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DEPARTMENT OF GEOSPATIAL & SPACE TECHNOLOGY

Use of Geographic Information System (GIS) in Land Suitability Analysis for Urban Development; Case Study of Kisii Town, Kenya

Ontumbi Godfrey Momanyi

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DECLARATION

This is my original work and has not been presented for a degree in any another university.

Signature. ---. Date------------------------------

Ontumbi Godfrey Momanyi.

This project has been submitted for examination with my our approval as the university supervisor

Signature--. Date----------------------------

Dr. David Nyika

Abstract

Land use planners often make complex decisions within a short period of time when they must take into account sustainable development and economic competitiveness. Land suitability analysis would be very useful in this respect. Kisii town is one of the fastest growing urban areas in western part of Kenya. The present urban development and growth in situation in the town is characterized by a state of mixed and conflicting land uses. This has been partly attributed to lack of land suitability analysis to guide proper land use allocation strategies. During the last 20 years, Geographic Information Systems (GIS) has emerged from the scientific laboratories into the heart of conventional urban planning practice. During this period, urban planners have been aggressive adopters and adapters and strong advocates for local governments deploying GIS. This is true at least in part because GIS provides spatial analysis and data manipulation capabilities that align closely with the professional needs of urban and regional planners.

The objective of this study was to demonstrate how GIS can be use based in multi criteria evaluation technique in land suitability analysis for urban development. This process involves a consideration of five factors, that is, slope, road proximity/accessibility and ecological sensitivity by using multi-criteria decision analysis (MCDA) method in decision making process. With the support of Geographic Information System (GIS) and multi-criteria evaluation techniques, these four factors were selected and be used in the analysis of the land suitability analysis for urban growth in Kisii town, Kenya. The main source of data were LiDAR image that was acquired in 2012. Interviews were also conducted with various stakeholders in urban planning in Kisii town. Direct observations were done. The process considers multiple land use objectives, determines the amount of land required by each together with their environmental requirements. This was in view of the fact that the practice of urban land use allocation has all along been begged on economic factors devoid of environmental concerns which play a vital role for sustainable urban development.

The results showed that from the study approximately 18.46km^2 of the study area is very suitable and this is represented by nearly 26% of the study area. The area under suitable criteria for urban development is 31% represented by 22.01 km^2. In addition nearly 21% of the study area of moderate suitability for urban development and this is represented by 14.91km^2. Areas of least suitable for urban development are represented by 9.23km^2 which makes up 13% of the study area. Unsuitable areas for urban development consist approximately 6.39km^2 represented by 9% of the study area.

Dedication

To my mum and dad for their moral and material support to ensure that I am who I am today.

Acknowledgement

The preparation and writing of this project required patience, support and encouragement of many individuals. I would therefore like to pay a glowing tribute and express my profound thanks to the persons and institutions that guided me in writing this thesis.

The undertaking of this study would not have been possible without the support and contributions of various individuals. Firstly, I would wish to sincerely thank my supervisor Dr. David Nyika for his tireless support and guidance throughout the study. He was always readily available for any assistance and his concrete advice and constructive comments were my great asset during the preparation of this report.

I also wish to acknowledge the support I got from my colleagues who provided me with relevant assistance in data analysis and writing this thesis. The members of staff, Department of Geospatial and Space Technology, for their self-less effort to ensure that I achieve my academic goals.

Lastly I am greatly indebted to my family members for their moral and material support which has made me realize my academic success up to this level.

Table of Contents

List of Tables

List of Figures

List of Maps

List of plates

List of Abbreviation and Acronyms

AHP	Analytic Hierarchy Process
DEM	Light Detection and Ranging
DTM	Digital Terrain Model
GDP	Gross Domestic Product
GOK	Government of Kenya
GPS	Global Positioning System
INS	Inertial Navigation Systems
ISUDP	Integrated Strategic Urban Development Plan
LiDAR	Light Detection and Ranging
MCDA	Multi Criteria Decision Analysis
MCDM	Multi Criteria Decision Analysis
MCE	Multi-Criteria Evaluation
NEMA	National Environmental Management Authority
UTM	Universal Transverse Mercator
WGS84	World Geodetic Systems of 1984
WRMA	Water Resource Management Authority

CHAPTER 1: INTRODUCTION

1.1 Background

The combination of expanding populations and shifting demographics during the 20th century has resulted in a radical reshaping of both urban and rural landscapes in countries around the world. Urban areas in developing countries have witnessed tremendous changes in terms of population growth and urbanization. In the absence of proper urban management practices, uncontrolled and rapid increase in population pose enormous challenges to urban governments in providing adequate shelter to the millions homeless and poor in urban areas (Rossiter 2001). Major characteristics of urbanization include: urban construction is continuously spreading, the demand for urban land use is rapidly swelling, and a lot of agricultural land is converting into non-agricultural land (CHEN, 1999). Serious problems addressed in sustainable urban development and growth include how to properly make use of limited land resources, how to balance actual land use capacities and theoretic capacities. Urban areas of nowadays are more described as sprawling regions that become interconnected in a dendritic fashion (Carlson and Arthur, 2000). The positive aspects of urbanization have often been overshadowed by deterioration in the physical environment and quality of life caused by the widening gaps between supply and demand for essential services and infrastructure.

Urbanization, like elsewhere in Africa has taken a firm root in Kenya (Obudho, 2001). Over the last decades, not only the capital Nairobi tripled its population, but also the many smaller and medium sized urban centres doubled or tripled in size. At the end of the previous century, the Kenyan government embarked on five-year development plans for each town and urban centre to help planning for such unprecedented urban development and growth as many of the many towns focused on infrastructure and services, protection of natural resources, such as springs, and fertile land for food production were insufficiently addressed.
Urban planning is the process of influencing, controlling or directing changes in the use of land overtime and space in an urban area (Healey, 1992). The sustainable urban development or best use of the land will be carried out by assigning the land use zones on the basis of capability, compatibility, use of proper technology and measures to protect environmental degradability (NEMA, 2004). In the past, planners and developers ignored the natural and physical environment (Arthur and Nalle, 1997). Planning was dominated by an emphasis on physical building and re-development which ignored social issues and environmental concerns. Among the aims are to tackle urban decline, reduce the use of greenfield land and

limit urban sprawl[1] and to improve the quality of design of the built environment (UN-Habitat, 2005).

Part of the solution to the land-use problem is land suitability analysis in support of rational land-use planning, appropriate and sustainable use of natural resources (Rossiter 2001). The identification of suitable land for urban development and growth is one of the critical issues of planning as noted by Rossiter 2001. The suitability of the land for urban development is not only based on a set of physical parameters but also very much on the economic factors. The cumulative effect of these factors determine the degree of suitability and also helps in further categorizing of the land into different orders of urban development and growth.

One of the most useful applications of GIS for planning and management is the land suitability mapping and analysis (McHarg, 1969; Hopkins, 1977; Brail and Klosterman, 2001; Collins et al., 2001). The GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitant for animal and plant species (Pereira and Duckstein, 1993; Store and Kangas, 2001), geological favorability (Bonham-Carter, 1994), suitability of land for agricultural activities (Cambell et al., 1992; Kalogirou, 2002).

Application of GIS can manage a large quantity of spatial information and facilitate integration of multiple data layers with land suitability models. Therefore, integrated GIS-based Multi-Criterion Decision Analysis (MCDA) process is used to evaluate land suitability for future land-use planning (Zolfaghari 2008, Dai 2010). Furthermore, the purpose of integrating the GIS-based land suitability analysis using the multi-criteria evaluation (MCE) approach is that it is the most suitable method for solving complex problems related to land-use planning and any other kind of development. It has also been recognized as an effective multi-criteria decision support system (Malczewski 2004).

The assessment of the physical parameters of the land for urban development is possible by analyzing terrain, geology, physiography and distance from road among others. and which is much amenable to GIS analysis.

[1]Urban growth through scattered development followed by a gradual filling in of space without any plan. Spread of urban growth in a disorganized manner without advance planning or regard for subsequent needs for transport, employment, services.

1.2 Problem Statement

Kisii is the fastest growing town in Western Kenya and it is the second most populous town after Kisumu (Kisii Town ISUDP, 2012). Kisii town is the 8th most populous town in Kenya and its population has grown from 3000 people in 1963 to about over 180,000 people today within the past fifty years. This high rate of urbanization in Kisii poses a challenge to relevant authorities to manage and control urban development and growth (Kisii Town ISUDP, 2012). Major planning and urban development challenges facing Kisii town include but not limited to the following: high population growth straining the available infrastructural facilities, urban sprawl, lack of adequate basic physical infrastructure like, sewer, water supply, solid waste disposal and surface water drainage, environmental degradation, riparian reserve and informal settlements and encroachments on fragile ecosystem like wetlands and hilltops (Kisii Town ISUDP, 2012).

The town has in recent past remained an ever green and eco-friendly town in Kenya despite few environmental challenges of rudimentary solid and liquid waste disposal and air pollution management hiccups (Maronga, 2005). However until recently unprecedented infrastructural development and housing construction in most parts of the town has seen both exotic and indigenous trees species cleared to pave way for the new buildings compromising the purification of air and putting the lives of residents of Kisii town in jeopardy.

Kisii town has a relatively high population density of approximately 2862 per km^2 which is partly due to scarcity of land within the town boundaries spurring further expansion of settlement in the outlying urban fringe areas (Nyamwange, 1994). Both population increases and the process of urbanisation have increased the pressure on land resource for urban development and agricultural land use. This increased pressure on the available land resources may result in land degradation. Reliable and accurate land suitability analysis is therefore indispensable to the decision-making processes involved in developing land use policies that will support sustainable urban development.

Empirical results of the feasibility study conducted during the preparation of Kisii Town Integrated Urban Development Plan (2011-2030) revealed that the outward expansion of Kisii town has tended to follow the major roads radiating from the town. A part from roads, households and business operators are also influenced by essential infrastructure such as water and electricity in their locational patterns. Topography has also played a significant role in shaping the spatial dimension of Kisii town. This spatial growth of the town is not supported by land suitability analysis hence the likely impacts of unsustainable urban development.

Due to rapid growth of the town, a challenge for a town decision maker is on how to manage urban development in order to minimize the negative impacts for unsustainable development and achieve smart urban growth[2]. GIS appears to be a significant tool for planning, assessment and monitoring of urban development and natural resources. Limiting urban development to such areas where the town's characteristics are most suitable will, to an extent, reduce negative impacts compared to areas which are more fragile in nature (Boyd et al, 1995). In light of the above, it is imperative that only some areas are suitable for urban development and ensure that urban development criteria are matched with the basic resource characteristics of the area.

This study set out to identify suitable areas for urban development and spatial growth of Kisii town. From the land suitability analysis that will be derived that will help re-affirm land use areas that are suitably allocated, re-allocate areas that are in conflict with environmental planning considerations and conserve fragile ecosystems.

1.3 Study Objectives

The objective of this study was to carry out land suitability analysis for urban development of Kisii town using Multi-Criteria Evaluation (MCE) and GIS approach. This process involves a consideration of five factors, i.e. slope, road proximity and ecological sensitivity and aspect. With the support of Geographic Information Systems (GIS) and multi-criteria evaluation techniques, these five factors were selected to be used in the analysis of the land suitability analysis. The specific objectives of the study include the following:

i. To develop a conceptual framework for GIS in land suitability analysis for urban development;
ii. Carry out land suitability analysis using various parameters for urban development; and
iii. Identify and prioritize potential urban development sites.

[2] Smart urban growth means building urban and suburban areas that supports local economies and protects the environment.

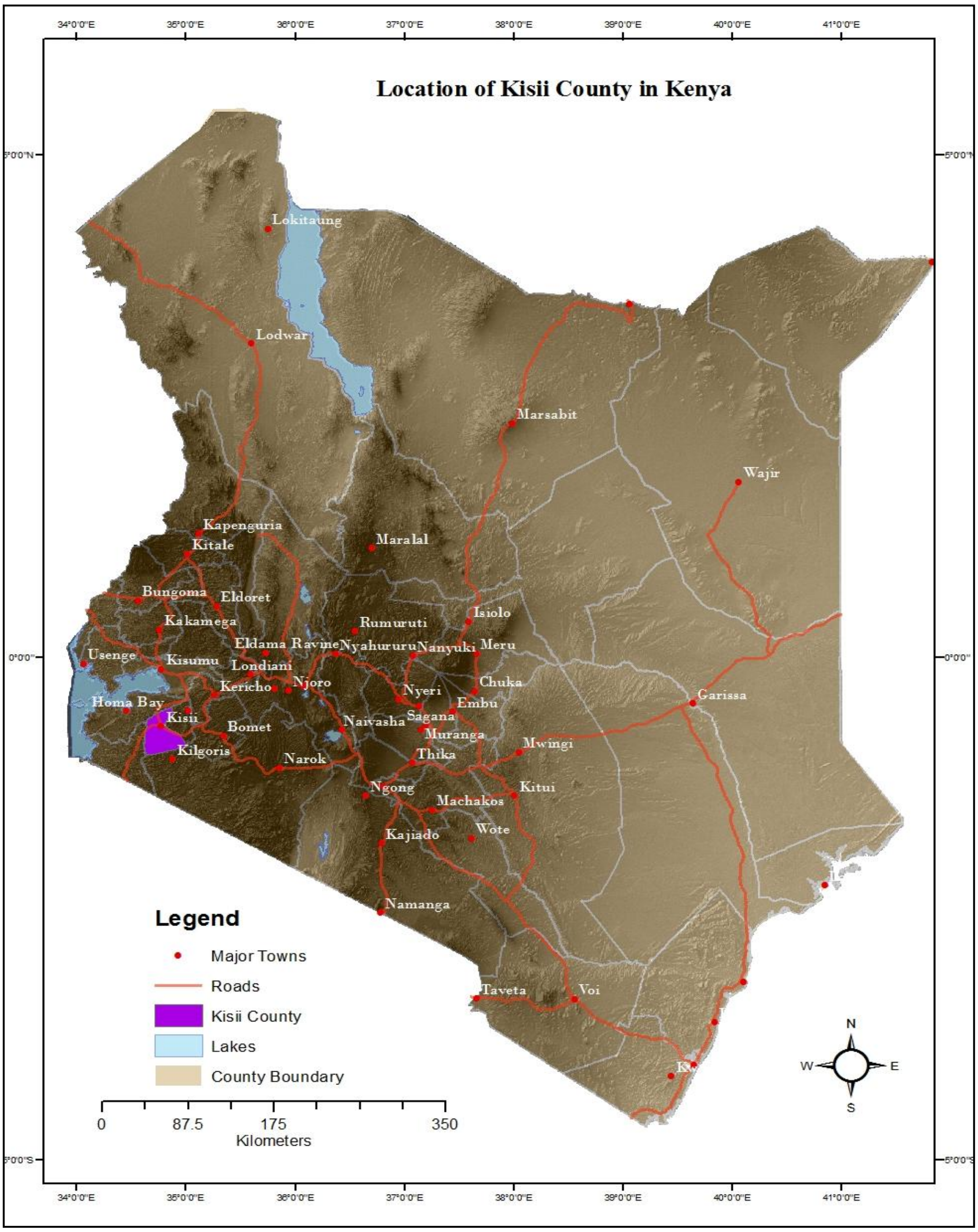
1.4 Research Questions

The task of solving the growing problems related to urban development growth and urban sprawl in fast growing urban areas of developing countries is huge. The main research question is how can GIS be used as one of the tool in land suitability analysis for urban development and growth?

1.5 Study Area

This study will be conducted within Kisii town covering approximately covering 70Km^2. Kisii town is located about 350 km to the south-west of Nairobi.

