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DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

APPLICATION OF GIS-BASED ANALYTICAL HIERARCHY PROCESS (AHP) IN IDENTIFYING SUITABLE AREAS FOR URBAN DEVELOPMENT.

CASE STUDY: TRANS-NZOIA COUNTY.

BY

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A Project submitted in partial fulfillment of the requirements for the Degree of Master of Science in Geographic Information Systems, in the Department of Geospatial and Space Technology of the University of Nairobi

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Declaration

I, **Embanga Purity Mideva**, hereby declare that this project is my original work. To the best of my knowledge, the work presented here has not been presented for a degree in any other Institution of Higher Learning.

………………………………………………… …**29/07/2022**…………

Embanga Purity Mideva Date

This project has been submitted for examination with our approval as university supervisor(s).

………………………………………………… …**29/07/2022**………

MR. P.C. Wakoli Date

Dedication

To my mum… thank you for the sacrifices you made to ensure I achieve my dreams.

To my son, Aiden for being the reason why

Acknowledgment

The preparation and writing of this project is a result of the patience, psychological support and intellectual advice, and encouragement of many people. Therefore, I would like to express my deep gratitude to the individuals and institutions that provided me with guidance in achieving the prescribed goals of this thesis.

Firstly, many thanks to my supervisor, Mr. Peter Wakoli, for his support and refined advice along with thoughtful suggestions on the study. His intellectual inspiration and invaluable insight were instrumental and helpful.

Secondly, I wish to acknowledge the support of my mentor and colleagues (work and school) for their intellectual advice, financial support, and assistance in data collection and analysis.

Thirdly, I am grateful to the staff, the Department of Geospatial and Space Technology for their selfless effort in ensuring I achieve my academic goals.

Lastly, I am appreciative to my family especially my husband and my mum for their immense support which pushed me to the realization of my academic success.

Abstract

The world is undergoing rapid urbanization. In the developing world, Africa has the highest urbanization rate. Kenya is among the leading African countries with high urbanization rates as evidenced by the increasing urban population that currently stands at 28%. This rapid urbanization is mostly unplanned and is manifested by the sporadic emergence of small urban settlements in the country.

The Kenyan counties, Trans Nzoia included have not been spared from these adverse impacts of rapid unplanned urbanization. The county is characterized by small patches of built areas scattered all over the county's landscape haphazardly and with the new devolved governance system in place, urbanization in the county is expected to increase. The increase in urbanization means more land will be required for urban land use. For planned sustainable urban development to occur in the county, the identification of suitable areas for expansion and development of urban areas is critical for the County government of Trans Nzoia.

This study focused on the identification of areas suitable for urban development and expansion in Trans Nzoia County using the GIS-based Analytical Hierarchy Process. Based on comprehensive literature review and consultations with experts in the urban development field, eight criteria namely road proximity, distance to water bodies, distance to protected areas, population, slope, soils, land use land cover, and elevation were considered. In the generation of weights for each criterion, Analytical hierarchy process method was employed. The weights were assigned based on expert opinions using pairwise comparison matrix. A constraint map was generated using Binary Overlay Method. Weighted Sum Overlay was used to generate the maps based on AHP weights. Integration of the two maps using masking tool produced the final suitability map indicating suitable areas for urban development in Trans Nzoia County.

The analysis results indicated a large portion of Trans Nzoia County is not suitable for urban development with 5% of the total areas considered highly suitable for urban development. The results also indicate that approximately 64% of the existing main urban centers in the county are located in areas not suitable areas for urban development.

Although the results of the study are subject to field verification, the study recommends the consideration of the results in formulation of urban development strategy for the county and the adoption of the conceptual procedure used in this study for other planning projects.

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CHAPTER 1 : INTRODUCTION

1.1 Background

The world is undergoing urbanization at a rapid rate (Kimani et. al., 2010). By the year 2050, the percentage of the global urban population is expected to rise to 57%. Among the developing global continents, the highest urban growth has been experienced in Africa in the last two decades with the rate expected to continue to increase in the next decades. Although this rapid urbanization has changed Africa's demographic landscape, it has failed to achieve inclusive urban growth in urban areas. This phenomenon in Africa has been associated with mushrooming of unplanned urban settlements, inequality, and increasing poverty (African Development Bank, 2012).

Like most African countries, Kenya is also urbanizing at a fast rate (Kimani et al 2010). The country's urban population has risen from 23.57% in 2010 to about 28% in 2020, with this percentage expected to increase (Statista, 2021). Rural-urban migration has been attributed to be the main cause of the increase in the urban population. The main causes of this migration are rural poverty, inequalities, and poor performance in the agricultural sector. This rapid urbanization has resulted in increased demand for urban land as more centers continue to emerge all over the country.

In Trans Nzoia County, the impact of urbanization has largely been manifested by mushrooming of unplanned urban settlements (Trans Nzoia County Government (CGTN, 2020)). Unevenly distributed and haphazardly located patches of built-up areas all over the county's landscape illustrate these unplanned urban settlements. Through the devolved system of governance; the urbanization rate in the county is expected to increase tremendously in the next two decades (enshrined in the Kenyan Constitution 2010). Therefore, it is critical to identify potential areas suitable for urban development so that the county government can plan for the provision of urban infrastructure thereby sustainable urban development and expansion.

Suitability analysis for urban development has proven to be an effective technique worldwide in managing urban development. It determines the suitability of certain areas for urban development using different weights and criteria. Different alternatives are evaluated based on expert opinions, public interest, stakeholders, and decision-makers. The resultant output often differs depending on the opinions of stakeholders and analysts involved together with the techniques and technology used to arrive at the decision (Myagmartseren et. al., 2017). Therefore, it is paramount that the decision-makers have the necessary data and decision-making tools available at their disposal to enable them objectively and optimally make these crucial decisions.

The determination of suitable areas is a multidisciplinary venture, hence a complex process for urban planning. The process of decision-making in selecting suitable areas for urban development uses large data sets of spatial and non-spatial data with numerous alternatives that have multiple conflicting evaluation criteria (Malczewski, 2006). Therefore, it is crucial to use the best tools and techniques to determine probable areas for urban development. An effective technique that is best suited for land suitability modeling is combining GIS and Multi-Criteria Decision Analysis (MCDA) techniques (Malczewski, 2006).

Geographic Information system (GIS) is a computer-based system that can integrate spatially referenced data from diverse sources for informed decision-making in urban planning (Han & Kim, 1989). Analytic Hierarchy Process is a Multiple Criteria Decision-Analysis tool that is used to evaluate different alternatives to arrive at a viable solution based on their weights (Omkarprasad, 2004). This study integrated GIS tools and Analytical Hierarchy Process (AHP) technique to determine suitable areas for urban development in Trans Nzoia County based on factors influencing urban growth in the county and expert opinions.

1.2 Problem Statement

Rapid and unregulated urbanization caused by an increase in population and rural-urban migration is a major urban planning issue in Trans Nzoia County. Its impacts in the County are depicted by the growing demand for urban land, mushrooming of unplanned urban and informal settlements, urban sprawl, the emergence of linear developments along major transport routes, and environmental degradation.

This rise in urban population and the number of urban markets in the county is welcomed because it is essential for economic and social development. However, this growth should be assisted by identifying the potentially suitable areas for urban development and expansion. This would not only promote a desirable pattern of urban development but would also ensure the provision of adequate urban infrastructure in advance in the best and most economical manner (Morgan, 1969).

The decision to determine potentially suitable areas for urban development and expansion is still a challenge to urban planners. Using GIS and MCDA (AHP) for identifying suitable areas for urban development and expansion, Trans Nzoia County would benefit by limiting urban development and expansion to areas with characteristics that are most suitable for this purpose thereby minimizing the negative impacts of urbanization such as urban sprawl, mushrooming of informal settlements, and the emergence of unplanned market centers. This will eventually result in a sustainable urban development pattern in the county.

1.3 Objectives

The main objective of the study was to use the GIS-based Analytical Hierarchy Process (AHP) technique to identify areas suitable for urban development in Trans Nzoia County.

The specific objectives were to:

- Identify the factors that influence the suitability of a given area for urban development
- Generate criterion-based urban development suitability maps
- Perform GIS-based Analytical Hierarchy Process analysis to identify the most suitable areas for urban development in Trans Nzoia County.
- Assess the suitability (for urban development) of the existing trading centers in Trans Nzoia County.

1.4 Justification for the Study

As the urbanization rate of Trans Nzoia County is expected to continue increasing, its county government must come up with a mitigating measure to control the sporadic emergence of small unplanned urban markets and also control urban sprawl in the county.

The study identified potential areas where urban growth can be concentrated by limiting urban growth to only areas where such a development is suitable. This was in contrast to the current conventional approach to urban planning that has seen the county lag behind the urbanization process.

The proposed techniques and methods used in the study has been recommended to form the basis for research; application and or an adaptation framework for planning in other counties in the country not only in urban development planning but also in other large planning projects.

1.5 Scope of work

This study aimed at identifying areas suitable for urban development as a mitigating measure for the uncontrolled emergence of small urban markets. This was done by evaluating the suitability of the study area for urban development through multiple influencing criteria based on weights. Urban development, GIS spatial analysis tools, and AHP are the three elements in this research project. This research was conducted in Trans Nzoia County.

CHAPTER 2 : LITERATURE REVIEW

Urbanization is a phenomenon that has occurred since the 5000B.C. Human settlements emerged along rivers where people had access to water and transport and their source of livelihood. These settlements grew and eventually turned into towns.

An increasing global population is directly proportional to an increase in population in urban areas because of rural-urban migration. This global phenomenon is termed as urbanization. Kempe (2012) defines urbanization as a global dynamic process that involves the growth of the urban portion of the country's entire population. Urbanization is a population movement from rural to urban areas, which acts as a springboard for urban development. Urban areas are perceived to have made significant steps economically, politically, and socially compared to rural areas. The latter plays a pivotal role in influencing urbanization (Rinkesh, 2020).

By the year 2050, due to urban migration, 68% of the total world's population will inhabit urban areas (Miranda, 2019). According to UNDAP, by the year 2050, 2/3 of the global population reside in cities and 90% of this growth will occur in developing countries, especially in Africa (Brillault, 2018). This projected rise in urban population has led urbanization to be acknowledged as a significant phenomenon that should be taken into consideration for sustainable development (UN Habitat, 2017).

Africa is a growing continent with the number of Africans moving to urban areas expected to rise to 50% by the year 2030 (UN-Habitat, 2017). An increase in natural population and rural-urban migration are the main causes of rapid urbanization in Africa. Despite this unprecedented rate of urbanization in Africa, the process is characterized by unplanned and unregulated urban growth, urban poverty, urban sprawl, mushrooming of informal settlements, and rising inequality (AFDB, 2012; Güneralp et al, 2017). These problems posed by rapid urbanization in Africa and in particular the mushrooming of unplanned urban settlements, and urban sprawl need to be addressed urgently before they become irreversible. It is, therefore, crucial to develop an effective urban development strategy that will include identifying potential sites for urban development within the African continent as a contingency measure for the increasing number of unplanned small urban centers.

2.1 Urbanization in Kenya

After the country attained its independence in 1963, the process of urbanization has considerably risen as more people began moving to urban areas. The independence allowed Africans to migrate to urban areas without any legal or administrative restrictions which has resulted in a steady increase in urban population and the number of urban centers. Compared to the urban population of 8% at the time of independence from Britain, the urban population currently stands at 28% of the total population. (Nabutola, 2012; Statista, 2020).

Initially, the urban population was concentrated in the major cities and towns in the country, but recent studies have indicated that smaller secondary towns are emerging at a relatively fast pace (Majale, 2009). Urban planning has in the past lagged behind the rate of urban development (Nabutola, 2010). As a result, the emergence of small urban centers has been spontaneous and sporadic, as the country did not have an urban development strategy in place (GoK, 2015). The emergence of these centers was facilitated mainly by the construction of the Kenya-Uganda Railway and extensive road network.

These urban centers are haphazardly located and unevenly distributed across the country along major transport routes. The distribution of urban centers is sparse in the northern, lower eastern, and parts of the Coastal regions while the highest concentration is in the south, north, western, central, and upper Easter regions of the country (GoK, 2015). A deliberate distributive strategy and policy is needed to promote balanced urbanization in the country.

Today most of the towns established can no longer sustain themselves due to the impacts of urbanization such as inadequate social and physical infrastructure, environmental degradation, lack of employment opportunities, and stagnated economic development (Mulongo, 2022).

2.2 Urbanization in Trans-Nzoia County

Urban areas in the County are growing rapidly and uncontrollably posing serious challenges. Due to this unplanned rapid urbanization, the number of urban markets in the county has been increasing steadily over the years. Currently, the county has 169 small urban markers with the number expected to increase in the future ((TNCG, 2015). The rapid increase in the number of market centers is due to rural-urban migration, lack of opportunities in the rural areas, the dwindling agricultural outcome, and rural development.

Among these urban markets, only two urban centers i.e., Kitale and Kiminini have been planned. Due to the unplanned nature of these urban centers, ribbon developments are occurring along the major transport routes in the country resulting in scattered patches of built-up areas on the County's landscape in a haphazard manner. A common defining feature of urban areas in the County is the outward expansion along transport routes far beyond administrative boundaries that is brought about by the increase in urban population, land speculation, and unregulated developments.

Kiminini and Kitale town are the two main planned towns in the county. These two have also not been spared from the impacts of rapid unplanned urbanization. As per the 2019 population census, these two towns recorded an increase of 11.61% and 5.46% in their population respectively. This increase has been brought about by rural-urban migration that is caused by in-migration from other centres, natural population growth, and decreasing economic opportunities in the outlying farmlands. As a result, these two towns are facing immense pressure on existing infrastructure and natural resources. The problems manifested in the towns include - urban sprawl manifested by the proliferation of informal settlements like Kipsongo and Tuwani in Kitale town; infringement on agricultural land; environmental degradation. As a result, there is a huge demand for more urban land to accommodate the expansion of the existing urban centers and the establishment of new urban areas.

Although urbanization is inevitable (Kempe, 2012), urban settlements need detailed site suitability assessment in consideration of the available resources as well as the influencing factors of urban growth (Ganesh 2020). Suitability analysis for urban developments means guiding urban growth towards the most suitable areas where the provision of basic infrastructure and services would be economical and efficient. This will alleviate the problems of spontaneous urban growth. It is therefore critical that urban planners in the county identify potentially suitable areas for urban development for sustainable urbanization. Trans Nzoia County is known for its maize production in the county which is the origin of its name as the 'country's breadbasket.' Therefore, limiting urban development in certain areas will help conserve high agricultural lands in the county.

2.3 Managing Urbanization

Many policymakers allude to urbanization as an inevitable element of economic growth and a means to end poverty. Therefore, the question that arises is ‘how can urbanization be used for economic development? This could be interpreted as mitigating measuring emanating from urbanization as opposed to curbing urbanization (Kempe, 2012). Perroux growth pole theory formed the foundation of urban growth management in Kenya. The theory makes an assumption of a center as a focus possessing centrifugal force. The theory assumes that growth does not appear everywhere due to attraction and repulsion. This theory formed the basis for the development of the growth center policy that has been part of the urban development planning in Kenya since the 1970s (Mireri, 2006).

Although the growth center policy was core to regional development in the country, the implementation of the policy faced obstacles. The absence of clear and objective selection criteria made it challenging to identify areas with the best growth potential. This limited the selection to subjective considerations such as politics and personal interests. The unavailability of comprehensive data on the urban areas and their hinterlands made it challenging to establish an effective selection criterion. Additionally, the establishment of a stable database was challenging due to the haphazard changes in the boundaries of the urban areas caused by urban sprawl. There were also difficulties in the determination of the required population to qualify a center for growth center status because of the periodic nature of markets which made it challenging in determining a static population of these centers to qualify them for growth center status (Mireri, 2006).

