University of Nairobi

Faculty of Engineering

Using GIS to Assess Sustainability of Urban Development in Kenya's Emerging Cities: Case Study of Nakuru City

BY

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F56/37144/2020

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

July 2022

Declaration

I, Joseph Wachira Kariuki, 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.

Joseph Wachira Kariuki 25th July 2022

Name of student Signature Date

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

Prof. Dr. - Ing John Bosco Kyalo Kiema 25th July 2022

Name of supervisor Signature Date

Dedication

I dedicate this work to my lovely wife Rosemary Mambo and my son Kariuki Wa Wachira for the great love and support they have shown me throughout my studies.

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Acknowledgements

My deepest gratitude goes to the Almighty God for giving me strength and gratitude to complete this research project. It is by God's grace that I have made it this far.

I sincerely thank my supervisor Prof. Dr.-Ing. John B. Kyalo Kiema for his great support, guidance, inspiration, patience and important insights throughout all the stages of this research project. It was such a humbling experience to be your supervisee.

Special thanks to my aunt Rev. Hellen Kiama and my Mum Saumu Asuman for investing into my education and always believing in me. Your prayers and support has enabled me to successfully complete this research. Thank you for always believing in me and encouraging me to go beyond my limits.

Special thanks to Madam Eklah Maina, Head of GIS Kenya Power and Lighting Company and Mr. Solomon Mbugua Head of GIS Nakuru County Government for providing me with important insights and data required for this research project. It would have been difficult to carry out this research without your kind and generous support.

I am also thankful to the entire Department of Geospatial and Space Technology faculty for imparting knowledge and providing an enabling environment to complete my studies. It gives me much pride to be an alumni trained by the best members of faculty.

Kind regards to my family, classmates and colleagues for their love and support. Without you this research project would have been difficult to carry out.

Abstract

The aim of this study was to assess the sustainability of urban development in Nakuru as one of Kenya's emerging cities. The main criteria and sub-criteria used as indicators of Suitability of Urban Development (SUD) were identified through literature review. They were then subjected to expert opinion by use of questionnaires and priorities and weights identified through Analytical Hierarchy Process (AHP). There was a 61.9% consensus among all the experts. Weighted overlay analysis (WOA) was used to produce the final SUD map of Nakuru city. From the results; 0.9% of the study area was regarded as being very highly sustainable, 13. % highly sustainable, 28.2% moderately sustainable, 31% low sustainable and 26.6% very low sustainable. The central business district of Nakuru City was generally considered highly sustainable, but the periphery of the city was identified as still needing improvement for it to be considered to have sustainable urban development especially with the new city status.

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List of Abbreviations/Acronyms

AHP: Analytical Hierarchy Process

FANP: Fuzzy Analytic Network Process

GFBWM: Group Fuzzy Best Worst Method

GDP: Global Domestic Product

GIS: Geographical Information Systems

NEMA: National Environment Management Authority

OWA: Ordered Weighted Average

SDG: Sustainable Development Goals

SUD: Sustainable Urban Development

UTM: Universal Transverse Mercator

UN: United Nations

WGS: World Geographic System

WLC: Weighted Linear Combination

WOA: Weighted Overlay Analysis

CHAPTER 1: INTRODUCTION

1.1 Background

The concept of sustainable urban development is at the center of many local, national and many international organization development plans (Amy J.L. et al., 2011). The United Nations sustainable development goal number 11 advocates for 'making cities and human settlements inclusive, safe, resilient and sustainable',https://sdgs.un.org/goals/goal11, [accessed on 6 April 2022]. Sustainable development has been defined as development that meets the needs of the present generation without compromising the ability of future generations to meet their own needs (Gro H.B., 1987). The dimensions of sustainable urban development include social, economic and environmental. These are complementary and not mutually exclusive. With urban centers contributing to over 70% of global GDP and acting as centers of economic development, there have been renewed efforts by national and international organizations, government and non-governmental organizations to have sustainable urban development.

The world is rapidly urbanizing with Africa and Asia leading in terms of the rate of urbanization (UN-Habitat, 2015). Sustainable urbanization contributes greatly to improving the quality of life (UN-Habitat, 2015) but can be a source of environmental degradation, poor living standards and other societal menaces where it occurs haphazardly. Kenya as one of the countries within Africa is also experiencing a significant amount of urbanization (Statistica, 2020). Initially with three cities i.e. Kisumu, Mombasa and Nairobi, Nakuru city has now gained city status (www.president.go.ke, accessed on 16th February 2022) evident of how the country is rapidly urbanizing. With this come the many benefits and challenges in equal measure as a result of increased pressure for resources within the city. By theory, the conferment of city status in Kenya is guided by Urban Areas and City Act of 2011. In practice, GIS can be an important tool for scientific assessment of how cities are sustainable before decisions are made to upgrade towns to city status or once they have been upgraded since the concept of sustainability is not fixed in space.

Geographically, Nakuru lies in a very unique setting (Albrecht et.al, 2004) with Mau escarpment to the West, active faults to the East, a recently expanding Lake Nakuru to the South, and

Menengai crater to the North. This makes expansion of the city difficult despite an increasing demand for land.

This research will try to assess the current state of affairs of Nakuru City in terms of sustainable urban development of the city with its new status from which important decisions can be made by various stakeholders such as the county government of Nakuru, investors who are likely to move into the city.

1.2 Problem Statement

Nakuru City has recently gained its city status. Consequently, it is expected that there will be more pressure for resources as investors, industries as well as people look for new opportunities in the city. The conferment of city status to Nakuru Municipality was guided by urban areas and cities act of 2011 which gives a legal and theoretical framework for classification of various urban areas. In addition, there are planned major facelifts within the city, https://nation.africa/kenya/counties/nakuru/nakuru-kenya-s-newest-city-rolls-out-grand-facelift-plans--3650646, (accessed on 11th May 200).

It therefore becomes imperative to assess the SUD of Nakuru City as an important reference point for decision makers within the city on current state of affairs and areas that need urgent attention. GIS provides an important tool that can be used to make such assessments. This research project will use GIS to assess sustainability of urban development in Nakuru City as one of Kenya's emerging cities.

1.3 Objectives

The main objective is to assess the sustainability of urban development in Nakuru City.

The specific objectives are:

1) Identify the main criteria and sub-criteria for assessing sustainable urban development.
2) Construct a model for carrying out a weighted overlay analysis of the various sustainable urban development assessment criteria using a multi-criteria decision making approach.

3) Construct sustainable urban development assessment map of Nakuru City.

1.4 Justification for the Study

Assessment of sustainability of urban development in Nakuru City is an important aid tool for decision making. Firstly, it shows the current state of affairs in Nakuru City. This demonstrates the strength that exists within the content of urban sustainability. Secondly, urban sustainability maps help identify areas which Nakuru City needs to improve in order for it to be sustainable now and into the future.

1.5 Scope of Work

This research study uses GIS to assess the sustainability of urban development within Nakuru City as one of the emerging cities. The dimensions of sustainability covered include economic, social-cultural and environmental. The study employs indicators and gives a weight to each indicator before coming up with a sustainability map. As the development is in itself dynamic, the study is only limited to the period of study i.e. from February to May 2022. The study is limited to available data and only includes those indicators that are spatially interpretable and quantifiable using GIS

CHAPTER 2: LITERATURE REVIEW

2.1 Sustainable Urban Development

According to Roberto C. (1998), SUD ensures a harmonious coexistence between the various components of the city ecosystem there by guaranteeing a good quality of life for the city inhabitants and making sure that developments are not detrimental to the environment now and into the future. SUD should therefore ensure the social, economic and environmental aspects of urban development are well taken care of. To track progress towards sustainable urban development, assessments are usually conducted. Maria B. et al. (2017) identified many emerging and existing challenges that come with urban development and advocates the use of SUD assessments as an important tool for assessing existing and current development in cities and identifying priorities areas to improve on.

2.2 Sustainable Development Goals

Sustainable development goals are the global aspirations adopted by the United Nations in 2015 which are aimed at eliminating poverty, safeguarding planet earth and ensuring that all human races enjoy peace and prosperity (https://www.undp.org/sustainable-development-goals accessed on 9th May 2022). In total there are 17 sustainable development goals that the world hopes to achieve by the year 2030.

Figure 2.1: The 17 Sustainable Development Goals ***(Source: United Nations)***

Sustainable development goals act as a reference for many national and international development agendas such as Kenya's vision 2030 that greatly borrow from the SDG. The importance of having sustainable cities is underscored in the sustainable development goals number 11 which advocates for sustainable cities and communities. To measure progress towards achieving these goals, the SDG provides various targets and indicators for sustainable urban development.

This study uses some of the indicators included in the SDGs. Some of the indicators include those on assessments for:

i. Access to open and green spaces

The SDG indicator on access to open and green spaces considers people to have access to open and green spaces if they are within 400 meters distance from such centers. Open and green spaces must be accessible to the public without any limitations and at no charge.

Plate 2.1: An aerial view of Nyayo Gardens in Nakuru City. ***(Source: Nakuru County Government twitter handle)***

ii. Access to public transport

According to the SDG 11 indicator, access to public transport is considered if one has access to a public stop within 500 meters for low capacity systems such as rapid transit or 1 km for a high capacity system such as rail along a transport network. Public transport should be at designated places such as bus terminals and also safe.

Plate 2.2: A public stop at KMA stage in Nakuru City ***(Source: fieldwork)***

iii. Access to water

According to the millennium development goal, the precursor of sustainable development goals, people are considered to have access to water if sources of water are within 1 kilometer walking distance. Such sources of water should be safe and free from contamination.

2.3 Sustainable urban development indicators

Indicators are used to measure the level of sustainability and thus the progress made (Albert M. et al., 2020). Within the context of urban development, there are many indicators and frameworks used to measure urban sustainability. While the process of developing sustainable development assessment indicators is a complex one (Albert M. et al., 2020), there has been considerable progress towards provision of assessment frameworks.

The Global Platform for Sustainable Cities, 2018 developed an urban sustainability framework that was meant to serve as a policy tool to support cities in collecting and integrating data as well as providing a common assessment framework for urban sustainability. Various nations have also been at the forefront in developing SUD indicators (Municipality of Malaga, 2018; LEED, 2019). The number of indicators may vary. However indicators should cover all the aspects of sustainability that include economic, social and environment.

2.4 Analytical Hierarchy Process

The Analytical Hierarchy Process (AHP) is a method used in decision making to enable analysis and solving of complex problems.

The process involves:

i. Developing a model (goal).

This is based on criteria or alternatives.

ii. Making a pairwise comparison.

This involves making a comparison between two criteria or sub-criteria. The AHP proposes a scale of 1 to 9 to assign relative importance of one element to another.

iii. Deriving priorities (weights) for criteria.

The most famous method for deriving weights was developed by Saaty, 1972. The weights of two elements being compared is derived from their relative importance. The fundamental scale developed is illustrated in table 2.1.

Table 2.1: Fundamental scale based on Saaty (1980)

Intense of importance	Definition	Explanation
1	Equal importance	Two elements contribute equally to the objective
3	Moderate importance	Experience and judgment moderately favors one element over another
5	Strong importance	Experience and judgment strongly favors one element over another
7	Very strong importance	One element is strongly favored and its dominance is demonstrated in practice

9	Extreme importance	The evidence favoring one element over another is of the highest possible order of affirmation
2,4,6,8	Intermediate values between two adjacent judgments	When compromise is needed
1.1,1.2 etc. used for elements that are very close in importance		

2.5 Weighted Overlay Analysis

The Weighted Overlay Analysis (WOA) is a raster based modeling approach used in suitability analysis or sustainability assessment in the context of our present study. The input cells in the raster are assigned weights based on relative importance. Generally, the process involves the following steps:

i. Defining the overall problem or goal.

It is important to understand what one is ranking and what is required.

ii. Determination of the evaluation criteria.

iii. Finding spatial data representing the criteria

iv. Determine scores for the criteria

This involves determining what values are most suitable or least suitable.

vi. Determining weights for each individual criterion

The AHP may be used for this.

vii. Model validation

This involves determining whether the model makes sense

vii. Sensitivity analysis

This involves determining how the WOA model varies based on:

-Varying scores/weights

-Changing criteria

-Changing data source choice.

2.6 Sustainable Urban Development Assessment

SUD assessment is meant to be an aiding tool for city authorities in making decisions and policies. This field has been the subject of recent studies and different approaches have been employed such as multicriteria evaluation, mathematical modeling, spatial simulation models, expert systems (Jimenez P. et al., 2020). In carrying out a SUD of the municipalities in North West Spain, Andres N. et al., (2019) used 38 indicators that include all the three pillars of sustainability (environment, social, economy) using two weighting methods (equal weighting and measured weighting attributed through AHP method).According to the results obtained, there was no significant difference between the results obtained with the two weighting methodology. In a similar study, Ayyoob S. et al., (2020) used 13 main criteria and 44 sub-criteria to carry out SUD assessment in East Azerbaijan Province, Iran. The study used FANP to derive criteria weights and their significance. The OWA method was used to aggregate the indicators and develop SUD maps. In a most recent study by Abdolrassoul S. et al (2021), SUD assessment of Karaj City in Tehran, Iran, was carried out using GIS and a hybrid decision making approach. In the study, the influencing factors on SUD were selected based on literature review. In total 7 criteria and 24 sub criteria were selected. The criteria were then weighted and prioritized using GFBWM and AHP. Fuzzy logic and WLC in a GIS environment were used to determine the sustainability. Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) was used as the basis for ranking the identified. The results from the study socioeconomic and employment as the most important criterion and sub-criterion respectively with about 30% of the study areas identified as highly sustainable in terms of sustainable urban development.

This study used GIS and AHP in decision making to assess the SUD of Nakuru City being one of the emerging cities in Kenya. Results from the study can be used as a policy guide in decision making by the authorities in-charge of Nakuru City.

CHAPTER 3: MATERIALS AND METHODS

3.1 Study Area

The study area is within Nakuru City. The city which was started by colonial government in the 20th century as railway station along the Kenya-Uganda railway has grown to become the fourth largest city in Kenya. It is the headquarter of Nakuru county and consists of two constituencies; Nakuru Town West and Nakuru Town East. It lies between longitude 36^0 00' 00" & 36^0 10' 00" East and Latitude 0^0 15' 00" & 0^0 30' 00" South. Rising at an altitude of 1800m above sea level, the city is located approximately 160 kilometers North West of Kenya's main capital city Nairobi. To the north of the city is the Menengai crater, Lake Nakuru and Lake Nakuru National Park to the south, Bahati Highlands to the East and Mau Escarpment to the West. According to the 2019 census, the town has a population of approximately 392,000 people. The town is traversed by the Njoro River that slowly winds its way into Lake Nakuru. The city is well connected to other centers by the busy Nairobi-Malaba highway and Mombasa-Kisumu meter gauge railway. The study area map is as shown in figure 3.1.

