University of Nairobi

Faculty of Engineering

Application of GIS in physical and land use planning:

Case study: Gatundu town

BY

Daniel Murage Gachihi

F56/33871/2019

A project report 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

July 2022

Declaration

I (Daniel Murage Gachihi) 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.

Daniel Murage Gachihi .....

Name of student 28/07/2022

Approval

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

Mr. P.C. Wakoli .....

Name of supervisor 28/07/2022

Dedication

Dedicated to my lovely wife Lucy Wangari and my son Warren Gachihi Murage.

Acknowledgment

First and foremost, I thank God for the strength he has bestowed upon me during this pandemic. I wish to acknowledge the following people for their contributions, guidance, encouragement, and financial and moral support, which have enabled and facilitated my journey in this research project. Mr. P.C Wakoli, my supervisor, whose knowledge and thoughts on the subject directed me through my research. I also thank the Department of Geospatial and Space Technology staff in the School of Engineering at the University of Nairobi, led by our chair, Prof. Faith Karanja, for the invaluable assistance, criticism, and direction throughout this study research project. I'd also like to express my gratitude to my family, friends, and coworkers for their support during this time of my study. May you all be blessed.

Abstract

Physical planning is a key tool that guides development within a local area, nationally, and globally. It is through physical planning that land uses are organized in an orderly and effective manner to achieve compatibility or coordination. GIS is an important tool that can be incorporated to bring out the spatial aspect of planning to ensure sustainable development. In Kenya, you will find that most physical planning departments within the private and government sectors have incorporated a GIS department, and both work concurrently. Several efforts by the government have also been made to achieve this, such as the (Physical and Land Use Planning Act, 2019), which gives the directive that all development plans should be GIS-based. With these efforts, however, physical planning is yet to fully integrate GIS to achieve the development of sustainable spatial plans.

This research, therefore, has identified this gap in GIS application in physical and land use planning in Kenya, the case study being Gatundu town in Gatundu South Sub County, Kiambu County, and achieved a proposed GIS-based physical and land use development plan for Gatundu Town.

The physical planning problems facing Gatundu town include uncontrolled development, incompatible land uses, urban sprawl, poor infrastructure in general and poor sanitation.

These problems are attributed to unsustainable and ineffective development plans, which can be resolved by incorporating GIS techniques to accurately analyze the land dynamics in Gatundu and aid in coming up with proper countermeasures.

The current land use has been identified and equated against the set physical planning standards and the county's existing development plans. A base map has also been generated to give the general character of the study area. Data obtained from the interviews and questionnaires administered within the study area have also been analyzed.

The study's main findings shed light on a new dimension not captured in the previous studies on GIS application to physical planning in Kenya. Despite there being various development plans in the county to guide development within the urban area, their implementation has not been realized. Therefore, this finding creates a question of monitoring and implementing these physical plans. The study has demonstrated the use of GIS-based applications in preparation and ensures monitoring and successful implementation of these plans.

Table of Contents

List of Figures

List of Maps

List of Plates

List of Tables

List of acronyms

CBO	Community-Based Organisation
CCA	County Government Act
CGK	County Government of Kiambu
ESRI	Economic and Social Research Institute
GIS	Geographical Information Systems
GPS	Global Positioning System
ISUDP	Integrated Strategic Urban Development Plan
KNBS	Kenya National Bureau of Statistics
KUSP	Kenya Urban Support Program
NCT	National Capital Territory
NMR	Nairobi Metropolitant Region
NPPD	National Physical Planning Department
NSDI	National Spatial Data Infrastructure
UACA	Urban Areas and Cities Act
PLUPA	Physical And Land Use Planning Act
PDP	Part Development Plan
SoK	Survey of Kenya

CHAPTER 1: INTRODUCTION

1.1. Background

The intent of any developed, developing, or underdeveloped country is to ensure developments that take place are sustainable in that they will sustain the country for present and future generations. This is what GIS technologies bring about when integrated into the development process. Hardware, software, and data are integrated to capture, manage, analyze, and visualize different geographically referenced data that enable to comprehend, query, construe, as well as envisage data in many ways (Judith, 1994).

Developing operative development plan strategies and monitoring their influence requires structural and practical land cover maps that display the current urbanization progression (Van Maarseveen et al., 2019). GIS, therefore, allows us to appreciate and unravel physical planning problems (Van Maarseveen et al., 2019).

The world is becoming rapidly urbanized. According to a report by the UN (United Nations, 2021), in the year 2007, greater than half of the world's population dwelled in cities. It is projected to be 60% by 2030. The study further explains that urban areas and their metropolitan areas are centers of economic growth that contribute about 60 percent of global GDP. Still, hasty urbanization is resulting in growth in slums and inadequate and overburdened infrastructure and services.

The average annual rate of urban expansion in Africa is anticipated to be 3.6 percent in Sub-Saharan Africa around the year 2030 (Reddy, 2021). Furthermore, per the UN-Habitat Condition of the World's Cities Report, 2006/7, urban development in Africa has transpired in the lack of a stable economic foundation, while the latest economic developments show mediocrely excellent GPD ratios for many nations. Because lingering impoverishment is generally widespread, urbanization as well as slum construction, are inseparably related (UN-Habitat, 2007). Exacerbating these issues, facts in 2012 reveal the slums in Africa increased at a pace of 4.53 percent annually. In contrast, overall urban production levels were 4.58 percent, practically flattening the urban growth is, therefore, a counterpart to slum development (Lwasa & Njenga, 2012). Africa is the second-fastest growing urban continent, following Asia with an average annual pace of 1.4 percent between 2010 and 2015. However, urbanization in Africa has failed to put forth all-encompassing development that, in response, has led to a proliferation of squalor, urban poverty as well as rising inequality (Barofsky et al., 2015).