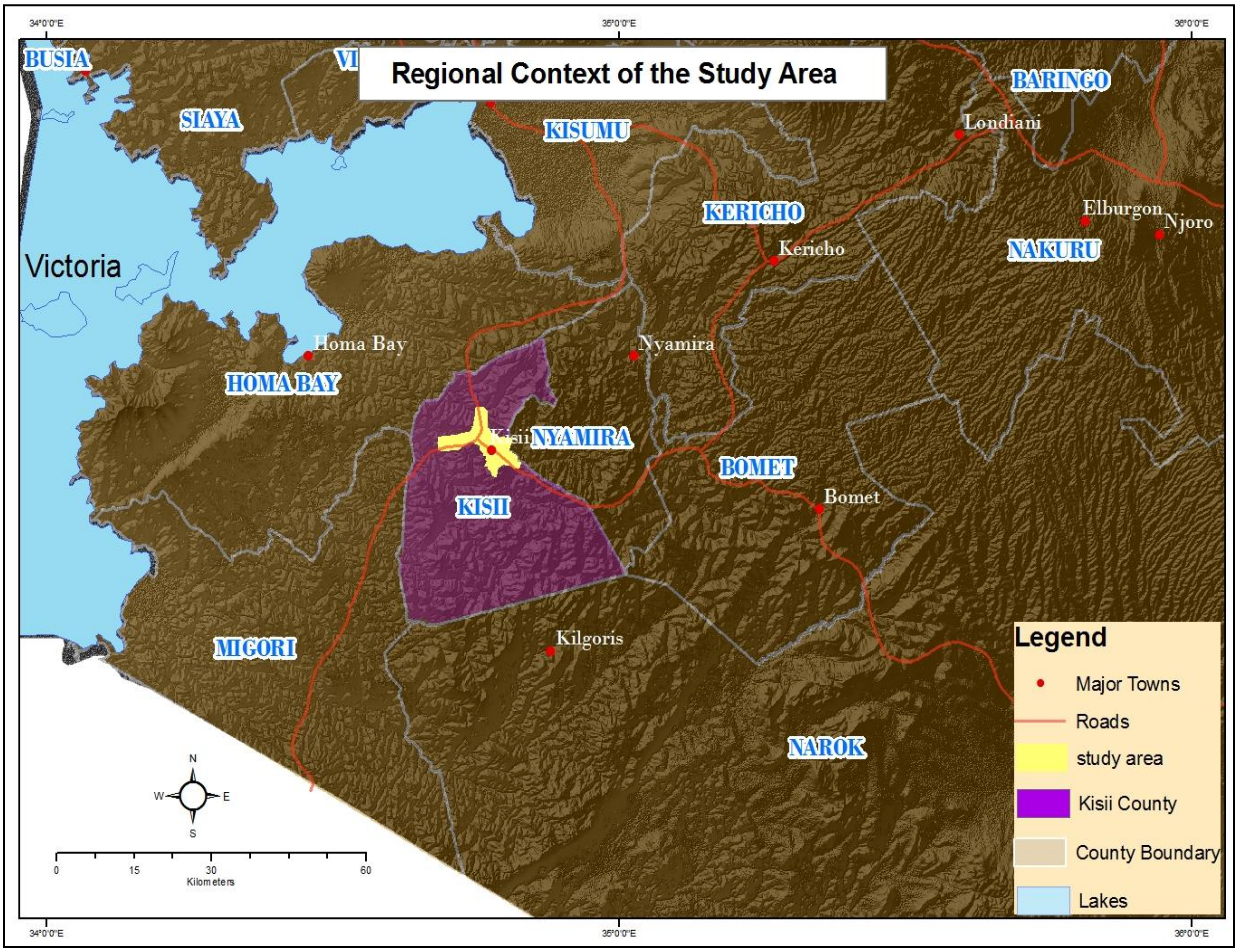
Map 1: Study Area at the national Context



Source: Author, 2014

The town falls within the larger Kisii County surrounded by four other counties namely, Narok to the south east, Migori to the south west, to the Homa Bay North and Nyamira to the west.

Map 2: The Study Area at the Regional Context



Source: Author, 2014

The town was originally established by British soldiers who were being forced to retreat from Lake Victoria by heavy gunfire from German soldiers' gunboats during the First World War. In 1905, when Kisii town was a small trading centre, the British colonial government encouraged by the good road access and availability of water decided to establish an administrative centre. The town grew to become the administrative headquarters of the region then known as South Kavirondo comprising of Kisii and Nyanza District in 1907. At that time, the town consisted of a small British administrative station, a commercial area dominated by Indian traders and a location for the Africans with a market shed built for periodic market activities. In 1911, Kisii town was raised to the status of a township with a boundary covering 8km^2. It was upgraded to a town council in 1973 when boundaries were extended to include the surrounding rural areas covering an area of 29km^2. Currently, the town has outgrown it municipality boundary and is now growing towards Nyamataro, Nyakoe, Mosocho, Kiogoro, Kegati and Kiabiraa which are expected to become future dormitory towns. Kisii town is growing towards Suneka town mainly along the major highway. Today, Kisii town is an economic hub hosting several businesses, organizations, educational institutions and government agencies serving not only Kisii County but the entire region at large.

1.6 Justification for the Study

Land suitability analysis is one of the most useful areas of applications of Geographic Information System (GIS) by planners and land managers. This study borrows techniques found useful in other fields like geography and urban planning to explain and analyze land sustainability analysis for purpose of determining the suitable areas for urban development. The study will provide GIS techniques for the selection of suitable sites for urban development with a minimum or no risk for the environment. The research results could be used to improve Kisii town urban planning policies and regulations. It is anticipated that the findings from this study will form a significant basis for application and replication in other urban areas thus leading to sustainable urbanization.

1.7 Scope of work

Land use planning, suitability and GIS based tools are the three elements in this research. This research will be conducted in Kisii town and its environs with an area measuring approximately 70km^2. The research will deal will spatial analysis of topographical data, and environmental data and development of land suitability indices.

CHAPTER 2: LITERATURE REVIEW

2.1 Overview

Land utilization varies from one town to another due to varied characteristics of terrain conditions, population, legal restrictions, and culture, among others. Land use allocation and policies should be made to fit local characteristics of land. Although the policies may differ in specific standards and regulations, they serve a common objective to adapt the practical land conditions and serve for building a sound legal system of land development and management. This chapter describes urbanization in Kenya, historical development of Kisii town, multi criteria decision making and land suitability analysis using GIS.

2.2 Urbanization and Urban Growth in Kenya

Urbanization in developing countries and Kenya in particular, has been and is still taking place rapidly. According to Vision 2030 it is estimated that by the year 2015, the level of urbanization will have reached 44.5%, and eventually the percentage is set to reach 54% by 2030 with nearly 30 million people living in urban areas. This increase in urban population will lead to urban growth[3] in the country.

Urbanization is taking place rapidly in Lake Victoria Basin where Kisii town is located due to increasing rural to urban migration. Urban land use is therefore increasing and in many cases taking up good agricultural land. It is thought that 50% of the population in the basin will be living in urban settlements by 2050 (LVEMP, 2005). Urban growth and development in Kenya urban growth refers to both spatial extension and population increase of urban settlements.

Urbanization can be planned urbanization or organic (Nabutola, 2010). Planned urbanization, i.e.: planned city is based on an advance plan, which can be prepared for aesthetic, economic or urban design reasons. Examples can be seen in many ancient cities; although with exploration came the collision of nations, which meant that many invaded cities took on the desired planned characteristics of their occupiers. Nabutola (2010) noted that UN agencies prefer to see urban infrastructure installed before urbanization occurs. Kisii town has been growing with minimal provision of infrastructure.

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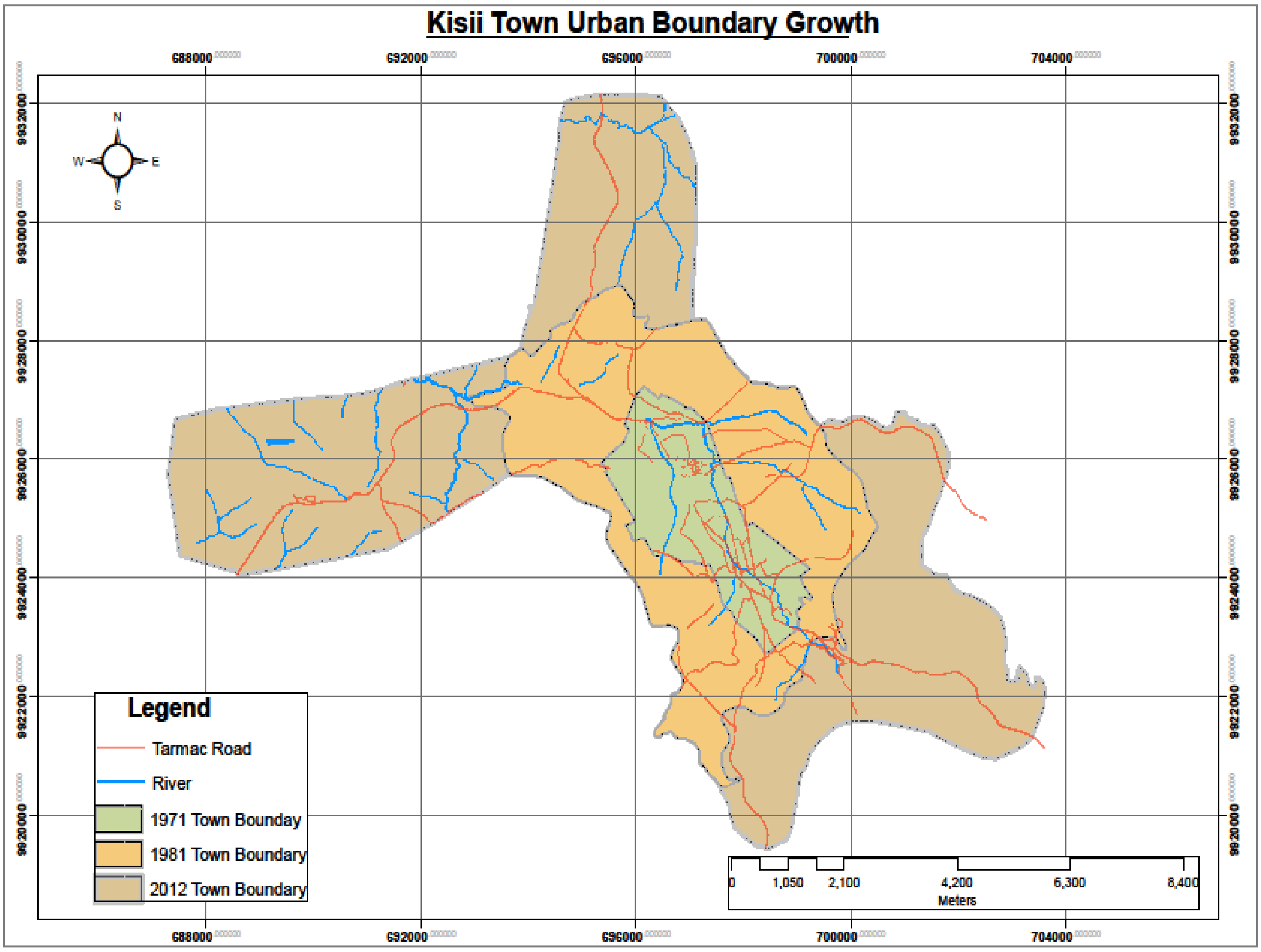
[3] Urban growth is the increase in urban area or community in which the population and spatial extent increases.

2.3 Historical Development and Growth of Kisii Town

Kisii town has grown as an administrative centre for Kisii and south western Kenya since 1905 during the colonial rule. By then Kisii was a small trading centre when the British colonial government established an administrative centre for both Kisii and South Nyanza Districts. During that time Kisii and South Nyanza Districts were collectively known as South Kavirondo. It is believed that the British colonial government set their base in the town due to its greater accessibility to all parts of Gusii land and due to availability of water resources. In 1911 the town's boundaries were demarcated covering an area of about $8km^2$. By then the town consisted of a small British administrative station, a small Indian commercial area an African location market and a market shed built to encourage periodic market activities. The town was populated by non- indigenous Nubians, Indians, Swahili and British.

In 1955 the town consisted of several areas each with a specific function and this include; Jogoo, Nyanchwa, Mwembe Tayari, Daraja Mbili and the Nubia village. The administrative centre is still the present county headquarters. The commercial area is located around the bus park and continues to grow outwards. Jogoo area served as low cost government housing. The first shop was located at Mwembe Tayari in 1951 but the centre started to 1967 as other areas were gradually growing. Kisii town became an urban centre and district headquarters for Kisii district in 1963. Ten years later in 1973, it was elevated to town council status and its boundaries were extended to cover an area of $30km^2$. In in 1981 the town became a municipal council.

Map 3: Growth of Kisii Town



Source: Kisii Town ISUDP, 2012

Apart from administrative functions, the town has also grown from Rural Trade and Production Centre (RTPC) for both Kisii and South Nyanza districts. In order for the government to provide services more efficiently in rural areas it embarked on a Rural Trade and Production Centre in which small and medium towns were earmarked as growth centres. Kisii is one the towns which were selected. Various factors are considered in the process of selection including likelihood of rapid growth, functions as a service centre for rural economic development and geographical distribution in various regions of the country. Its role became more pronounced when the government came up with the policy of decentralised planning: District Focus for Rural Development (DFRD) in 1983. The town has grown as an administrative, commercial and industrial and residential centre. Most of the commercial activities and service industries are agricultural based.

2.3.1 Kisii Town and Its Catchment

There exist strong ties between Kisii town and its hinterland. Being the headquarters, Kisii town provides its catchment population with urban services and infrastructure. The town serves smaller urban centres and markets within the county and other neighbouring counties. The growing commercial and industrial enterprises depend on the agricultural production from the catchment area.

2.4 Kisii Town Urban Development

2.4.1 Kisii Town Relief and Drainage

The topography of Kisii town is characterized by a series of valleys and ridges and is said to be gentle undulating to rolling. The town is located in a confluence of a number of valleys and surrounded by gentle to steep hills. To the south west lies Nyanchwa Hills to an altitude of 1800m above sea level and to the north east are the Mwamosioma Hills rising to about 1800m above sea level. To the south of the town is the mountainous Bobaracho and Gesarara which rise up to 1950 m above sea level. The town is drained by a number of streams which are tributaries of river Riana. Plate 1 below shows Kisii town and the hilly terrain at the background.

Plate 1: Panoramic view of Kisii town and the hilly background

Source: Fieldwork, 2014

2.4.2 Potential and thresholds for urban developments in Kisii town

Using sieving method, one is able to come up with areas with potentials and constraints for urban development. The land for agriculture is in itself a constraint for agriculture. Duchhart et al (1988) used slope to determine the suitability for land within the town and according to

Nyamwange (1994) areas which are flat to gentle slopes (approximately 0-4%) and undulating (slope approximately 4-8%) is said to be suitable for urban development. On the other hand, rolling slopes (approximately 8-16%) are suitable for urban development. Within the town, some land units are very steep (more than 16%) hence not suitable for development since the cost of construction and provision of infrastructure could be highly prohibitive. This include areas such as Bobaracho, Mwamosioma, Gesarara, Nyanchwa Hills etc. Valleys are considered unsuitable for urban development due to high risks of flooding and cost of establishment of infrastructure.

2.5 Land Use Planning

2.5.1 Urban Planning Theory

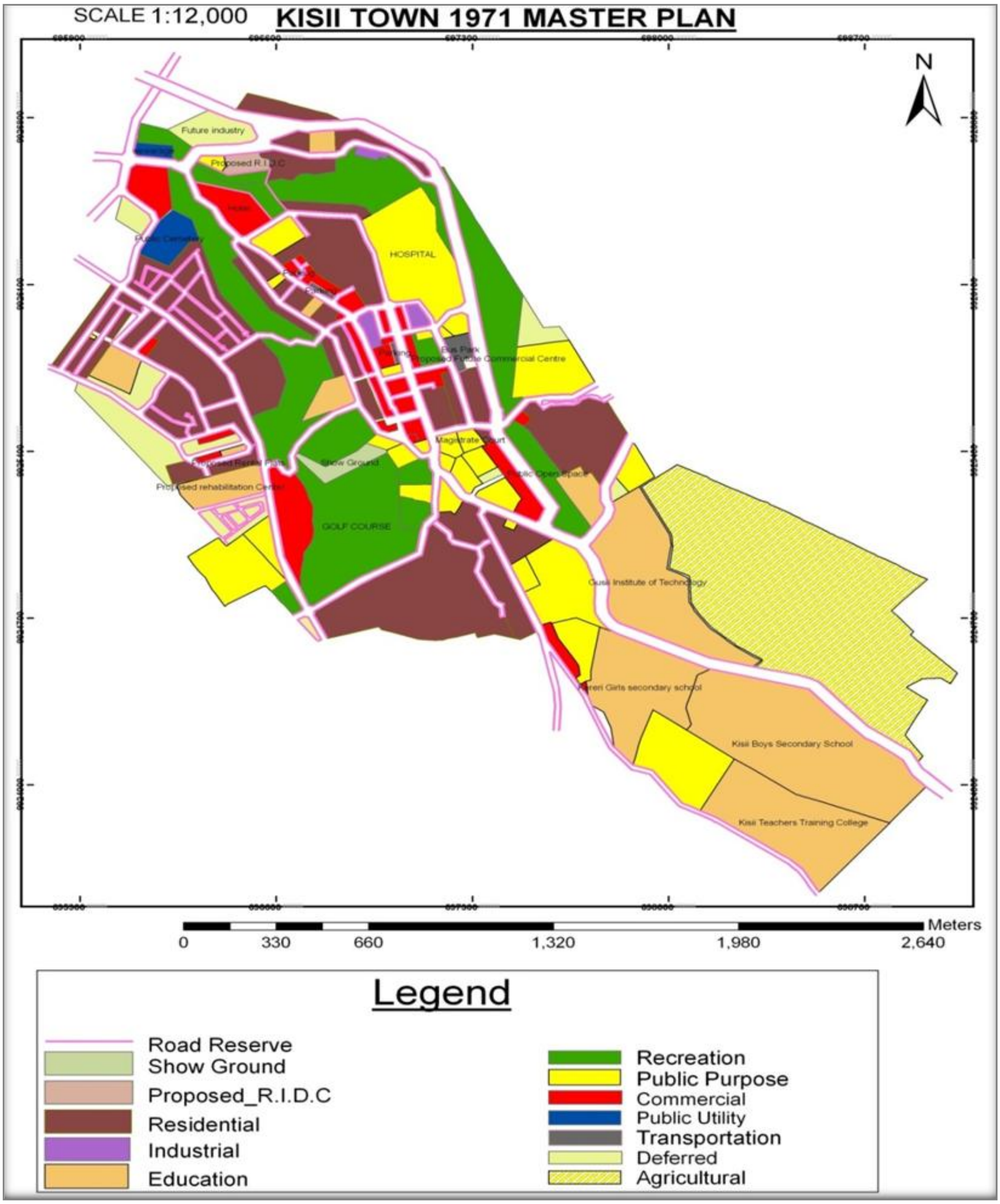
As one sign of civilization and social progress, as city's effects on national politics, economics and culture become prominent increasingly (Fan Wenbing, 2006). Land use planning or urban planning as a discipline is based on the premise of order, convenience, economy and beauty. Pointing out these aspects, Keeble (1965) described planning as the art and science of ordering the use of land and the siting of buildings and communication routes so as to secure the maximum practicable degree of economy, convenience and beauty. Ratcliffe (1981) emphasized the same by defining town planning as that field concerned with providing the right site, at the right time, and in the right place, for the right people. With respect to land suitability analysis for urban development GIS is employed in the following among others generation of spatial framework in GIS environment for perspective and development plans, integration of thematic maps using GIS techniques for suitability analysis, calculation of land requirements for urban development, projection of urban land use suitability analysis.