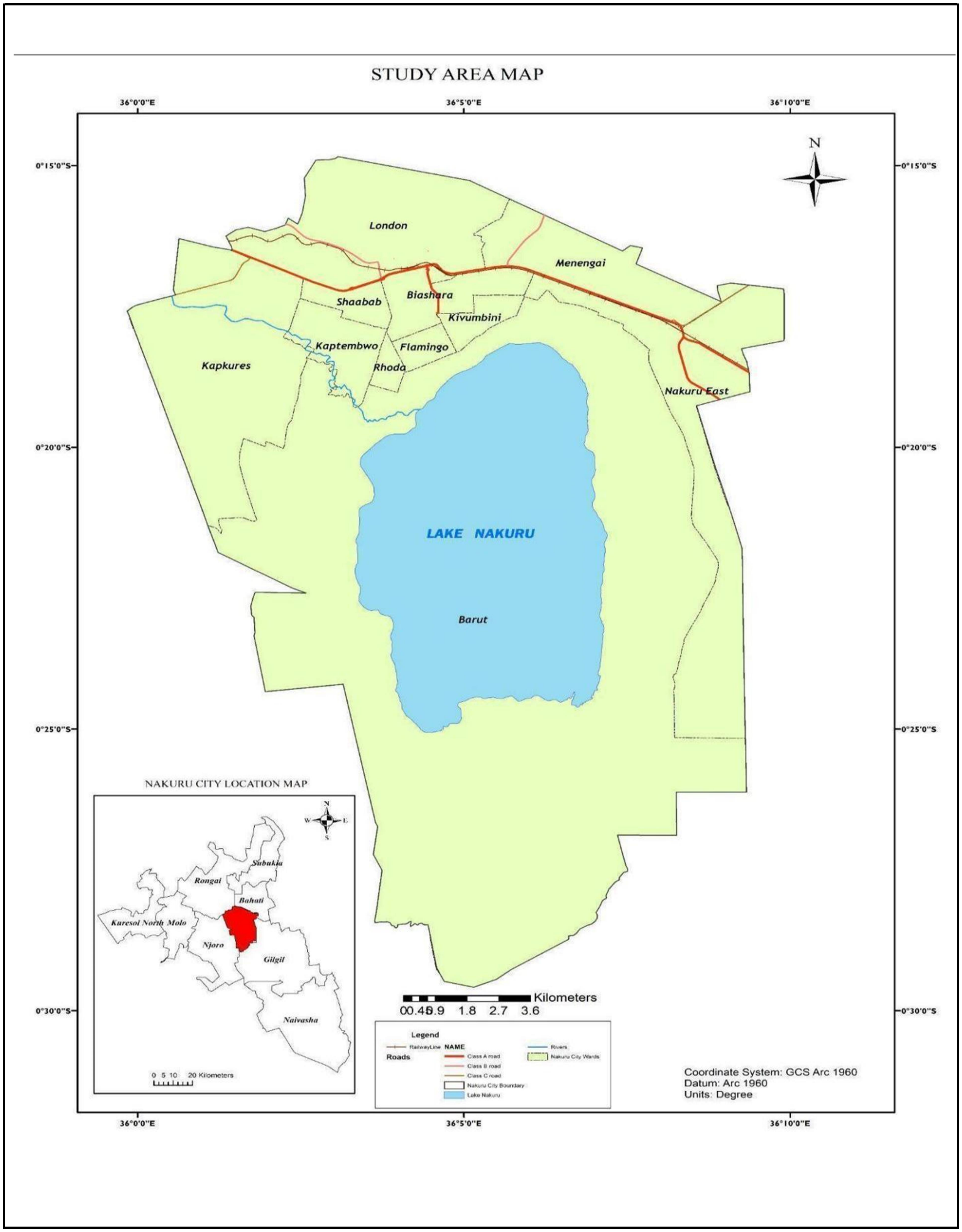

Figure 3.1: Location of the study area in Nakuru County, Kenya

3.2 Overview of the Methodology

The research methodology was carried out in three parts. Having identified the study area, the first step involved identifying the main criteria and sub criteria for assessing sustainable development. This was mainly guided by; a review of previous literature on sustainable development assessments, national and international guidelines and practices on sustainable urban development assessments and availability of data. The data required for the assessment was then collected from fieldwork and secondary data sources. It was then edited, formatted and modified into a uniform datum and projection system. The second part involved subjecting the identified criteria and sub-criteria to expert opinion to identify their weights. The weights were determined through analytical hierarchy process. After identifying the weights for the various criteria and sub criteria, a GIS model using a multi-criteria decision making approach was developed in ARCMAP. Three models were developed namely; a sustainable urban development assessment model, a restriction model and a final urban sustainability assessment model combining the two models to produce the final sustainable urban development assessment map of Nakuru City. The methodological workflow is as shown in figure 3.2.

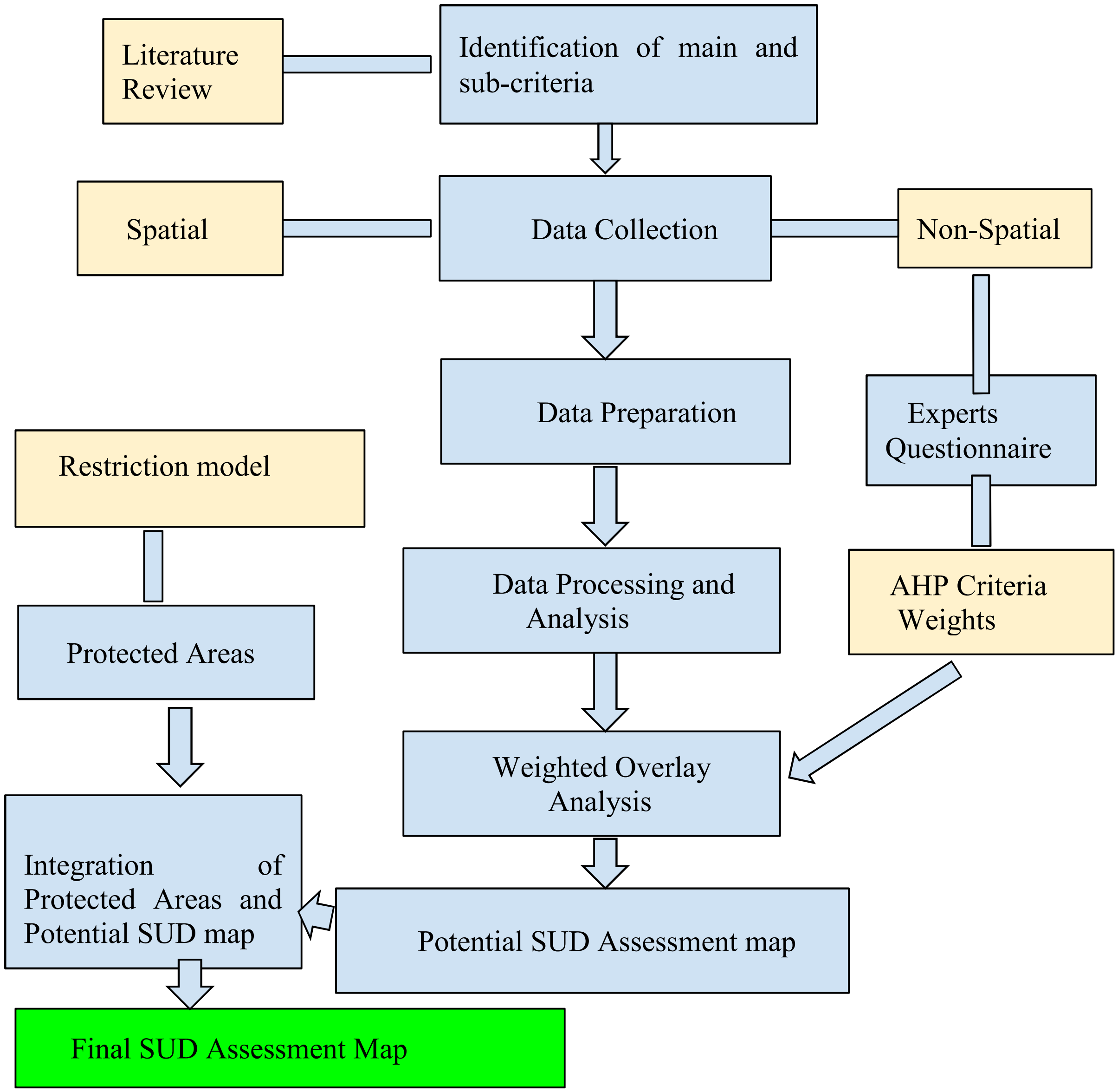

Figure 3.2: Methodology Workflow

3.2.1 Identification of Main and Sub-criteria for Assessing SUD

The main criteria and sub-criteria used in assessing SUD were identified through literature review of previous studies, experts' opinion, SUD assessment frameworks and available data. The sustainable development goals particularly number 3, 6, 7 and 11 also provided important reference. The identified criteria and sub-criteria for the assessment are as shown in figure 3.3.Due to the need to localize our assessment and use only the most significant criteria and sub-criteria, the identified criteria and sub-criteria were further subjected to expert opinion using a questionnaire in the AHP process. Based on the expert's advice, only the most significant criteria and sub-criteria were adopted for the studies. The final criteria and sub-criteria adopted for the study is as shown in figure 3.4

Urban Infrastructure
Access to public transport
Access to sewerage collection network
Access to open and green spaces
Access to water
Access to solid waste collection services
Access to security infrastructure
Access to water
Access to health facilities

Physical characteristics of land
Geological formation
Slope

Economic and social environment
Population density
Housing price

Buffer and distances
Distance from military center
Distance from flood plain

Land use
Land use compatibility ratio
Land use suitability

Figure 3.3: Initial list of criteria and sub-criteria identified

Urban Infrastructure	Buffer and Distances	Land use
Access to security infrastructure ratio	Distance from flood plain	Land use compatibility
Access to electricity		
Access to water		
Access to sewerage collection network	**Economic and social environment**	
Access to water	Population density	
Access to health facilities		
Access to open and green spaces		

Figure 3.4: Final list of criteria and sub criteria

The indicators used in the assessment are as discussed below.

i. Access to health facilities.

From experts' advice, access to health facilities within the city was considered very high if it was available within a walking distance of 400 meters.

ii. Access to electricity.

According to Kenya Power and Lighting Company, only areas within a distance of 600 meters along the power line network from an electricity power transformer have access to electricity connection. This was adopted in the assessment.

iii. Access to water.

The millennium development goal indicator 7c on access to safe drinking water considers access to water to be within 1 kilometer from a safe source of water.

iv. Access to security infrastructure.

Based on expert's advice and previous literature (Mohammed A. et al., 2013), access to security infrastructure was considered to be very high if it was within a 1 kilometer walking distance.

v. Access to public transport.

Sustainable development goal indicator 11.2.1 considers access to public transport if it is within a 500 meter walking distance to a public stop along a transport network for a low capacity transport system such as bus transit or I kilometer for a high capacity system such as rail or metro.

vi. Access to open and green spaces

Sustainable development goal number 11 considers people to have access to open and green spaces if they are accessible within a 400 meters distance from where they live.

vii. Distance from flood plain.

According to experts' advice and previous literature(Ameen R. et al., 2019), areas close to the floodplain are considered to be least sustainable while areas away from flood plain are considered to be very highly sustainable.

viii. Population density

Based on previous literature (Abdolrassoul S. et al., 2022) , a high population density was considered to cause a strain to available resources and therefore not suitable while a low population density was considered favorable.

ix. Land use compatibility ratio

x. Access to sewerage collection network

Areas connected to the sewerage network and within a distance of 200 meters from the main sewer line were considered to have a high access to have a very high access to sewerage collection network.

3.3 Data sources and Tools

3.3.1 Data sources

Data used in the study was obtained from secondary data sources through data transfer and from fieldwork data collection using qfield mobile GIS application. The data sources and their characteristics are as shown in table 3.1.

Table 3.1: Data sources and their characteristics

Data	Source	Characteristics
Protected areas	Kenya geoportal	Shapefile
Power line network, power transformers	Kenya power and lighting company	Shapefile
Open and Green spaces	Nakuru Local urban observatory project	Shapefile
Rivers	Nakuru Local urban observatory project	Shapefile
Roads	Open street map	Shapefile
Water meters	Water for GIS	Shapefile
Schools	Nakuru Local urban observatory project	Shapefile
Hospitals	Nakuru Local urban observatory project	Shapefile
Police facilities	Fieldwork	Shapefile

Administrative boundaries	Human data org	Shapefile
Lake Nakuru	Open street map	Shapefile
Criteria weights/Expert opinion	Previous literature review, Consultation from county government officials, NEMA , Planners and Survey/GIS professionals	Filled in questionnaires

3.3.2 Tools

a) **Hardware**

Computer with 500GB Memory, 8 GB RAM and 2.50GHZ Processor speed

Flash disk with 16GB memory

Printer

b) **Software**

ARCGIS 10.8

Microsoft office 2016

QGIS 3.20.1

Global Mapper 22.1

Google Earth Pro

Windows 11 (64 bits)

Qfield

3.4 Data Collection

Data was collected in the field using qfield mobile GIS software. The shapefiles and base maps used in the application were prepared in QGIS Desktop and exported to the mobile application. By visiting the study area, the coordinates of the police stations were picked on site. Data obtained through direct data transfer from secondary sources included; schools, hospitals, open and green spaces from Nakuru's Local Urban Observatory project, power line network, electric power transformers from Kenya Power and Lighting Company GIS department all in shapefile format.

Questionnaires were also sent to various professionals that included NEMA officials, planners, county government officials and Surveyors/GIS experts from which expert weights and opinions were obtained. A full list of all data used is as shown in table 3.1.

3.5 Data Preparation

Various operations were performed on the collected data before it could be used for further processing and analysis. The processes included:

a) **Editing**

Some features were reshaped and realigned to the required boundary. This was done using the editor tool in ARCGIS.

b) **Re-projection**

All data collected was transformed into a uniform projection using the batch conversion/reprojection tool in Global Mapper 22.1. The projection for all data was in UTM Zone 37S and the global WGS 84 datum was used.

c) **Digitization**

This involved on screen digitization to fill the gaps identified in the data. To do this, QGIS 3.20.1 software was used. This had the advantage of having a high resolution Google satellite images base map. Some of the data digitized included roads, Lake Nakuru and rivers.

d) **Merging**

Data digitized to fill identified gaps was merged with data from secondary sources to obtain a uniform layer.

e) Rasterization

This involved conversion of vector data in shapefile format to a raster data in GeoTIFF format. This was done using ARCGIS polygon to raster conversion tool. A uniform cell size of 30, and 1 bit raster was adopted for all images. The images classes ranged from 1 to 5.

f) Clipping

This involved extracting data to fall within Nakuru City boundaries. To do this, ARCGIS features and raster clipping tools were used.

g) Data entry

Data collected from questionnaires was entered into an excel sheet containing the AHP formula for calculation of weights.

