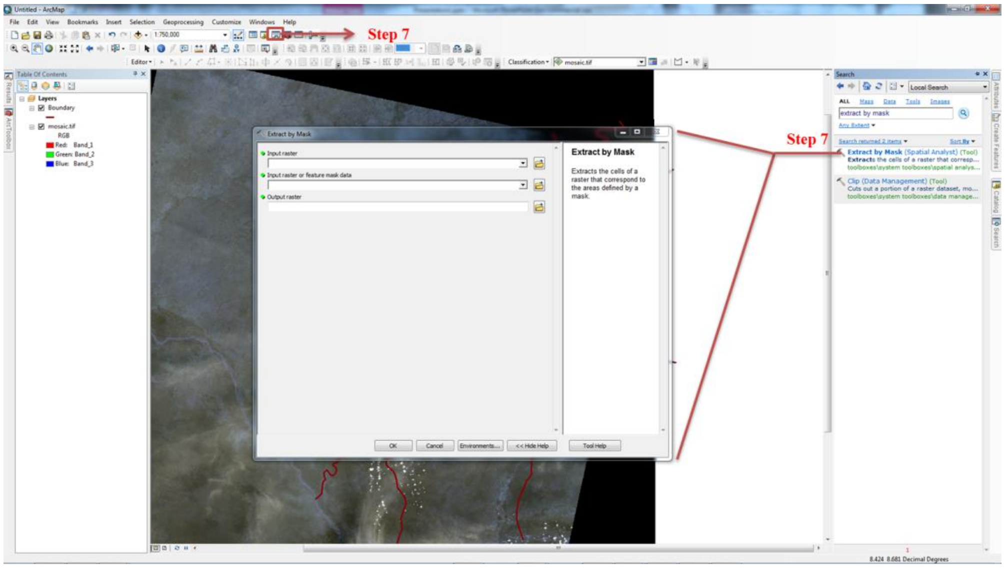
5- Open Arc Toolbox – Data management tool – Raster – Raster Dataset – Mosaic to new raster (double click). Mosaic to new raster windows open.



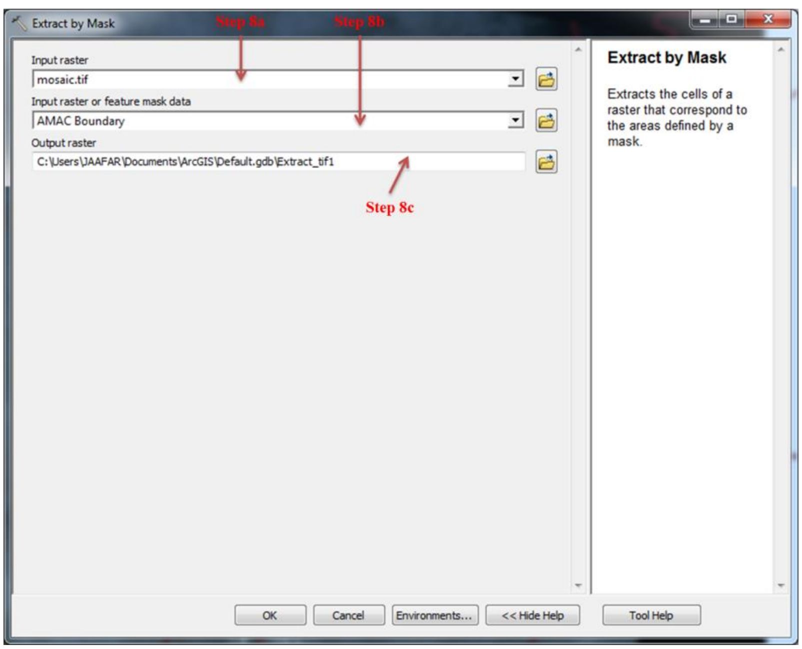
6- Drag and drop the output images from step 4, ‘output location’ pane to specify where d output to be save, ‘raster dataset name with extension’ pane to specify the name and format of the output, ‘number of bands’ pane to be set same with the number of Landsat images in step 1 and click ok.