2.5.2 Previous Kisii Town Urban Development Plans

Various urban development plans have been prepared for Kisii town. The first urban plan for Kisii town was prepared in 1972. It was supposed to cover a period of 20 years. The plan covered approximately 15% of the entire municipality measuring approximately 8km^2. The master plan has been outdated and overtaken by rapid urban growth and developments in town. This culminated into the Kisii Municipality Strategic Urban Development Plan (2009-2029). The Kisii Strategic Urban Development Plan is one in a series of six similar plans which have been prepared under the UN-HABITAT supported Urban Planning programme in the Lake Victoria Basin Region. Integrated Strategic Urban Development Plan for Kisii town

(2012-2030) was initiated by the Directorate of Urban Development in the Ministry of Lands, Housing and Urban Devolvement. The plan was to provide an urban development blue print to guide the spatial growth and transform Kisii town into a modern urbanized area. Land use planning and land allocation in the aforesaid plans was not guided by land suitability analysis but on development trends.

Map 4: 1971 Kisii Town Master Plan



Source; Kisii Town Integrated Urban Development Plan (2011-2030), 2012

2.6 Kisii Town Factors for Growth and Development

The strategic location of Kisii in South Nyanza makes it to main urban and commercial centre/hub in the region. Firstly, Kisii town is the second largest urban agglomeration in Nyanza province after Kisumu. Due to this, the town is the commercial hub in the region serving areas such as TransMara, Migori, Homa Bay, Sotik and Oyugis among other small towns. In addition to the passage of the constitution of Kenya 2010, Kisii town is the anticipated headquarters of Kisii County hence more functions and services are likely to be located there. Lastly, Kisii town is endowed with major education institutions hence acting as a pull for both people and investments causing the area to urbanize. Notable educational institutions in the area include Kisii University, Nyanchwa Adventist College, Kisii Medical Training College among others. The town also hosts campuses of various universities such as the University of Nairobi, Moi University, Egerton University among other private universities. Small and medium sized colleges are also located in Kisii town.

2.7 Land Suitability for Urban Development

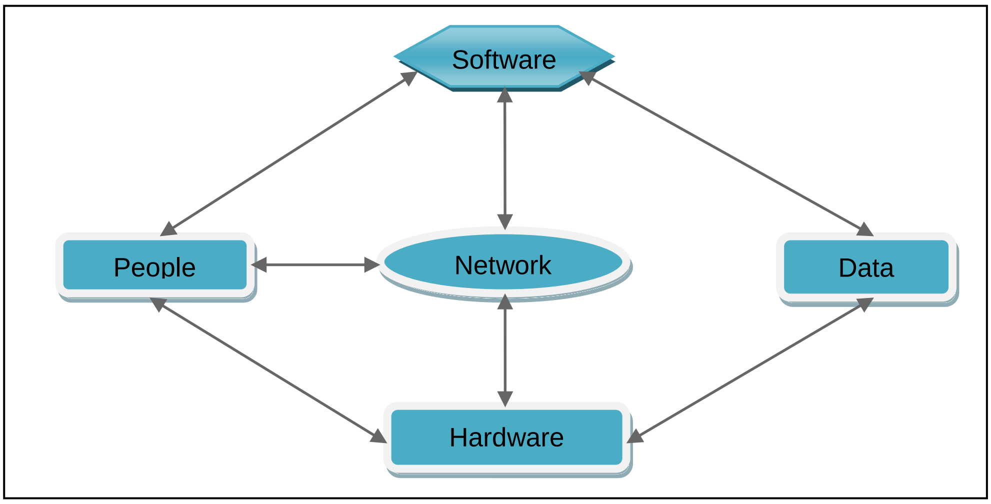
The concept of land suitability for particular uses is successfully developed by the late Ian McHarg. Ian McHarg's seminal text (1969), *Design with Nature*, suggests that each place on the land is a sum of natural processes and these processes constitute social values. Broadly defined, land-use suitability analysis aims at identifying the most appropriate spatial pattern for land uses according to specific requirements, preferences, or predictors of some activity (Hopkins, 1977; Collins et al., 2001). Once this potential is determined, land-use planning can proceed on a rational basis, at least with respect to what the land resource can offer (FAO, 1993). Thus, land suitability analysis is a tool for strategic land-use planning. High land suitability means the land has relatively high numbers of the component parts it needs to serve a particular use or purpose, while low land suitability analysis means the land has relatively low numbers of the component parts it needs to serve a particular use or purpose. The main technical problem associated with land suitability analysis is ensuring the parity of factors. The results of the analysis will be qualified if the factors are of disproportionate weights.

2.7.1 GIS Approach for Land Suitability Analysis

There have been a number of attempts to define a Geographic Information System (GIS) (Cowen, 1987; Longley et al., 1999; Heywood et al., 2002). It is an integrating system which links together a diversity of fields, like computing, surveying, geography, economics and etc. Due to this, it is almost certain to be difficult to define GIS (Longley, 2005). Geographic

Information System (GIS) is conventionally seen as a set of tools for the input applied to computerized information storage; processing and retrieval system that have hardware and software specifically meant to cope with geographically referenced spatial data and the corresponding attribute data (F.N. Karanja, Unpublished Class Notes, 2012). The various components of a GIS system are shown in figure 1 below.

Figure 1: The Anatomy of an efficient GIS system



F. N. Karanja, Unpublished Class Notes, 2012

The distinguishing feature of GIS is its capability to perform an integrated analysis of spatial and attributes data. Culbertson et al. (1994) noted the great potential for GIS technology in planning for sustainable development, as an extension of its traditional use in environmental analysis by integrating common database operations such as query and statistical analysis with the unique visualization and the geographic analysis benefits offered by maps.

From the perspective of land suitability analysis, it is important to note that the layered approach involving the idea of breaking the geography of a real world (landscape) into a series of attribute layers was used to develop the first map overlay technique. The layers are the bases for combining a set of maps displaying land suitability for different land uses (McHarg, 1969). In general, the raster data model has traditionally be recognized as the more appropriate approach for land-use suitability applications. Consequently, such functionality as Boolean operations, proximity analysis, buffer operations, and overlays can be more easily implemented in the raster model. If a set of data layers contains both data in the raster and vector format, the vector data are usually rasterized and the land suitability analysis is performed in the raster environment. It is important to stress that any given real world situation can be represented by both raster and vector models and that data modeled in one system can be converted into the other; that is, raster data can be vectorized and vector maps can be rasterized.

In addition, GIS-based land-use suitability analysis has been applied in a wide variety of situations including ecological approaches for defining land suitability/habitat for animal and plant species (Pereira and Duckstein, 1993; Store and Kangas, 2001), geological favorability (Bonham-Carter, 1994), suitability of land for agricultural activities (Cambell et al., 1992; Kalogirou, 2002) and regional planning (Janssen and Rietveld, 1990).

2.8 Multi-Criteria Decision Analysis (MCDA) in Land Suitability Analysis

Multi-Criteria Decision Analysis is defined as the set of alternatives in terms of a decision model consisting of two or more objective functions and a set of constraints imposed on the decision variables (Massam1988). Diamond and Wright (1988) developed a framework of spatial multi-criteria decision analysis that integrates the different phases of decision-making and major elements of MCDA. This framework is given as;

i) **Problem definition:** Any decision making process begins with the recognition and definition of the problem. It is a gap between the desired and existing states as viewed by a decision maker.

ii) **Evaluation criteria:** Once decision problem is identified or defined, the spatial multi-criteria analysis focuses on the set of evaluation criteria (i.e. objectives and attributes).

iii) **Alternative and Constraints:** The process of generating alternatives could be based on the value structure and related to the set of evaluation criteria. Decision variable is assigned to each alternative.

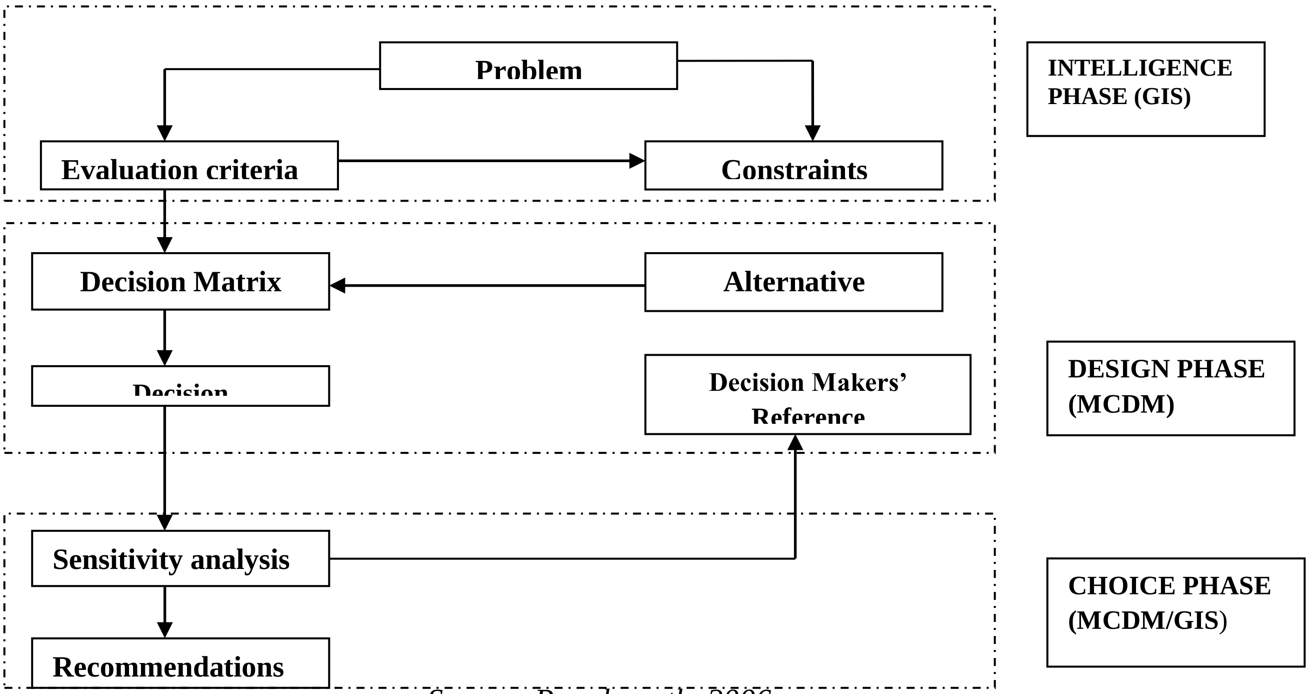
iv) **Decision maker's preferences and decision matrix:** The preferences are expressed in terms of weights of relative importance assigned to the evaluation criteria under consideration. The purpose of criteria is to express the importance of each criterion relative to the other criterion.

v) **Decision rule:** This step brings together the result of the preceding three steps. This is accomplished by an appropriate decision rule of aggregation function. Decision rules dictate how best to rank alternative or to decide which alternative is preferred to another.

vi) **Sensitivity analysis:** Sensitivity analysis is performed to determine the robustness of outcomes. It aims at identifying the effects of changes in the inputs (i.e. geographical data and decision maker's preferences) on the outputs.

Raughunath (2006) developed a Framework of Spatial Multi-Criteria Decision Analysis to guide in land suitability analysis which is illustrated figure 2 below.

Figure 2: Framework of Spatial Multi-Criteria Decision Analysis



Source: Raughunath, 2006

2.9 GIS Spatial Analysis for Land Use Suitability

In addition to storing, retrieving and displaying spatial data, a GIS enables the user to create buffers, overlays, intersections, proximity analysis, spatial joins, map algebra, and other analytical operations. Spatial analysis in GIS helps to define the criteria data, and operation of analysis, run the analysis model and analyze the results. The greatest advantage of spatial analysis is that it is easy to refine the created model rather than create new one. The data used for the analysis model can be vector or raster. In a vector data model, multiple attributes are associated with each feature. Vector data enable analysis only on two layers at a time in an operation. The raster model represents features in grids of pixels, where each attribute is represented in one grid; however, it is possible to combine different layers in one raster layer where pixels will have different values for different features. For spatial analysis using raster data, defining the suitable resolution is very important, as the very large pixel size can cause missing information and too small pixels size will produce very large size file. Raster data are used for land suitability modeling because analysis can be performed on several raster layers at once and the process is more efficient than in vector data.

2.10 Criteria for Land Suitability Analysis for Urban Development

Land Suitability analysis for urban development requires consideration of a comprehensive set of factors and balancing of multiple objectives in determining the suitability of a particular area for a defined land uses (Al-Shalabi *et al.*, 2006). Specific factors can be chosen for specific kinds of development. The factors used for land suitability analysis for urban development include but not limited to: topography, land use, drainage and accessibility.

2.10.1 Topography

Topography is considered one of the most frequent required criteria for determining the land use suitability. Topography is represented by both elevation and slope. For elevation; the lower the land the more the suitability, since low areas have more accessibility for basic facilities, such as transportation and water supply which is more difficult and expensive to be accessible for higher lands. Topography is the shape of the ground formed by highlands, slopes, rivers, swamps, coast, and river network which have their own aesthetic values. According to the Physical Planning Handbook (2008) a hill area is an elevated land that has a slope of more than 12 degrees while a highland areas are land situated more than 150 metre from sea level and slope that exceeds 25 degrees. Hilly areas are natural assets that can be developed as tourist attractions sites such as hotels, apartments, condominiums, and multi storey housing. Development in hilly areas requires several physical criteria that must be observed not to endanger stability, balance and harmony of natural environment. The Physical Planning Handbook outlines the following development criteria with slopes areas:

i) Between 5 degrees to 15 degrees are considered as medium slopes and could be developed with the implementation of slopes control measures.
ii) Between 15 degrees to 15 degrees could be developed with the implementation of control measures.
iii) Areas with slopes that exceed 25 degrees are not allowed any development these are considered critical for safety of human settlements.

Slope is an important criterion in hilly terrain for finding suitable sites for urban development. Steep slopes are disadvantageous for construction. Steeper slopes increase construction costs, limit maximum floor areas and contribute to erosion during construction and subsequent use.

2.10.2 Land Cover

Some land covers are least or not suitable for land use. Land use/cover map of Kisii town area has been categorized as follows: built-up, barren, agricultural and vegetation. In this study, built up area is not suitable for the future development because once a building is constructed, it remains there for minimum of 50-75 years. Thus barren land is considered highest suitable. For example, wetlands and granitic mountainous parts are least suitable, while gravelly and sandy plains are more suitable.

2.10.3 Drainage/Riparian Analysis

High rates of urban developments in an area lead to increase of impervious areas which produce high quantities of storm water. There is need to protect the riparian reserves[4] in the town. According to the Physical Planning Handbook (2008), a riparian reserve ranging from a minimum of 10m-60m should be provided. Development activities should not be located on the course of the main streamlines and a considerable buffer around these main drainage lines should be taken into consideration.

2.10.4 Accessibility/Road Proximity

Road accessibility is one of the important parameters for urban development as it provides linkage between the settlements. Road is also an important criterion in land suitability for urban development suitability because of the need to transport people, goods and services. Construction of new road is expensive in hilly regions. Therefore, effort should be made to locate the major urban developments nearer to any existing road if possible. The study area has been classified under two-type road viz: major roads and minor roads. In this study, Major roads are considered, and a road map was prepared using LiDAR data.

Table of evaluation criteria were generated based on topography, roads infrastructure and constraint maps. Measurement indicators as used in the tables refer to the factor of consideration used in modeling while the scale ranges are specific intervals for units of

[4] Riparian reserve is defined as land on each side of a water course (Physical Planning Handbook, 2008).

measurement. Table 1 below shows criteria for evaluation urban development adopted from urban land use suitability assessment using geoinformation techniques for Kisumu Municipality, 2012.