3.6 Creation of a Geodatabase

The need to have a uniform collection of data of all data used in the projected necessitated creation of a Geodatabase using ARCGIS ArcCatalog. The process of Geodatabase creation is as shown in Figure 3.5.

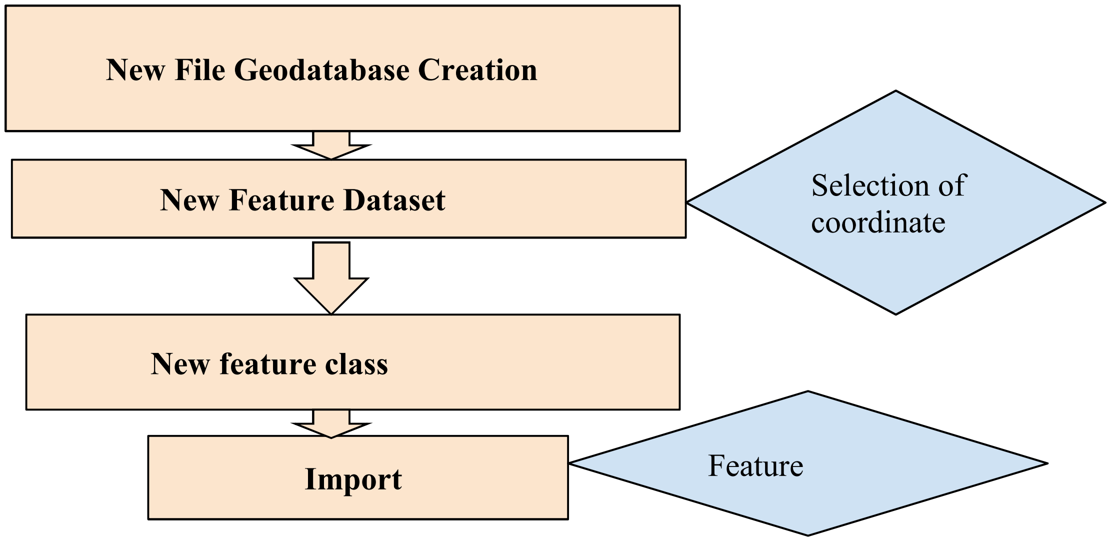

Figure 3.5: Geodatabase creation process

3.7 Determination of Weights

This involved administration of questionnaires to various professionals as highlighted in table 3.1. The professionals gave their judgment on relative importance based on Saaty's 9 point scale ranging from 1 to 9. Responses were given by 5 respondents. The weights were then calculated through a pairwise comparison in the analytical hierarchy process.

The weights were determined in an iterative manner. First, the main criteria and sub criteria obtained from literature review were subjected to their opinion and the less significant factors were discarded. The most significant sub-criteria were then subjected to experts' opinion to determine new criteria weights.

A comparison was made between various weights from all respondents and combinations of 3 and 4 respondents. Each category had different weights, consistency ratio and consensus.

3.8 Sustainable Urban Development Assessment

Sustainable urban development assessments are important tools providing information to policy makers and managers of urban settings on state of affairs and areas that need attention to ensure a better quality of life for the urban population (Sala et al., 2015).

After obtaining the final list of criteria and sub-criteria, their weights were determined based on experts' opinion. The weights were incorporated into a weighted overlay analysis of the criteria in the sustainability model. The final sustainability assessment map was obtained by incorporating a restriction model of protected areas. The maps produced using different weights were compared for any significant differences before adopting one map that could be used for the assessment.

3.8.1 Data Analysis

a) **Network analysis**

A network analysis of the power network was carried out in order to determine the service areas along the network which had access to electric power connection with an impedance length of 600 meters. This was done using ArcCatalog tool and ARCGIS network analysis extension tool.

The ArcCatalog tool was used to create the power network dataset which was further analyzed using ARCGIS' network analysis tool in order to determine the service areas which had access to power . An overview of the process is as shown in figure 3.7

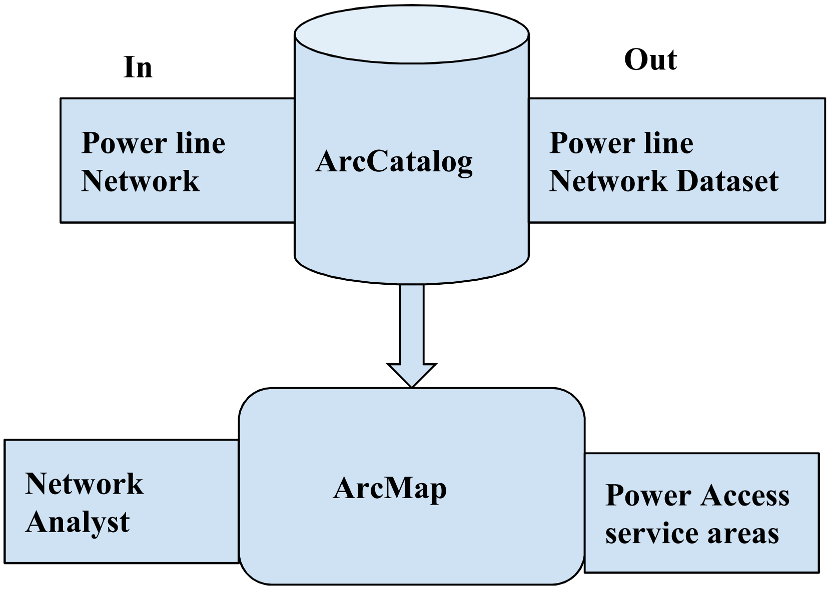

Figure 3.6: Network analysis process

b) **Proximity analysis**

This is a spatial analysis used to examine the relationship between a feature or a cell and its neighboring feature/ cells separated by a distance. The analysis can either be feature based or raster based. Example of a feature based proximity analysis is a buffer or Euclidean linear distance for a raster based analysis. For this study the feature based multiple ring buffer with equal distances was used. This gave five levels of access from very low, low, moderate, high and very high access. This was done in ArcGIS multiple ring buffer tool.

c) **Polygon to raster conversion**

The final analysis was carried out using raster data. It was therefore necessary to convert the multiple rings buffer and access service areas into a raster data format. The resulting raster had a uniform cell size

d) **Reclassification**

The sustainability was ranked into a five level scale as shown in table 3.2.The input criteria raster were also reclassified in a five level scale before being used in the weighted overlay analysis. The raster used in the restriction model was reclassified into two values; 1 and 0 with zero depicting the protected areas and 1 depicting non-protected areas.

Table 3.2: SUD assessment scale

Scale	SUD Assessment Scale
1	Very Low Sustainability
2	Low Sustainability
3	Moderate Sustainability
4	High Sustainability
5	Very High Sustainability

e) **Weighting of the Criteria**

Experts gave their judgment on the relative weights of various factors in the analytical hierarchy process. The weights indicated the relative importance of the various sub-criteria used. The weights added up to 100%. Only weights with the recommended less than 10% consistency ratio were considered for the analysis. The weighted overlay tool in ArcMap was used.

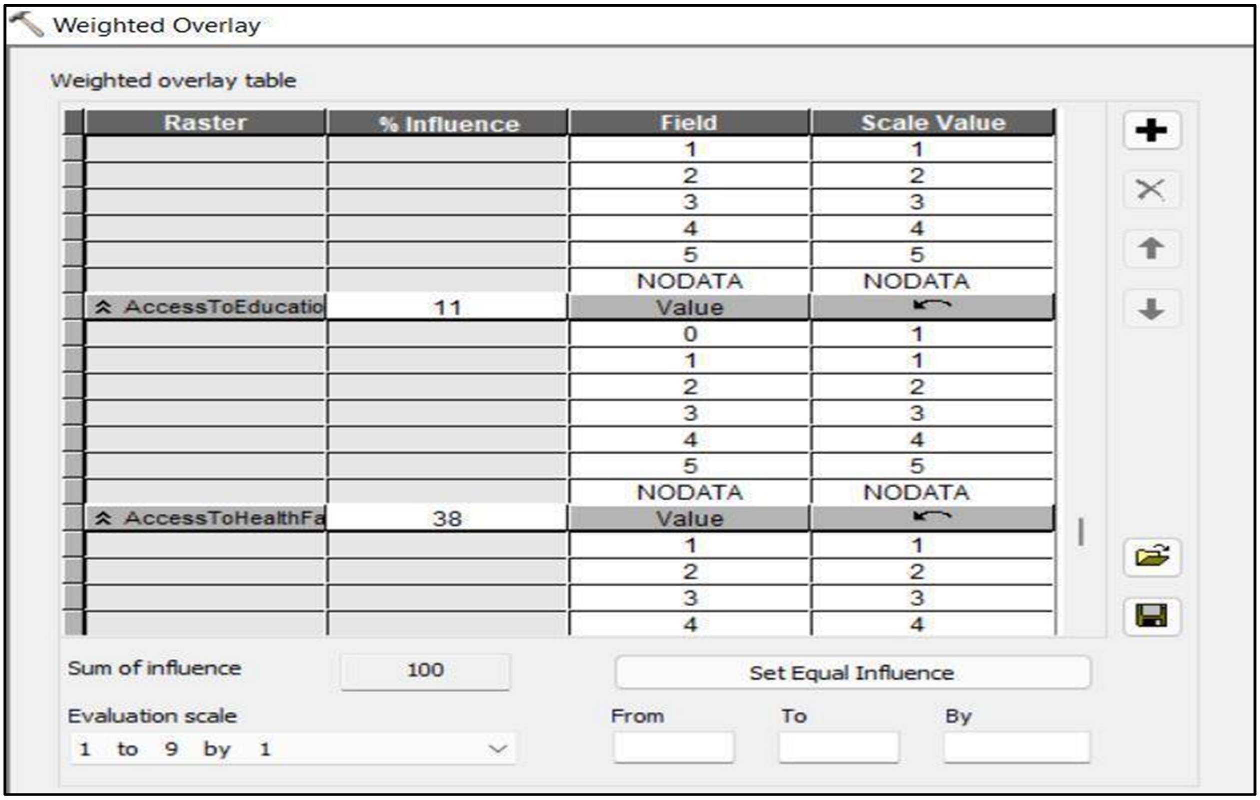

Figure 3.7: Part of Weighted overlay tool used in ArcMap for various sub-criteria

3.8.2 Model Building

a) **Sustainability model**

Five levels of SUD assessment levels were used as shown in table 3.2. The sub-criteria were assigned weights by experts through AHP. The result of the restriction model was potential SUD assessment map which was further processing by incorporating restricted areas in the restriction model

b) **Restriction model**

Protected areas were used in this model. The protected areas were assigned the value zero as no data values since they needed not to be included in the assessment. On the other hand, the non-protected areas were assigned the value 1 so that they could participate in the assessment.

c) **Final SUD assessment model**

This was obtained by incorporating the sustainability model with the restriction model to obtain the final SUD assessment model that produced Nakuru City's SUD assessment map. This was done using the Times function in ArcGIS.

CHAPTER 4: RESULTS AND DISCUSSIONS

4.1: Overview

This chapter includes all the deliverables from the analysis, which are the sub-criteria maps, models, weights and final SUD assessment maps among others.

4.2: Results

4.2.1: SUD criteria and sub-criteria weights

Questionnaire responses from all the participants were processed in an AHP excel template which was downloaded from https://bpmsg.com/ website. The excel template is authored by Goepel, 2013.

i. Main criteria

The identified main criteria were first subjected to expert advice to determine their relative importance to this assessment. The results of the assessment are as shown in figure 4.1

Resulting Priorities

Priorities

These are the resulting weights for the criteria based on your pairwise comparisons:

Cat		Priority	Rank	(+)	(-)
1	Urban Infrastructure	44.6%	1	7.9%	7.9%
2	Buffer and distances	27.6%	2	7.7%	7.7%
3	Physical characteristics of land	10.5%	4	1.8%	1.8%
4	Economic and social environment	13.3%	3	4.2%	4.2%
5	Land use	4.0%	5	1.1%	1.1%

Decision Matrix

The resulting weights are based on the principal eigenvector of the decision matrix:

	1	2	3	4	5
1	1	2.00	5.00	3.00	9.00
2	0.50	1	3.00	3.00	5.00
3	0.20	0.33	1	1.00	3.00
4	0.33	0.33	1.00	1	5.00
5	0.11	0.20	0.33	0.20	1

Figure 4.1: Main criteria priorities

Based on the above results, the main criteria with less than the average of 20% were considered least significant for the studies. They were thus discarded and only urban infrastructure and Buffer and analysis proceeded to the next phase of the analysis.

ii. Sub-criteria weights

Only the sub-criteria from the adopted main criteria were used in the analysis. They were subjected to an iterative AHP pairwise comparison and in order to come up with a final list of most significant sub-criteria for this study based on their weights. The initial list of sub-criteria and their weights are as shown in figure 4.1 and 4.2.