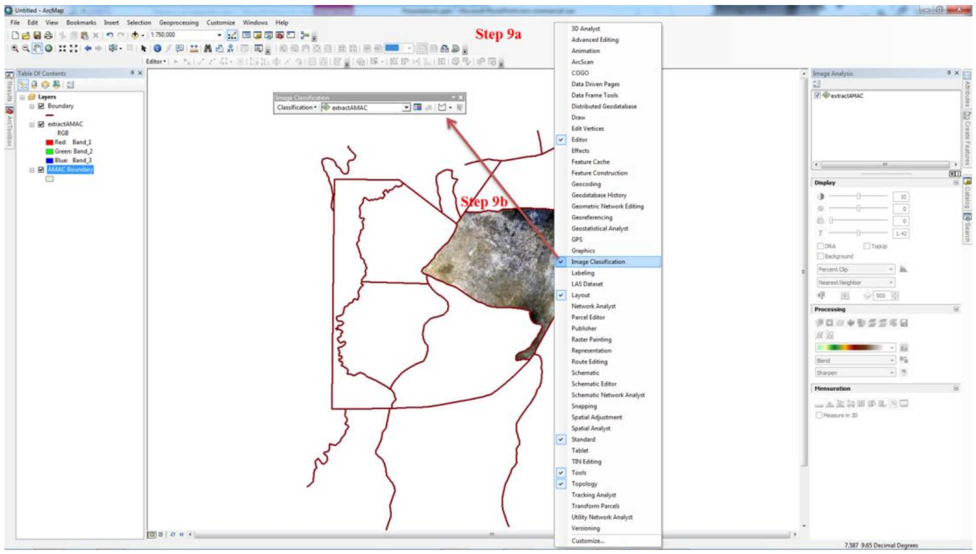
7- Click on the Search icon – type ‘extract by mask’ and click on it, the ‘extract by mask’ windows appears. The extract by mask is to remove-out the study area from the Landsat image.



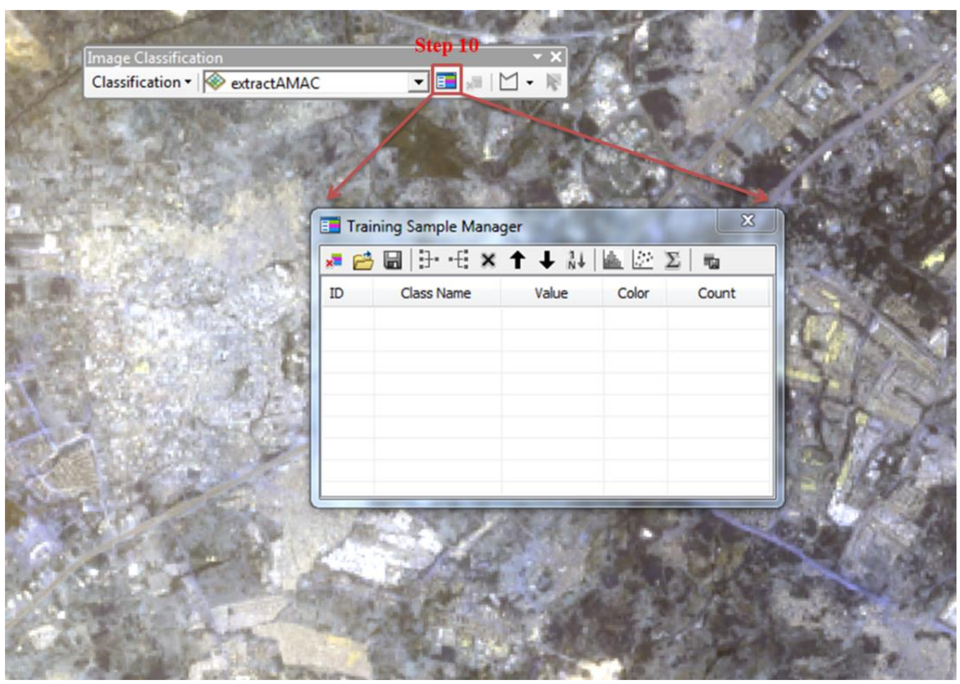
8- Drag and drop the ‘mosaic’ layer file from the table of content into the ‘input raster’ pane. Drag and drop the study area polygon layer file from the table of content into ‘input raster or feature mask data’ and specify name and where the extracted output will be save in ‘output raster’ pane. Click ok.