Table 1: Evaluation criteria for various land uses

Evaluation Criteria For Industrial Land Use			
Criteria	**Measurement Indicator**	**Scale Range**	**Classification**
topography	Slope	0-37%	0-6% very suitable 7-13% suitable 14% not suitable
Road infrastructure	Euclidean distance	300-1000m	Within 300m suitable Beyond – decreasing suitability
Constraints/Buffers (rivers etc)	Buffer distance	20m – 60m	Suitable beyond buffer zone
Evaluation criteria for residential land use			
Criteria	**Measurement Indicator**	**Scale Range**	**Classification**
Topography	Slope	0-37%	0-3% - Not suitable 4-25% - Suitable 25% and above - Not suitable
Road infrastructure	Euclidean distance	200-10000m	Within 200m - Not suitable Beyond 200m - Increasing suitability
Constraints/Buffers(rivers etc)	Buffer distance	20m – 60m	Suitable beyond buffer zone
Evaluation criteria for Commercial land use			
Topography	Slope	0-37%	0-10% - Very suitable 10 – 20% Suitable 20% and above – Not suitable
Road infrastructure	Euclidean distance	300-10000m	Within 300m – Suitable Beyond 300m –Decreasing suitability
Constraints/Buffers (rivers etc)	Buffer distance	20m – 60m	Suitable beyond buffer zone
Evaluation Criteria For Recreational Land Use			
Criteria	**Measurement Indicator**	**Scale Range**	**Classification**
topography	Slope	0-37%	0-25% - Not reserved 25% and above – Reserved
Road infrastructure	Euclidean distance	300-10000m	Within 300m – Suitable Beyond 300m –Decreasing suitability
Land cover	Land use type	1 – 10 levels	Swamps, Forested Hills, Plantation, Open low shrubs, conservation areas – Suitable and reserved Others –Decreasing suitability
geology	Bearing strength	80-200km/m2	0.5m – 1.5m - Unsuitable Beyond 1.5m – Increasing suitability
Constraints/Buffers	Buffer distance	20m – 60m	Within buffer zone- Reserved

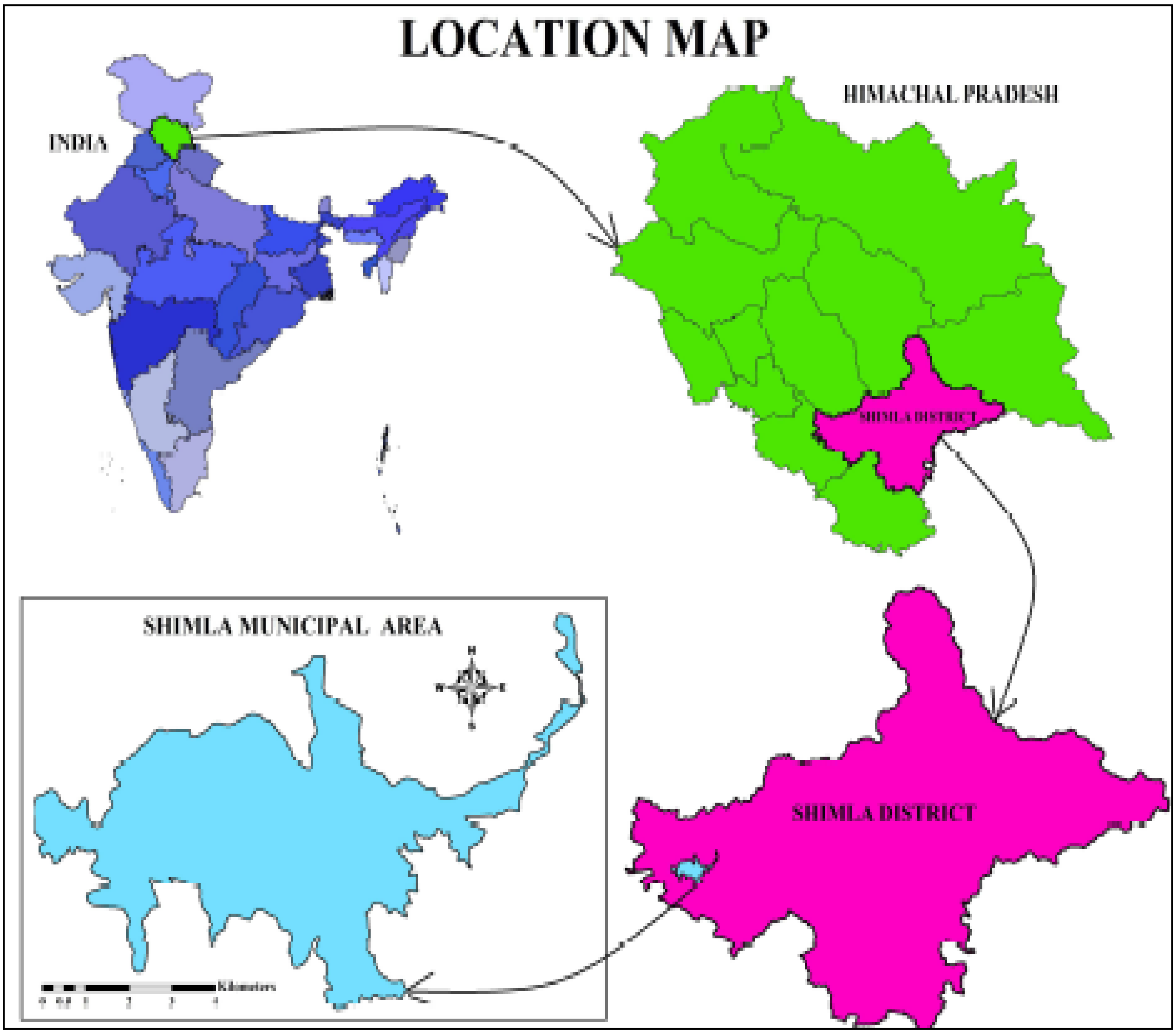
Khaemba, Mwasi and Opata, 2012

This criteria and parameters will be used in land suitability analysis for land suitability analysis in the study area.

2.11 Identification of Potential Sites for Urban Development Using GIS Based Multi Criteria Evaluation Technique, a Case Study of Shimla Municipal Area, India

Shimla Municipal area is one of the oldest municipalities of India and encompasses an area of 27.58 km². Its average altitudinal height is 2012.30 meters above mean sea level. Shimla lies in the north-western ranges of the Himalayas. As a large and growing city, Shimla is home to many well-recognized colleges and research institutions in India. Map 5 below shows location of Shimla Municipal Area, Shimla District, India.

Map 5: Location of Shimla Municipal Area, Shimla District, India



Source: Manish Kumar, 2004

2.11.1 Data Collection and Integration

In order to develop site suitability map for urban development Cartosat-1 panchromatic stereoscopic satellite data at a resolution of 2.5 m were used. With the help of stereoscopic satellite data a Digital Terrain Model (DTM) was created which was further used for preparing slope and aspect map. A high resolution Cartosat-1 Satellite data was also used for generating land use/cover and road proximity map. A lithology map was obtained through Geological Survey of India, Dehradun. All these information layers were integrated and analyzed under ArcGIS environment.

2.11.2 Selection and Preparation of Criteria Maps

In this study five criteria were selected. The principal criteria that are used for spatial analysis are slope, road proximity, land use/cover, lithology and aspect. These criteria were used in the preparation of criteria maps.

2.11.3 Suitability Scoring/Ranking and Development of Pairwise Comparison Matrix

For suitability analysis it is necessary to give some score to each of the criteria as per their suitability for urban development. For this purpose the pairwise comparison matrix using Saaty's nine-point weighing scale was applied. To develop a pairwise comparison matrix different criteria are required to create a ratio matrix. These pairwise comparisons are taken as input and relative weights are produced as an output.

2.11.4 Computation of the Criterion Weights

After the formation of pairwise comparison matrix, computation of the criterion weights is done.

2.11.5 Rasterization of Criteria Maps

Different criteria maps are converted into raster data environment for further analysis because in raster data format computation is less complicated than vector data format.

2.11.6 Site suitability analysis

The criteria in site suitability analysis for urban development were given below along with their individual importance.

i. Slope

Steep slopes are disadvantageous for construction. Steeper slopes increase construction costs, limit maximum floor areas and contribute to erosion during construction and subsequent use.

Slope < 10 degree is considered gentle slope having the highest intensity of importance. Slope greater than 10 degree has been classified as unsuitable because it increases the construction cost.

ii. Road Proximity

Construction of new road is expensive in hilly regions. Therefore, effort is made to locate the site nearer to any existing road if possible. Moreover, in order to find out better accessibility to the existing road, buffer zones have been created by taking 50 meter distance from the road.

iii. Land Use/Cover

Land use/cover map of Shimla Municipal area has been categorized as follows: built-up, barren, agricultural and vegetation. In this study, built up area is not suitable for the future development because once a building is constructed, it remains there for minimum of 50-75 years. Thus barren land is considered highest suitable for the development.

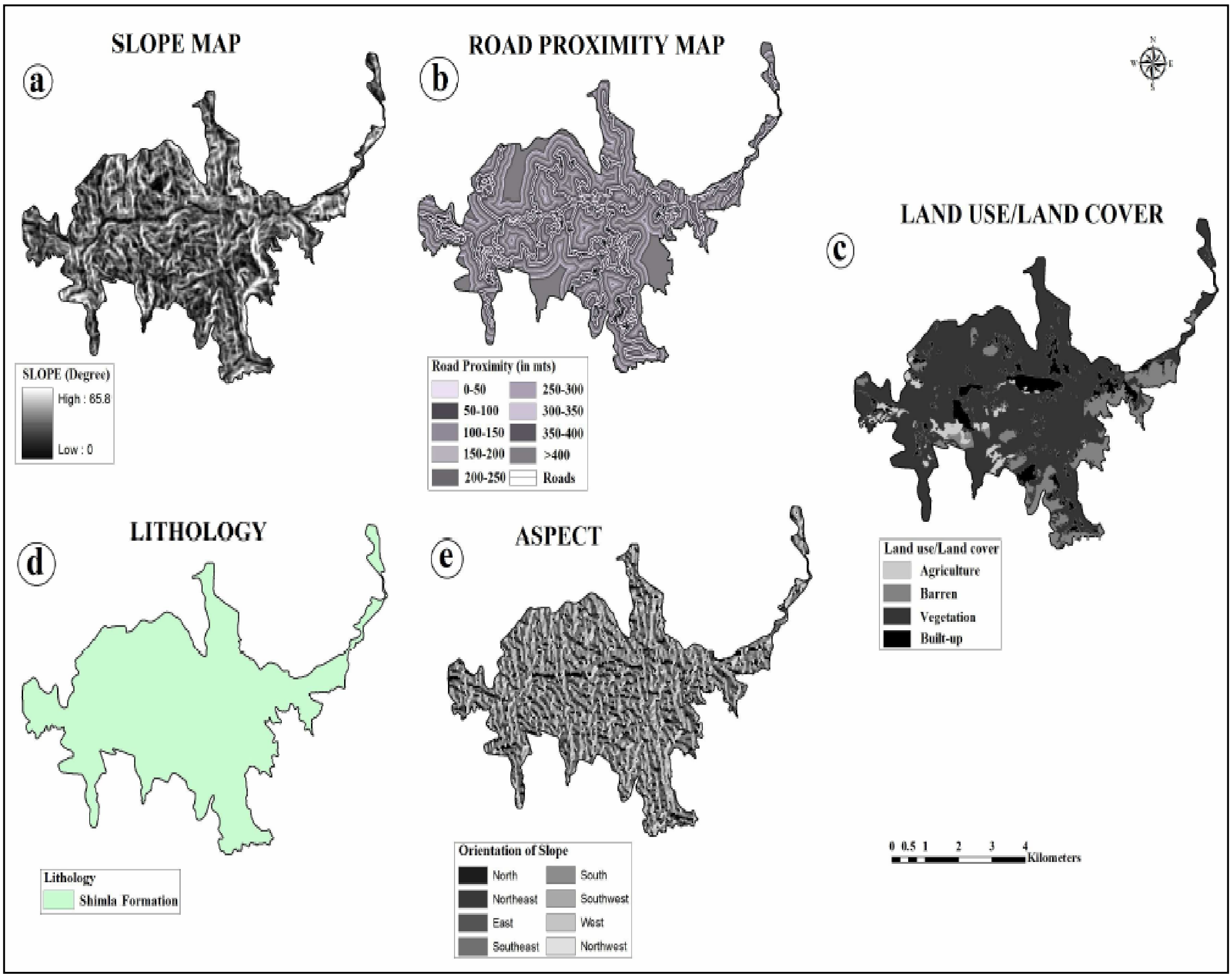
iv. Lithology

Shimla town is situated on the rocks of Jutogh Group and Shimla Group. Jutogh group occupies most of the Shimla area and extends from Annadale-Chura Bazaar-Prospect Hill-Jakhoo-US Club and highland area. Shimla Group comprising of earlier Chail Formation and Shimla Series represented by shale, slate, quartzite greywacke and local conglomerate is well exposed in Sanjauli-Dhalli area. Therefore, the rocks mainly found in the study area are metamorphic rocks which are harder and relatively more resistant to erosion.

v. Aspect

Aspect generally refers to the horizontal direction to which a mountain slope faces. In the northern hemisphere north facing slopes receive very little heat from the sun in mid-winter. Conversely, south facing slopes receive much more heat. Therefore, south facing slopes tend to be warmer than the northern ones. In hilly areas people prefer building their houses on the sunny faced slopes. Thus, southern facing slopes have higher intensity of importance. East facing slopes catch sun only in the morning when temperatures are colder while west facing slopes catch the sun in the warm afternoon. Consequently, east facing slopes are colder than west facing slopes.

Figure 3: Slope, Road Proximity, Land/Use Cover, Lithology and Aspect Analysis

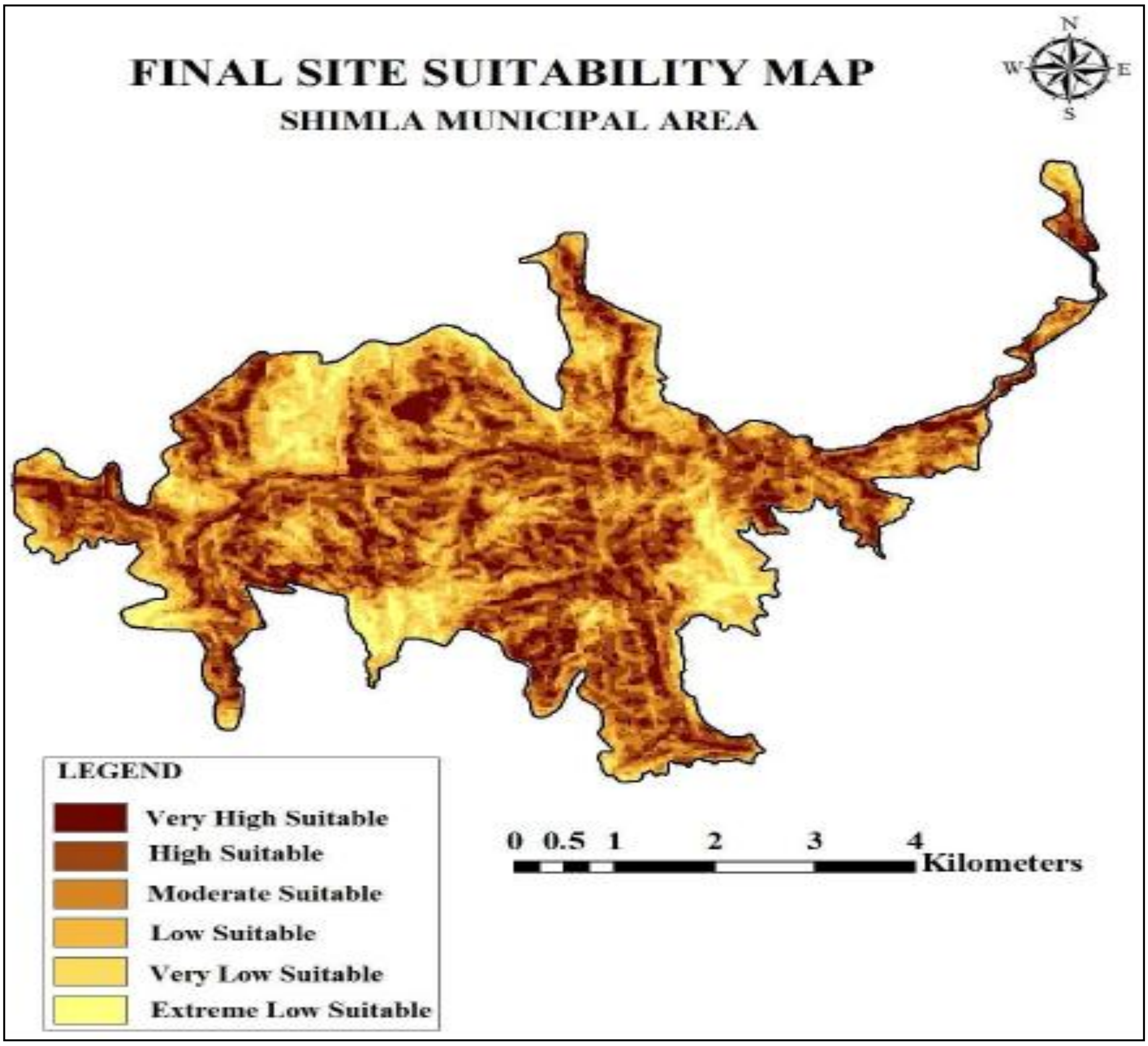


Source: Manish Kumar, 2004

2.11.7 Integration of Maps and Preparation of Final Suitability Map

All five criteria maps were converted into raster format, so that for each pixel, a score can be determined. All the criteria maps were integrated and overlaid and the final site suitability map as shown in map 6 below. After rasterization, these classified raster maps were integrated in raster calculator of ArcGIS and multiplied by weightage, and then the final suitability map was prepared. The final site suitability map revealed that the study area was divided into six different suitability categories. The area under extreme low, very low, low, moderate, high and very high lands stand at 4.95 km^2, 2.8 km^2, 1.18 km^2, 7.23 km^2, 3.74 km^2 and 7.68 km^2.