The formulation of the National Urban Policy in 2016 is part of the Government’s recent efforts in achieving the objective of exploiting the benefits of urbanization contained in the Constitution. Vision 2030 identifies unplanned rapid urbanization as one of the four key challenges facing the country (World Bank, 2016). The National Urban Development Policy formulated under Medium Term Plan (2013-2018) in the overarching framework of Vision 2020 which envisioned secure, well-governed, competitive urban areas. Among the strategies under the objective of mainstreaming spatial planning to drive sustainable urban development, the policy proposes the identification and classification of urban areas based on an identified and clear set of criteria and the development of urban areas based on comparative advantage as opposed to traditional approaches. The traditional approach to urban planning does not utilize the comparative advantage of each area as a basis for urban development (GoK, 2016). Under the same objective, the policy also identifies the importance of public participation in urban planning which is currently unstructured and ineffective. The policy recommends mainstreaming public opinions in urban development initiatives (GoK, 2016).

This research study aimed at integrating the above strategies to achieve sustainable urban development. The repackaging of the growth center policy by incorporating the strategies identified in the National urban development policy could provide a sustainable way of managing urban growth in the country. This was achieved through land-use planning that encompassed suitability analysis using GIS and MCDA techniques.

2.4 Land Use Planning

Land-use planning involves allocating land between competing and occasionally conflicting uses to ensure an orderly and balanced development in an environmentally sustainable manner for sustainable human settlements (Thomas, 2001). The primary objective of land use planning is to designate land-use forms in an area where change is inevitable. It aids in answering the questions of what, where, when, and how from a planning perspective. Answering these questions contributes to the development of a good and sustainable community (Wang & Hofe, 2007).

Human activities on land have been rapidly multiplying in recent decades, contributing to rapid urbanization, which has had negative effects on the environment and human settlements. Land use planning is critical in achieving sustainable development. The classification of land based on proposed and existing human activities is a fundamental component of land use planning (Shen et al., 2015). Suitability analysis which forms an integral part of land use evaluation is a crucial stage in land use planning. (Ullah, 2014).

Land suitability is a method for identifying future land uses according to a specific set of constraints, and preferences of predictors (Malczewski, 2004). The identification of areas within a specific planning area that is best suited for specific land use such as urban development, agriculture, and industrial development is the primary objective of land suitability analysis. (Puntsag, 2014). This is accomplished by mapping the index of suitability in a specific area based on identified criteria. The best site is selected by ranking different sites based on their suitability.

2.5 GIS

GIS is a computer-based decision-support system with the capabilities of integrating spatially referenced data in a problem-solving setting. It includes a set of procedures for facilitating data input, storage, manipulation, analysis, and output for both spatial and non-spatial data to support decision-making activities (Malczewski, 1999).

Initially, land suitability analysis was carried out using hand-drawn maps; however, GIS technology now plays an integral role in analyzing and mapping large data sets (Willoughby, 2005). GIS has become increasingly important in land suitability mapping and modeling with the recent advancements in spatial analysis technology. (Malczewski, 2006).

2.6 Analytical Hierarchy Process (AHP)

Presently, AHP is one of the most effective techniques under the multi-criteria decision analysis approach for decision-making in land suitability. This method was developed by Thomas Saaty as a response to the lack of a standardized, simple, and easy-to-implement methodology for making complex decisions. It helps the decision-makers in setting the priorities to make the best decision as it captures both the objective and subjective aspects of the decision made.

AHP works by considering a given evaluation of multiple criteria from which an informed decision is made. The best decision is the one that gives the most suitable trade-off between the available options (Saaty, 1980). This technique divides the problem into three distinct parts. The first section points out the issue at hand needs to be resolved. The second section discusses the alternative solutions to the problem at hand. The third and most important aspect of AHP is the criteria used to evaluate the alternative solutions.

AHP was used in this research because its advantages outweigh other techniques. First, it offers a structured framework for evaluating the suitability of a site. It will decompose the issue at hand in hierarchical units allowing for an in-depth review of each factor. Secondly, AHP is not entirely dependent data set's completeness but rather on experts' opinions and or observations about the factors and their observed influence on site suitability. Thirdly, this method of approach is more transparent and thus has a high chance of acceptability. The fourth and final reason is that AHP allows for experts and stakeholders in providing a site's suitability measure relative to the problem under study thus allowing for the incorporation of both qualitative and quantitative criteria for assessing site suitability.

Recent technological advancements in GIS software have enabled AHP to be successfully integrated into a GIS environment. The basic steps in the GIS-based AHP used in this study are shown in the figure below.

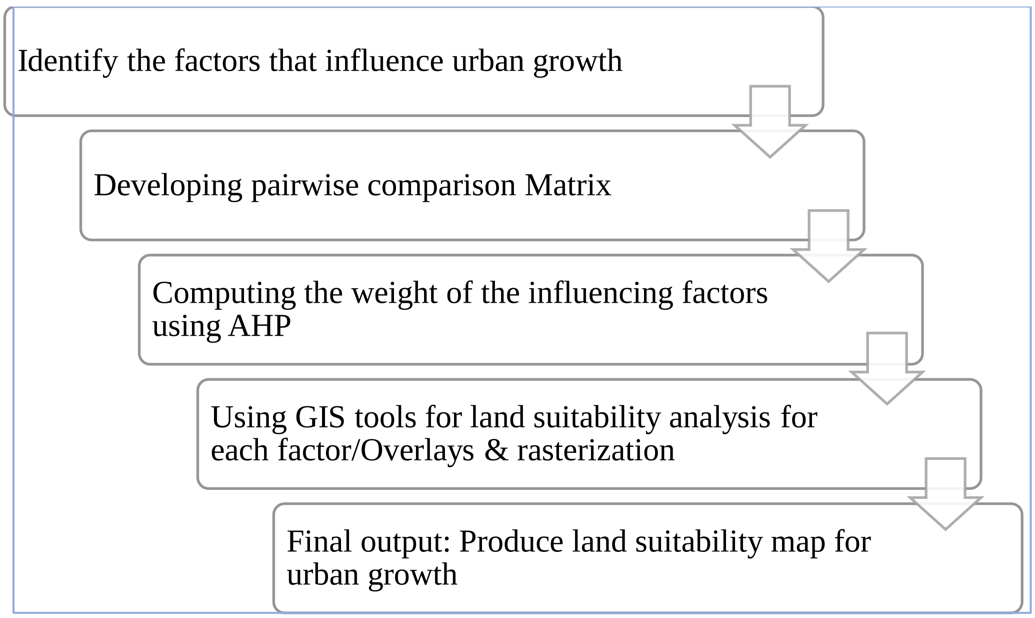

Figure 2.1: AHP framework within a GIS environment

Several studies on GIS-based suitability analysis have been conducted in a variety of situations, including urban planning, environmental planning, agricultural suitability analysis, and selection of the best site for the location of facilities. Arjun Saha (2021) wrote an article on an integrated approach to identifying suitable areas for built-up development using GIS-based multi-criteria analysis and AHP in the Siliguri planning area, India. V Navin Ganesh (2020) also authored an article on Site Suitability Assessment for Neelambur Panchayat using GIS and AHP techniques. Other researchers in the field include - Nayama Valsa Scariah (2016), Suraj Kumar Singh (2014), and Maher Milad Aburas (2015) among many others. The current study concentrates on land suitability analysis using an analytical hierarchy process for selecting the best sites for urban developments and provides an overview of the main criteria used to determine these sites.

2.7 Factors that influence urban development

There are no universally accepted factors or criteria for urban development in urban planning. Thus, the selected criteria used were determined by synthesizing literature reviews and expert opinions. Data availability and significance of data were also factored in criteria selection. To achieve the main objective of this study, one accessibility factor (road proximity), three environmental factors (distance to protected areas and water bodies & land use land cover), three physical factors (elevation soil and slope), and one socio-economic factor (population) were used.

2.7.1 Accessibility factor

i. Road Proximity

This is a crucial component of urban development because it enables the movement of people, goods, and services and provides connectivity between settlements. Areas near major roads in the county have smooth and efficient mobility as well as better connectivity to other parts of the country. As such, these areas are the prime locations for urban development.

From interviews carried out, expert opinions favored areas near major transport routes. As such, areas located near existing major roads (≤500m) were considered more suitable for urban development. Suitability of declined as one moved away from the main roads. Areas more than ≥2Km were considered not suitable.

2.7.2 Environmental factors

i. Distance to protected areas

In identifying suitable for urban development in Trans Nzoia County, it was critical to preserve the natural ecosystem. Therefore, developments in any protected area were restricted.

These areas are areas that have been surveyed, demarcated, and gazetted as areas of significant biodiversity and or endangered species for purpose of protection and conservation. Such areas include national parks and game reserves. The Physical Planning Handbook recommends a buffer of 50m around national parks and areas of significant biodiversity.

ii. Distance to Water bodies/wetlands/swamps

The physical planning handbook prohibits the development of 30m on either side of watercourse, swamps, and wetlands. These areas were not suitable for development because the presence of water has a strong influence on the soil characteristics and vegetation. Developments on riparian land are usually limited to conservation planning.

The suitability of urban development improved with an increase in distance from water bodies. This is because soil characteristics change. Water bodies normally depict clayey to sandy soils both of which were unsuitable for urban development. Stable loamy soils were considered suitable for development were found away from water bodies.

iii. Land use/land cover

Land Use/Land Cover is the categorization of natural elements and human undertakings on the landscape over time. In attaining sustainable urban development, it is essential to monitor the land use /land cover patterns to predict the direction of growth of urban centers while ensuring optimal use of available land.

In considering areas suitable for urban development bare land was considered more suitable than built-up areas because no new construction/development can be done in built-up areas in the future. Similarly, forested areas were also restricted as they are to be preserved in their natural state. However, shrub land and grassland were considered moderately suitable for urban development, as minimal costs would be incurred in clearing the shrubs and grassland to pave way for urban development.

2.7.3 Physical factors

i. Soils

When considering suitable areas for urban development, soil characteristics play a pivotal role in determining stable areas for the construction of urban infrastructure. Some soils are perfect for construction while others are not good based on the soil characteristics. The study are had four types of soil namely: -loamy, sandy, clayey, and very clayey. Loamy soils were considered most suitable for urban development followed by clayey because of their good drainage. Very clayey and sandy soils were considered least suitable for urban development due to their poor drainage and water retention capacities respectively (Arego, 2020).

ii. Slope

A hilly area is defined as elevated land with a slope greater than 12 degrees, whereas a highland area is defined as land located more than 150 meters above sea level with a slope greater than 25 degrees (Physical and Land Use Planning Handbook, 2007).

Because hilly areas were considered natural assets, development in these areas must adhere to several physical criteria to preserve the natural environment's stability, balance, and harmony of the natural environment. Development on a steep slope is next to impossible or very expensive and will eventually result in ghost towns as residents will abandon the area in favor of flat grounds. On slopes where trees have not been planted, there’s is a high potential for the surface run-off. As such, areas on steep slopes were considered not suitable for urban development.

Areas with a slope of 0^0-5^0 were more suitable for urban development because they have optimum suitability. Areas with slopes of more than 15^0 were not suitable for urban development because steep slopes require operational and construction costs therefore unsuitable for urban development.

iii. Elevation

Elevation has been considered in this study because it greatly influences urban growth in terms of the location of buildings. In this study, areas with low elevations were considered more suitable because of the low provision costs for basic infrastructure such as water supply, and transport as compared to higher lands. The areas with low elevations had more weight than those on high grounds.

2.7.4 Socio-economic factor

i. Population

Undoubtedly, rapid population increase is the main contributor to urbanization. Population growth is the main determinant of the speed and size of urban expansion (UN-Habitat, 2004). In Kenya, the population of 2000 persons in a concentrated settlement qualifies areas as an urban area (Ngayu, 2011). Urban areas in the past and even now continue to emerge within areas with high population densities. From expert opinions, population increase is the main driving force of urban population making it the most important factor that influences urban development. It is also economical to develop areas with high population as service and infrastructure provision is made easier than areas that has sparsely distributed population. In this study, an assumption was made that minimum population of an urban area is 2000 persons, which was considered in the first criteria of 0-5000 people.

CHAPTER 3 : MATERIALS AND METHODS

3.1 Study area

The study was conducted in Trans Nzoia County. It is located on the country's western edge at latitudes 00° 52' and 10° 18' north of the equator and longitudes 340° 38' and 350° 23' east of the great Meridian.

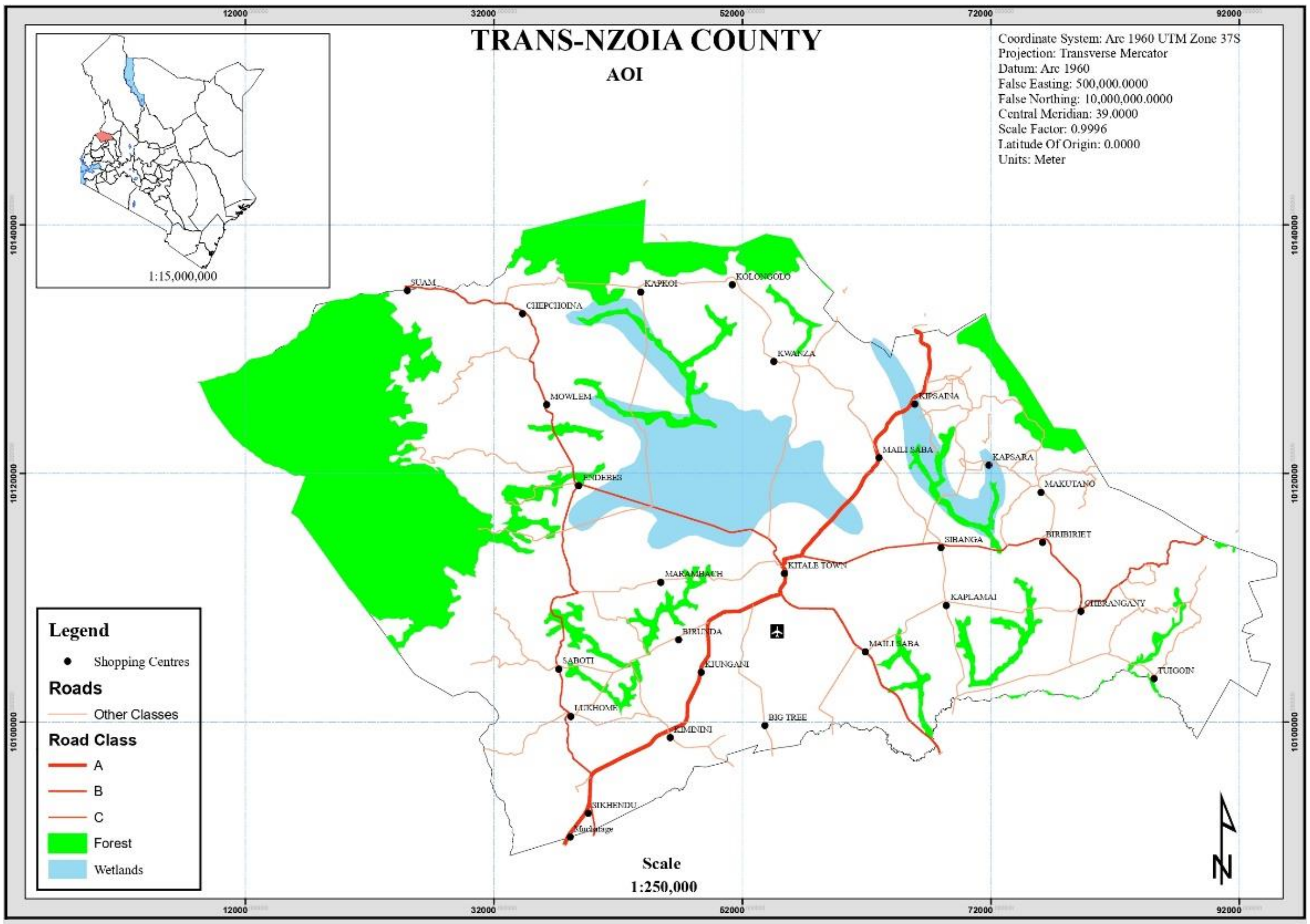

Figure 3.1: Study area

The county's topography is generally flat, with gentle undulations rising steadily towards Mt. Elgon in the northwest. The altitude ranges from 4,313m above sea level in Mt. Elgon to 1,400m above sea level in the north. Mt. Elgon and Cherengany Hills are two notable water towers in the area. The county's major forests include Mt. Elgon Forest Reserve, Kitale Town Forest Reserve, Sikhendu Forest Reserve, and Kapolet Forest Reserve. It has two national parks: Mt. Elgon National Park and Saiwa Swamp National Park, which is famous for its Sitatunga antelope and is drained by the rivers Nzoia and Suam.