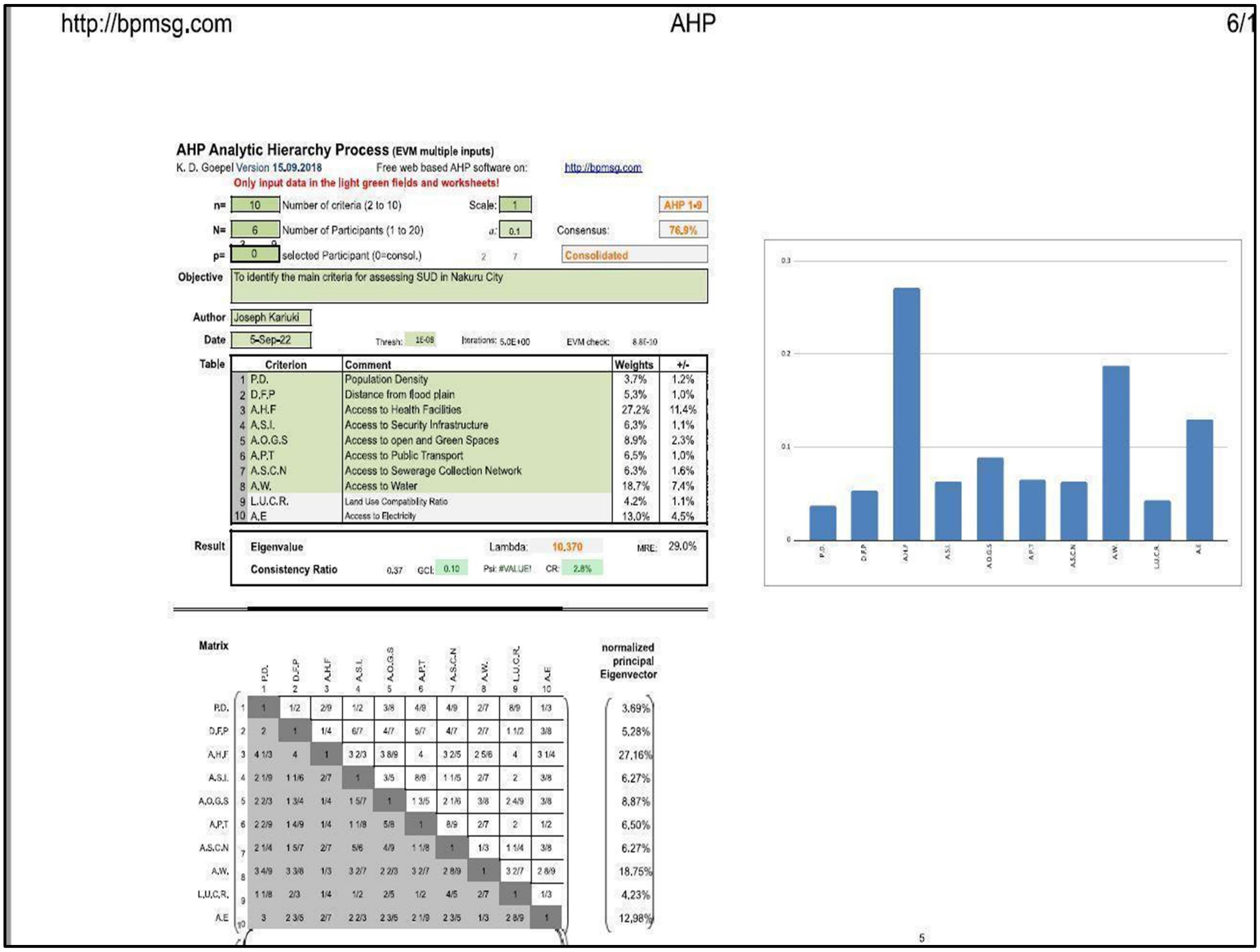

Figure 4.2: Initial sub-criteria and their weights

Initial results of the sub-criteria with a 76.9% consensus among the respondents and a consistency ratio of 2.8 identified access to health facilities, open and green spaces, water, electricity, security infrastructure and schools as having a high weighted average and were thus used in the next stage of analysis. Population density, distance from flood plain, land use compatibility ratio and access to sewerage collection network were disregarded at this stage.

The identified sub-criteria in the first stage were again subjected to experts' opinion with only 5 respondents making responses. The weights are as shown in table 4-1.

Table 4.1: Sub-criteria weights

Number of participants	**3**	**4**	**5**
Sub- criteria	Percentage weight		
Access to health facilities	37.8%	38.4%	28.6%
Access to water	26.9%	28.8%	27.6%
Access to electricity	8.0%	6.9%	12.8%
Access to educational infrastructure	11.2%	10.8%	12.3%
Access to open and green spaces	8.7%	7.2%	9.6%
Access to security infrastructure	7.4%	7.9%	9.2%
Total	100	100	100
Consensus	93.1%	93.0%	61.9%
Consistency Ratio	6.5%	4.4%	2.4%

The graphs of weights from 3, 4 and all the 5 respondents are as shown in figure 4.2, 4.3 and 4.4.

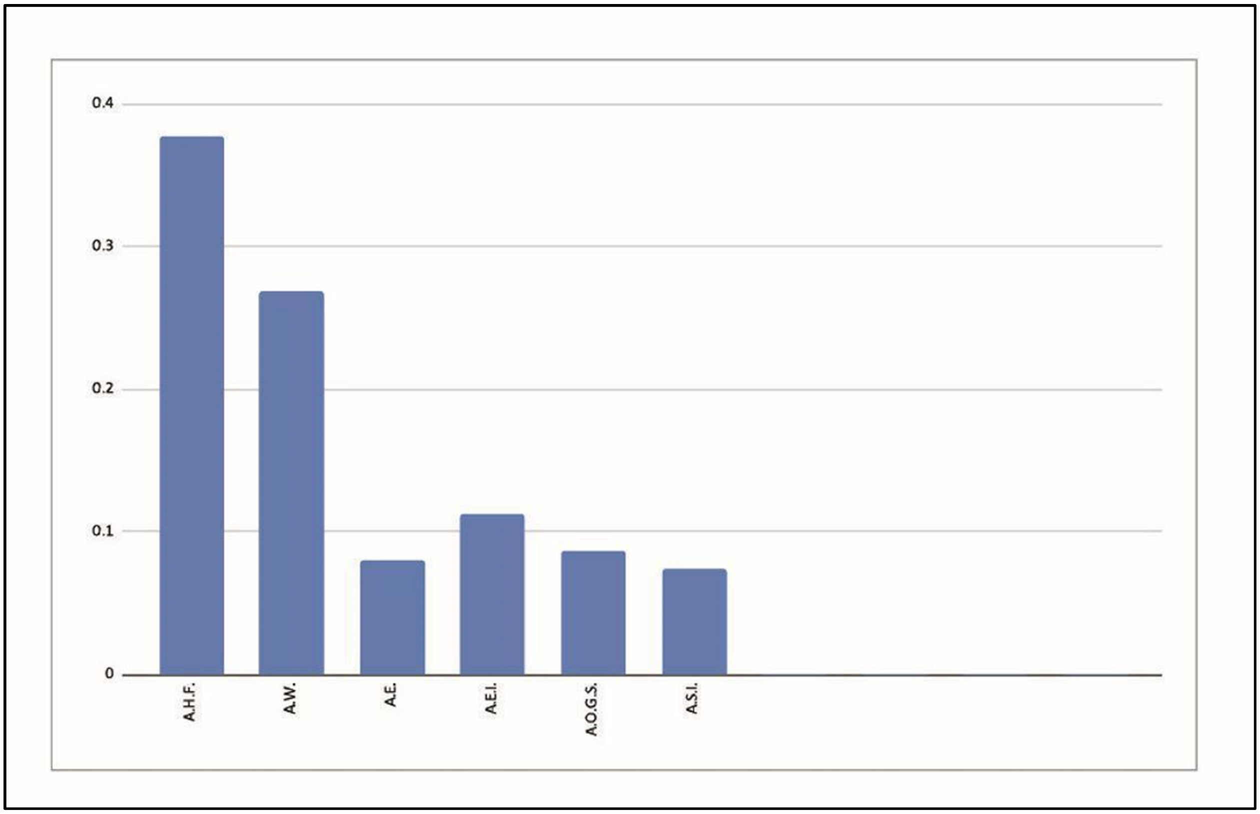

Figure 4.3: Sub-criteria weights from 3 participants

As can be seen from figure 4.2, considering 3 respondents yielded a 93.1% consensus among respondents with a consistency with a 6.5% consistency ratio. Access to health facilities was considered the most important criteria with a 37.8% weight and access to security infrastructure had the least weight at 7.4%.

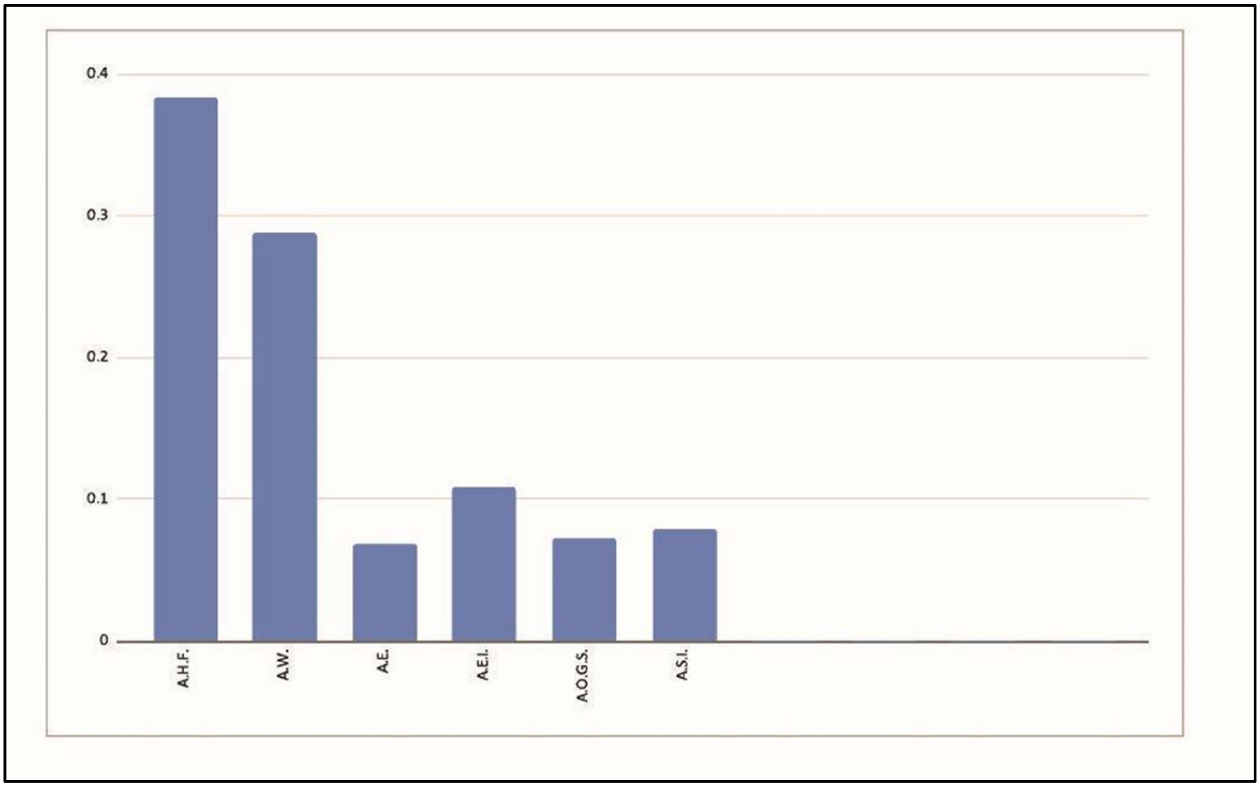

Figure 4.4: Sub-criteria weights from 4 participants

Results from four participants yielded a 93% consensus among respondents with a consistency ratio of 4.4% which was below the minimum acceptable 10%. Access to health facilities was considered the most important criteria with a 38.4% weight while, unlike the results of three participants, access to electricity had the least weight.

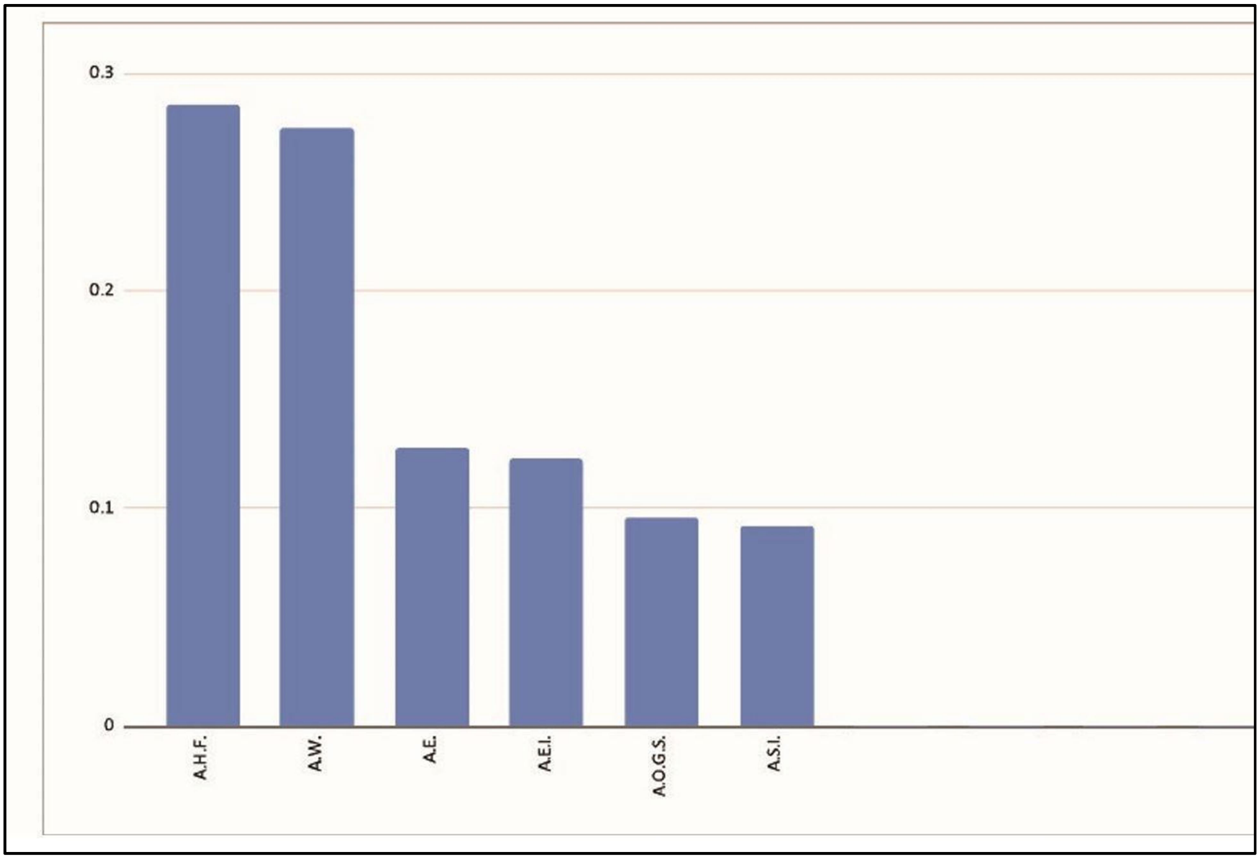

Figure 4.5: Sub-criteria weights from all 5 participants

Results from all the five participants yielded a low consensus of 61.9% as can be seen from the reference in table 4.1. However this had the lowest consistency ratio of 2.4%. Access to health facilities had the highest weight of 28.6% while access to security infrastructure had the least weight of 9.2%.