Map 6: Final Site Suitability Map for Shimla Municipal Area



Source: Manish Kumar, 2004

Approximately 32.36% of the total area falls under the categories of low, very low and extremely low suitable areas. Only 41.43% of land falls under high and very high suitable categories.

CHAPTER 3: RESEARCH DESIGN AND METHODOLOGY

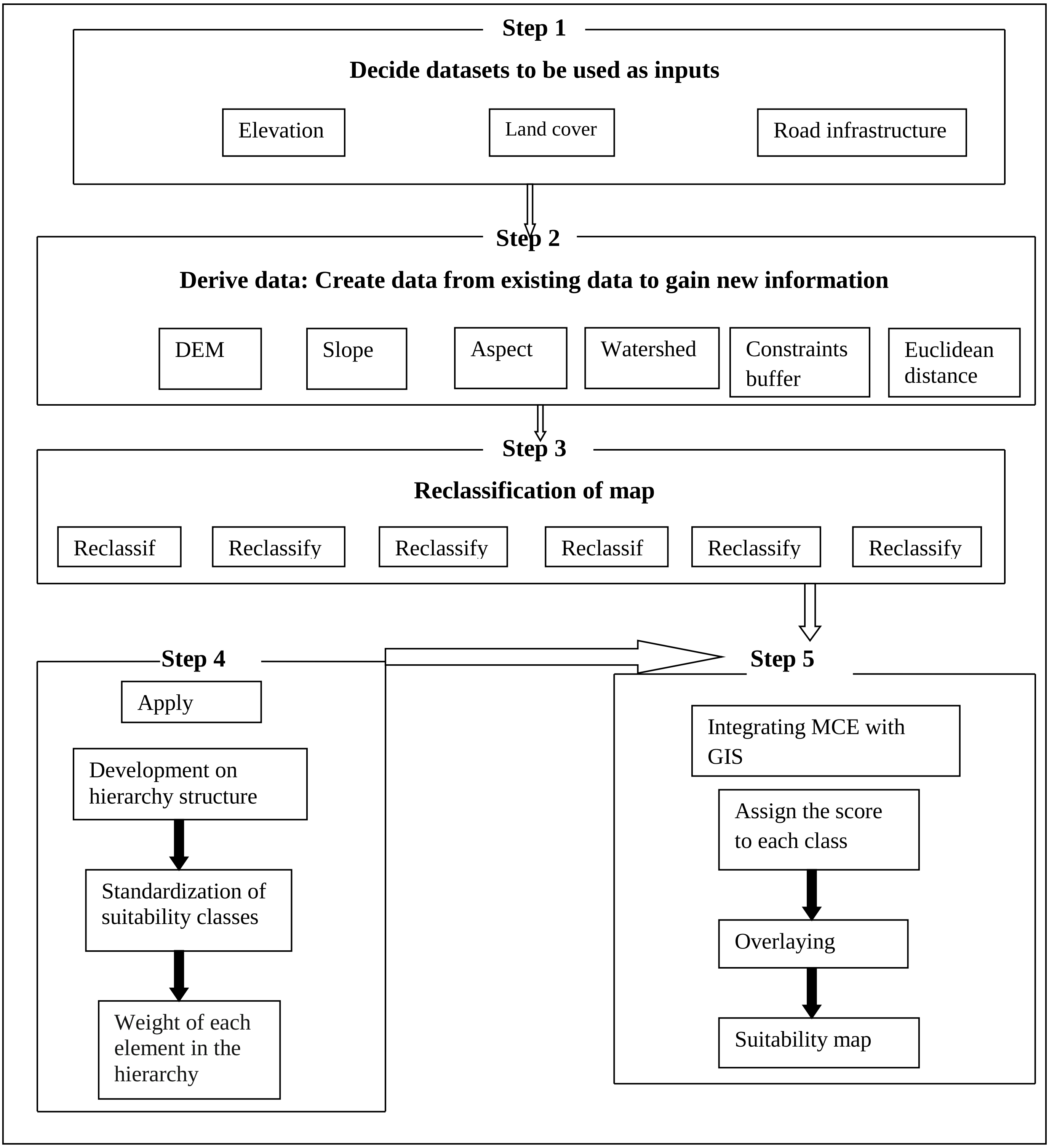
3.0 Introduction

The overall methodology adopted for land suitability analysis for urban development is given in the figure 4 below. Various important factors relevant for Kisii town such as present land use/land cover, proximity to existing road, terrain and riparian resources were chosen. These factor vector layers are weighted according to the weights derived by the Saaty's AHP method by creating a separate field in each layer. Each class or category in each layer is given rank and these ranks are stored in the database as separate field. And also the product of weight and rank are computed and stored in another filed. Finally all the vector layers are combined together by applying GIS UNION operation on two layers at a time. UNION operations are carried out to seven factor vector layers to get the final weighted combined factor vector layer. Similarly, constraints such as built-up area and water bodies were considered. These vector layers were combined together by applying Boolean AND operation on two layers at a time. Finally, the constraint combined vector map is obtained by applying two Boolean AND operations on constraint layers. Ultimately the INTERSECTION of the factor map and the constraint map give the site suitability for urban development. The final parcel level urban land suitability map is obtained by INTERSECTION of urban land suitability map.

3.1 Data and Data Processing

Data preparation is the first fundamental step in land suitability analysis. The data collected for this study scanned and georeferenced topographic maps at a scale of 1:50,000 covering Kisii town, hydrological data including rivers and wetlands, land cover maps, satellite imagery consisting of LIDAR satellite imagery and infrastructure data including major roads covering the delineated area. All the maps were geo-referenced to the Universal Transverse Mercator (UTM) coordinate system. Up to date LiDAR data was used to generate a Digital Terrain Model (DTM) for the town.

Figure 4: Flowchart for proposed methodology for the study

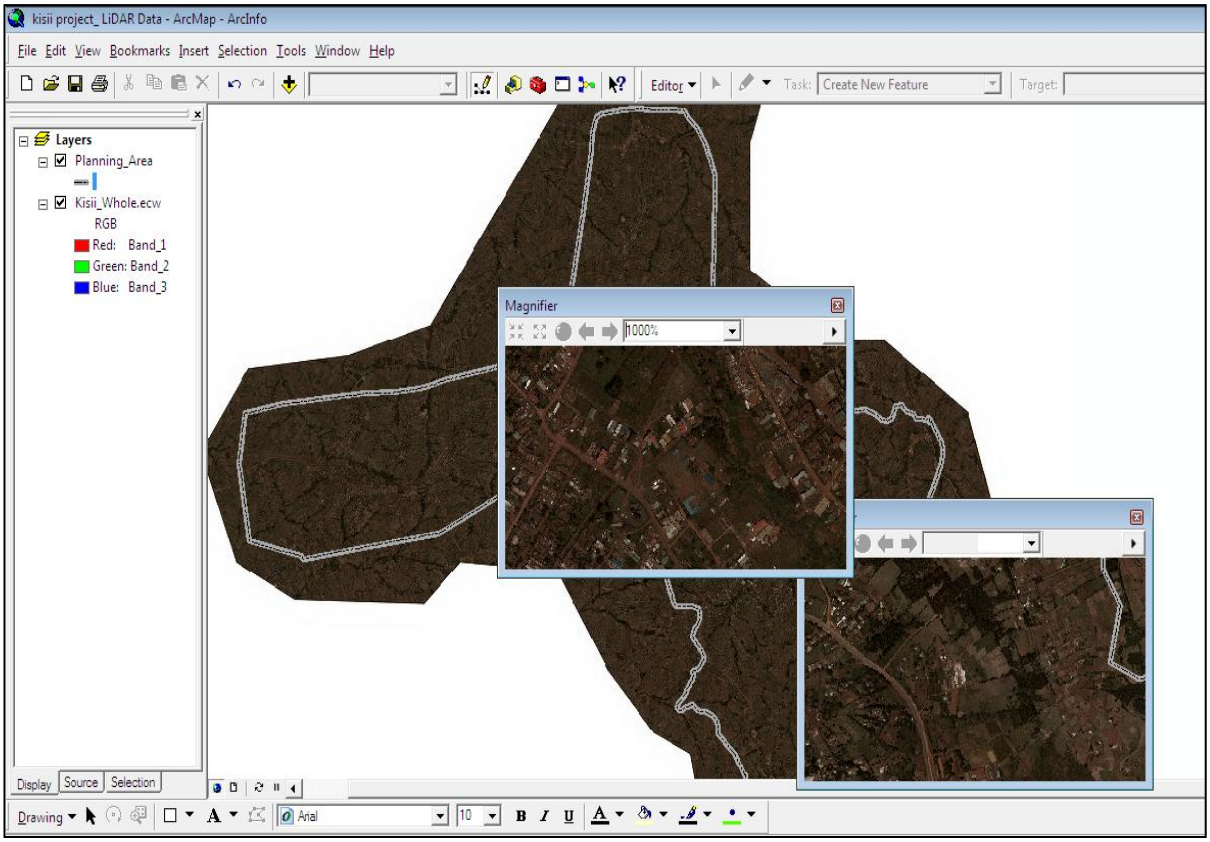


Source: Adapted from J. Malczewski, 2004

3.1.1 Acquisition of LiDAR data

The mapped area covered approximately 70 kilometers squared within Kisii town as shown in figure 5. This was to provide LiDAR data and aerial images to support the detailed planning of Kisii town. The Aerial LiDAR team mobilized for the mission on 21st January, 2012 and the works was successfully completed on, 22nd January, 2012. This data consisted of LiDAR point clouds, airborne GPS and INS data, camera calibration and aerial images.

Figure 5: LiDAR data for Kisii town study area



Source: Author, 2014

Slope information was derived from Digital Elevation Model (DEM) using ArcGIS. Constraint and factor maps were generated from this data and criteria identified that formed the basis for multi-criteria analysis.

3.3 Building GIS Database

The digitizing specification of maps was defined according to the available themes. The different digital maps were corrected from different errors and edge-matched after the geo-referencing processes. Figure 7 shows compilation of various datasets used in the study.

3.4 Software and Technology

The software used for the analysis was ArcGIS 10 and the ArcGIS Spatial Analyst extension from Environmental Systems Research Institute (ESRI). Quantum GIS open source GIS software which serves the same functionalities as ArcGIS but with some additional functionality such as direct mosaicing as compared to ArcGIS. Microsoft Excel was used to create the tables and spreadsheet data used for analysis.

3.4.1 Testing the Database

Once the database was developed, it was necessary to test for its functionality. Such tests were done via various ArcMap analytic functions including:

3.4.2 Query

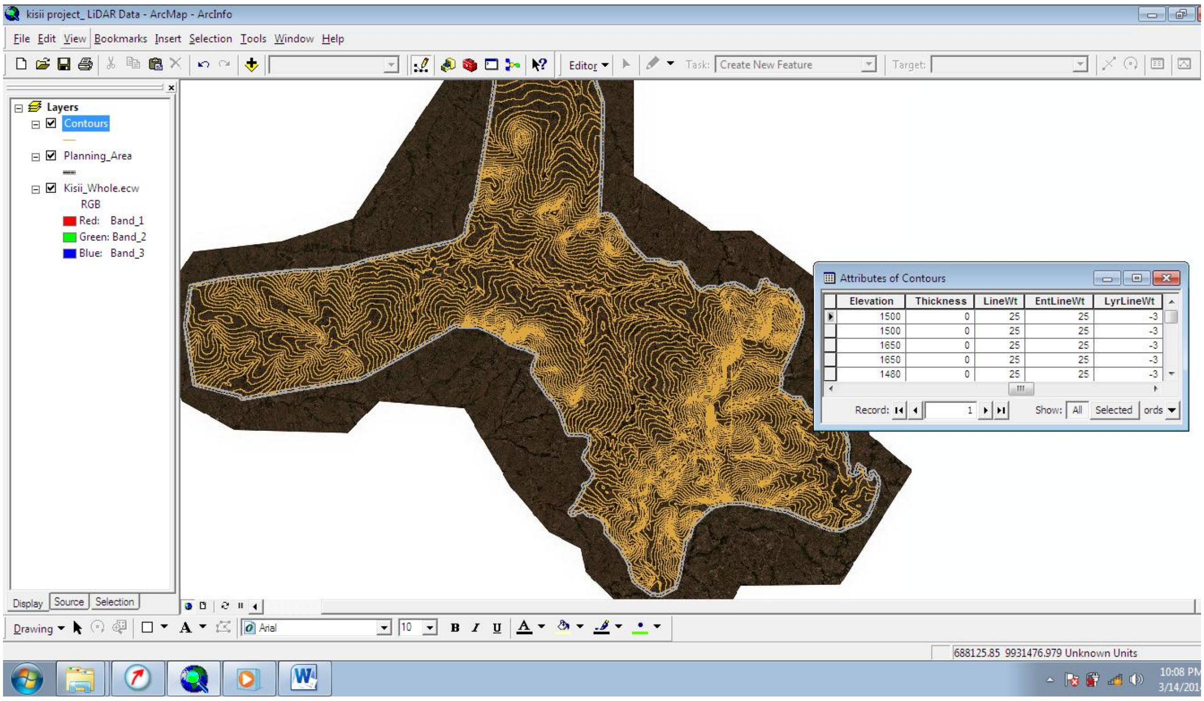
The database was queried to find out some basic information about the urban development factors. The query was done by attribute.

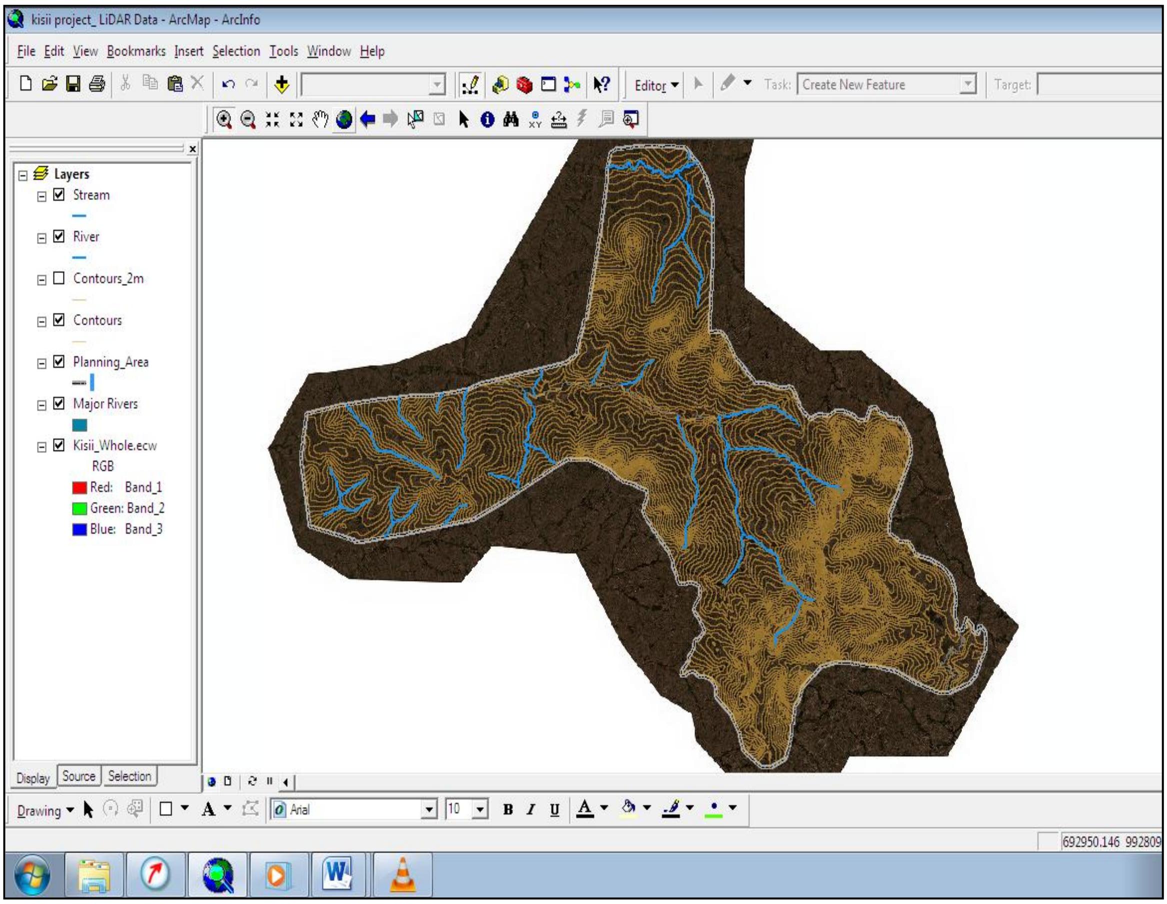
3.5 GIS Operations

Land suitability is evaluated by applying different GIS analytical techniques, including interpolation and overlay based on multi-criteria analysis. Based on the established criteria and data, the next step is to define what operations need to be performed in order to determine land suitability. Many layers will have to be converted from vector to raster. Once in raster format, each layer's values need to be reclassified into scoring system. Buffering will have to be done on many layers to determine what values should be assigned inside/outside the extent of the feature and it's buffer. Operations used in this analysis:

- Raster to Vector Conversion
- Buffer
- Reclassification
- Map Algebra

Map 7: Datasets used in GIS land suitability for urban development





Source: Author, 2014

3.6 Analysis of the Evaluation Factors for Urban Development

3.6.1 Slope Analysis

The slope raster was created from TIN. Slope was evaluated using the various ranks of suitability. Figure 6 below illustrates the process of slope analysis. Figure 6 below show Triangulated Irregular Network (TIN) Surface Model use to derive slope data.