The county had a population of 990,341 in the 2019 population census, which is a 1.2% increase from the 2009 population census. The majority of the county's population is rural with only 18% urban population. The urban population is concentrated in two main towns in the county namely Kiminini and Kitale with the rest of the population distributed unevenly among the 167 urban markets in the county.

The area was selected for study because it is undergoing rapid urbanizing in an unsustainable manner. This is depicted by the rising number of unsustainable and unevenly distributed small urban centers throughout the county. These centers are usually inactive and offer minimal services that hardly meet the demand of the targeted population. On the other hand, the existing main urban centers such as Kitale and Kiminini are experiencing urban sprawl due to the rapid increase in their respective urban populations and unplanned expansion initiatives depicted by mushrooming of normal settlements (TNCG, 2020). The county has also experienced tremendous land use change as more land is being converted from agricultural to commercial land use. As the county is the breadbasket of the country, it is important that urban growth is controlled and limited to areas optimal for commercial use. This will in turn ensure conservation of fertile agricultural lands.

The unplanned rapid urbanization in the county has made it prudent to develop a sustainable solution to manage urban growth. This study aimed at assessing the suitability of the locations of the existing urban centers and delineate potential areas for future urban development as a strategy for managing urban growth in the county

3.2 Data Collection and Data Processing

The data used in the study was obtained from varied secondary sources in various formats. They were then converted to a uniform projection system using a common platform in Esri Arc GIS version 10.5. Available data on roads, protected areas, forests, soils, water bodies, slope, and elevation, and built-up areas were acquired from RCMRD and ILRI. Population Data was collected from KNBS 2019 population census. See the table below for the list of datasets and sources used in this study.

Table 3.1: Summary of Data and Data Processing

Define Goal	Dataset	Data Type	Data Source	Analysis Method
Suitable sites for Urban Development	LULC	Raster	RCMRD	Weighting
	Population	Raster	KNBS- 2019 Census Data	Weighting
	Slope	Raster	Ministry of Mining/RCMRD	Weighting
	Soil	Raster	Ministry of Mining/RCMRD	Weighting
	Elevation	Raster	RCMRD	Weighting
	Transport	Vector	Ministry. Transport	Binary overlay (Buffer, Intersect, erase & combine)
	Water Bodies	Vector	RCMRD/ Min. Mining & Natural Resources	Binary overlay (Buffer, Intersect, erase & combine)
	Protected Areas	Vector	RCMRD/ Min. Mining & Natural Resources	Binary overlay (Buffer, Intersect, erase & combine)

Software:

- ESRI ArcGIS
- AHP 2.0
- Google Earth Pro
- Microsoft Office 2016

Research Equipment:

- Handheld GPS
- Mobile phones
- Digital Camera
- Personal laptop with specifications': Intel(R) Core (TM) i5-6200U CPU @ 2.30GHz 2.40 GHz, 4.00GB RAM

3.3 Methodology

This section focused on the research methodology used in this study. The methodology used in this study included integrating AHP into GIS environment to determine suitable sites for urban development. A comprehensive literature review and expert opinions were used to identify the criteria. The relative weights of criteria were determined using an analytical hierarchy process. The two GIS spatial analytical methods used in the study were weighted sum overlay and binary overlay.

All data relating to the criteria were sourced from relevant agencies as illustrated in table 3.1 above.

The overall methodology adopted in this study is shown in the flowchart.

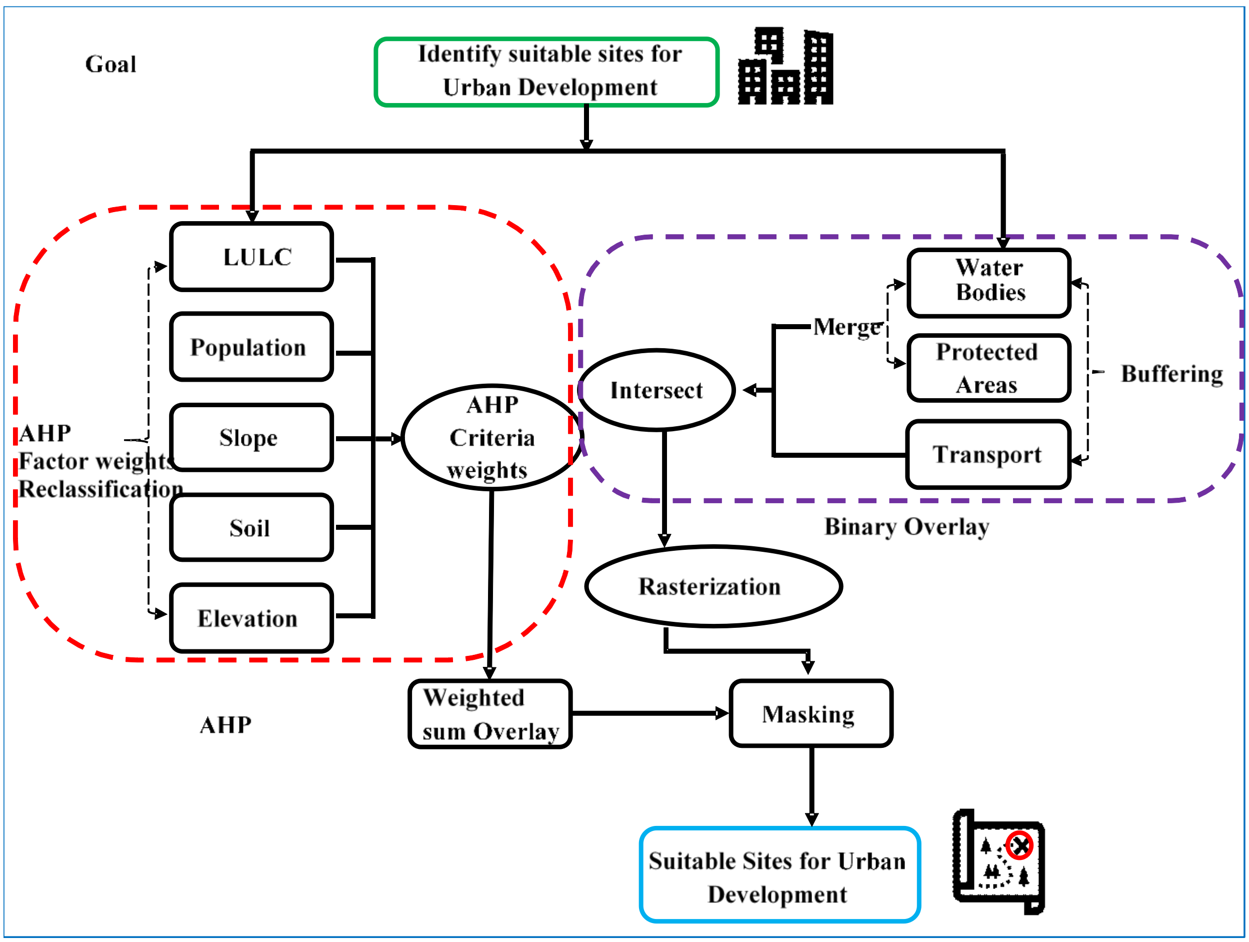

Figure 3.2: Stepwise flow chart of GIS based AHP methodology

Step 1: Identifying factors that affect urban growth

To achieve the main objective of this study, eight criteria were identified namely: - Land Use Land Cover, Population, Slope, Soil, Elevation, Transport, Water Bodies, and Protected Areas.

Step 2: Calculating criteria weights using AHP

Analytical Hierarchy Process (AHP) was used to determine the criteria weights. The weights in this study were determined using a questionnaire survey administered to two experts in the field of urban planning. One of them is a professor and an experienced urban planner specializing in development studies while the other is a licensed physical planner specializing in environmental and urban planning. Both participated in the preparation of the Trans Nzoia County Spatial Plan and were most instrumental in proposing strategies for urban development in the county.

They were asked to give a numerical score based on Saaty's 1 to 9 scale using the pairwise comparison matrix. The numerical score given expressed their judgment of the relative preference of one criterion against another

Table 3.2: Nine-point weighting scale for pairwise comparison

Intensity Of Importance	Definition	Explanation
1	Equally important	Two criteria/sub-criteria equally contribute to achieving the study's objective
3	Moderate importance	Experience and judgment slightly favor one criterion over another
5	Essential	Experience and judgment strongly favor one criterion
7	Strong Importance	A criterion is strongly favored, and its dominance is demonstrated over a practice
9	Extreme Importance	There's strong evidence of favoring one criterion over the other
2,4,6,8	Compromise/Intermediate values	Absolute judgment cannot be given, and a compromise is needed

Source: Saaty, 2008

Normalization of each value was done by dividing each factor value in each column by the sum of their respective column. The weights were then derived by the arithmetic mean method. The **consistency ratio (CR)** was calculated to measure the degree of consistency of expert judgments. For the judgments to be accepted, the value of CR must be less than 10% or 0.10.

Equation (1) was used to calculate the CR value is -

$$\frac{CI}{RI} = \mathbf{CR} \qquad (1)$$

Where RI is the Random Consistency Index in which the value depends on the number of factors as per the Random Index Table below. CI is the Consistency Index calculated using the equation (2)

$$\mathbf{CI} = \frac{(\boldsymbol{\lambda}\mathbf{max} - \mathbf{n})}{\mathbf{n} - \mathbf{1}} \qquad (2)$$

Where n is the number of factors/criteria used and λmax is the largest eigenvalue (Han and Tsay, 1998; Malczewski, 1999). The number of criteria used in the study must be less than the λmax value.

Table 3.3: Saaty's AHP table of Random index

n	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**
RI	0	0	0.52	0.59	1.11	1.25	1.35	1.4	1.45	1.49

Source: Saaty, 2008

Step 3: Generation of weighted criteria Maps

Different Criterion maps were prepared in a GIS platform. A total of eight maps were generated with five in Raster formal and three in vector format. Different analytical tools were used based on the data formats.

Step 5: Spatial analysis of criteria maps and generation of final suitability map

The generation of the final urban suitability map was done using three GIS spatial analysis methods that encompassed binary overlay, weighted sum overlay, and masking. Criteria maps were categorized into two depending on data formats and spatial analytical tools to be applied to them

i. Binary Overlay Analysis

Binary Overlay method was used to generate a Constraints map that indicated the areas where urban development is barred. Map layers used in binary overlay analysis comprised of transport, water bodies, and protected areas.

Buffers were applied on all datasets depending on the selected base criteria for individual datasets such as Transport-2000m, 1500m, 1000m, 500m, and >30m on each side of the water bodies.

Union was applied to the water bodies and protected areas to produce one dataset. Erase tool was used to subtract the resultant dataset from the county shapefile. The resultant map from erasing was then intersected with the transport dataset to produce areas suitable for urban development based on the three datasets. The resultant map was then rasterized for further analysis.

ii. Weighted Sum Overlay

As discussed above, the AHP technique was used to determine the criterion weights for Land use/Land Cover, slope, elevation, and population. Weighted maps for each criterion were then created in a GIS platform. The layers were then rasterized. The sub-layers of each thematic map were then reclassified on a scale of 1-5 ranging from highly suitable to not suitable. Using the weighted sum overlay tool and the overall preference Matrix; suitable areas for urban development were delineated.

iii. Masking

The final suitability map was generated using masking tool. The resultant map from the binary overlay analysis was used to mask the resultant map from the weighted sum overlay analysis. The resultant output map has pointed out the most suitable areas for urban development in Trans Nzoia County.

CHAPTER 4 : RESULTS AND DISCUSSIONS

4.1 Factors Influencing Urban Development in Trans Nzoia County

a) Accessibility Factor- Road proximity

Roads are the main means of transport in the county, therefore areas close to major transport routes were considered more suitable for urban developments. To retain the connectivity between existing and future areas for urban development, a map of major transport routes in the county was prepared. A buffer of 0-2000m was established with areas outside the buffer restricted for urban development. Areas closest to the road <500m were highly suitable for urban development. However, areas >2000m were considered not suitable.

Table 4.1: Base Criteria& Ranking for Road Accessibility and Transport network

DATASET	CLASSES	CRETERIA	
Transport	0 - 500	1	Buffer
	501 - 1000	2	"
	1001 - 1500	3	"
	1501 - 2000	4	"
	Roads (m)		

DATASET	Base Criteria	Ranking	Category
Transport	0 – 500	1	Highly suitable
	501 – 1000	2	Moderately suitable"
	1001 – 1500	3	Less suitable"
	1501 – 2000	4	Least suitable

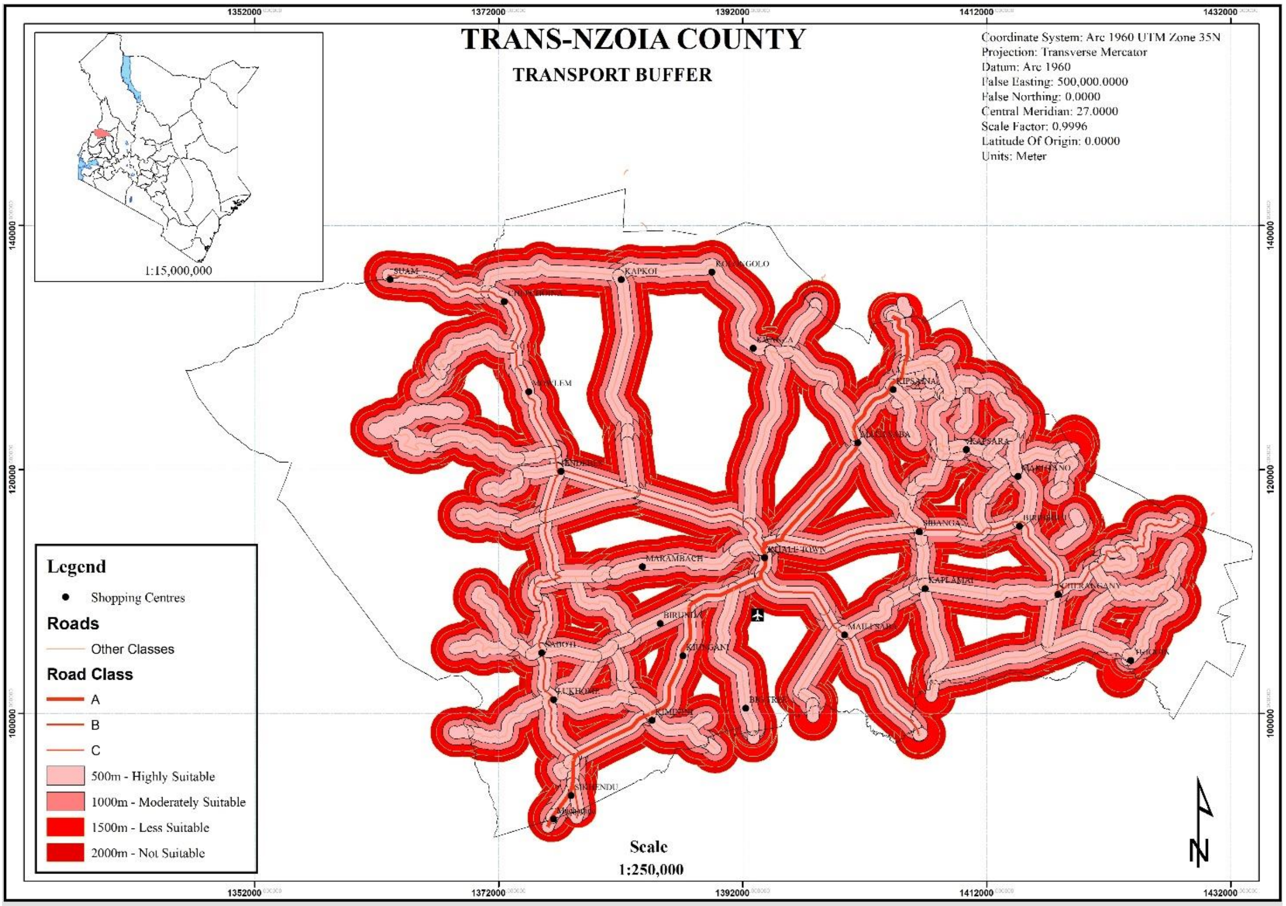

Figure 4.1: Road proximity urban suitability Map

Analysis results indicated that the study area has good road connectivity as evidenced by the large portion of land suitable for urban development. Areas with poor road connecctivity were found mainly in protected areas such as Cherangany Hill and Mt. Elgon forest and National Park where development was restricted.