Table 4.2: Interpretation of AHP consensus indicators S^* (Goepel, 2013)

S^*	Consensus
≤50%	Very Low
50%-65%	Low
65%-75%	Moderate
75%-85%	High
≥ 85%	Very High

4.2.2: Sub-criteria Maps

Maps produced for use in weighted overlay analysis are as shown below

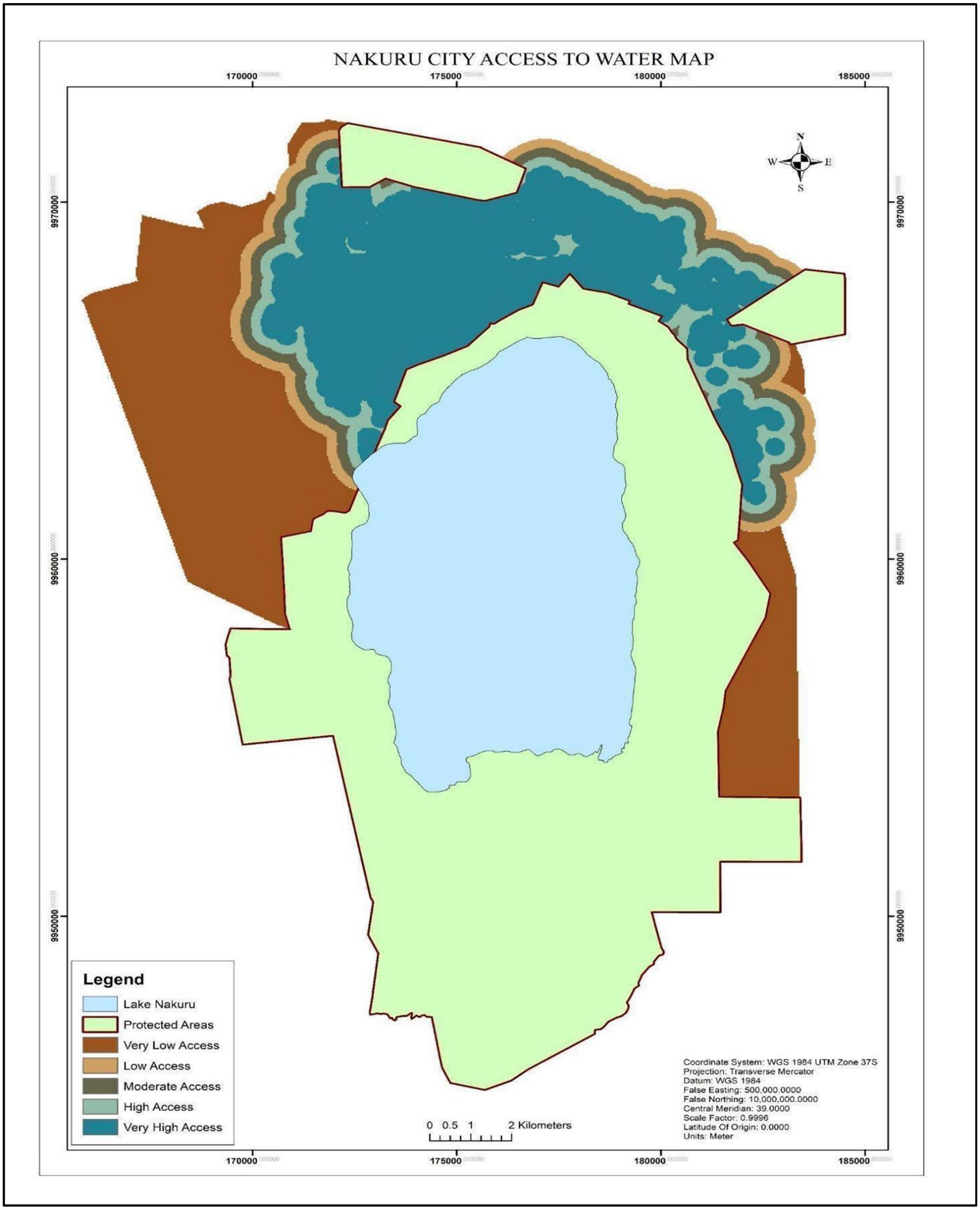

Figure 4.6: Access to water map

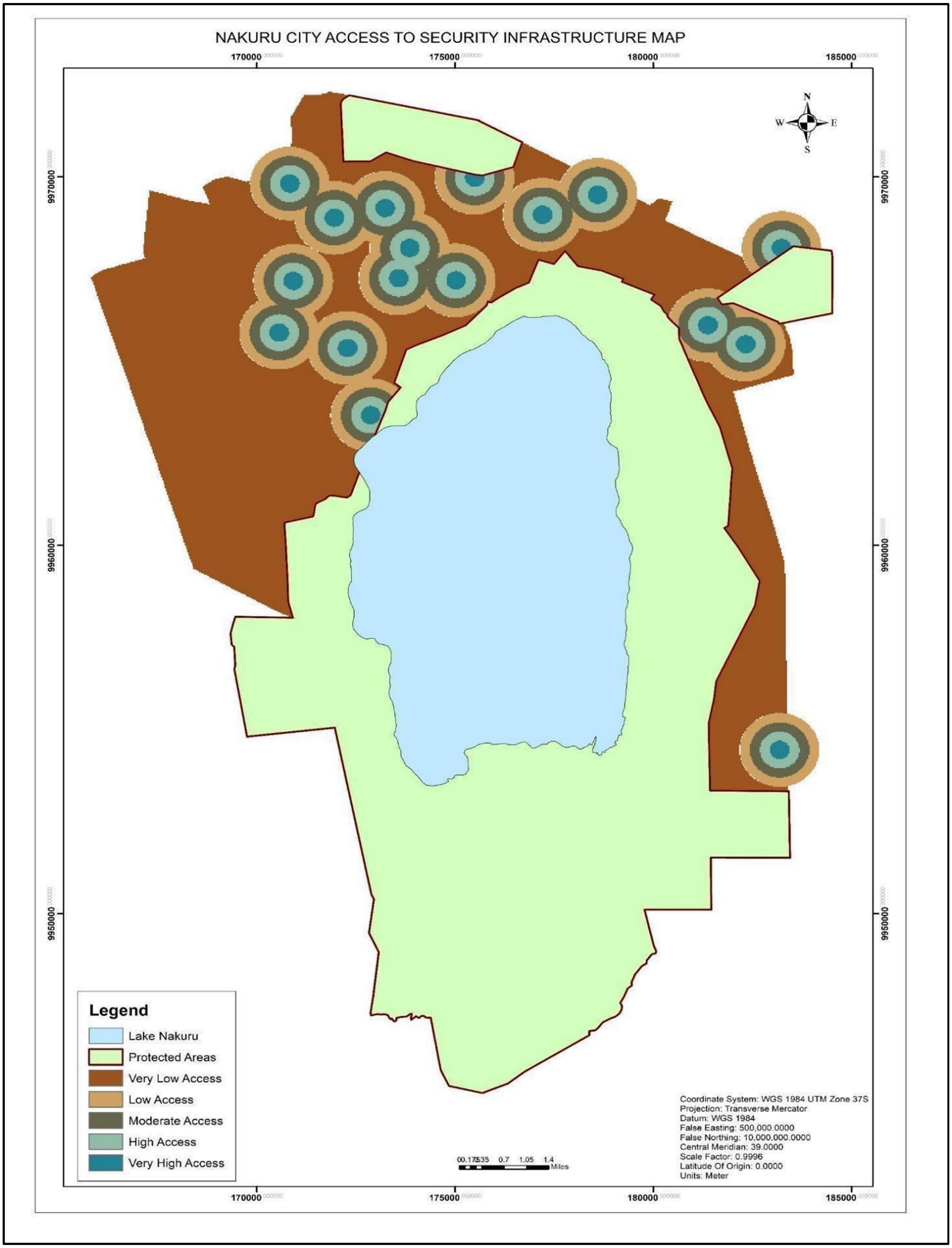

Figure 4.7: Access to security infrastructure map

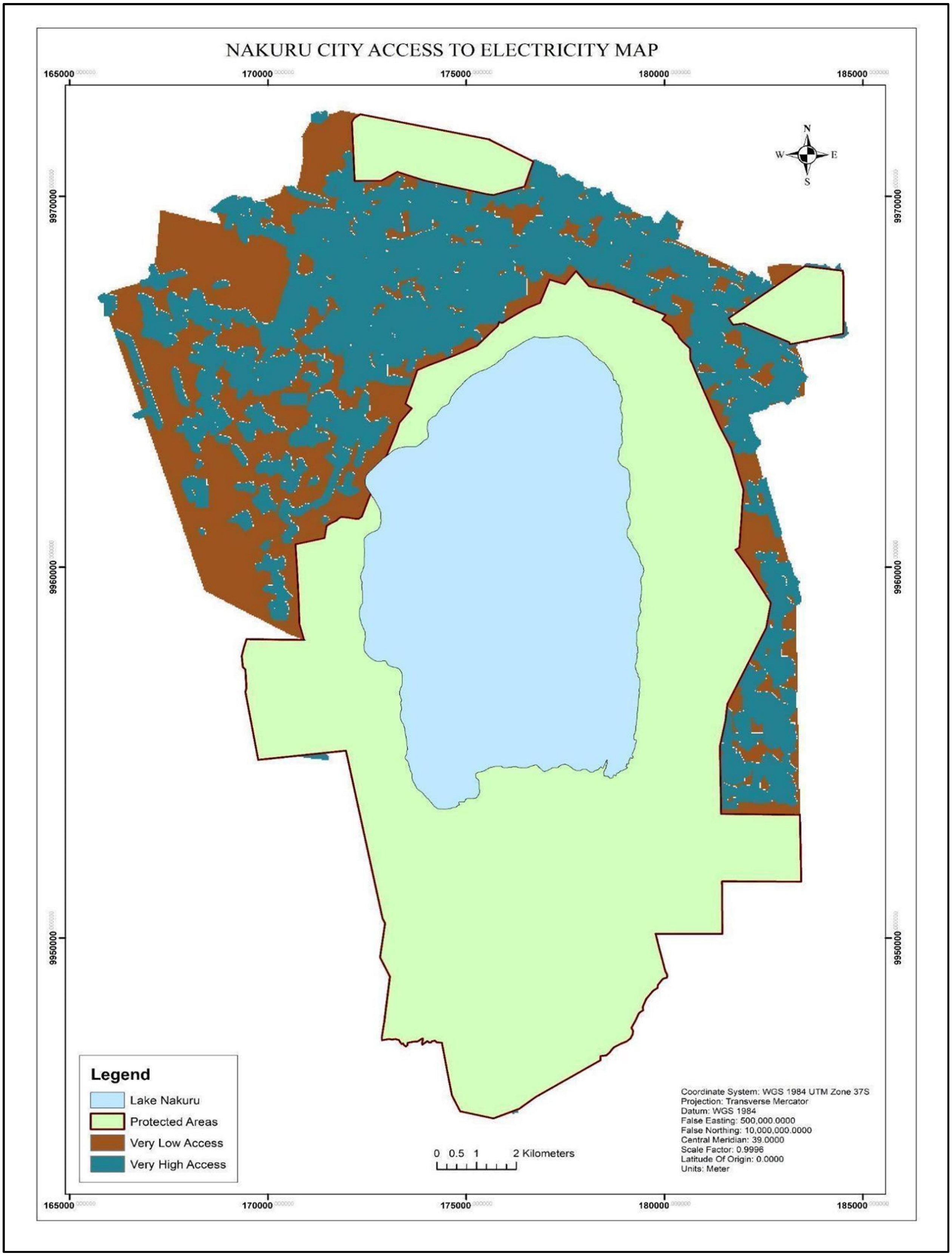