Figure 6: Slope analysis for urban development

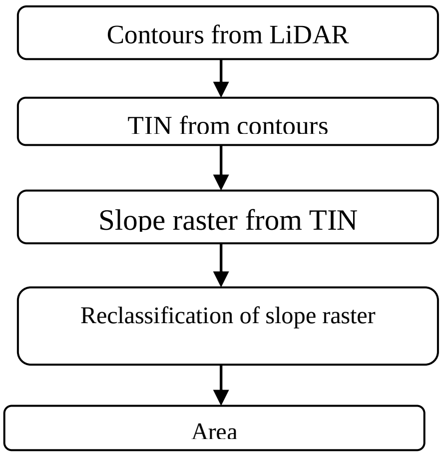


Figure 7: Triangulated Irregular Network (TIN) Surface Model and Slope derived from TIN of Kisii town

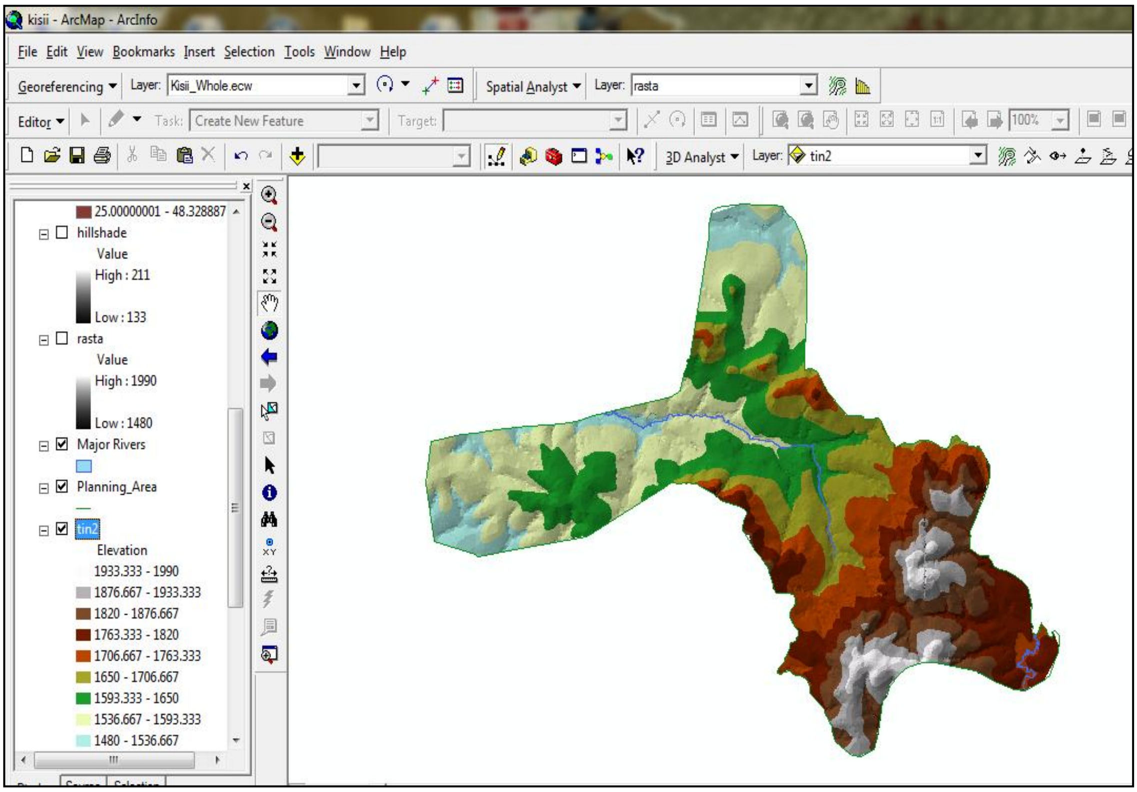
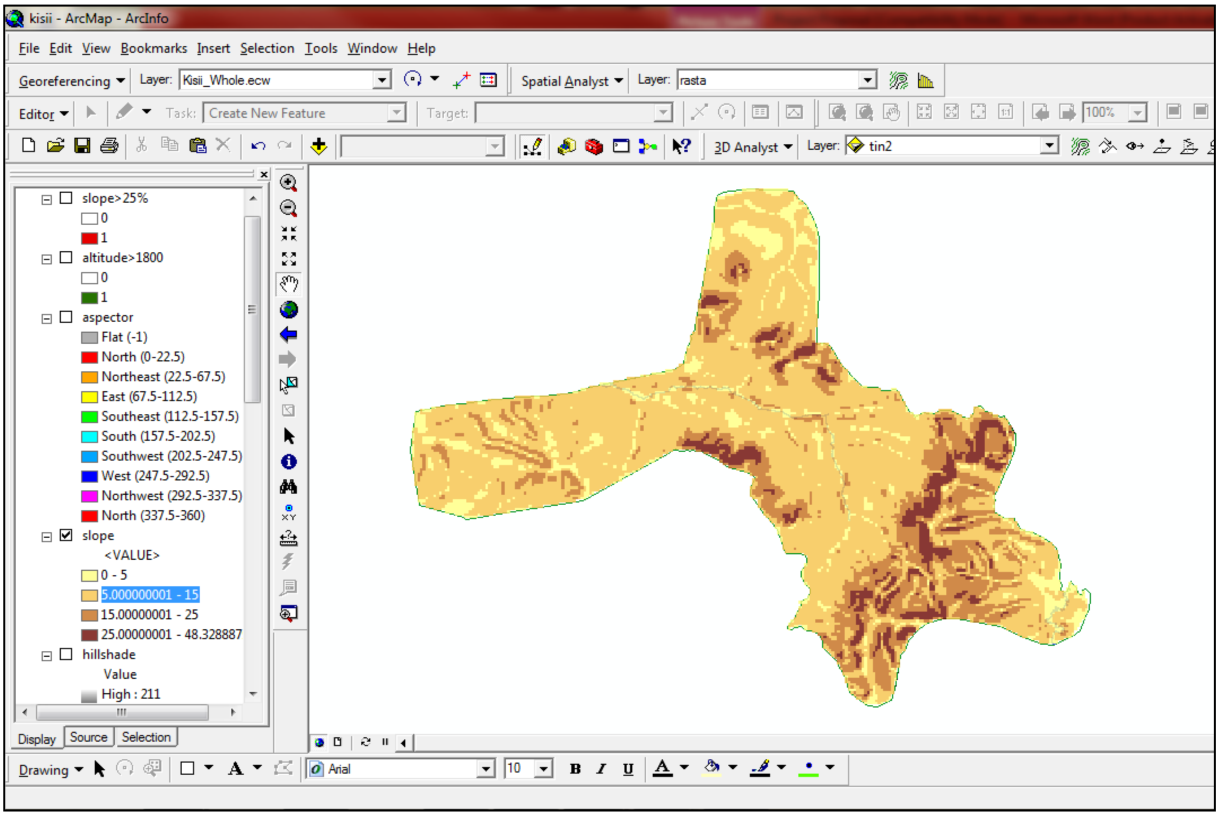


Figure 8: Slope Data Derived From TIN Used To Carry Slope Analysis



Source: Author, 2014

3.6.2 Accessibility/Proximity to Major Roads

The study area was classified under two-type road viz: major roads and minor roads. In this study, major roads were considered, and a road map was prepared using road data from Kenya Urban Roads Authority. For the purpose of land use suitability analysis for the development purpose, road buffer zone was classified according to zones of 200m, 500m, 1000m and outer (>1000m), with zones of 200m zone being the most suitable for urban development whereas outer zones of (>1000m) being the least suitable for urban development.

3.6.3 Ecological Sensitivity/Riparian Analysis

For mapping the rivers and contours from LiDAR were used to for preparation of elevation raster. From elevation raster slope direction raster and water accumulation was prepared. Then based on the two rasters link raster was prepared to generate river pattern. This was then converted to into vector line feature class. Distance buffers were created for the major roads, according to the distance criteria noted in the suitability criteria.

3.7 Data Manipulation and Analysis

ArcGIS Spatial Analyst was used for suitability modeling. Suitability modeling involved calculating optimal site locations by identifying possible influential factors, creating new data sets from existing data, reclassifying data to identify areas with high suitability, and finally aggregating these data into one logical result of optimal land suitability. The first step in the spatial analysis involved the creation of raster data. All layers had to be converted from vector to raster before the Spatial Analyst could be used to perform any type of analyses. The rasters created were in floating point format which represented continuous data that possessed no attribute tables. The Raster calculator was used to convert floating point raster data to integer raster data, which was then used for reclassification.

3.8 Algorithm for Land Suitability Analysis

Steps involved in MCDM technique (ESRI, 2007; Malczewski, 2006; Saaty, 1980) are as follows:

1. Creating importance or priority matrix base on scale of importance for pair wise comparison.
1. Calculating the weights of criteria.
2. Summation of every column.
3. Dividing every matrices element by the summation of column.

4. The average of components in every line of normalized matrices, i.e. dividing the summation of normalized weights by the number of criteria.
5. After calculating the consistency vector, value for Lambda (λ) is calculated. The value for lambda is simply the average of the consistency vector.

λ= (5.952607+6.085837+6.742268+5.148148+ 5.278955)/5=5.845366

6. Calculation of the consistency ratio (CR) which is defined as CR = CI / RI. The aim of this is to determine whether the comparisons are consistent or not. To calculate the consistency index, CI the formula used is given as: CI= (λmax-n) / (n-1), where n is the matrix size.
7. The calculation of CI is based on the observation that λ is always greater than or equal to the number of criteria under consideration (n) for positive, reciprocal matrixes, and λmax-n can be considered as a measure of the degree of inconsistency and can be normalized as: CI= (λmax - n) / (n-1) = (5.845366-5) / (5-1) = 0.211341
8. RI is the random index and depends on the number of elements being compared.
9. Judgments consistency can be checked taking the consistency ratio (CR) of CI. If CR is satisfactory, if does not exceed from desired range i.e.>0.10. If CR value is undesirable range, the obtained judgment matrix is needed to review till these values should be improved and satisfactory.

3.9 Computation of the Pair-Wise Comparison Matrix and Consistency

Pair-wise comparison matrix is created to assign weights by experts. Weights are evaluated to find alternatives and estimating associated absolute numbers from 1 to 9 in fundamental scales of the AHP (Saaty 2008). Currently, the obtained weights can be computed automatically in IDRISI (Eastman 1995) as well as in Expert Choice (Expert Choice Quick Start Guide, 2000-2004) softwares called MCDA tool. The results of relative weightage of land suitability criterion Scenario 1 Accessibility and Scenario 2 Environment are shown in Table 1 and 2 based on criterions. Thus, pair-wise comparison matrixes are calculated into Expert Choice determining priority weightages in this paper. Then, these will be entered in ArcGIS for spatial analysis to determine the suitability for hillside development.

Table 2: Computation of the Pair-Wise Comparison Matrix

Criteria	**Slope**	**Accessibility**	**Riparian Area**	**Land cover**	**Priority Factor**
Slope	1				0.478
Accessibility	1/2				0.182
Riparian Area	1/3	1/2	1		0.235
Land use/cover	1/4	2	2	1	0.105
Weightage					

Source: Author, 2014

3.10 Results and Ranked Suitability Maps

The suitability maps resulting from the spatial overlay of factors in consideration in Kisii town will be shown in from of maps. The ranked land suitability maps were presented in a graduated scale of 1 to 5 which will show levels of spatial suitability within the town and its environs for urban development. The following categories will be considered very suitable, suitable, moderate, least suitable and unsuitable represented by 5,4,3,2,1 respectively. The levels reduce gradually with declining suitability upto level 1 which is an indicator of total exclusion meaning that the location is not suitable at all for the given land use.

3.11 Preparation of Final Land Suitability Map

All the criteria maps were are converted into raster format, so that for each pixel, a score can be determined. All the criteria maps were integrated and overlaid and the final site suitability map developed. The final results of a land suitability analysis will be presented as maps on a common base of land units: areas of land with distinctive qualities and different levels of land suitability. In addition the results will be presented in form of graphs and tables.

CHAPTER 4: RESULTS AND ANALYSIS

4.0 Introduction

The main objective of this study was to to carry out land suitability analysis for urban development and growth of Kisii town using Multi-Criteria Evaluation (MCE) and GIS approach. This process involves a consideration of five factors i.e. slope, road proximity and ecological sensitivity. From these findings, possible policy implications and recommendations are drawn to ensure that these businesses contribute to development in a sustainable manner.

4.1 Urban Development Patterns in Kisii town

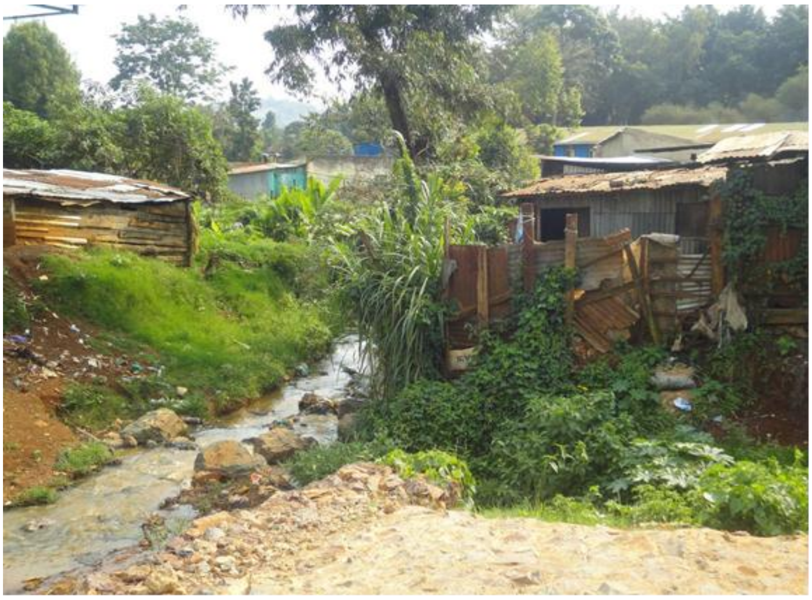
Kisii town continues to undergo metamorphosis. This change is shaped by economic, social, cultural and institutional factors. These changes require innovative intervention; demand for land in the town centre has exerted pressure on the neighboring residential and agricultural zones. Plate 2 below shows a hilly agricultural area with Kisii town boundary where urban development is rapidly taking place.

Plate 2: Hilly Agricultural Area in Kisii Town with Rapid Urban Development

Source, Field Survey, 2014

It was observed that most of the developments near water courses have not observed riparian reserves as recommended by WARMA, the lead agency in water resources management recommends a riparian of between 6 and 30 meters. It is therefore important that different authorities and developers observe riparian reserves. There has also been noted encroachment onto riparian reserves and other wetlands in the study area. Soil erosion exists but only at a moderate level. Environmental awareness on the need to protect riparian reserves has been carried out with minimal impacts as indicated by plate 3 below.

Plate 3: Informal Settlement Encroachments on Riparian Reserves



Source, Field Survey, 2014

In addition there is heavy quarrying in the town and the rural hinterland. Unregulated quarrying has had negative impacts on water quality along the tributary of rivers in addition to contributing to land degradation. Some of the quarrying activities have led to derelict land places that are an eye sore.