The results also indicated that urban centers in Trans Nzoia County consider road proximity as an important factor in their location as all the existing urban areas in the county fall within the 500 radii of existing major roads. This is the main cause of urban sprawl and unplanned urban areas occurring rampantly along major crossroads and transport routes in the county.

b) Protected areas and water bodies

Water bodies and protected areas in Trans Nzoia County comprised forests, wetlands, rivers, swamps, and national parks. Notable area were: Mt. Elgon Forest, Saiwa Swamp, Cherangany Hills, Ewaso-Rongai, and Sabwami Rivers.

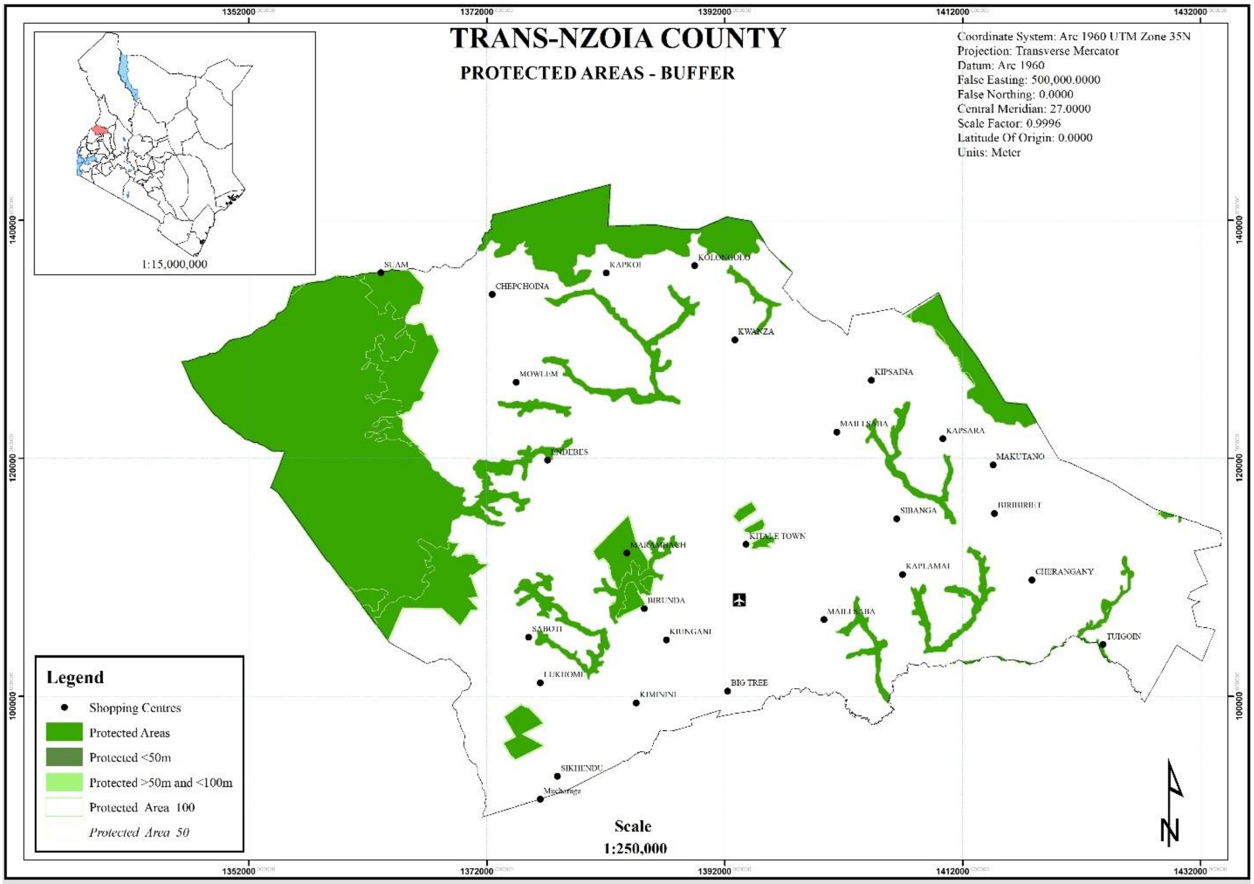

Figure 4.2: Protected areas constraints map

For protected areas, a buffer of 100m and 50m was established as the minimum distance. Areas within the 50m buffer are restricted to conservation measures.

Table 4.2: Base Criteria and Ranking for Protected areas

DATASET	CLASSES	CRITERIA	
Protected Areas	>100m	1	Highly suitable
	100 – 50	2	Moderately suitable
	50 – 0	3	Not suitable

For water bodies, a buffer of 60m and 30m was established on either side. Highly suitable areas were limited to areas outside the buffer zone.

Table 4.3: Base Criteria and Ranking for water bodies

DATASET	Base Criteria	Ranking	
Water Bodies/wetlands/swamps	>60m	1	Highly suitable
	60 – 30	2	Moderately suitable
	30 – 0	3	Not suitable

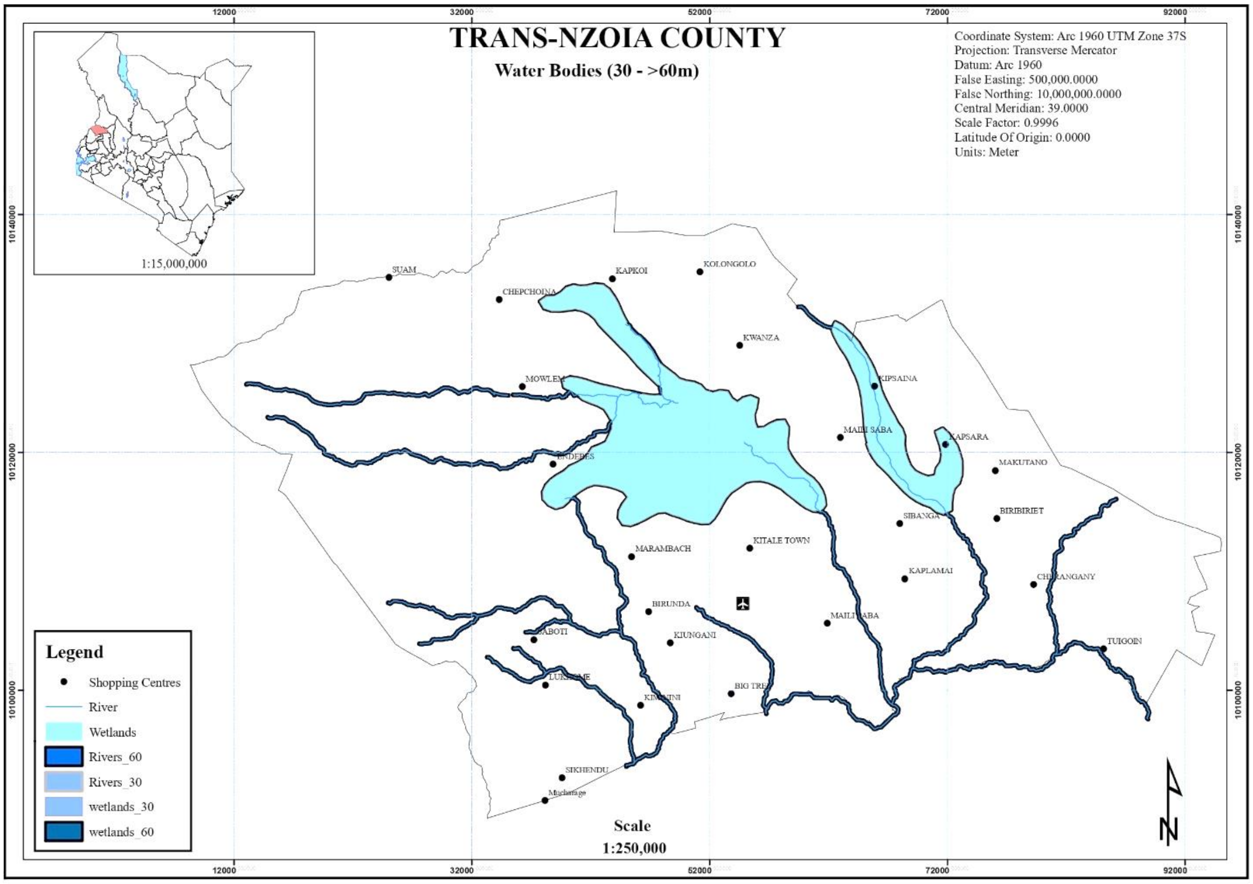

Figure 4.3: Water bodies constraints map

From the analysis done, protected areas were found mainly in the Northern and western parts of the study area. The study also highlighted two large prominent swamps in the central part of the study area namely Saiwa and Sabwami swamps. These areas were considered unsuitable for urban development.

The results also indicated that all, with the exception of Tugoin, Kapsara and Kipsaina which fall within protected areas, all other existing urban centers were found to be appropriately located outside the 100m and 50m buffer radius in relation to existing protected areas and water bodies.

c) Elevation

Analytical results showed that the altitude of the study area varied from 1500m to 4300m above sea level. AHP weights for different altitude categories were as shown in the table below.

Table 4.4: Elevation sub-factor AHP weighting

Criteria Weights	0.4713	0.3380	0.0984	0.0923	**Weighted Sum Value**	**Creteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Elevation	**1500 - 2000**	**2001 - 2500**	**2501 - 3000**	**>3000 (m)**					
1500 - 2000	0.4713	0.3380	0.4921	0.6890	1.9903	0.4713	4.2232	47.13%	1
2001 - 2500	0.4713	0.3380	0.2953	0.2953	1.3998	0.3380	4.1419	33.80%	2
2501 - 3000	0.0943	0.1127	0.0984	0.0984	0.4038	0.0984	4.1022	9.84%	3
>3000 (m)	0.0673	0.1127	0.0984	0.0984	0.3768	0.0923	4.0815	9.23%	4
						1.0000	16.5488	100.00%	
λ_{max} =	4.1372								
Consistency Index	0.0457								
Consistency Ratio	0.0775	**should be <10% or 0.10**	7.7512%						

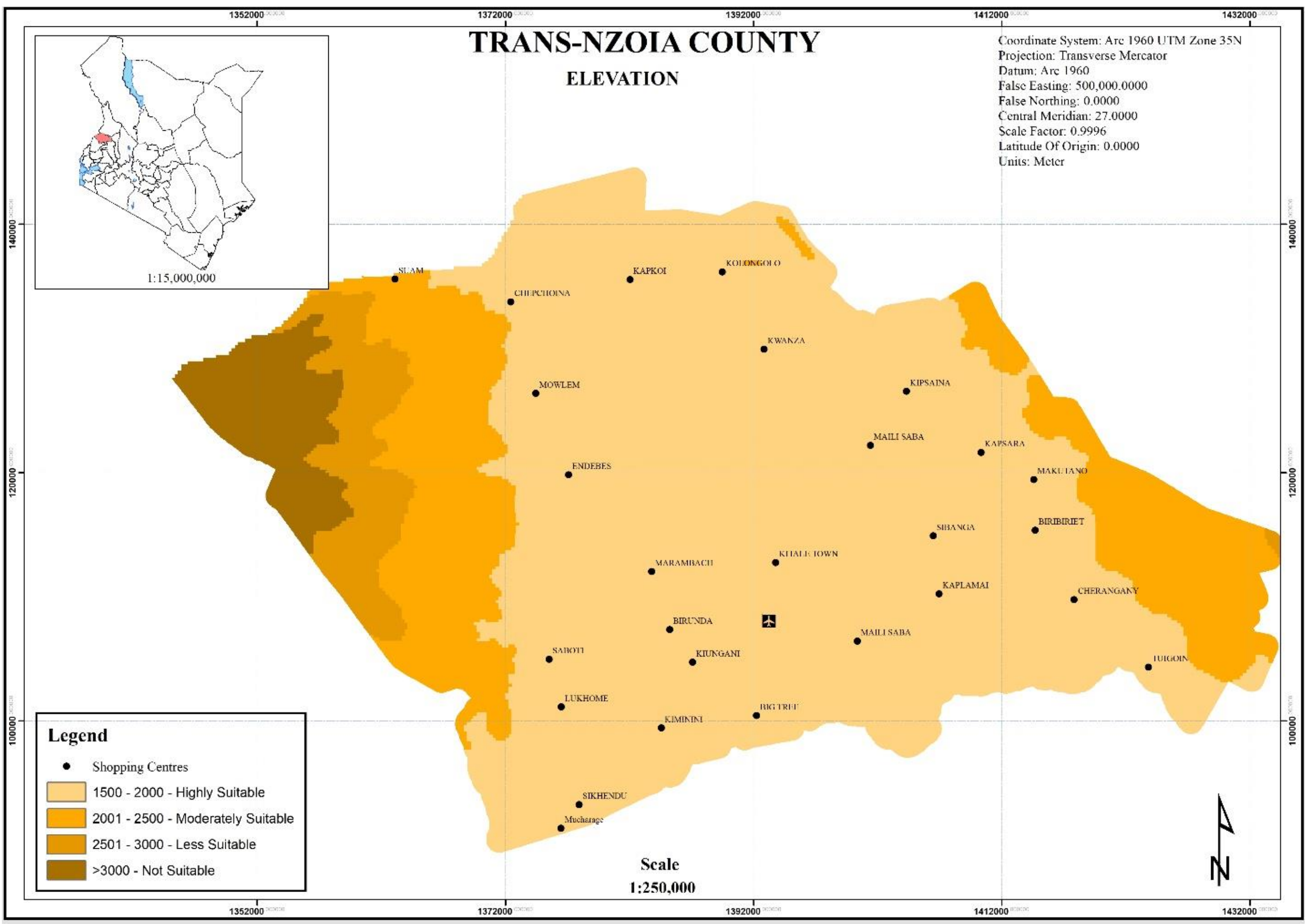

Figure 4.4: Elevation urban suitability map

The highest altitude was found on the northeastern side of the area at Mt. Elgon. This is the only area in the >3000m altitude category which was considered not suitable for urban development. The area currently hosts one of Mt. Elgon Forest, a major water tower in the country and it is expensive to provide basic infrastructure and services in high-altitude areas where the possibility of natural hazards occurring is very high.

In line with the analysis results, no existing urban area was found within the >3000m. Most of the study areas fall within the 1500-2000m altitude category that was considered highly suitable for urban development because they are economical in terms of provision of basic infrastructure and services. The majority of the existing urban areas were found in this area. Areas of moderate suitability for urban development were found in Cherangany hills and Suam urban areas. In determining suitable areas for future urban development, priority was given to areas within 1500-2000m.

d) Slope

Slope is a crucial criterion for identifying suitable areas for urban development because it is directly proportional to construction costs and maximum floor limits. Based on experts' opinions, areas with steep slopes of >15% had low weights when considering suitable areas for urban development as shown in the table below.