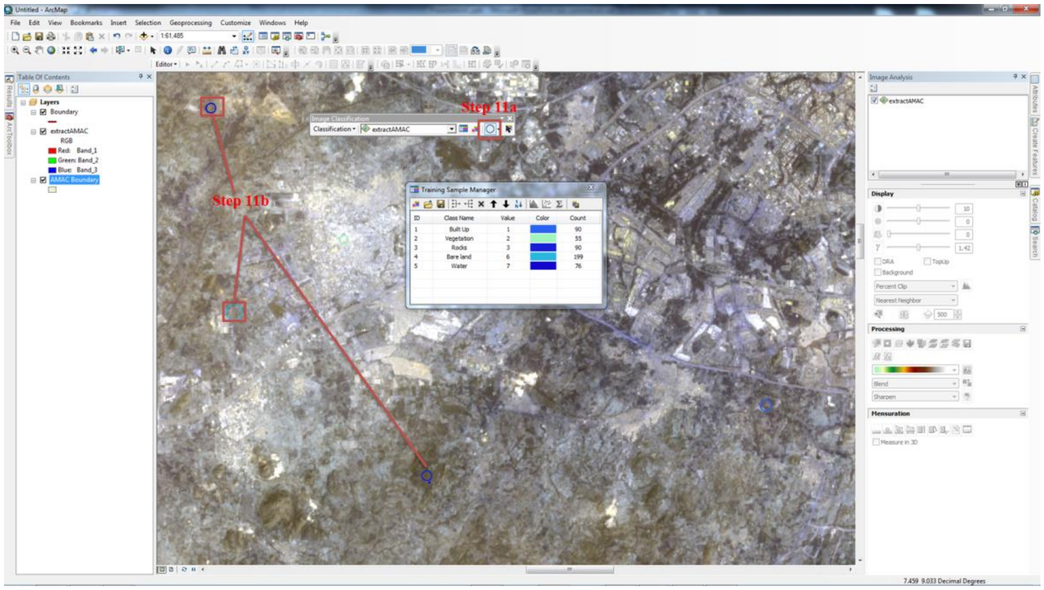
9- Right-click on the standard tab bar on the ArcMap window, select ‘image classification’ and the image classification bar appears.



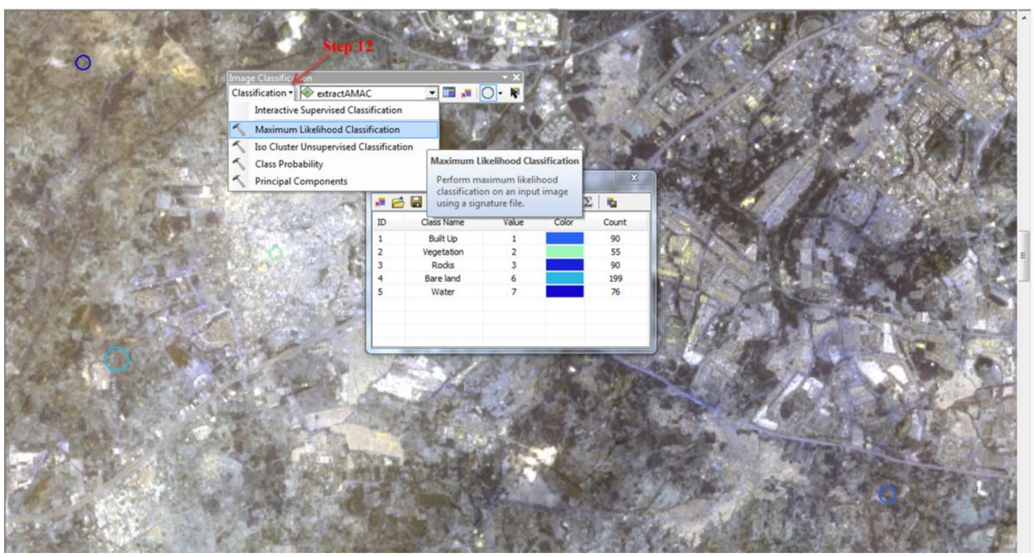
10- Zoom into the extracted Landsat image, on the ‘image classification’ bar click on ‘training sample manager’ and the windows appears.



11- With the ‘draw polygon’ icon mark out pixel samples from the Landsat image the various features of the map and label in the training sample manager.