4.2 Analysis and Discussions

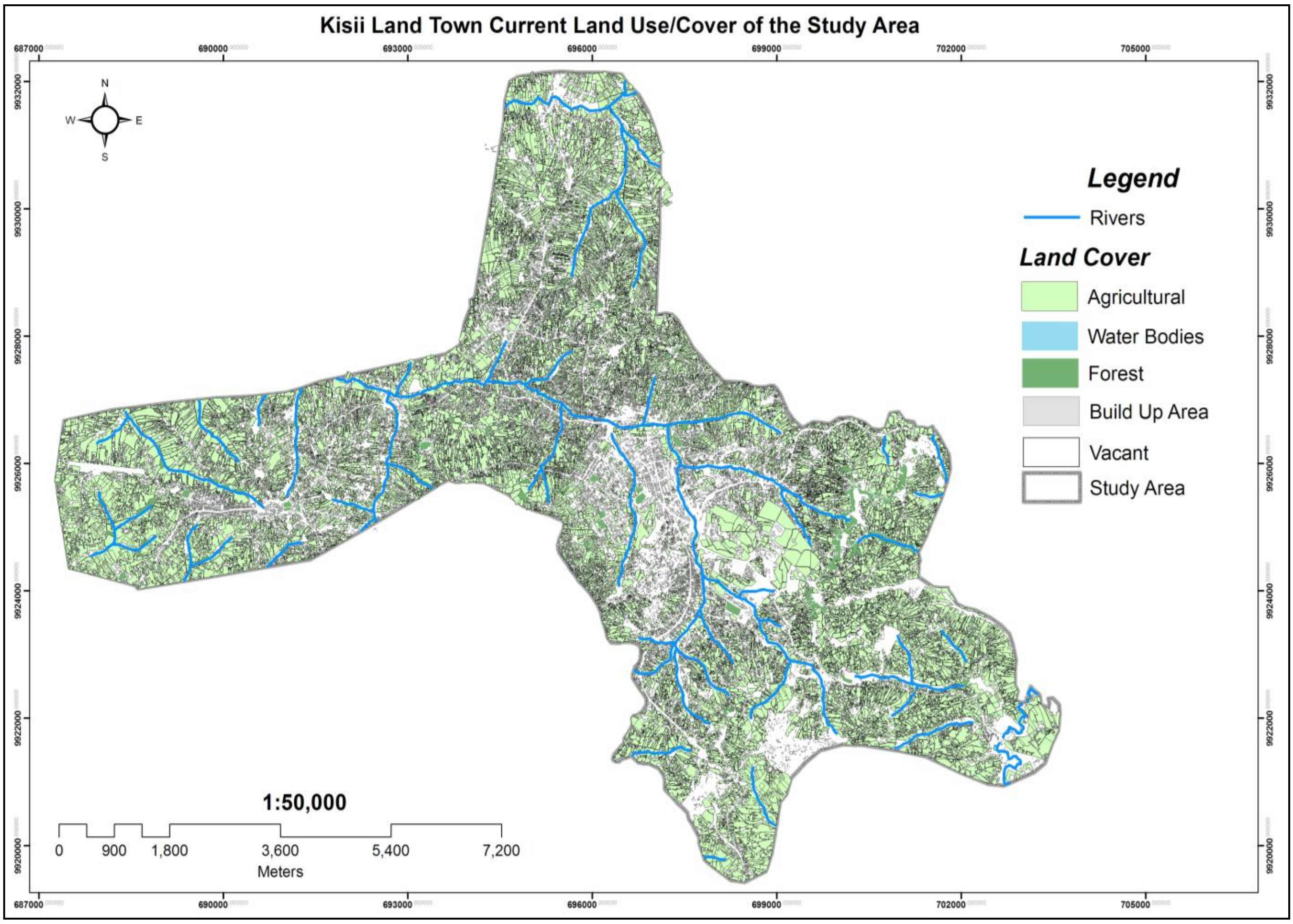
4.2.1 Land Use/Land Cover Map

Land use/Land cover map is necessary for planning of any development activity as it gives the present condition as well as view for scope of future development. The Land use/Land cover analysis is shown by map 9 below.

1. **Built-up:** It includes all man-made structure which are used for different purposes and activities, e.g. residential, institutional, commercial etc, to which the following belong.
2. **Vacant land:** This is mainly non built-up land without any land use activity or land cover. Waste land it is described as land which is not used for human activities as well as forest.
3. **Agricultural land:** the area used for producing.
4. **Forest land:** It consists of lands on which trees grown natural forms.

5. **Water bodies:** The land covered under natural drainage system like rivers, streams and as well as man-made linear drainage system like canal (used or unused) and natural or man-made structure like reservoir or ponds is classified under water bodies. In this project, river stream/canal and lake/tanks/ponds is considered.
6. **Others:** It includes the lands, which are not classified by above classes.

Map 8: Study Area's Land Use/Cover Map



Source: Author, 2014

4.2.2 Slope Analysis

As per special regulation for urban development, construction is not allowed on steeper slopes of 1:3. Therefore it becomes critical to identify areas of land having slope flatter that 1:3. The development can be concentrated on these areas and the rest is preserved or used for conservation and recreation. Road networks may also be designed to connect these developable areas. Results for slope analysis and different ranks of land suitability for Kisii town are shown in table 5 and figure 9.

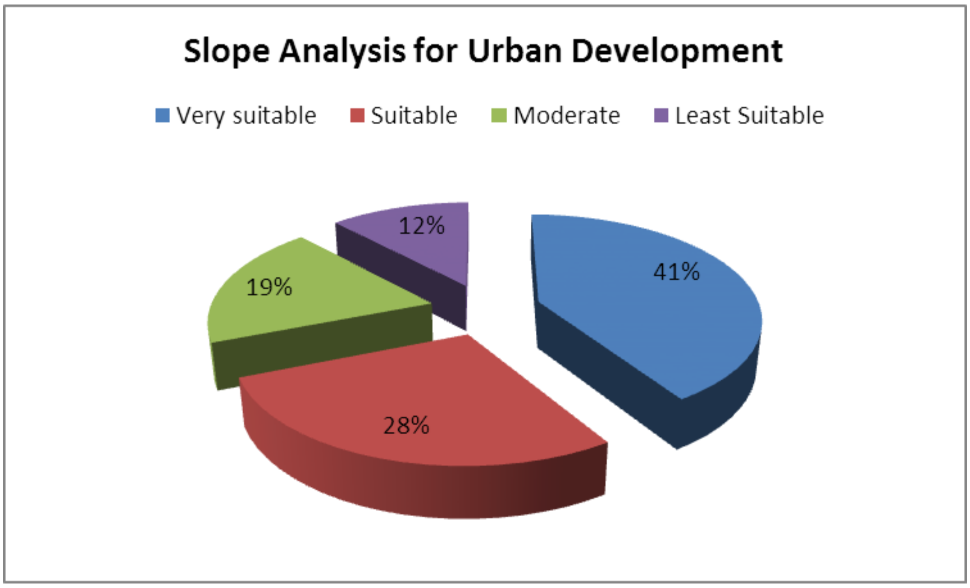
Table 3: Slope Analysis for Urban Development

	Category	*Slope Degree*	*Area(in Km²)*	*Percentage*
1.	Very suitable	0-5 degrees	29.11 Km^2	41%
2.	Suitable	5-15 degrees	19.88 Km^2	28%
3.	Moderate	15-25 degrees	13.49 Km^2	19%
4.	Least Suitable	>25 degrees	8.52 Km^2	12%
			71.00Km^2	**100%**

Source: Author, 2014

Analysis results indicate that 29.11 Km^2 of the study area representing 41% of the study area is very suitable for urban development. This includes areas within 0-5 slope degrees.

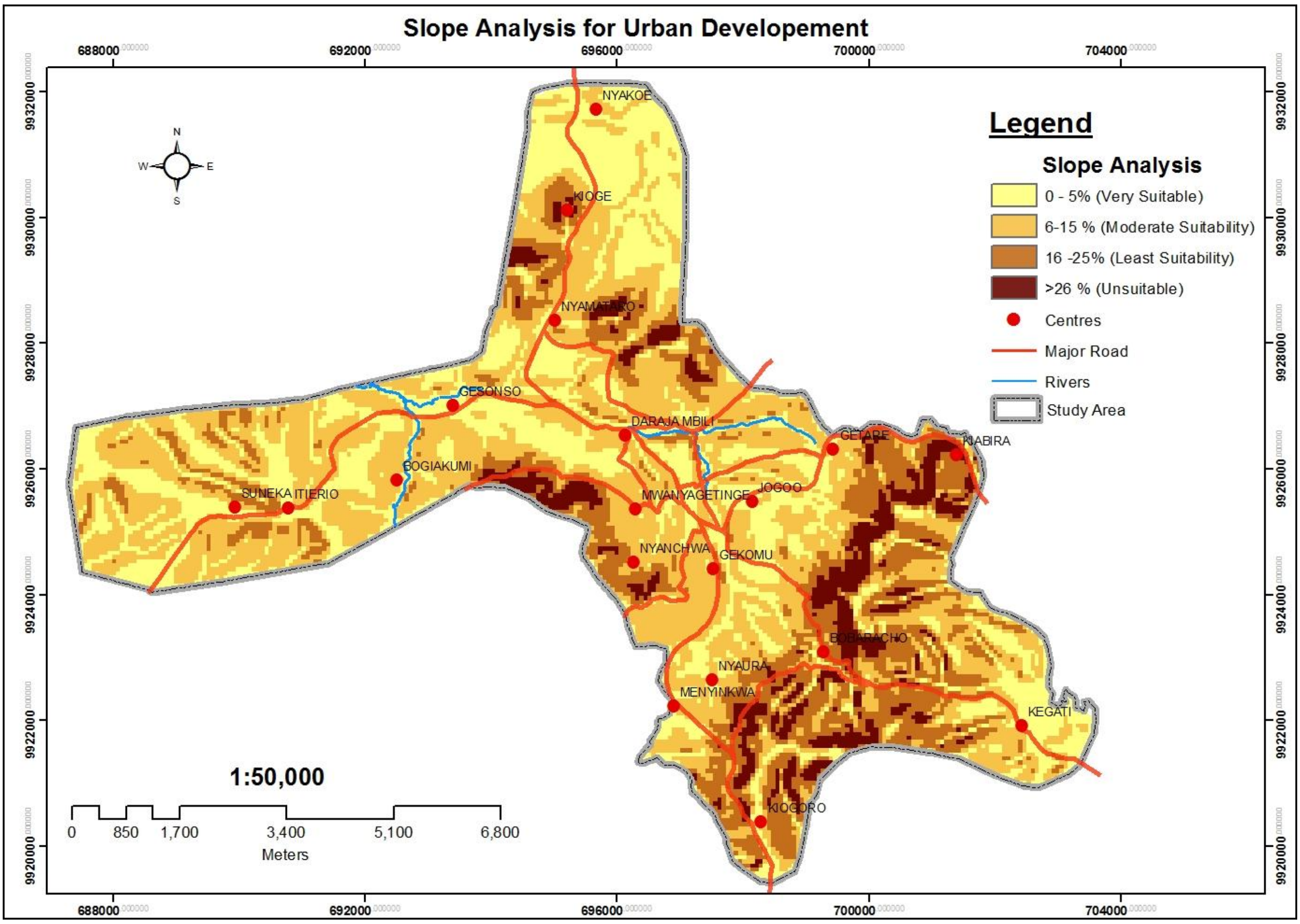
Figure 9: Slope Analysis for Urban Development



Source: Author, 2014

About 19.88km^2 of the study area is suitable for urban development. This consists of approximately 28% of the study area. Area with moderate suitability for urban development are made up of 13.49km^2 made up of approximately 19% of the study area. Least suitable areas for urban development consist of areas in more than 25 slope degrees and this constitute 12% of the study area and is made up of 8.52km^2. Map 10 depicts the various degrees of suitability for urban development from slope analysis.

Map 9: Slope Analysis for Urban Development



Source: Author, 2014

4.2.3 Accessibility/Proximity to Major Roads

Study findings indicated that approximately 29.71% of the study area represented by 20.67km^2 is very suitable for urban development. About 27.72% of the study area is considered being moderately suitable for urban development. Result findings for road proximity analyses for urban development are indicated in table 6 and figure 9 below.

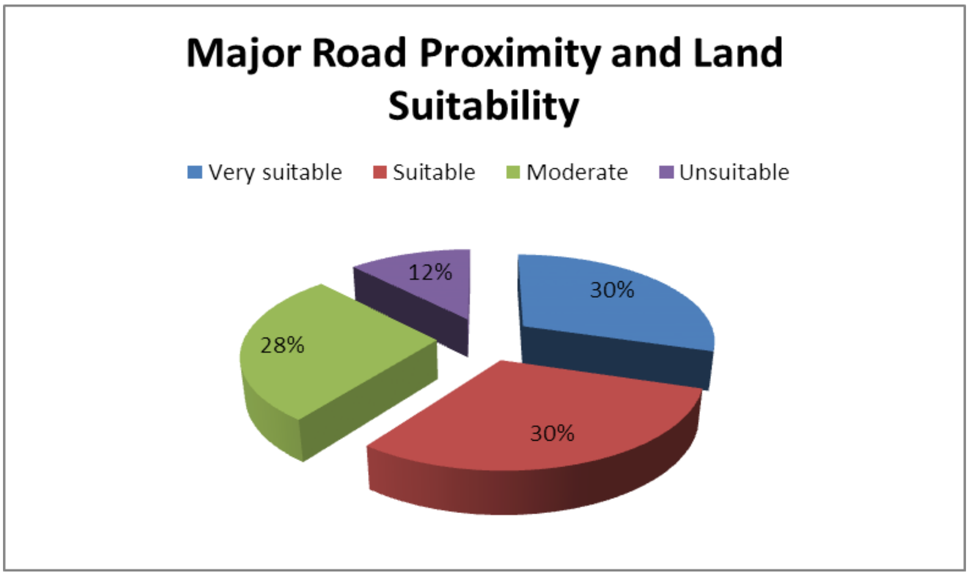
Table 4: Land Suitability for Urban Development Using Road Proximity Criteria

	Category	*Road Proximity*	*Area(in Km^2)*	*Percentage*
1.	Very suitable	200M	20.67 Km^2	29.71%
2.	Suitable	201-500M	21.60 Km^2	30.42%
3.	Moderate	501-1000M	19.68 Km^2	27.72%
4.	Unsuitable	1000M	9.72 Km^2	12.15%
			71.0 Km^2	**100%**

Source: Author, 2014

This is represented by nearly 21.60 km^2. Approximately12.15% of Kisii town study area is unsuitable suitable for urban development with respect to major road accessibility. This presents nearly while 9.72km^2 of the total area of the study area.

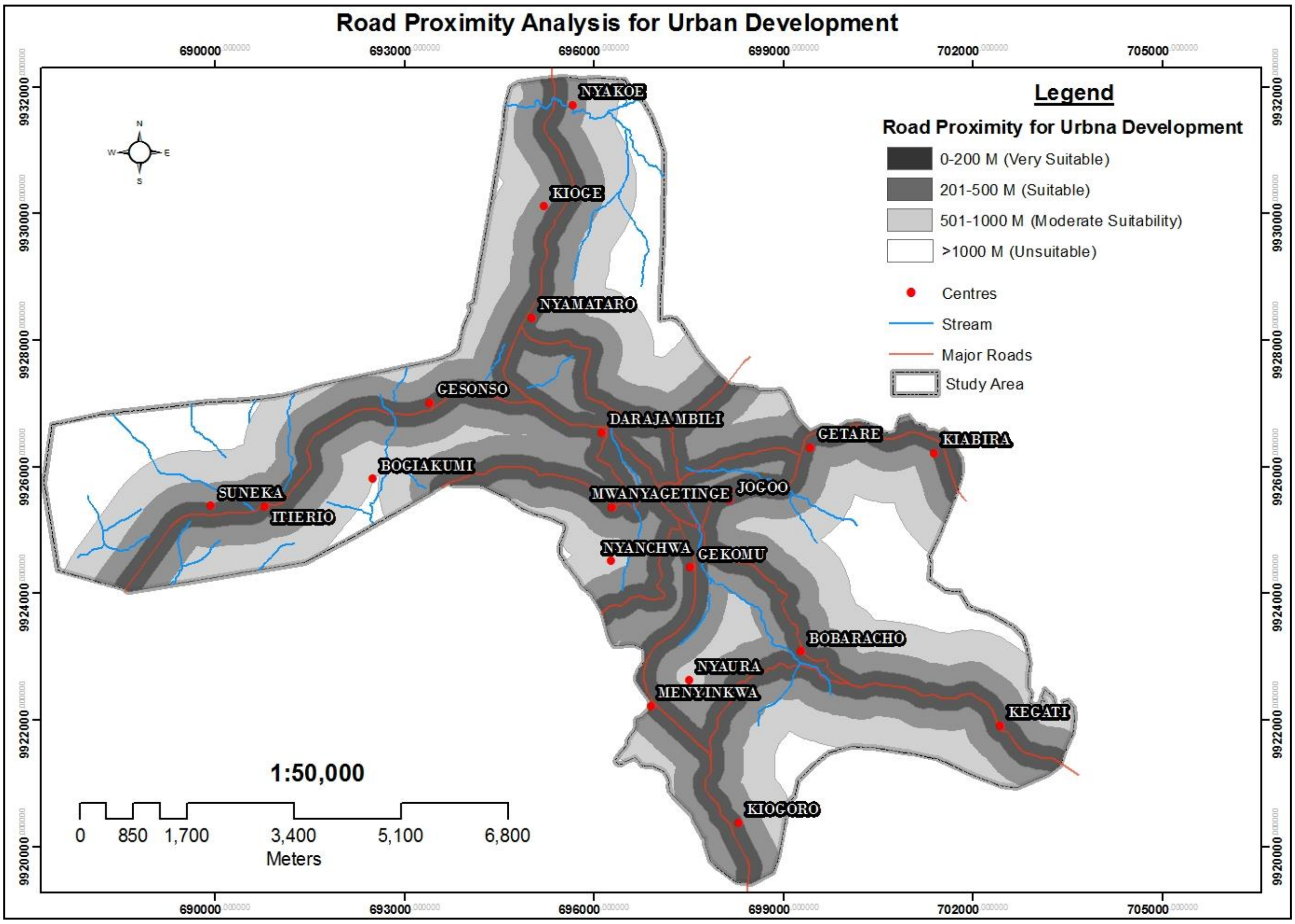
Figure 10: Major Road Proximity Analysis and Land Suitability for Urban Development



Source: Author, 2014

Analysis of road proximity for urban development is indicated by map 11 below.