Figure 4.8: Access to electricity map

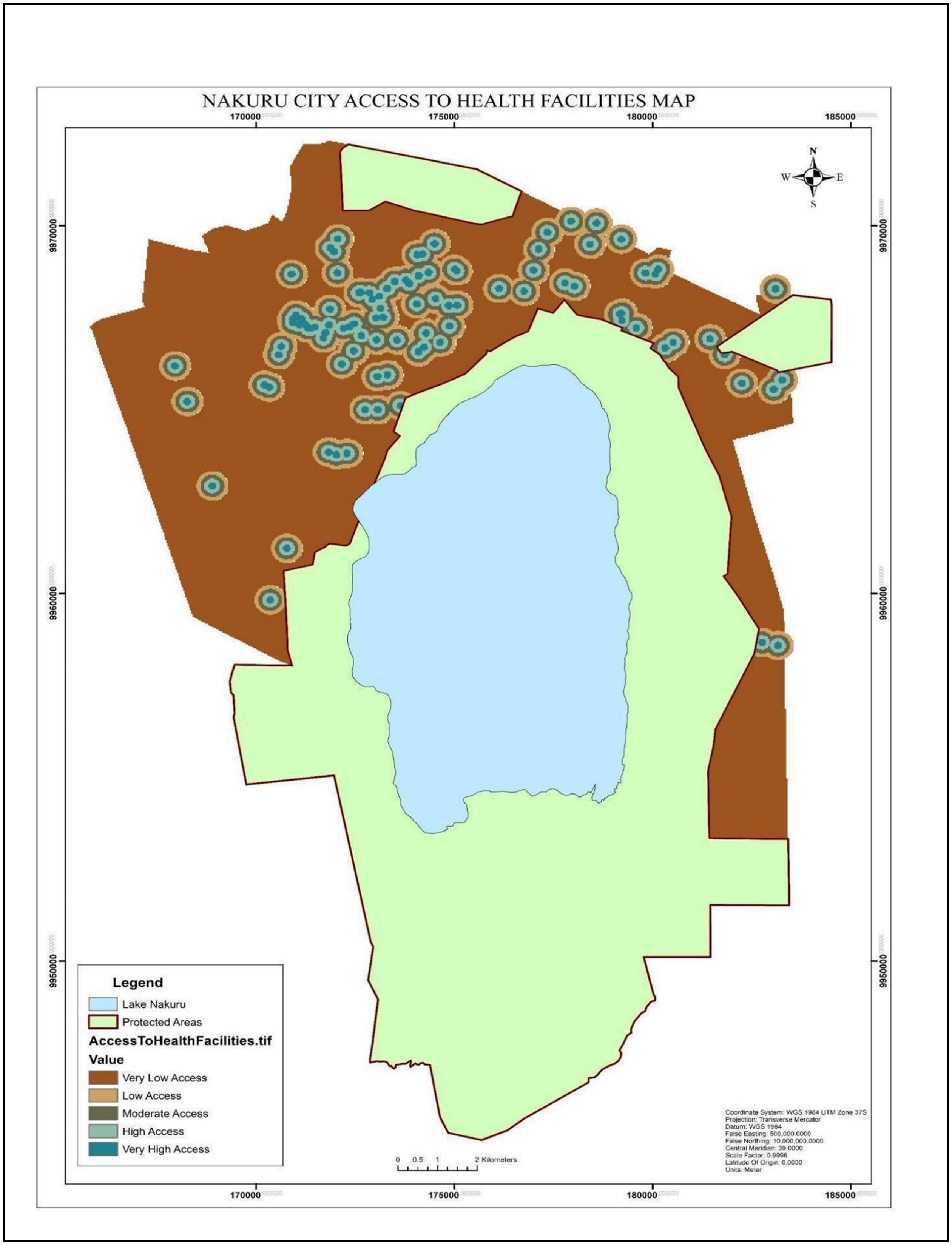

Figure 4.9: Access to health facilities map

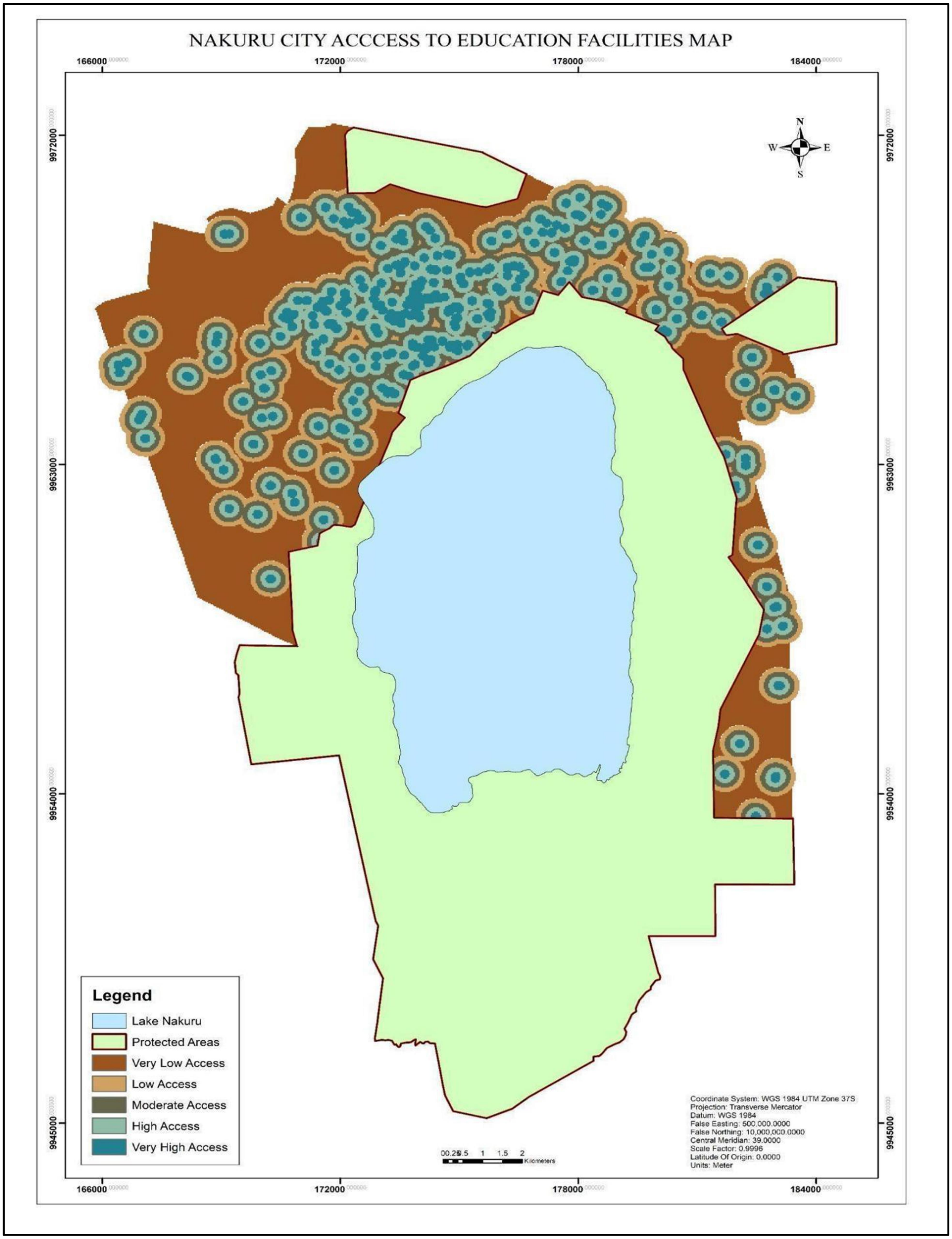

Figure 5.0: Access to education facilities map

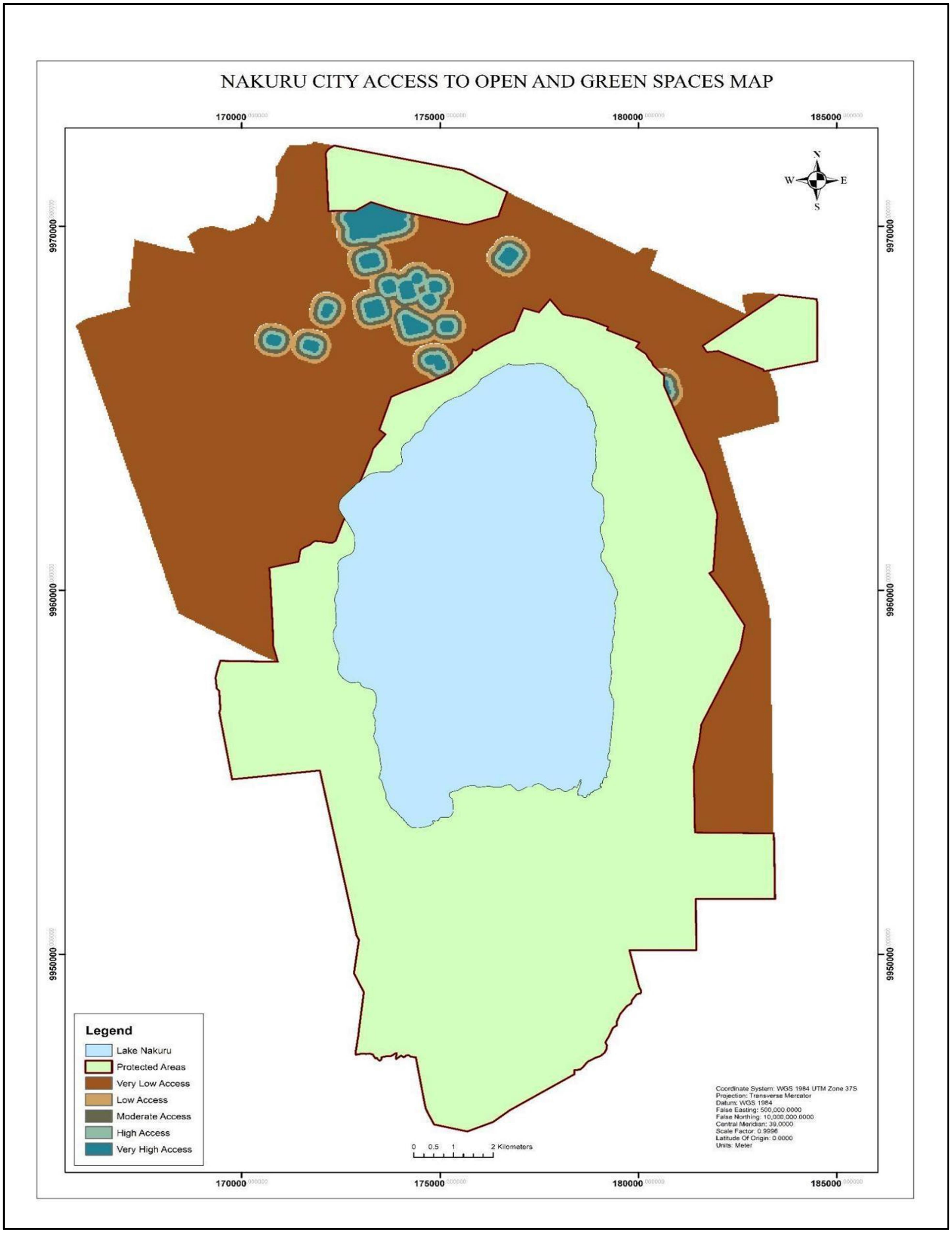

Figure 5.1: Access to open and green spaces map

4.2.3: Models

The ArcGIS model builder was used to develop models used in the analysis. The following models were used.