Table 4.5: Slope sub-factor AHP weighting

Criteria Weights	0.6689	0.2674	0.0637	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Slope	**0 - 5%**	**5 - 15%**	**>15%**					
0 - 5%	0.6689	0.8022	0.5736	2.0447	0.6689	3.0570	67%	1
5 - 15%	0.2230	0.2674	0.3187	0.8090	0.2674	3.0256	27%	2
>15%	0.0743	0.0535	0.0637	0.1915	0.0637	3.0051	6%	3
λ_{max} =	**3.0292**							
Consistency Index	**0.0146**							
Consistency Ratio	**0.0281**	**should be <10% or 0.10**	**2.8088%**					

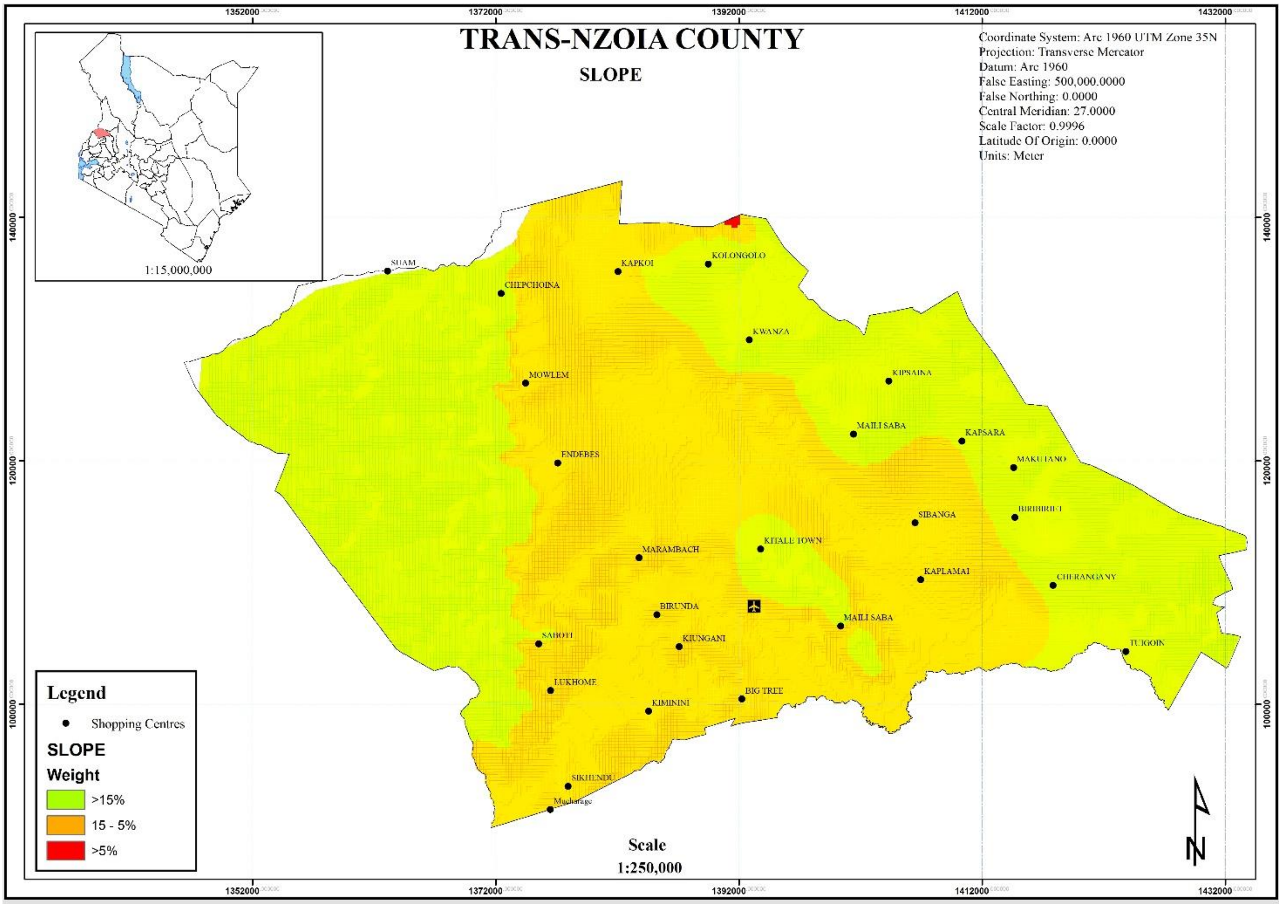

Figure 4.5: Slope urban suitability analysis

A large portion of the study area falls under the 5^0 - 15^0 Category. As per the Physical Planning Handbook, these are areas with medium slopes and could be developed by incorporating slope control measures in proposed developments. Areas with slopes of $<5^0$ are very few and were found around Kiminini, Mucharage, Sikhendu, Kapokoi, and Kolongolo. If all factors were held constant and only slope is considered, these areas would be highly suitable for urban development.

Areas around Mt. Eldon and Cherangany Hills on the extreme western and eastern sides respectively had slopes $>15^0$. Urban development in these areas was restricted because they were considered unsafe for human settlements. No urban settlements were found within these areas and they were avoided when determining future areas for urban developments.

e) Soils

Results indicated that the study area had four different types of soils namely: -loamy, sandy, clayey, and very clayey. As per AHP analysis results, loamy soil had the highest weight in terms of suitability for urban development.

Table 4.6: Soil sub-factor AHP Weighting

Creteria Weights	0.0763	0.1788	0.0763	0.6686	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Soils	**Clayey**	**Very Clayey**	**Sandy**	**Loamy**					
Clayey	0.0763	0.0596	0.0763	0.0955	0.3077	0.0763	4.0336	7.63%	4
Very Clayey	0.2288	0.1788	0.2288	0.0955	0.7321	0.1788	4.0932	17.88%	2
Sandy	0.0763	0.0596	0.0763	0.0955	0.3077	0.0763	4.0336	7.63%	4
Loamy	0.5340	1.2519	0.5340	0.6686	2.9885	0.6686	4.4698	66.86%	1
λ_{max} =	**4.1576**								
Consistency Index	**0.0525**								
Consistency Ratio	**0.0890**	**should be <10% or 0.10**	**8.9013%**						

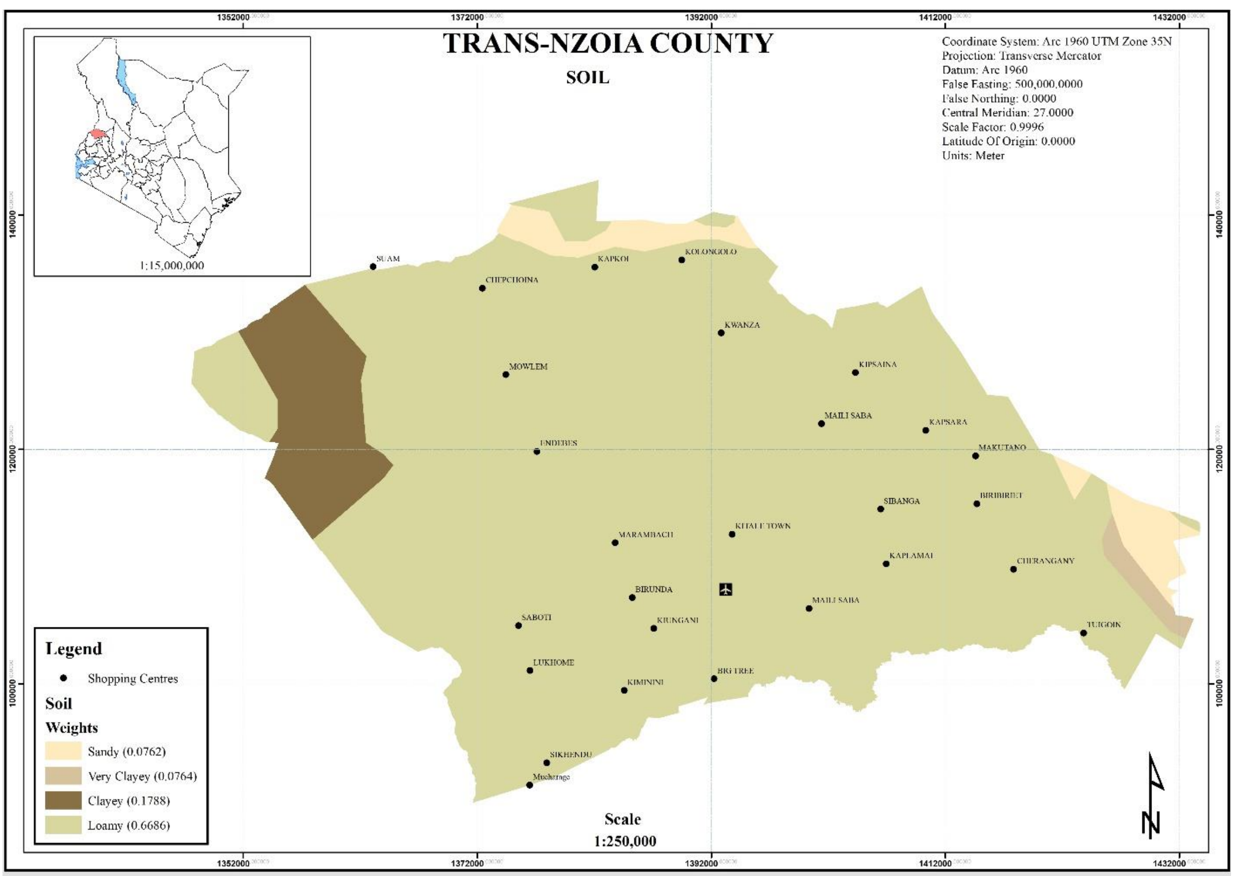

Figure 4.6: Soil urban suitability map

In identifying suitable areas for urban development, priority was given to areas with loamy soils due to their good drainage capabilities making them suitable for construction purposes. Loamy soil was found to be the dominant soil in the study area, therefore based on soil types; a large portion of the study area was considered suitable for urban development.

Existing centers also fall within the zone with loamy soils. Areas with sandy soils found at Cherangany Hills on the extreme western side at areas near Kapkoi and Kolongolo market centers were not recommended for urban development due to the instability of the soil.

f) Land Use/Land Cover

The study categorized Land use /land cover into a built-up area, forest, bare land, shrub land, and grassland. AHP analysis was undertaken to determine the weights of each sub-factor.

The results from the AHP analysis indicated that the built-up area had the least weight and is ranked last compared to other sub-factors. This is because no new development can occur in built-up areas in the future. The results from AHP analysis were indicated in the table below.

Table 4.7: Land use Land Cover Sub factor AHP weighting

Criteria Weights	0.1121	0.2812	0.0899	0.0658	0.4510	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
LULC	**Grass Land**	**Shrub Land**	**Forest**	**Built-up Areas**	**Bare Land**					
Grass Land	0.1121	0.0402	0.1798	0.1316	0.1128	0.5764	0.1121	5.1423	11.21%	3
Shrub Land	0.7846	0.2812	0.2696	0.1974	0.1503	1.6832	0.2812	5.9855	28.12%	2
Forest	0.0560	0.0937	0.0899	0.1316	0.0902	0.4615	0.0899	5.1342	8.99%	4
Built-up Areas	0.0560	0.0937	0.0449	0.0658	0.0902	0.3507	0.0658	5.3301	6.58%	5
Bareland	0.4483	0.8437	0.4494	0.3290	0.4510	2.5214	0.4510	5.5906	45.10%	1
							1.0000	27.1826	100.00%	
λ_{max} =	5.4365									
Consistency Index	0.1091									
Consistency Ratio	0.0983	**should be <10% or 0.10**	9.8315%							

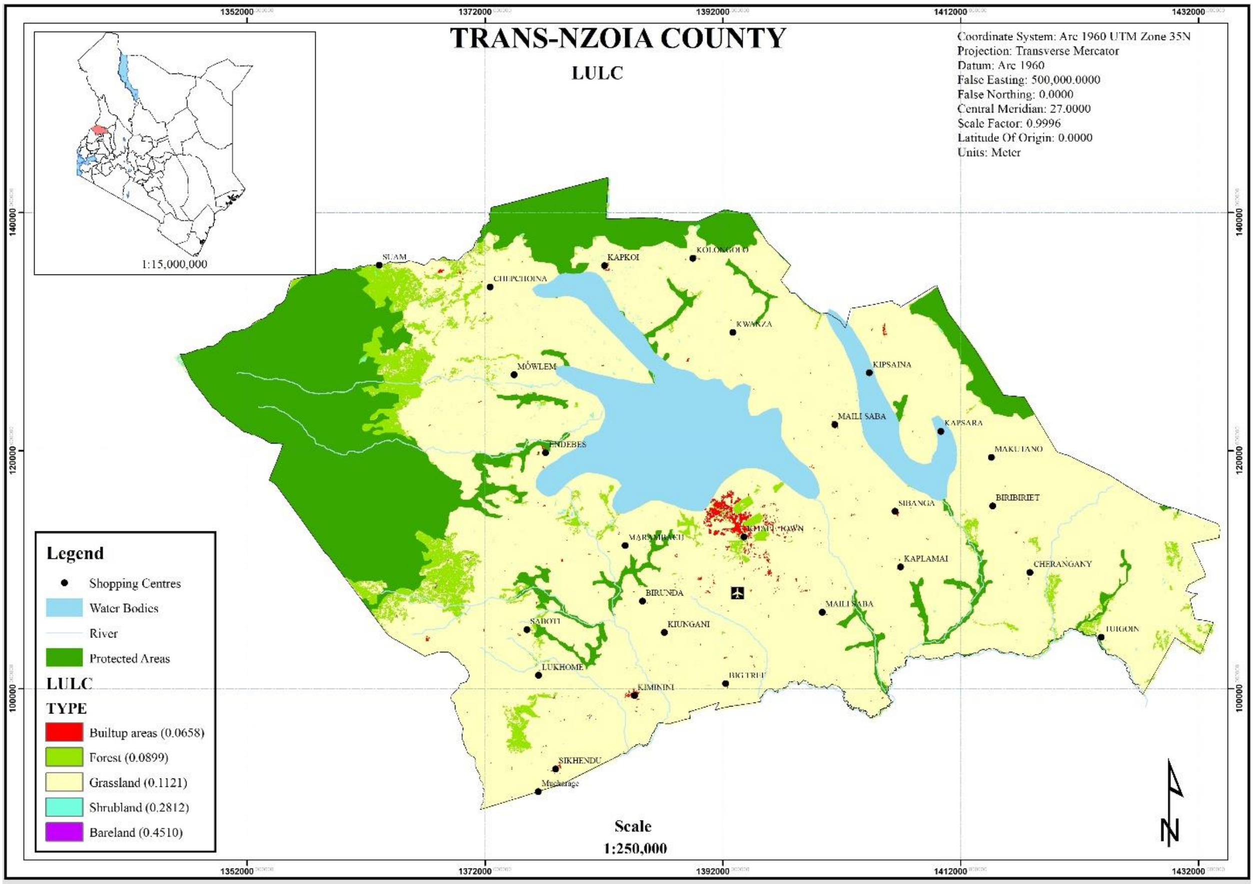

Figure 4.7: Land use land cover urban suitability analysis map

Analysis results indicated that build-up areas are found scattered within the county's landscape an indication of the haphazard location of urban settlements. Kitale town had the highest concentration of built-up area that is expanding rapidly along major transport routes depicting urban sprawl.

Analysis results also indicated that a large portion of the study area was under grassland land cover which is moderately suitable for urban development. Bare land that was given the highest priority for urban development was found in the northern part of the study area near Kolongolo and Kapkoi market centers. Scattered patches of bare land were also found scattered in the county though in very small sizes not capable of accommodating urban development.

g) Population

Based on resultant weights from AHP analysis, areas with >30000 persons had more weights compared to other areas and were ranked first as shown in the table below.