Map 10: Road Proximity Analysis for Urban Development



Source: Author, 2014

4.2.4 Riparian Analysis

Analysis results show that approximately 3.19km^2 of the study area is unsuitable for urban development. This s represents approximately 4% of the study area and this includes areas within the 20 M riparian reserve.

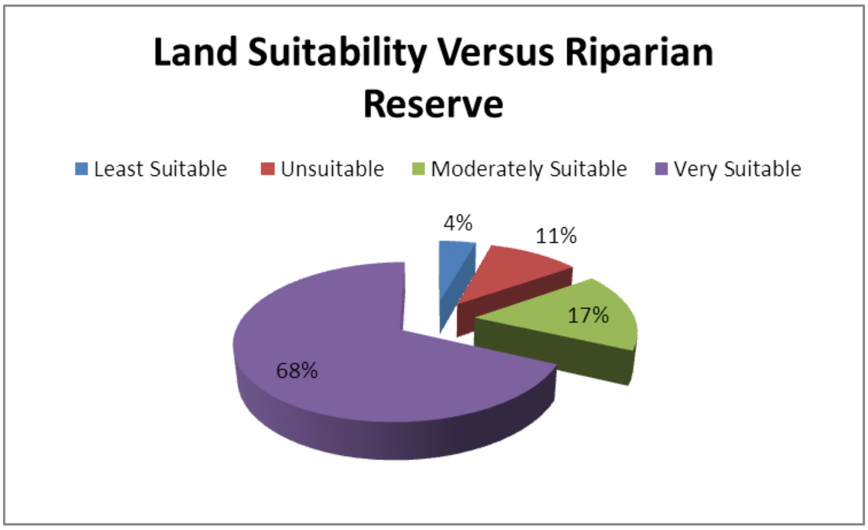
Table 5: Riparian Analysis for Urban Development

	Category	*Riparian Reserve*	**Area(Km^2)**	**Percentage**
1.	Least Suitable	20 M Riparian Reserve	3.14 Km^2	4%
2.	Unsuitable	40 M Riparian Reserve	7. 82 Km^2	11%
3.	Moderate	60 M Riparian Reserve	11.89 Km^2	17%
4.	Very suitable /Suitable		48.85 Km^2	68%
			71 Km^2	**100%**

Source: Author, 2014

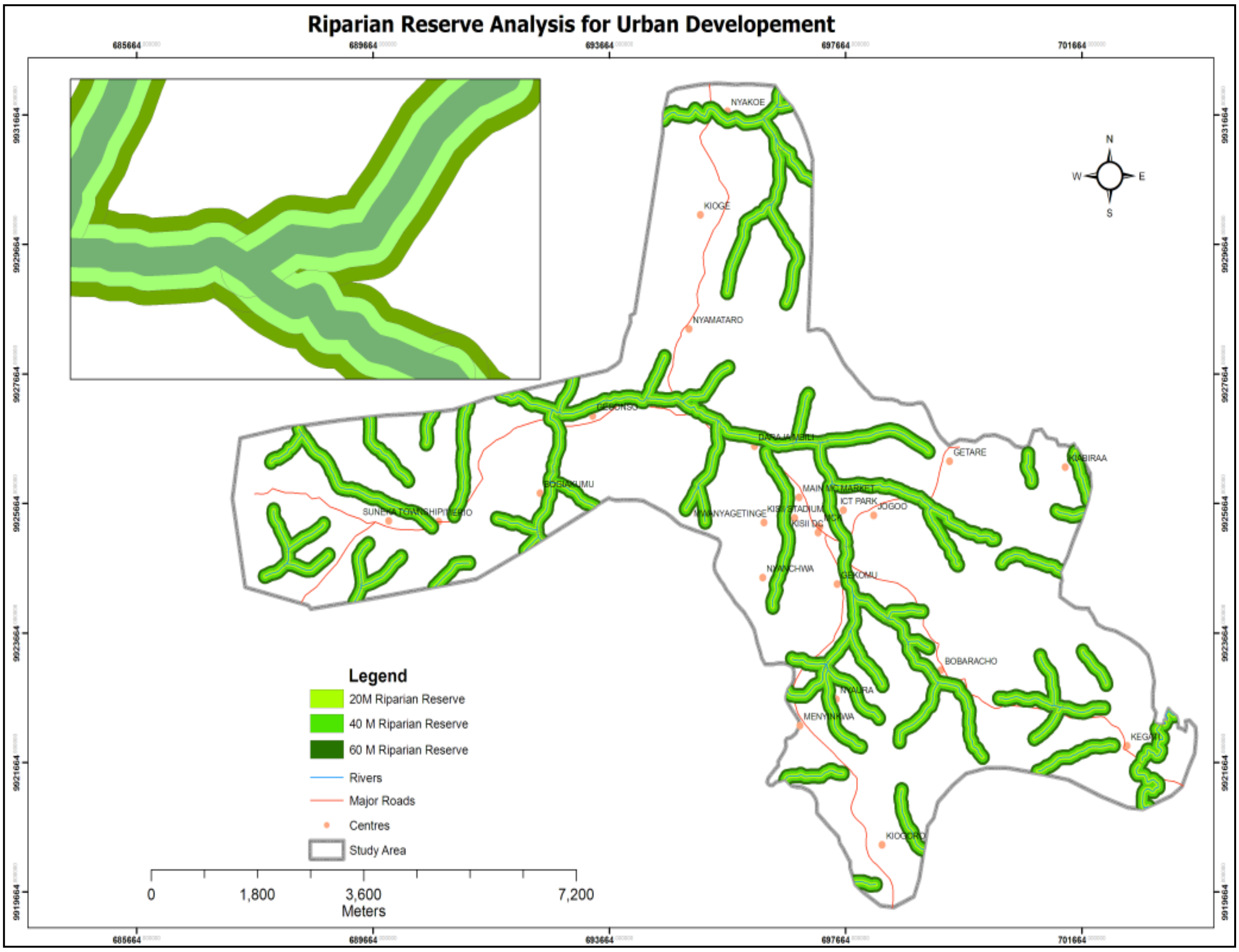
The results indicate that 7. 82km^2 representing 11% of the study area is least suitable for urban development. This includes areas within the 40M riparian reserve buffer. Area of moderate suitability for urban development is 11.89Km^2 which is represented by 17% of the study area is considered being moderately suitable for urban development. Approximately 68% of the study area represented by 48.85Km^2 of the study area is very suitable for urban development.

Figure 11: Riparian Analysis for Urban Development



Source: Author, 2014

Map 11: Riparian Suitability Analysis for Urban Development



Source: Author, 2014

No development should be considered in areas within 10M riparian reserve while riparian reserves of 20M-60M recreational areas such as nature trails should be encouraged.

4.4 Final Land Suitability for Kisii Town Urban Development

The overall objective of the study was to derive a land suitability map for the study area by combing the ranked evaluation criteria. The final site suitability map reveals the five different suitability categories or ranks as indicated table 8 and figure 10 below. Analysis results for the final land suitability analysis indicate that approximately 18.46km^2 of the study area is very suitable and this is represented by nearly 26% of the study area.

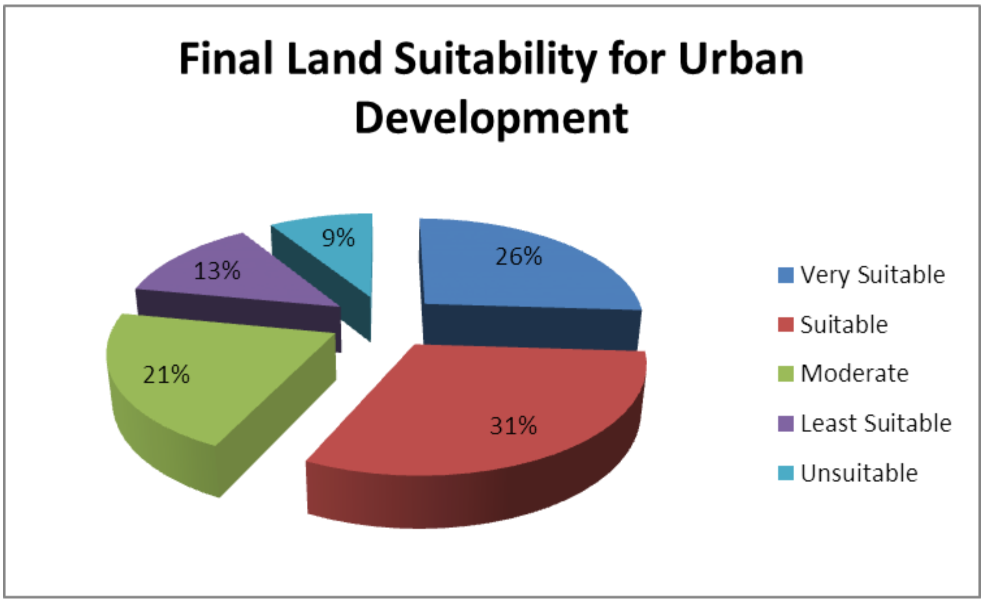
Table 6: Final Land Suitability for Urban Development

No.	Category	Area(sq.km)	Percentage (%)
1.	Very Suitable	18.46Km^2	26%
2.	Suitable	22.01 Km^2	31%
3.	Moderate	14.91 Km^2	21%
4.	Least Suitable	9.23 Km^2	13%
5.	Unsuitable	6.39 Km^2	9%
Total		71.00 Km^2	100%

Source: Author, 2014

The area under suitable criteria for urban development is 31% represented by 22.01 km^2. From the above table approximately 21% of the study area of moderate suitability for urban development and this is represented by 14.91km^2.

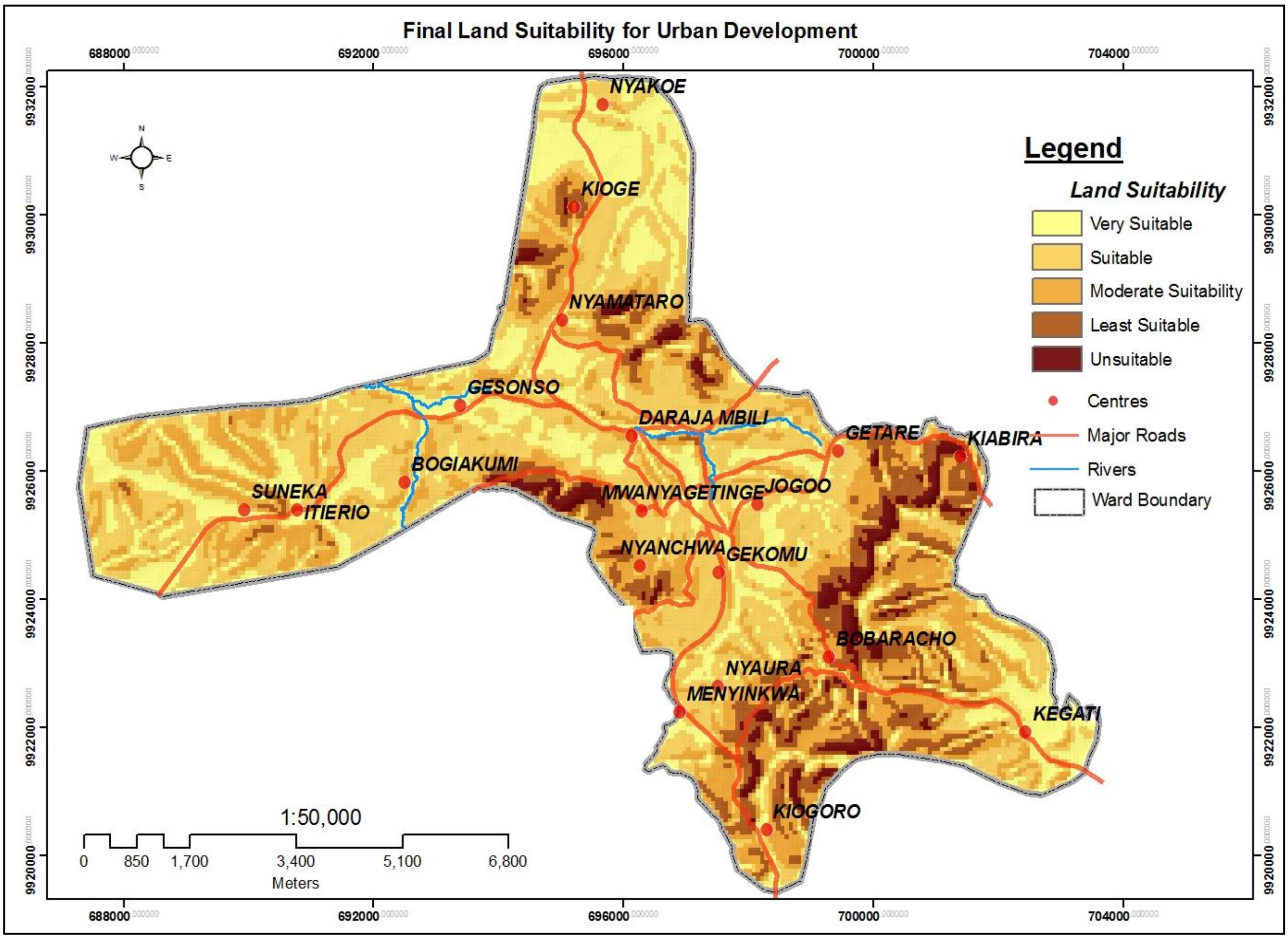
Figure 12: Kisii Town Land Suitability for Urban Development



Source: Author, 2014

Areas of least suitable for urban development are represented by 9.23km^2 which is 13% of the study area. Unsuitable areas for urban development consist approximately 6.39km^2 represented by 9% of the study area.

Map 12: Final Land Suitability for Kisii Town Urban Development



Source: Author, 2014

Areas of least suitable for urban development include areas around Nyanchwa Hillls, Mwamosioma Hills and Kioge and therefore urban development should be discouraged. Suneka, Nyamataro, Nyakoe, Kiogoro, and Kiabiraa and the town centre present areas of suitable criteria for urban development hence urban densification should be encouraged.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

The continued spread of urbanization will challenge the land's capacity to meet those demands. Integrating environmental dimensions into land management practices in urban areas from the earliest stages of the planning process can greatly contribute to the future sustainability of cities. Land use planning can certainly benefit from new technologies such as GIS. However, improvements in data access and analysis are critical issues for land planners. Sometimes, they are overwhelmed with data analysis, making subsequent decisions difficult. The objective of this study is to carry out land suitability analysis for urban development and growth of Kisii town using Multi-Criteria Evaluation (MCE) and GIS approach. In this study, spatial analysis techniques were applied to identify suitable areas for urban development. The results obtained from this study indicate that the use of GIS and application of Multi-Criteria Evaluation could provide a superior database and guide for decision makers in urban plan and management in order to achieve better and sustainable urbanization.

The database created brought together evaluation information about the town into one unit. This aspect enables the different stakeholders in the urban development and plan formulation to access information within a short time and hence timely decisions can be made from the database. Such databases also provide information for better urban planning practices.

The final site suitability analysis reveals that approximately 18.46km^2 of the study area is very suitable and this is represented by nearly 26% of the study area. The area under suitable criteria for urban development is 31% represented by 22.01 km^2. In addition approximately 21% of the study area of moderate suitability for urban development and this is represented by 14.91km^2.Areas of least suitable for urban development are represented by 9.23km^2 which is 13% of the study area. Unsuitable areas for urban development consist approximately 6.39km^2 represented by 9% of the study area.

5.2 Recommendations

Considering limited suitable land and drastic growth in the tertiary and quaternary sectors, the availability of suitable land for developmental work is going down. Land suitability analysis for urban development is essential to overcome this problem. In view of the findings and if urban planning and management in Kisii town is to succeed, the following recommendations are made.

Kisii County Government though Kisii Town Management Committee should consider revising its current urban providing policy guidelines to be in line with the results of the land suitability for urban development. Unsuitable areas for urban development should for conservation and urban forests/arboretums as this land uses pose minimal threats to urban population and are in line with increasing vegetation cover thus mitigating on climate change.

County Government of Kisii though Kisii Town Management Committee should consider reallocation of existing and proposed future land uses based on the results of land suitability analysis. The following land use allocation model should be adopted. Areas with very suitable characteristics for urban development should be considered for heavy land uses such as industrial, commercial and high density residential development. Less intensive land uses such as education public purpose (religious, institutional and social facilities) should be allocated. Area with moderate land suitability ranking should be designated for medium and low density residential and recreational land sues such as playground open spaces etc. least suitable area for urban development should be designated for periodic land uses such as motor cycle track fields, horseracing courses and golf courses. In addition open spaces should be allocated to these least suitable areas for development.

With regard to slope analysis, suitable areas for industrial development are areas falling under 5 degrees as these are considered very suitable for urban development. Land falling within 5 degrees to 15 degrees is considered as of moderate suitability for urban development and should be considered for residential development and related institutional developments such as religious institutions, education institution and other social services and facilities. Land parcels situated in areas of with more than 15 degrees are ideal for land uses that may not injurious to the pubic such areas should be considered for conservation, urban forest, arboretums and nature trails and recreational facilities.

Lastly for further study, the author proposes further research on a more number of factors/criteria like soil, geological characteristics and socio-economic factors which influence urban development

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