i. Sustainability model

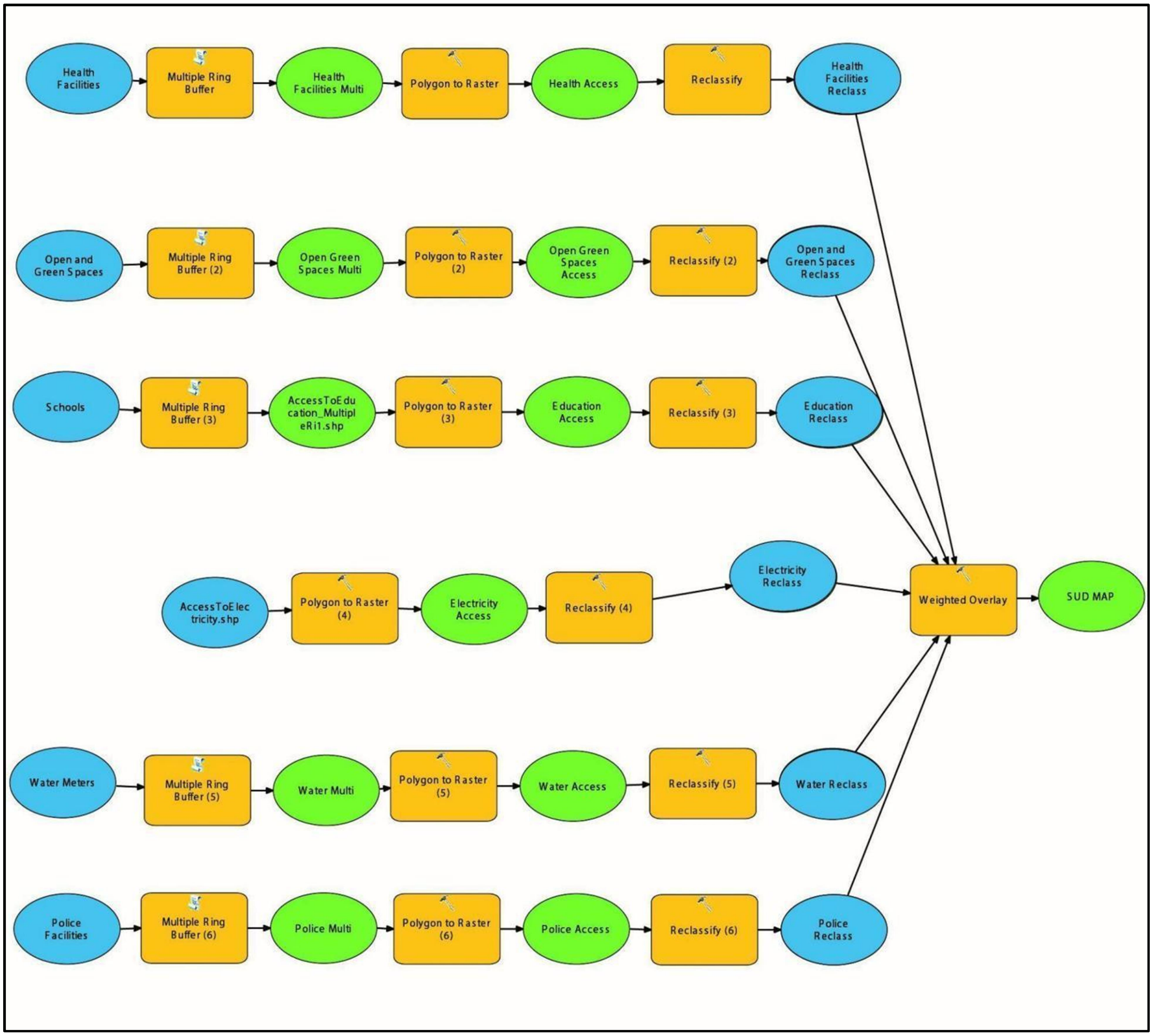

Figure 5.2: Sustainability model

ii. Restriction model

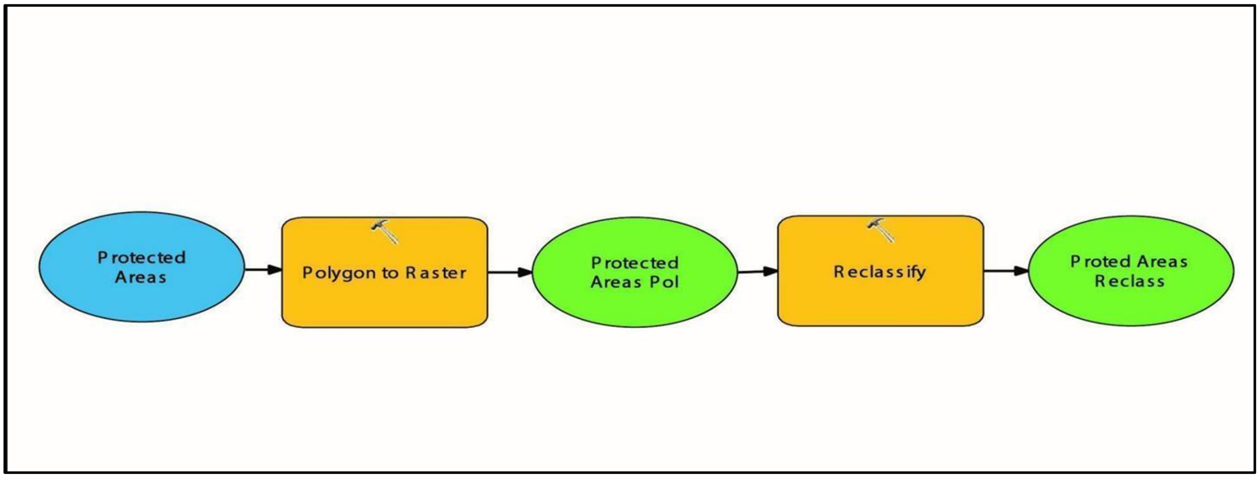

Figure 5.3: Restriction model

iii. Final SUD assessment model

The final sustainability model is as shown in figure 5.4

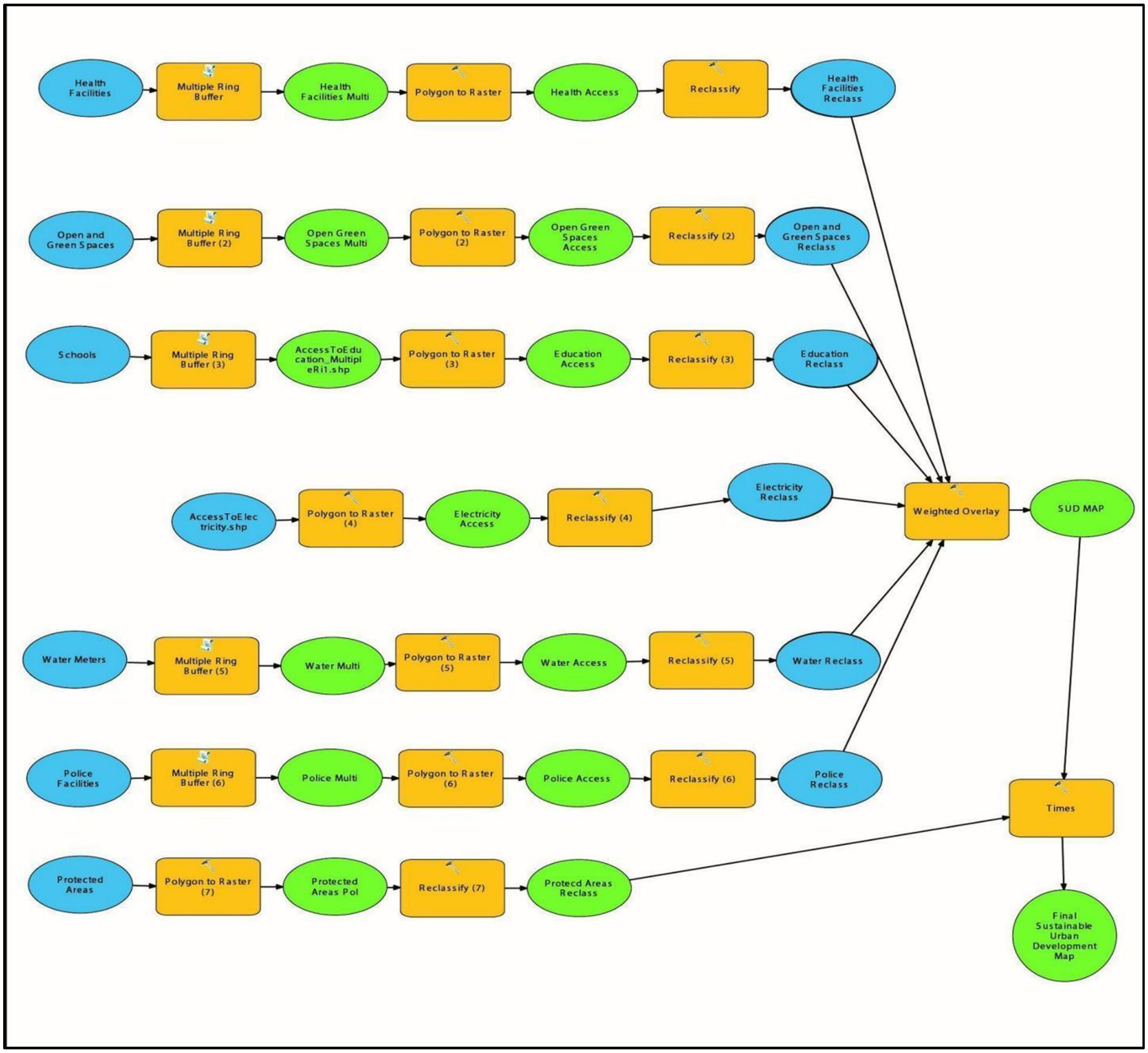

Figure 5.4: Final sustainability model

4.2.4 Sustainable Urban Development Assessment Maps

There was a need to develop maps based on the weights obtained in table 4-1 and see whether there was any significant difference between them. Results of consensus from three and four participants were very high. However, weights from the 93% consensus of four participants were considered since it had a better consistency ratio than that of 3 people. This was compared with weights from all participants who had a low consensus of 61.9%. Weights from all the participants had the best consistency ratio of 2.4. Maps from the two different weights are as shown in figure 5.4 and 5.5.

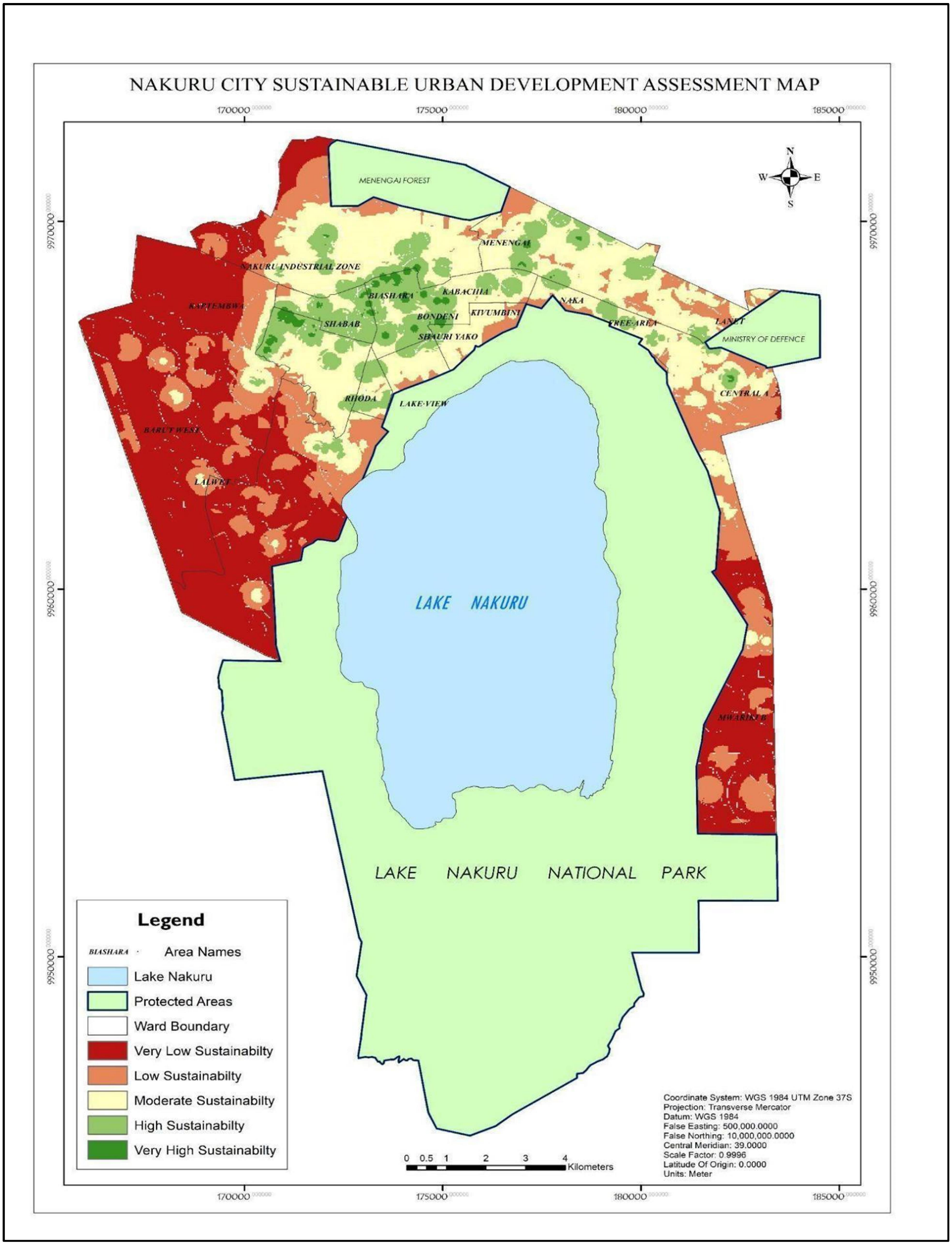

Figure 5.5: Sustainable urban development assessment map from 93.0% consensus

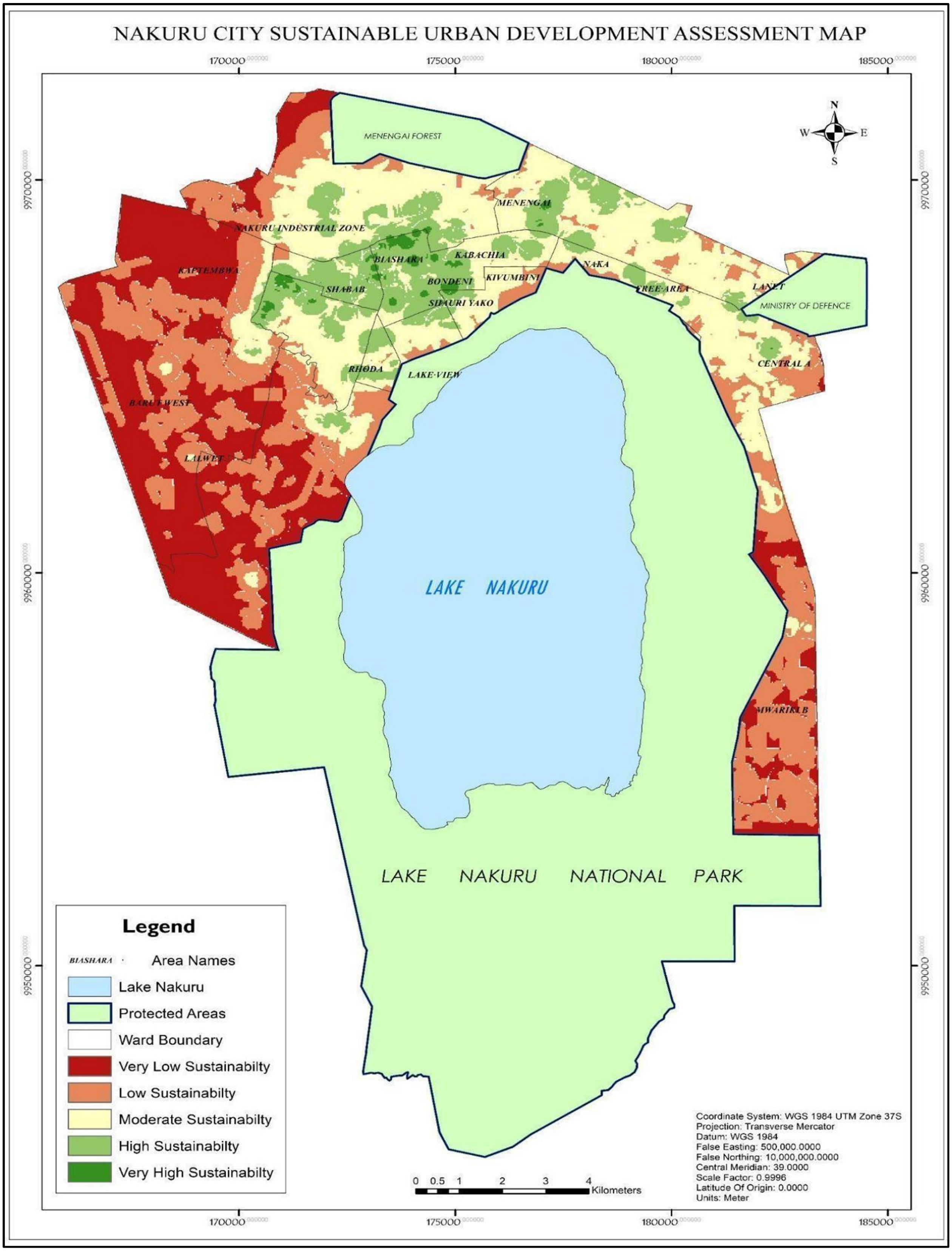

Figure 5.6: Sustainable urban development assessment map from 61.9% consensus

A visual interpretation of the two maps shows a significant difference especially on areas classified as having very low sustainable urban development levels. However opinion from a higher number of participants was considered better than that from few people and therefore the map produced from all people with a 61.9% consensus level was adopted and used for in further analysis.

4.2.5: Final Results

The area of the various SUD assessment levels is as shown in table 4.2.

Table 4.2.1: Area of various SUD levels from the assessment

SUD Level	Area(Ha)
Very low sustainability	29060.1
Low sustainability	33878.7
Moderate sustainability	30849.3
High sustainability	14458.5
Very high sustainability	971.1

The resultant SUD assessment pie chart from the results is as shown in figure 5.6.

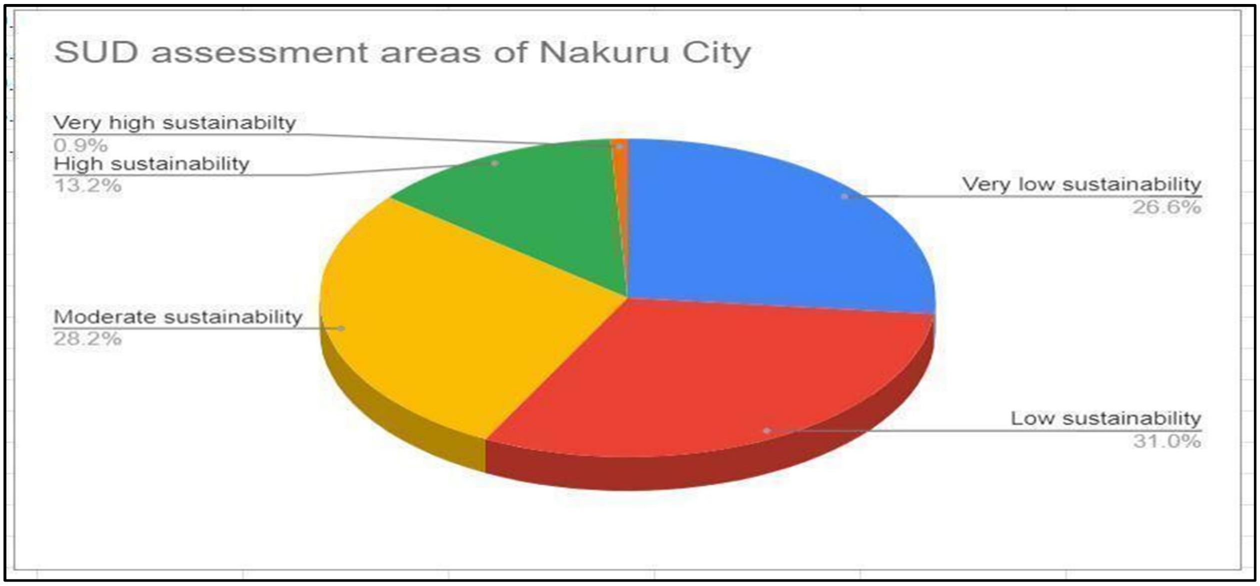

Figure 5.7: Nakuru City's SUD assessment pie-chart.

4.3: Discussion of the Results

Response from expert opinion used in the study prioritized urban infrastructure, buffer and distances and economic and social environment as the most important main criteria for assessment of SUD within our study area as can be seen in figure 4.1. In addition, from an initial list of 10 sub-criteria identified, only 6 were considered significant and therefore used in our study. Access to health facilities was considered the most important factor as can be seen in figure 4-2,4-3 and 4-4 perhaps agreeing with the famous Prof. Miriam Were (2022) assertion that "health is the foundation of economic development". Access to security infrastructure had the least weight.

The final sustainable urban development map showed a high level of sustainable urban development within the central business district of the city, especially in the areas around Biashara, Shabaab and some parts of Bondeni, Rhoda, Kabachia, Shauri yako and Industrial zone. This counted for about 13.2% of the total area as can be seen in figure 5-7. Only very small areas within the city could be considered as having a very high level of sustainable urban development. Approximately a third of the area within Nakuru city could be considered as having very low sustainability. This is particularly the case as one move into the periphery of the city in the areas around Kaptembwa and Barut West.