Table 4.8: Population sub-factor AHP weighting

Criteria Weights	0.0578	0.1454	0.2816	0.5152	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Population	**3500 - 5000**	**5001 - 15000**	**15001 - 30000**	**> 30000**					
0 - 5000	0.0578	0.0485	0.0563	0.0736	0.2361	0.0578	4.0888	5.78%	4
5001 - 15000	0.1733	0.1454	0.0939	0.1717	0.5843	0.1454	4.0184	14.54%	3
15001 - 30000	0.2888	0.4362	0.2816	0.1717	1.1783	0.2816	4.1844	28.16%	2
> 30000	0.4043	0.4362	0.8448	0.5152	2.2005	0.5152	4.2708	51.52%	1
						1.0000	16.5625	100.00%	
λ_{max} =	4.1406								
Consistency Index	0.0469								
Consistency Ratio	0.0794	**should be <10% or 0.10**	7.9442%						

From analysis results, the southern part of the study area which comprised of Kiminini, Birunda, and Big tree areas was considered to be highly suitable for urban development. Areas with moderate suitability comprised Saboti, Lukhome, Maili Saba, Marambach, Sibanga, Suam, Kaplamai, Maili Saba, Kaplamai, and Kwanza. However, Makutano and Biribiret were considered not suitable for urban development due to very low populations.

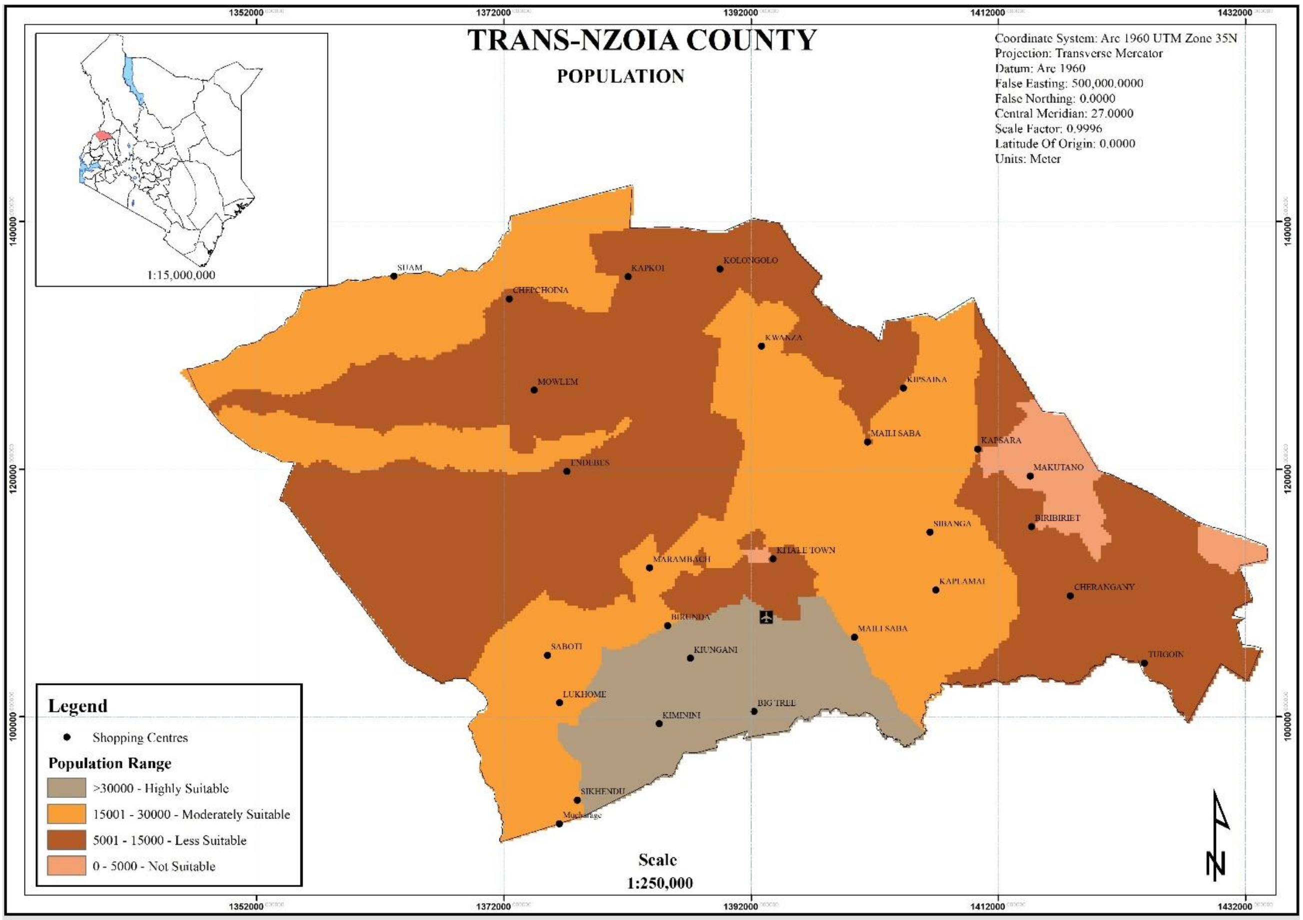

Figure 4.8: Population urban suitability map

As the county is still undergoing urbanization mainly caused by natural population growth and in-migration, it is expected that the population of these are to increase considerably during the next two decades. Therefore, suitability analysis should be undertaken each decade based on changing demographics.

4.1.1 Overall preference Matrix

The Overall preference matrix was computed to generate individual weights of each criterion that represented how much influence one criterion has over another in determining suitability for urban development. These weights were based on a questionnaire survey of two experts specializing in Urban development Planning.

Table 4.9: Overall preference Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation
LULC	1	1/7	1/5	1/3	5
Population	7	1	3	5	9
Slope	5	1/3	1	3	7
Soils	3	1/5	1/3	1	5
Elevation	1/5	1/9	1/7	1/5	1

Table 4.10: Sum of Overall Preference Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation
LULC	1.0000	0.1429	0.2000	0.3333	5.0000
Population	7.0000	1.0000	3.0000	5.0000	9.0000
Slope	5.0000	0.3333	1.0000	3.0000	7.0000
Soils	3.0000	0.2000	0.3333	1.0000	5.0000
Elevation	0.2000	0.1111	0.1429	0.2000	1.0000
Sum	**16.2000**	**1.7873**	**4.6762**	**9.5333**	**27.0000**

Each value was then normalized by dividing each factor value in the pairwise matrix by the sum of its column value. The relative weights (normalized principal Eigenvector weights) were then derived by the arithmetic mean method.

Table 4.11: Normalized Overall Preference Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation	Criteria Weights
LULC	0.0617	0.0799	0.0428	0.0350	0.1852	0.0809
Population	0.4321	0.5595	0.6415	0.5245	0.3333	0.4982
Slope	0.3086	0.1865	0.2138	0.3147	0.2593	0.2566
Soils	0.1852	0.1119	0.0713	0.1049	0.1852	0.1317
Elevation	0.0123	0.0622	0.0305	0.0210	0.0370	0.0326
※Check	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Calculating the Consistency Ratio for Overall Preference Matrix

Equations (1) and (2) were used to calculate Consistency Ratio. ($\mathbf{CR} = \frac{\mathbf{CI}}{\mathbf{RI}}$ & $\mathbf{CI} = \frac{(\boldsymbol{\lambda}\mathbf{max}-\mathbf{n})}{\mathbf{n}-\mathbf{1}}$)

λmax = 16.2000(0.0809) + 1.7873(0.4982) + 4.6762(0.2566) + 9.5333 (0.1317) + 27.0000(0.0326) = **5.3861*(Greater than number of factors, thus acceptable)***

Consistency Index (CI) = $\frac{\mathbf{5.3861-5}}{\mathbf{5-1}}$ **= 0.0965**

The Random index value for this study is 1.11, which corresponded to the number of factors in the study that is 5 as per Saaty's Random Consistency Index table.

n	1	2	3	4	5	6	7	8	9	10
RI	0	0	0.52	0.59	1.11	1.25	1.35	1.4	1.45	1.49

Therefore $\mathbf{CR} = \frac{\mathbf{0.0965}}{\mathbf{1.11}}$**= 0.0870** ***(should be < 0.10)***

The value of CR met the AHP criteria making the judgments made by expert opinions consistent and accepted. The CR values for all the sub-factors were also calculated and all the values complied with the >0.1% rule indicating that a consistent matrix had been established. Therefore, all the factor weights determined were eligible for use in the next step which was the analysis using the weighted sum overlay.

Table 4.12: Calculating consistency ratio and ranking of OPM

Criteria Weights	0.0809	0.4982	0.2566	0.1317	0.0326	Weighted Sum Value	Criteria Weights	Ratio	% Criteria Weights	Ranking
OPM	**LULC**	**Population**	**Slope**	**Soils**	**Elevation**					
LULC	0.0809	0.0712	0.0513	0.0439	0.1631	0.4104	0.0809	5.0717	8.09%	4
Population	0.5664	0.4982	0.7698	0.6584	0.2935	2.7864	0.4982	5.5929	49.82%	1
Slope	0.4046	0.1661	0.2566	0.3951	0.2283	1.4506	0.2566	5.6535	25.66%	2
Soils	0.2427	0.0996	0.0855	0.1317	0.1631	0.7227	0.1317	5.4878	13.17%	3
Elevation	0.0162	0.0554	0.0367	0.0263	0.0326	0.1671	0.0326	5.1247	3.26%	5
							1.0000	26.9306	100.00%	
ƛmax =	5.3861									
Consistency Index	0.0965									
Consistency Ratio	0.0870	**should be <10% or 0.10**	8.6963 %							

Based on the analytical results from the Overall preference matrix, in comparison to other criteria, population has much more influence in determining the suitability of an area for urban development. Population was also ranked first as the most influential factor in urban development from the results of overall AHP analysis. This is because as more people converge in an area, the provision of basic infrastructure and services is justified and economical.

Slope is ranked second while elevation is ranked last in comparison to other criteria.

4.1.2 Binary Overlay Analysis

Binary Overlay Method comprising of buffering, union, erase, combine and intersect were used to generate constraints map using transport, water bodies, and protected areas map layers.

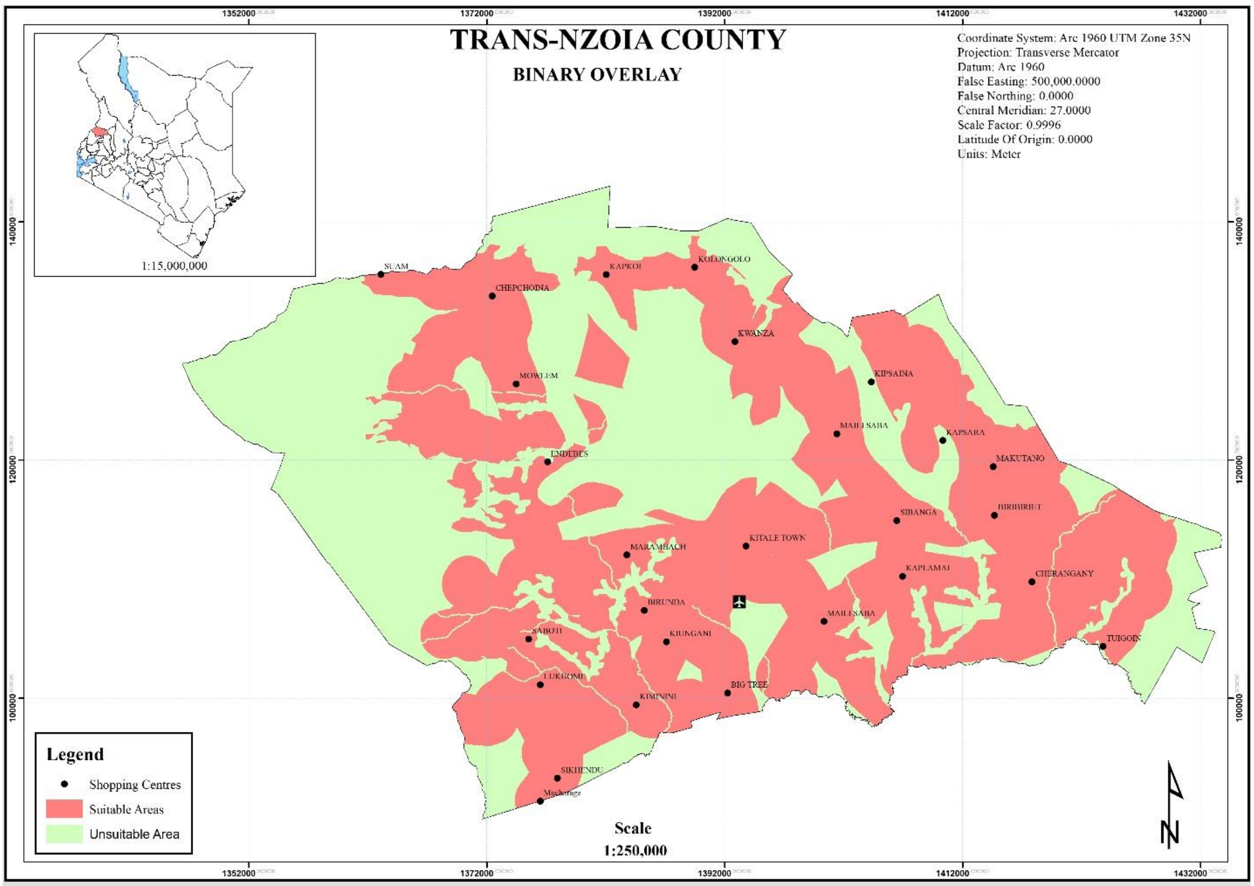

Figure 4.9: Constraints map

From binary overlay analysis results, the majority of the existing urban centers were found to be appropriately located in relation to distance from the roads, protected areas, and water bodies. Only three market centers namely Tuigoin, Kapsara, and Kipsaina were found in areas unsuitable for urban development. The bulk of the constrained areas came from protected areas and water bodies' buffer zones. The northern part of the study area comprising mainly forested areas and wetlands, greatly reduced suitable areas for urban development in the region. The southern part however had a larger portion of the most suitable areas suitable for urban development.

Suitable and unsuitable areas for urban development stood at 137042.82Ha (55%) and 109957.18Ha (45%) as per analysis results from binary overlay analysis.

4.1.3 Weighted Sum Overlay

Varying levels of suitability ranging from highly suitable to not suitable were determined using the AHP and weighted sum overlay tool. Map layers used in this analysis comprised of land use/land cover, soil, elevation, population, and slope map.