12- Click on the drop-down arrow on the ‘classification’ icon and select ‘maximum likelihood classification’



Digitizing

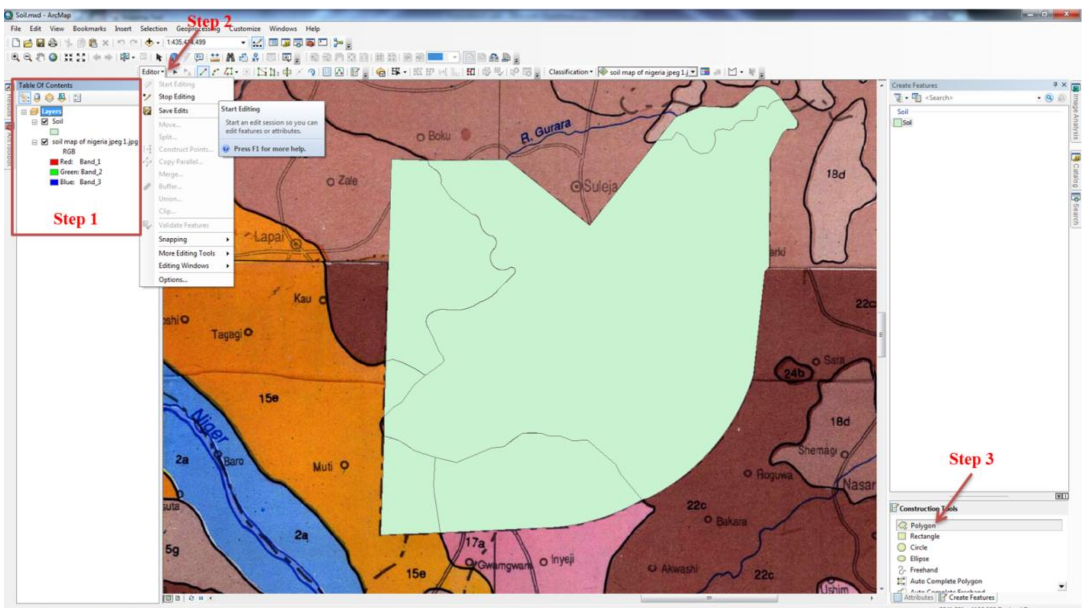
This is a spatial analysis whereby a raster file (jpeg, png, pdf etc.) is converted into a GIS file format called shapefile. This analysis was carried out on the soil criteria.

Steps:

1- Open ArcMap and insert the raster file and the newly-created shape file to be digitized into the table content.

2- Zoom to the exact place to be digitized and click on the 'editor' drop-down arrow and select 'start editing'

3- On the 'create features' pane click on polygon and trace out the area on the raster file and save.



APPENDIX 6

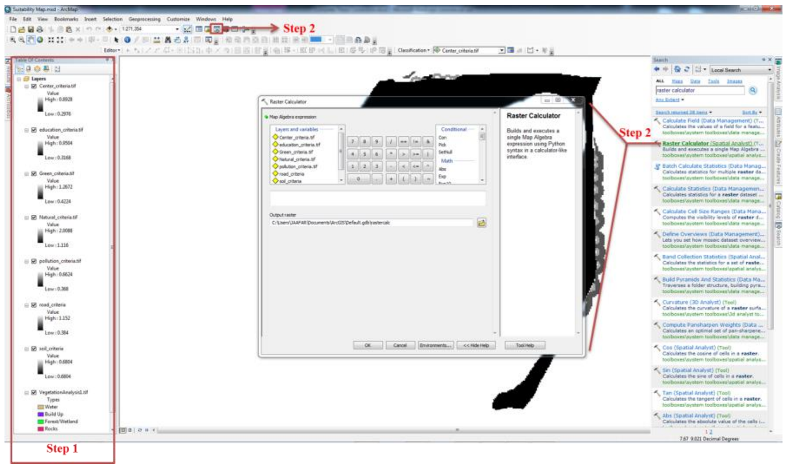
GENERATING THE SUITABILITY MAP

This is the GIS procedure for the generation of the final suitability map.

Steps:

1- Open ArcMap and insert all the reclassified layer files of the criteria on the table of content

2- Click on Search icon – type ‘raster calculator’ and the raster calculator window will appear



3- Input the data as per the suitability formula S = ∑ [Criteria map * Criteria Weight]. On the ‘output raster’ pane you specify the name and location of where the result will be saved and click on Ok.