CHAPTER 5: CONCLUSIONS AND RECOMMENDATIONS

5.1. Conclusions

The overall objective of assessing the sustainability of urban development in Nakuru City as one of Kenya's emerging cities was met. The results showed a high level of sustainable urban development at the city center in the areas around Biashara. There was a decline in levels of sustainability as one moves further away from the city center. This makes sustainable urban development within Nakuru city highly somehow appearing centralized.

GIS proved an important tool for sustainable urban development assessment by integrating different datasets to come up with a final sustainability map. It also provided an important tool for creating a Geodatabase from different data sources.

The use of AHP in multicriteria decision making proved to be an important tool for such a task. It was used in an iterative process in order to identify only the most important criteria and sub criteria. Finally, this study has inferred important insights regarding sustainability of urban development in Nakuru City.

5.2. Recommendations

The findings of this study can be used in decision making by national, county and national governments for planning and identifying priority areas for improvement within the city. In order to ensure equal quality of life within the city, special attention should be given to infrastructural development in the periphery of the city.

There is a need to develop a localized set of indicators for assessing sustainable urban development. The insufficiency of such indicators could be evident from the low consensus obtained from the study.

Further studies incorporating many criteria and sub-criteria and an expanded expert group can improve sustainable urban development assessment within the town. Such assessment should not be a one time off thing. Regular assessment can be important aid in understanding the state of affairs within the city.

The model developed model can be adopted in assessing sustainable urban development in other cities and towns within Kenya.

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APPENDICES

Appendix A: Sample Questionnaire Used

UNIVERSITY OF NAIROBI

DEPARTMENT OF GEOSPATIAL AND SPACE TECHNOLOGY

DATA COLLECTION QUESTIONNAIRE

INTRODUCTION

My name is Joseph Kariuki. I am a final year student at the Department of Geospatial and Space Technology and currently carrying out a final year research project on ***"Using GIS to Assess Sustainability of Urban Development in Kenya's Emerging Cities. Case Study of Nakuru City".*** I am kindly requesting you to respond to the questions below which are part of my study. Your response is confidential, highly valued and will be used for academic purposes only.

The following indicators have been identified as criteria for assessing sustainability of urban development.

1. Population Density
2. Distance from flood plain
3. Access to Health Facilities
4. Access to Security Infrastructure
5. Access to Open and Green Spaces
6. Access to Public Transport
7. Access to sewerage Collection Network

8. Access to Water
9. Land Use Compatibility Ratio
10. Access to Electricity

Guidelines

Kindly;

- Assign values **1, 3, 5, 7, 9** on the left hand side (LHS) or on the right hand side (RHS)
- Assign values on the LHS if the criterion is more important than the ones on the RHS
- Assign values on the RHS if the criterion is more important than the one on the LHS

The values 1, 3, 5, 7 and 9 are described below.

Value	Interpretation
1	Equal importance
3	Moderate importance
5	Strong importance
7	Very strong importance
9	Extreme importance

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Population Density										Distance from flood plain
										Access to

										Health Facilities
										Access to Security Infrastructure
										Access to Open and Green Spaces
										Access to Public Transport
										Access to Sewerage Collection Network
										Access to Water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Distance from flood plain										Access to Health Facilities
										Access to Security Infrastructure

										Access to Open and Green Spaces
										Access to Public Transport
										Access to Sewerage Collection Network
										Access to Water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**

Access to Health Facilities										Access to Security Infrastructure
										Access to Open and Green Spaces
										Access to Public Transport
										Access to Sewerage Collection Network
										Access to Water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	9	7	5	3	1	3	5	7	9	RHS is more important than LHS
Access to Security Infrastructure										Access to Open and Green Spaces
										Access to Public Transport
										Access to Sewerage Collection Networks
										Access to water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	9	7	5	3	1	3	5	7	9	RHS is more important than LHS
Access to Open and Green Spaces										Access to Public Transport
										Access to Sewerage Collection Networks

										Access to water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Access to Public Transport										Access to Sewerage Collection Networks
										Access to water
										Land use compatibility ratio
										Access to Electricity

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Access to Sewerage Collection Networks										Access to water
										Land use compatibility ratio

										Access to Electricity

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Access to water										Land use compatibility ratio
										Access to Electricity
										Distance from military centers

LHS is more important than RHS	**9**	**7**	**5**	**3**	**1**	**3**	**5**	**7**	**9**	**RHS is more important than LHS**
Access to Electricity										Distance from military centers

Suggestions/comments

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Occupation/Profession

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Name
[optional]………………………………………………………………………………………………

Signature………………………………………………………………………………………………

Date………………………………………………………………………………

Organization…………………………………………………………………………

THANK YOU!

Appendix B: Relative weights from 2 participants with 91.5% consensus

http://bpmsg.com AHP

AHP Analytic Hierarchy Process (EVM multiple inputs)
K. D. Goepel Version 15.09.2018 Free web based AHP software on: http://bpmsg.com
Only input data in the light green fields and worksheets!

n=	6	Number of criteria (2 to 10)	Scale: 1		AHP 1-9
N=	2	Number of Participants (1 to 20)	α: 0,1	Consensus:	91,5%
p=	0	selected Participant (0=consol.)	2 7		Consolidated

Objective To determine weight for criteria used in assessing SUD in Nakuru County

Author Joseph Kariuki

Date 05-05-2022 Thresh: 1E-08 Iterations: 7,0E+00 EVM check: 1.2E-09

Table

	Criterion	Comment	Weights	+/-
1	A.H.F.	Access to Health Facilities	34,6%	18,5%
2	A.W.	Access to Water	28,4%	9,4%
3	A.E.	Access to Electricity	9,0%	6,2%
4	A.E.I.	Access to Educational Infrastructure	12,2%	9,4%
5	A.O.G.S.	Access to Open and Green Spaces	8,6%	5,6%
6	A.S.I.	Access to Security Infrastructure	7,2%	1,5%
7			0,0%	0,0%
8			0,0%	0,0%
9		for 9&10 unprotect the input sheets and expand the	0,0%	0,0%
10		question section ("+" in row 66)	0,0%	0,0%

Result

Eigenvalue Lambda: 6,786 MRE: 56,7%

Consistency Ratio 0.37 GCI: 0,45 PsI: 18,3% CR: 12,6%

Matrix

		1 A.H.F.	2 A.W.	3 A.E.	4 A.E.I.	5 A.O.G.S.	6 A.S.I.	7	8	9	10	normalized principal Eigenvector
A.H.F.	1	1	1 1/6	7 1/2	5	1 4/7	3 4/9	0	0	0	0	34,65%
A.W.	2	5/6	1	1 5/7	3 7/8	3 7/8	5 1/2	0	0	0	0	28,42%
A.E.	3	1/8	4/7	1	1/4	2 4/9	1	0	0	0	0	9,04%
A.E.I.	4	1/5	1/4	3 7/8	1	1 2/7	1 2/5	0	0	0	0	12,18%
A.O.G.S.	5	5/8	1/4	2/5	7/9	1	1	0	0	0	0	8,56%
A.S.I.	6	2/7	1/6	1	5/7	1	1	0	0	0	0	7,16%
	7	0	0	0	0	0	0	1	0	0	0	0,00%
	8	0	0	0	0	0	0	0	1	0	0	0,00%
	9	0	0	0	0	0	0	0	0	1	0	0,00%
	10	0	0	0	0	0	0	0	0	0	1	0,00%

Appendix C: Relative weights from 3 participants with 93.1% consensus

http://bpmsg.com AHP

AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version 15.09.2018 Free web based AHP software on: http://bpmsg.com

Only input data in the light green fields and worksheets!

n= 6 Number of criteria (2 to 10) Scale: 1 AHP 1-9

N= 3 Number of Participants (1 to 20) α: 0.1 Consensus: 93.1%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective To determine weight for criteria used in assessing SUD in Nakuru County

Author Joseph Kariuki

Date 05-05-2022 Thresh: 1E-08 Iterations: 5.0E+00 EVM check: 8.7E-09

Table

	Criterion	Comment	Weights	+/-
1	A.H.F.	Access to Health Facilities	37.8%	17.0%
2	A.W.	Access to Water	26.9%	9.2%
3	A.E.	Access to Electricity	8.0%	2.6%
4	A.E.I.	Access to Educational Infrastructure	11.2%	3.8%
5	A.O.G.S.	Access to Open and Green Spaces	8.7%	4.8%
6	A.S.I.	Access to Security Infrastructure	7.4%	2.5%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
10		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 6.406 MRE: 40.1%

Consistency Ratio 0.37 GCI: 0.24 Psi: 18.3% CR: 6.5%

Matrix

		A.H.F. 1	A.W. 2	A.E. 3	A.E.I. 4	A.O.G.S. 5	A.S.I. 6	7	8	9	10	normalized principal Eigenvector
A.H.F.	1	1	2 1/7	6	5 1/3	2	2 8/9	0	0	0	0	37.78%
A.W.	2	4/9	1	2 1/9	3 1/9	4 2/9	5 1/3	0	0	0	0	26.87%
A.E.	3	1/6	1/2	1	1/2	1 1/4	1	0	0	0	0	8.00%
A.E.I.	4	1/5	1/3	2	1	2	1 3/5	0	0	0	0	11.25%
A.O.G.S.	5	1/2	1/4	4/5	1/2	1	1 1/4	0	0	0	0	8.68%
A.S.I.	6	1/3	1/5	1	5/8	4/5	1	0	0	0	0	7.42%
	7	0	0	0	0	0	0	1	0	0	0	0.00%
	8	0	0	0	0	0	0	0	1	0	0	0.00%
	9	0	0	0	0	0	0	0	0	1	0	0.00%
	10	0	0	0	0	0	0	0	0	0	1	0.00%

Appendix D: Relative weights from 4 participants with 93.0% consensus

AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version 15.09.2018 Free web based AHP software on: http://bpmsg.com

Only input data in the light green fields and worksheets!

n= 6 Number of criteria (2 to 10) Scale: 1 AHP 1-9

N= 4 Number of Participants (1 to 20) α: 0.1 Consensus: 93.0%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective To determine weight for criteria used in assessing SUD in Nakuru County

Author Joseph Kariuki

Date 05-05-2022 Thresh: 1E-08 Iterations: 5.0E+00 EVM check: 4.2E-09

Table

	Criterion	Comment	Weights	+/-
1	A.H.F.	Access to Health Facilities	38.4%	14.7%
2	A.W.	Access to Water	28.8%	8.4%
3	A.E.	Access to Electricity	6.9%	1.6%
4	A.E.I.	Access to Educational Infrastructure	10.8%	3.9%
5	A.O.G.S.	Access to Open and Green Spaces	7.2%	3.0%
6	A.S.I.	Access to Security Infrastructure	7.9%	2.1%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
10		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 6.274 MRE: 33.1%

Consistency Ratio 0.37 GCI: 0.16 Psi: 18.3% CR: 4.4%

Matrix

		A.H.F. 1	A.W. 2	A.E. 3	A.E.I. 4	A.O.G.S. 5	A.S.I. 6	7	8	9	10	normalized principal Eigenvector
A.H.F.	1	1	1 7/9	6 2/7	5 5/7	2 7/8	3 1/3	0	0	0	0	38.41%
A.W.	2	4/7	1	2 5/6	3 1/9	4 7/9	5 1/2	0	0	0	0	28.82%
A.E.	3	1/6	3/8	1	5/7	5/6	3/4	0	0	0	0	6.86%
A.E.I.	4	1/6	1/3	1 2/5	1	2 5/9	1 2/3	0	0	0	0	10.84%
A.O.G.S.	5	1/3	1/5	1 1/5	2/5	1	4/5	0	0	0	0	7.22%
A.S.I.	6	2/7	1/6	1 1/3	3/5	1 1/4	1	0	0	0	0	7.85%
	7	0	0	0	0	0	0	1	0	0	0	0.00%
	8	0	0	0	0	0	0	0	1	0	0	0.00%
	9	0	0	0	0	0	0	0	0	1	0	0.00%
	10	0	0	0	0	0	0	0	0	0	1	0.00%

Appendix E: Relative weights from 5 participants with 61.9% consensus

http://bpmsg.com AHP

AHP Analytic Hierarchy Process (EVM multiple inputs)

K. D. Goepel Version 15.09.2018 Free web based AHP software on: http://bpmsg.com

Only input data in the light green fields and worksheets!

n= 6 Number of criteria (2 to 10) Scale: 1 AHP 1-9

N= 5 Number of Participants (1 to 20) α: 0.1 Consensus: 61.9%

p= 0 selected Participant (0=consol.) 2 7 Consolidated

Objective To determine weight for criteria used in assessing SUD in Nakuru County

Author Joseph Kariuki

Date 05-05-2022 Thresh: 1E-08 Iterations: 5.0E+00 EVM check: 1.4E-09

Table

	Criterion	Comment	Weights	+/-
1	A.H.F.	Access to Health Facilities	28.6%	8.1%
2	A.W.	Access to Water	27.6%	6.0%
3	A.E.	Access to Electricity	12.8%	2.7%
4	A.E.I.	Access to Educational Infrastructure	12.3%	2.8%
5	A.O.G.S.	Access to Open and Green Spaces	9.6%	2.8%
6	A.S.I.	Access to Security Infrastructure	9.2%	2.1%
7			0.0%	0.0%
8			0.0%	0.0%
9		for 9&10 unprotect the input sheets and expand the	0.0%	0.0%
10		question section ("+" in row 66)	0.0%	0.0%

Result

Eigenvalue Lambda: 6.151 MRE: 24.5%

Consistency Ratio 0.37 GCI: 0.09 Psi: 18.3% CR: 2.4%

Matrix

		1 A.H.F.	2 A.W.	3 A.E.	4 A.E.I.	5 A.O.G.S.	6 A.S.I.	7	8	9	10	normalized principal Eigenvector
A.H.F.	1	1	1 1/4	2 4/5	3	1 6/7	2 2/7	0	0	0	0	28.56%
A.W.	2	4/5	1	1 5/9	2 4/9	3 1/2	3 8/9	0	0	0	0	27.56%
A.E.	3	3/8	5/8	1	1 1/5	1 2/7	1 2/9	0	0	0	0	12.82%
A.E.I.	4	1/3	2/5	5/6	1	1 5/7	1 3/4	0	0	0	0	12.33%
A.O.G.S.	5	5/9	2/7	7/9	3/5	1	1	0	0	0	0	9.56%
A.S.I.	6	4/9	1/4	5/6	4/7	1	1	0	0	0	0	9.18%
	7	0	0	0	0	0	0	1	0	0	0	0.00%
	8	0	0	0	0	0	0	0	1	0	0	0.00%
	9	0	0	0	0	0	0	0	0	1	0	0.00%
	10	0	0	0	0	0	0	0	0	0	1	0.00%