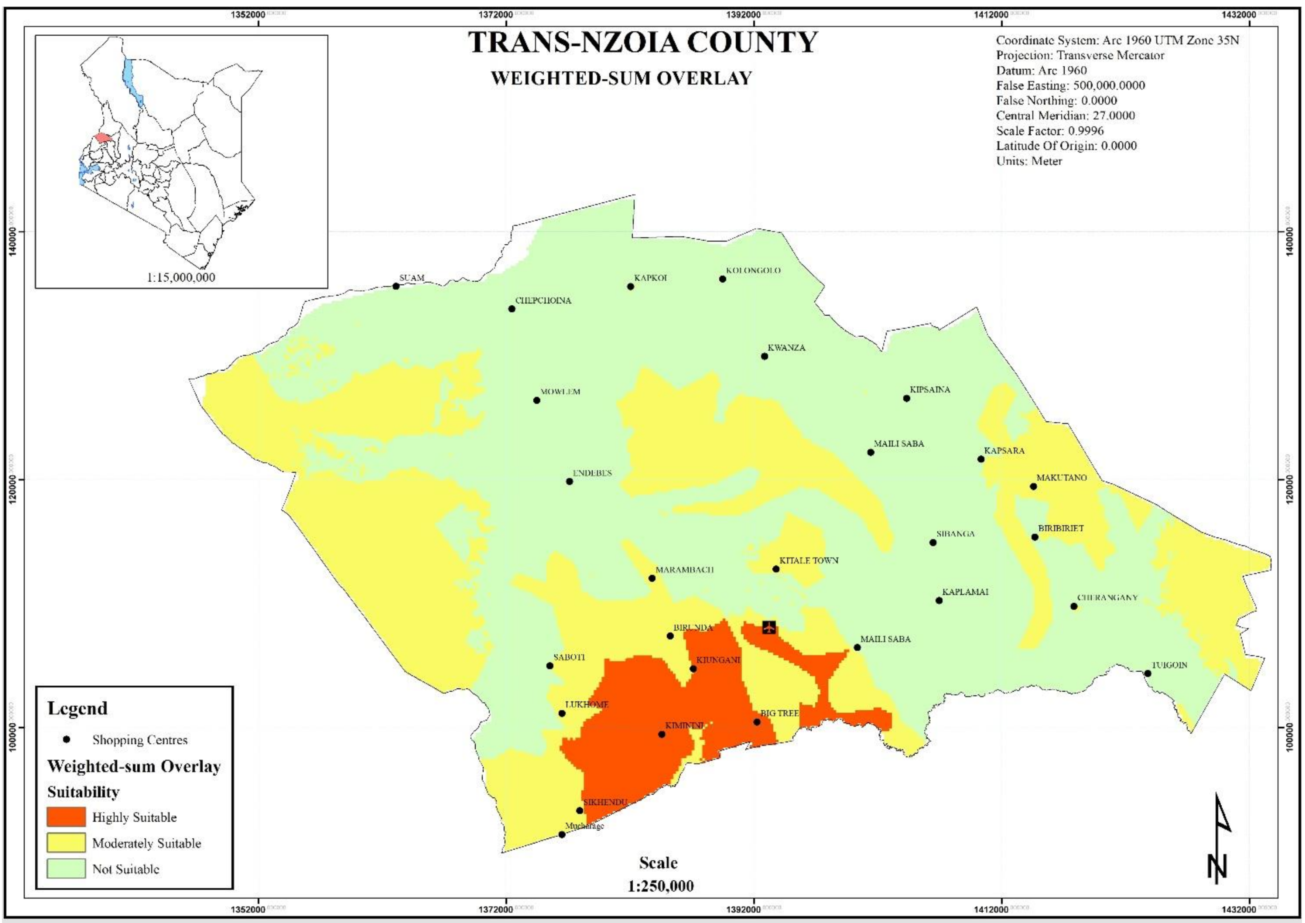

Figure 4.10: Weighted Sum Overlay Map

A suitability scale of 1 to 3 categorizing the study area into three categories namely highly, moderately, and not suitable was used. Analysis results showed that areas that were highly suitable, moderately suitable, and not suitable stood at 16340.459 Ha (7%), 24896.983Ha (10%), and 203798Ha (83%) respectively.

Highly suitable areas were the smallest and are found around Kiminini in the southwestern part of the study area. Apart from meeting all criteria requirements, the area was the most populated region in Trans Nzoia County. As such, it is justifiable that a new urban center is established in the region to offload some of the pressure currently being applied on Kiminini town and also to satisfy the needs of the rapidly growing urban population in the region.

The results also indicated that Kiminini town is strategically located with the highly suitable area for urban development and thus can expand sustainably in the identified areas adjacent to the town. Kitale town on the other hand is within an area that is moderately suitable areas for urban development. This is an indication that expansion for the town is possible through comprehensive urban planning is needed.

On assessing the suitability existing urban areas, analysis results indicated that several urban market centers in the study areas are located within the areas unsuitable for urban development. 64% of the main market centers in the county are in unsuitable areas as a result of unplanned development of towns.

4.2 Comparison of the constraints map and Weighted Sum Overlay map

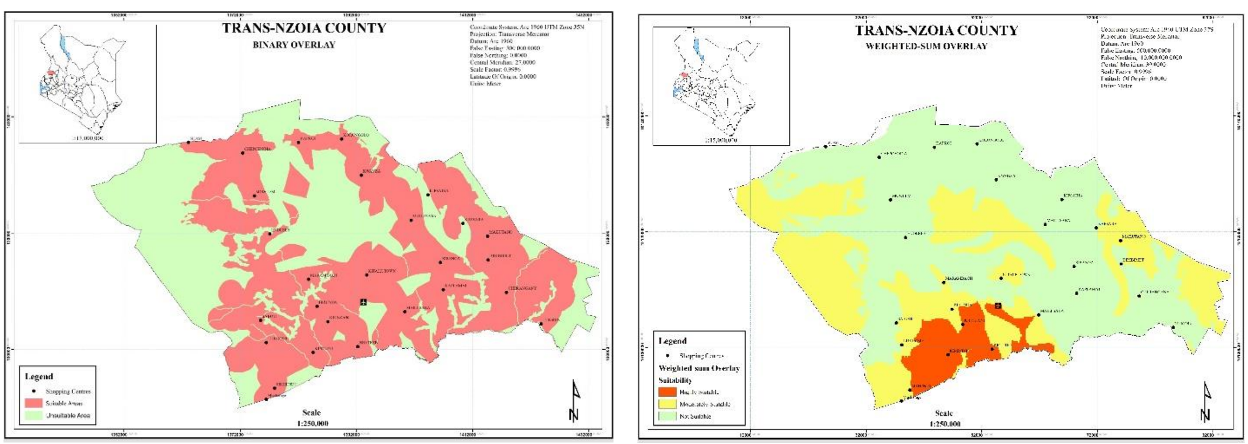

Figure 4.11: Comparison of Constraints map and weighted sum overlay map

As illustrated in 4.11 above, there were some significant variations between the constraints map from Binary Overlay Analysis and the weighted sum overlay map.

- The Constraints map indicated that 55% of the study area was considered suitable for urban development while only 7% of the study were considered highly suitable for urban development in the Weighted Sum Overlay Map.

- According to the constraints map, most of the areas suitable were in the southern, eastern, and northern parts of the study area. The weighted sum overlay map on the other hand indicated a small portion of southern eastern areas is highly and moderately suitable for urban development.
- The Weighted Sum Overlay map has included restricted areas in the constraints map as areas that were moderately suitable for urban development. These areas included Saiwa Swam located at the center of the study area and Mt. Elgon Forest and Cherangani Hills located in the Western and Eastern parts of the study area respectively.

The two maps however both indicated that areas around Kiminini on the southern-eastern part of the study areas were suitable for urban development.

The above comparison of the two map pointed out that although the two methods are powerful spatial analytical tools, a combination of results from both provided a more detailed analysis of the problem at hand as illustrated in the subsequent section of the study.

4.2.1 Trans Nzoia County Urban development suitability

The final suitability map indicating suitable areas for urban development in Trans Nzoia County was created by combining the output from Binary overlay and weighted sum overlay analyses. The maps were consolidated into one using the masking tool. The resultant output indicated the varying levels of urban development suitability ranging from highly suitable areas to areas completely not suitable for urban development.

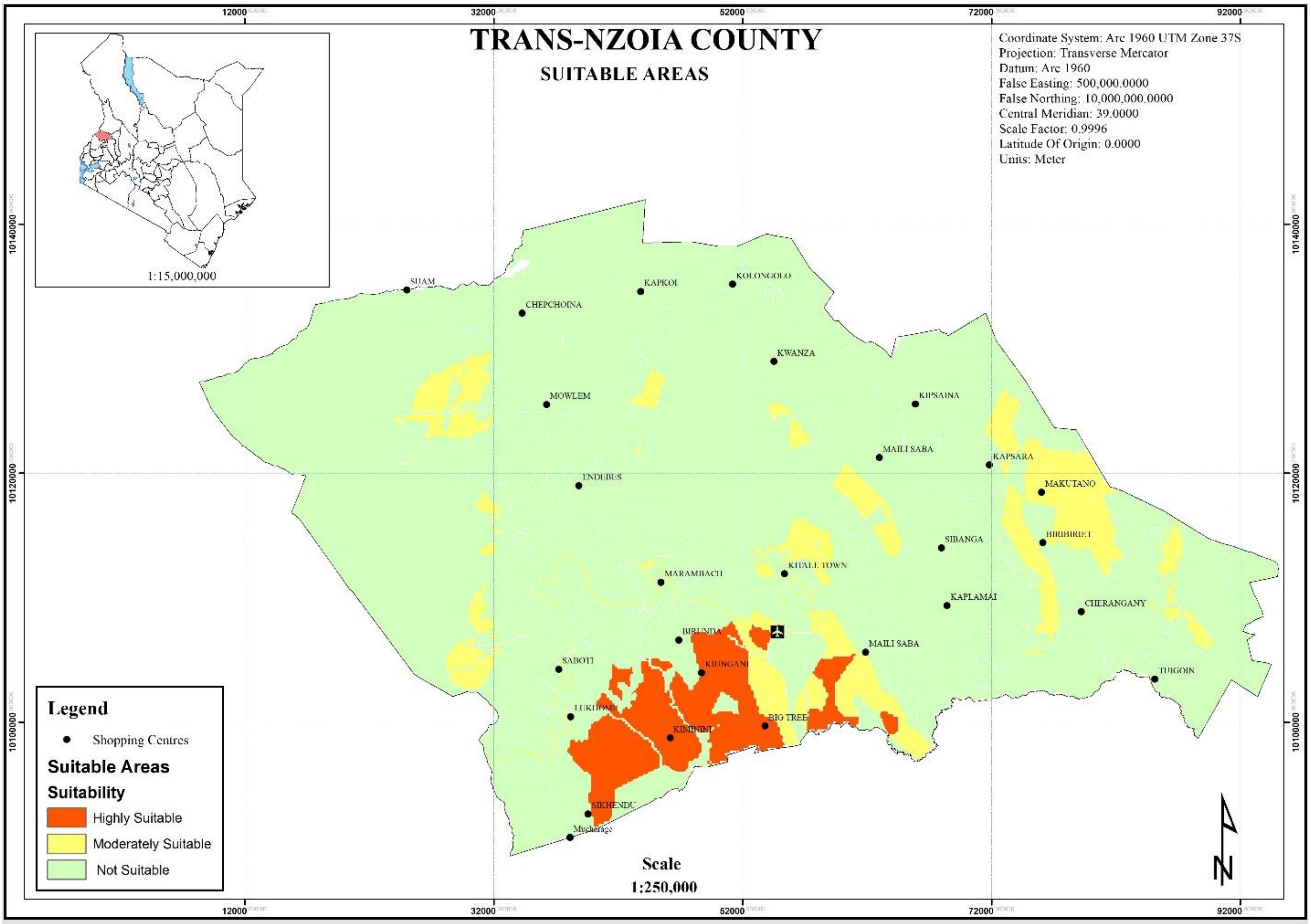

Figure 4.12: Final suitability map

The final suitability map was classified into three categories: - highly suitable areas, moderately suitable areas, and not suitable areas. About 13259.03Ha (5%) was highly suitable for urban development, 14889.06Ha (6%) was considered moderately suitable for urban development, and 218851.9Ha (89%) was considered not suitable for urban development.

The areas completely considered NOT suitable for urban development comprised protected areas such as Mt. Elgon National Park, Mt. Elgon Forest, Saiwa Swamp, Cherangany Hills located in the extreme north-western part, and other wetlands in the county.

A large portion of the areas highly for urban development covered Kiminini areas and the surrounding comprising Kiungani, Kiminini, and Big Tree. Areas of Saboti and Lukhome, Kitale town, Kapsara, Makutano, and Biribiret were considered also moderately suitable for urban development. This was due to the low elevation and flat even surface ground that is depicted in these areas. The areas also had the highest population density in the county making them prime locations for urban development.

Analysis results also indicated that most of the main urban centers in the county areas within areas that are NOT suitable areas for urban development. The presence of small patches of built up-areas in the land use land cover map also illustrates other small market centers mushrooming within the county in the unsuitable areas for urban development.

A substantial portion of the study area was found to be unsuitable for urban development. This is a good indicator since Trans Nzoia County is dependent on agricultural practices thus more fertile land will been conserved for agricultural use.

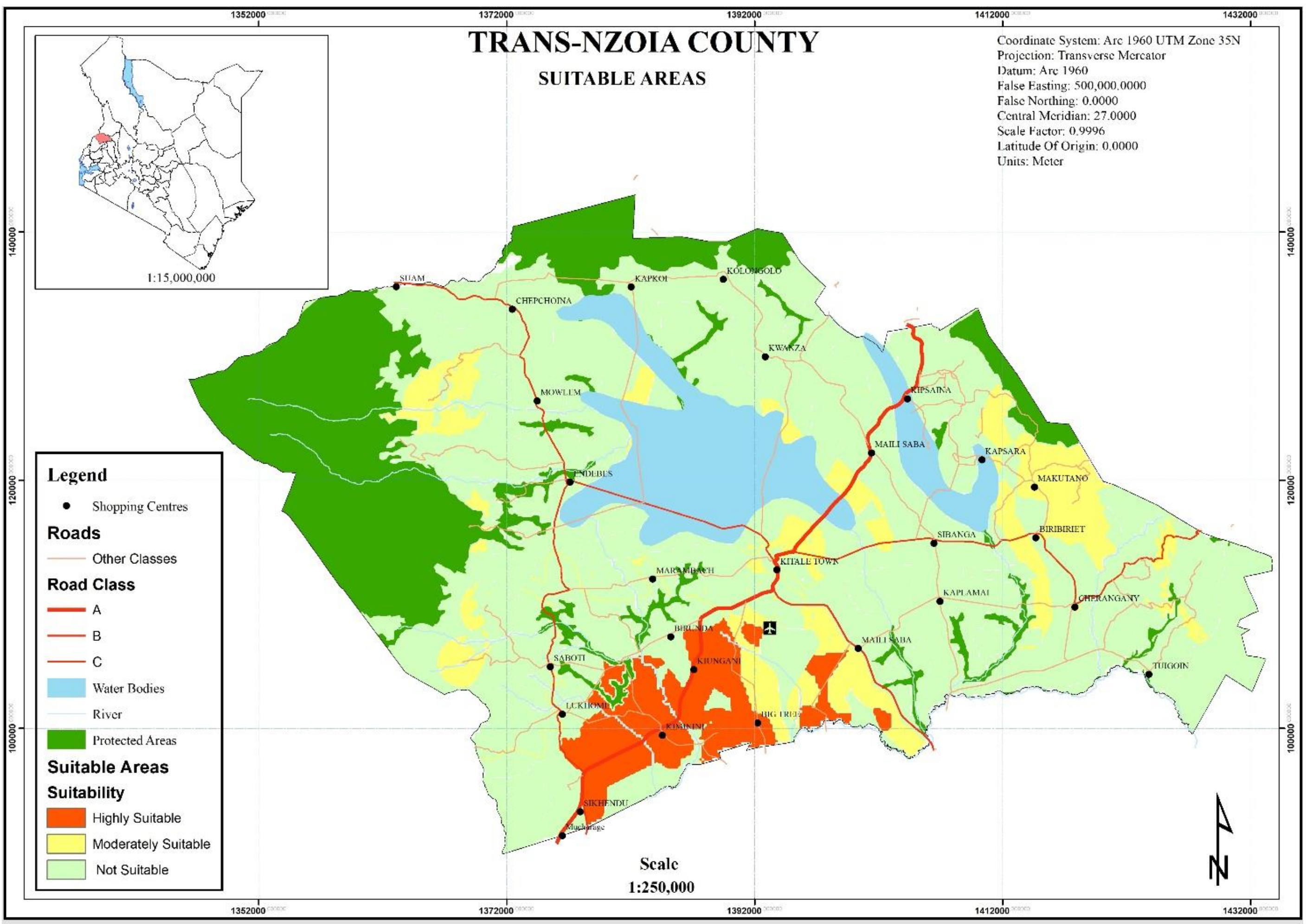

Figure 4.13: Suitable areas for urban development

4.3 Summary

Trans Nzoia County is experiencing unplanned rapid urbanization manifested by the proliferation of haphazardly located unplanned urban settlements. The identification of suitable areas for urban development is crucial for sustainability in urban development for Trans Nzoia County. The main objective of this study was to identify suitable areas for urban development in Trans Nzoia County using AHP and GIS. The analysis for identification of suitable sites was conducted using eight criteria namely land use land cover, distance to protected areas, distance to water bodies, soil type, slope, elevation, and population. Analysis done on the eight criteria has helped in assessing the suitability of existing urban centers and identifying the most suitable areas for urban development in Trans Nzoia County.

CHAPTER 5 : CONCLUSIONS AND RECOMMENDATIONS

5.1 Conclusions

This study aimed at identifying suitable areas for urban development in Trans Nzoia County, which will ensure sustainable urban development by controlling urban sprawl and sporadic emergence of small urban centers.

From the study, factors that influence urban development include road proximity, land use land cover, distance to protected areas, distance to water bodies, soil, slope, elevation, and population. All these factors have varying influences in determining the suitability of an area for urban development as illustrated by resultant weights from AHP analysis and the generated criterion-based urban suitability maps.

The combination of binary overlay and weighted sum overlay method provided more information about the suitability of an area as opposed to using one method. After performing the multi-criteria suitability analysis, suitable areas for urban development in Trans Nzoia County were delineated. Analysis results indicate in the study area, approximately 13259.03Ha (5%) was highly suitable, 14889.06Ha (6%) was moderately suitable, 218851.9Ha (89%) was not suitable for urban development.

On assessing the urban development suitability of the existing urban centres, analysis results established that only 36% of the existing urban areas were within the highly suitable and moderately suitable areas for urban development. The remaining 64% of the existing main urban centers were within the areas not suitable for urban development. The significant number of small highlighted built-up areas in the land use-land cover map were also in areas not suitable for urban development. This is a consequence of poor urban planning and the lack of proper urban development strategies in the county.

5.2 Recommendations

Based on the study findings, the following recommendtaions were made;

- The Trans Nzoia County government may consider the results from this study in the formulation and implementation of urban development strategy and plans in the county. It is however, imperative that further field verification is done before the adoption of the results.

- The future urban development to be focused in areas highly suitable for urban development.
- Appropriate urban planning measures to be implemented to limit and direct expansion of the urban centres found in areas not sitable for urban development in efforts to conserve fertile agricultural lands
- Suitability analysis for urban development based on urban population to be carried out in the next decade. This is mainly because of the rapidly changing county demographics and the fact that population is the main driving force of urban development. The combination of the results from this study and the resultant population urban suitability map at the time will help in determining those areas where the County Government should focus its urban development initiatives.
- Urban planners, decision-makers, policy makers among many other users can utilize the conceptual metholoogy used in this study in to only managing urban development but also identifying areas where intensive developmental projects can be undertaken sustainably. The method used is advantageous because of its simplicity and the inclusion of diverse types of criteria (both quantitative and qualitative) that provide accuracy when determining the suitability of an area. However, the use of AHP limits the number of experts involved because the more the number of experts the more time spent on computing the pairwise matrix.

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APPENDICES

APPENDIX A: AHP PAIRWISE MATRICES

Ai: Population AHP Pairwise Matrix

Step 1. Pairwise Matrix				
Population	**3500 - 5000**	**5001 - 15000**	**15001 - 30000**	**> 30000**
0 - 5000	1	1/3	1/5	1/7
5001 - 15000	3	1	1/3	1/3
15001 - 30000	5	3	1	1/3
> 30000	7	3	3	1

Step 2. Sum of Pairwise Matrix				
Population	**3500 - 5000**	**5001 - 15000**	**15001 - 30000**	**> 30000**
3500 - 5000	1.0000	0.3333	0.2000	0.1429
5001 - 15000	3.0000	1.0000	0.3333	0.3333
15001 - 30000	5.0000	3.0000	1.0000	0.3333
> 30000	7.0000	3.0000	3.0000	1.0000
Sum	**16.0000**	**7.3333**	**4.5333**	**1.8095**

Step 3. Normalized of Pairwise Matrix					
Population	**3500 - 5000**	**5001 - 15000**	**15001 - 30000**	**> 30000**	**Creteria Weights**
3500 - 5000	0.0625	0.0455	0.0441	0.0789	0.0578
5001 - 15000	0.1875	0.1364	0.0735	0.1842	0.1454
15001 - 30000	0.3125	0.4091	0.2206	0.1842	0.2816
> 30000	0.4375	0.4091	0.6618	0.5526	0.5152
※Check	1.0000	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix									
Criteria Weights	0.0578	0.1454	0.2816	0.5152	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Population	**3500 - 5000**	**5001 - 15000**	**15001 - 30000**	**> 30000**					
0 - 5000	0.0578	0.0485	0.0563	0.0736	0.2361	0.0578	4.0888	5.78%	4
5001 - 15000	0.1733	0.1454	0.0939	0.1717	0.5843	0.1454	4.0184	14.54%	3
15001 - 30000	0.2888	0.4362	0.2816	0.1717	1.1783	0.2816	4.1844	28.16%	2
> 30000	0.4043	0.4362	0.8448	0.5152	2.2005	0.5152	4.2708	51.52%	1
						1.0000	16.5625	100.00%	
λ_{max} =	4.1406								
Consistency Index	0.0469								
Consistency Ratio	0.0794	**should be <10% or 0.10**	7.9442%						

A2: Elevation AHP Pairwise Matrix

Elevation	1500 - 2000	2001 - 2500	2501 - 3000	>3000 (m)
1500 - 2000	1	1	5	7
2001 - 2500	1	1	3	3
2501 - 3000	1/5	1/3	1	1
>3000 (m)	1/7	1/3	1	1

Step 2. Sum of Pairwise Matrix

Elevation	1500 - 2000	2001 - 2500	2501 - 3000	>3000 (m)
1500 - 2000	1.0000	1.0000	5.0000	7.0000
2001 - 2500	1.0000	1.0000	3.0000	3.0000
2501 - 3000	0.2000	0.3333	1.0000	1.0000
>3000 (m)	0.1429	0.3333	1.0000	1.0000
Sum	**2.3429**	**2.6667**	**10.0000**	**12.0000**

Step 3. Normalized of Pairwise Matrix

Elevation	1500 - 2000	2001 - 2500	2501 - 3000	>3000 (m)	Criteria Weights
1500 - 2000	0.4268	0.3750	0.5000	0.5833	0.4713
2001 - 2500	0.4268	0.3750	0.3000	0.2500	0.3380
2501 - 3000	0.0854	0.1250	0.1000	0.0833	0.0984
>3000 (m)	0.0610	0.1250	0.1000	0.0833	0.0923
※Check	1.0000	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix

Criteria Weights	0.4713	0.3380	0.0984	0.0923	Weighted Sum Value	Criteria Weights	Ratio	% Criteria Weights	Ranking
Elevation	**1500 - 2000**	**2001 - 2500**	**2501 - 3000**	**>3000 (m)**					
1500 - 2000	0.4713	0.3380	0.4921	0.6890	1.9903	0.4713	4.2232	47.13%	1
2001 - 2500	0.4713	0.3380	0.2953	0.2953	1.3998	0.3380	4.1419	33.80%	2
2501 - 3000	0.0943	0.1127	0.0984	0.0984	0.4038	0.0984	4.1022	9.84%	3
>3000 (m)	0.0673	0.1127	0.0984	0.0984	0.3768	0.0923	4.0815	9.23%	4
λ_{max} =	**4.1372**								
Consistency Index	**0.0457**								
Consistency Ratio	**0.0775**	**should be <10% or 0.10**	**7.7512%**						

A3: Slope AHP pairwise Matrix

Step 1. Pairwise Matrix			
Slope	**0 - 5%**	**5 - 15%**	**>15%**
0 - 5%	1	3	9
5 - 15%	1/3	1	5
>15%	1/9	1/5	1

Step 2. Sum of Pairwise Matrix			
Slope	**0 - 5%**	**5 - 15%**	**>15%**
0 - 5%	1.0000	3.0000	9.0000
5 - 15%	0.3333	1.0000	5.0000
>15%	0.1111	0.2000	1.0000
Sum	1.4444	4.2000	15.0000

Step 3. Normalized of Pairwise Matrix				
Slope	**0 - 5%**	**5 - 15%**	**>15%**	**Creteria Weights**
0 - 5%	0.6923	0.7143	0.6000	0.6689
5 - 15%	0.2308	0.2381	0.3333	0.2674
>15%	0.0769	0.0476	0.0667	0.0637
※Check	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix								
Criteria Weights	0.6689	0.2674	0.0637	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Slope	**0 - 5%**	**5 - 15%**	**>15%**					
0 - 5%	0.6689	0.8022	0.5736	2.0447	0.6689	3.0570	67%	1
5 - 15%	0.2230	0.2674	0.3187	0.8090	0.2674	3.0256	27%	2
>15%	0.0743	0.0535	0.0637	0.1915	0.0637	3.0051	6%	3
λ_{max} =	**3.0292**							
Consistency Index	**0.0146**							
Consistency Ratio	**0.0281**	**should be <10% or 0.10**	**2.8088%**					

A4: Soil AHP Pairwise Matrix

Step 1. Pairwise Matrix

Soils	Clayey	Very Clayey	Sandy	Loamy
Clayey	1	1/3	1	1/7
Very Clayey	3	1	3	1/7
Sandy	1	1/3	1	1/7
Loamy	7	7	7	1

Step 2. Sum of Pairwise Matrix

Soils	Clayey	Very Clayey	Sandy	Loamy
Clayey	1.0000	0.3333	1.0000	0.1429
Very Clayey	3.0000	1.0000	3.0000	0.1429
Sandy	1.0000	0.3333	1.0000	0.1429
Loamy	7.0000	7.0000	7.0000	1.0000
Sum	**12.0000**	**8.6667**	**12.0000**	**1.4286**

Step 3. Normalized of Pairwise Matrix

Soils	Clayey	Very Clayey	Sandy	Loamy	Criteria Weights
Very Clayey	0.0833	0.0385	0.0833	0.1000	0.0763
Clayey	0.2500	0.1154	0.2500	0.1000	0.1788
Sandy	0.0833	0.0385	0.0833	0.1000	0.0762
Loamy	0.5833	0.8077	0.5833	0.7000	0.6686
※Check	1.0000	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix

Creteria Weights	0.0763	0.1788	0.0763	0.6686	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Soils	**Clayey**	**Very Clayey**	**Sandy**	**Loamy**					
Clayey	0.0763	0.0596	0.0763	0.0955	0.3077	0.0763	4.0336	7.63%	2
Very Clayey	0.2288	0.1788	0.2288	0.0955	0.7321	0.1788	4.0932	17.88%	3
Sandy	0.0763	0.0596	0.0763	0.0955	0.3077	0.0763	4.0336	7.63%	4
Loamy	0.5340	1.2519	0.5340	0.6686	2.9885	0.6686	4.4698	66.86%	1
						1.0000	16.6302	100.00%	
λ_{max} =	**4.1576**								
Consistency Index	**0.0525**								
Consistency Ratio	**0.0890**	**should be <10% or 0.10**	**8.9013%**						

A5: Land Use/Land Cover AHP Pairwise Matrix

Step 1. Pairwise Matrix					
LULC	**Grass Land**	**Shrub Land**	**Forest**	**Built-up Areas**	**Bare land**
Grass Land	1	1/7	2	2	1/4
Shrub Land	7	1	3	3	1/3
Forest	1/2	1/3	1	2	1/5
Built-up Areas	1/2	1/3	1/2	1	1/5
Bareland	4	3	5	5	1

Step 2. Sum of Pairwise Matrix					
LULC	**Grass Land**	**Shrub Land**	**Forest**	**Built-up Areas**	**Bareland**
Grass Land	1.0000	0.1429	2.0000	2.0000	0.2500
Shrub Land	7.0000	1.0000	3.0000	3.0000	0.3333
Forest	0.5000	0.3333	1.0000	2.0000	0.2000
Built-up Areas	0.5000	0.3333	0.5000	1.0000	0.2000
Bareland	4.0000	3.0000	5.0000	5.0000	1.0000
Sum	**13.0000**	**4.8095**	**11.5000**	**13.0000**	**1.9833**

Step 3. Normalized of Pairwise Matrix						
LULC	**Grass Land**	**Shrub Land**	**Forest**	**Built-up Areas**	**Bareland**	**Creteria Weights**
Grass Land	0.0769	0.0297	0.1739	0.1538	0.1261	0.1121
Shrub Land	0.5385	0.2079	0.2609	0.2308	0.1681	0.2812
Forest	0.0385	0.0693	0.0870	0.1538	0.1008	0.0899
Built-up Areas	0.0385	0.0693	0.0435	0.0769	0.1008	0.0658
Bareland	0.3077	0.6238	0.4348	0.3846	0.5042	0.4510
※Check	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix										
Creteria Weights	0.1121	0.2812	0.0899	0.0658	0.4510					
LULC	**Grass Land**	**Shrub Land**	**Forest**	**Built-up Areas**	**Bare land**	**Weighted Sum Value**	**Criteria Weights**	**Ratio**	**% Criteria Weights**	**Ranking**
Grass Land	0.1121	0.0402	0.1798	0.1316	0.1128	0.5764	0.1121	5.1423	11.21%	3
Shrub Land	0.7846	0.2812	0.2696	0.1974	0.1503	1.6832	0.2812	5.9855	28.12%	2
Forest	0.0560	0.0937	0.0899	0.1316	0.0902	0.4615	0.0899	5.1342	8.99%	4
Built-up Areas	0.0560	0.0937	0.0449	0.0658	0.0902	0.3507	0.0658	5.3301	6.58%	5
Bareland	0.4483	0.8437	0.4494	0.3290	0.4510	2.5214	0.4510	5.5906	45.10%	1

λ_{max} =	**5.4365**		
Consistency Index	**0.1091**		
Consistency Ratio	**0.0983**	**should be <10% or 0.10**	**9.8315%**

A6: Overall Preference Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation
LULC	1	1/7	1/5	1/3	5
Population	7	1	3	5	9
Slope	5	1/3	1	3	7
Soils	3	1/5	1/3	1	5
Elevation	1/5	1/9	1/7	1/5	1

Step 2. Sum of Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation
LULC	1.0000	0.1429	0.2000	0.3333	5.0000
Population	7.0000	1.0000	3.0000	5.0000	9.0000
Slope	5.0000	0.3333	1.0000	3.0000	7.0000
Soils	3.0000	0.2000	0.3333	1.0000	5.0000
Elevation	0.2000	0.1111	0.1429	0.2000	1.0000
Sum	**16.2000**	**1.7873**	**4.6762**	**9.5333**	**27.0000**

Step 3. Normalized of Pairwise Matrix

OPM	LULC	Population	Slope	Soils	Elevation	Criteria Weights
LULC	0.0617	0.0799	0.0428	0.0350	0.1852	0.0809
Population	0.4321	0.5595	0.6415	0.5245	0.3333	0.4982
Slope	0.3086	0.1865	0.2138	0.3147	0.2593	0.2566
Soils	0.1852	0.1119	0.0713	0.1049	0.1852	0.1317
Elevation	0.0123	0.0622	0.0305	0.0210	0.0370	0.0326
※Check	1.0000	1.0000	1.0000	1.0000	1.0000	1.0000

Step 4. Consistency Matrix

Criteria Weights	0.0809	0.4982	0.2566	0.1317	0.0326	Weighted Sum Value	Criteria Weights	Ratio	% Criteria Weights	Ranking
OPM	**LULC**	**Population**	**Slope**	**Soils**	**Elevation**					
LULC	0.0809	0.0712	0.0513	0.0439	0.1631	0.4104	0.0809	5.0717	8.09%	4
Population	0.5664	0.4982	0.7698	0.6584	0.2935	2.7864	0.4982	5.5929	49.82%	1
Slope	0.4046	0.1661	0.2566	0.3951	0.2283	1.4506	0.2566	5.6535	25.66%	2
Soils	0.2427	0.0996	0.0855	0.1317	0.1631	0.7227	0.1317	5.4878	13.17%	3
Elevation	0.0162	0.0554	0.0367	0.0263	0.0326	0.1671	0.0326	5.1247	3.26%	5
							1.0000	26.9306	100.00%	
ƛmax =	5.3861									
Consistency Index	0.0965									
Consistency Ratio	0.0870	**should be <10% or 0.10**	8.6963%							