Furthermore, most of the development in Africa is constituted by uncontrolled as well as uncontrolled development compounded by poor planning organizations (Pieterse, 2014).

In Kenya, each county is currently mandated by the physical and Land Use Planning Act of 2019-PLUPA to draft a GIS-oriented development plan to implement the growth of the region for another ten years (*The Physical and Land Use Planning Act*, 2019).

In the County Government's Act of 2012 importance of engaging GIS in physical and land use planning has been brought out also in UACA (*Urban areas and Cities Act*, 2011). Under part f of The County Government Act of 2012 Section 105, all counties in Kenya are required to establish a County planning unit which is mandated in establishing a GIS database system. This database is vital in general county growth (*The County Government Act*, 2012).

1.2. Problem Statement

Physical planning is the process of organizing the physical activities, and land uses to ensure logical and operative sitting and harmonization of land use. Without planning, cities, municipalities, remote communities, as well as neighborhoods will not operate efficiently. Modern Community encounters numerous obstacles, with pollution and traffic congestion being the primary ones. Careful and creative planning can address these issues (ESRI, 2006).

Kiambu County is among the counties in Kenya that have embraced GIS technology in its physical planning operations (Mutua, 2017). The county is, however, facing challenges due to its growing urban population as the existing infrastructure and amenities such as water, sewer, electricity, schools, commercial spaces, and recreational and industrial facilities cannot sustain the urban population. The development plans present at the moment are not sustainable enough to tackle these challenges faced by the towns in Kiambu, such as Gatundu town.

Kiambu County is about 41% rural and 59% urbanized, which is attributed to the city's, I.e., Nairobi's steady urban drift to the north. Out of this 60% urban population, Gatundu town, which is my study area, as of 2019, had a population of 13,000 (KNBS, 2019). The town is rapidly growing exponentially, mainly along the transport corridor. The town's previous planning attempt was made in 2009 for the then town plots, which covered less than 1 square kilometer compared to today's size of approximately 9.91 square kilometers. This part development plan was not approved (Gatundu Town Part Development Plan, 2009).

Plate 1: Photos of Gatundu's Current Situation

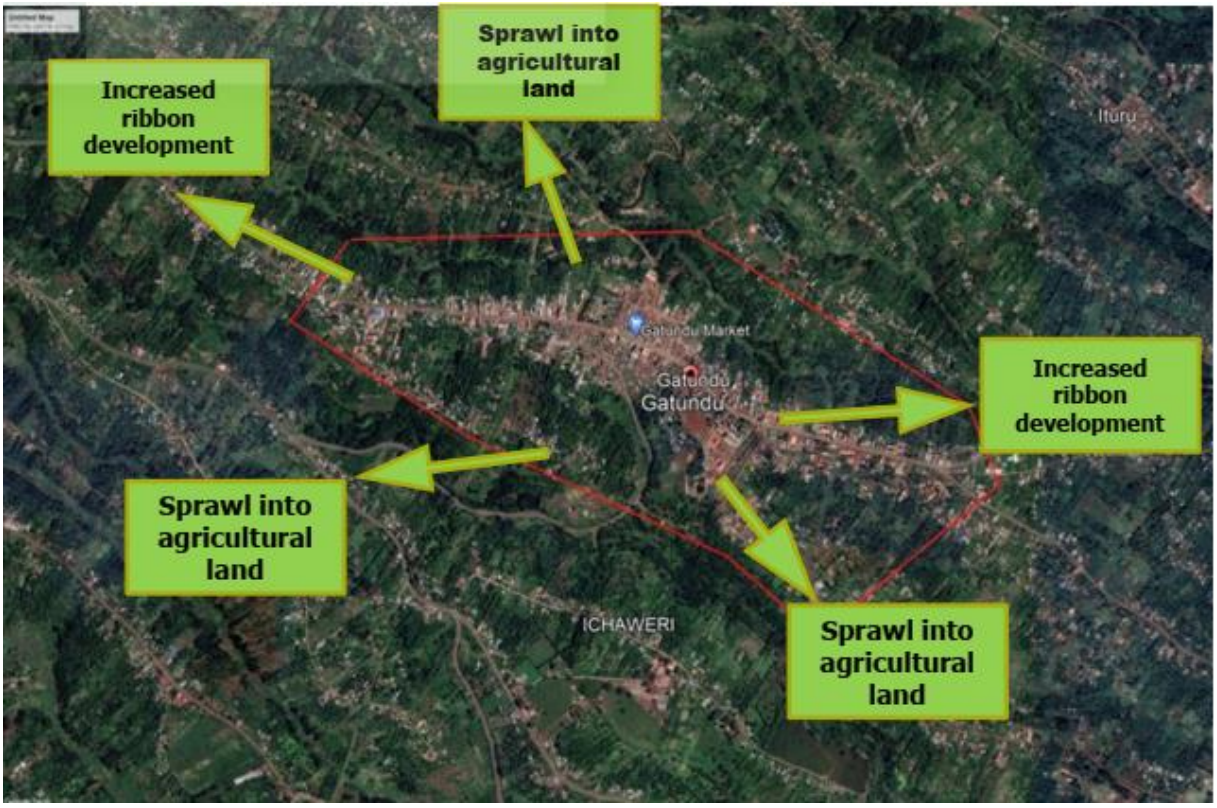
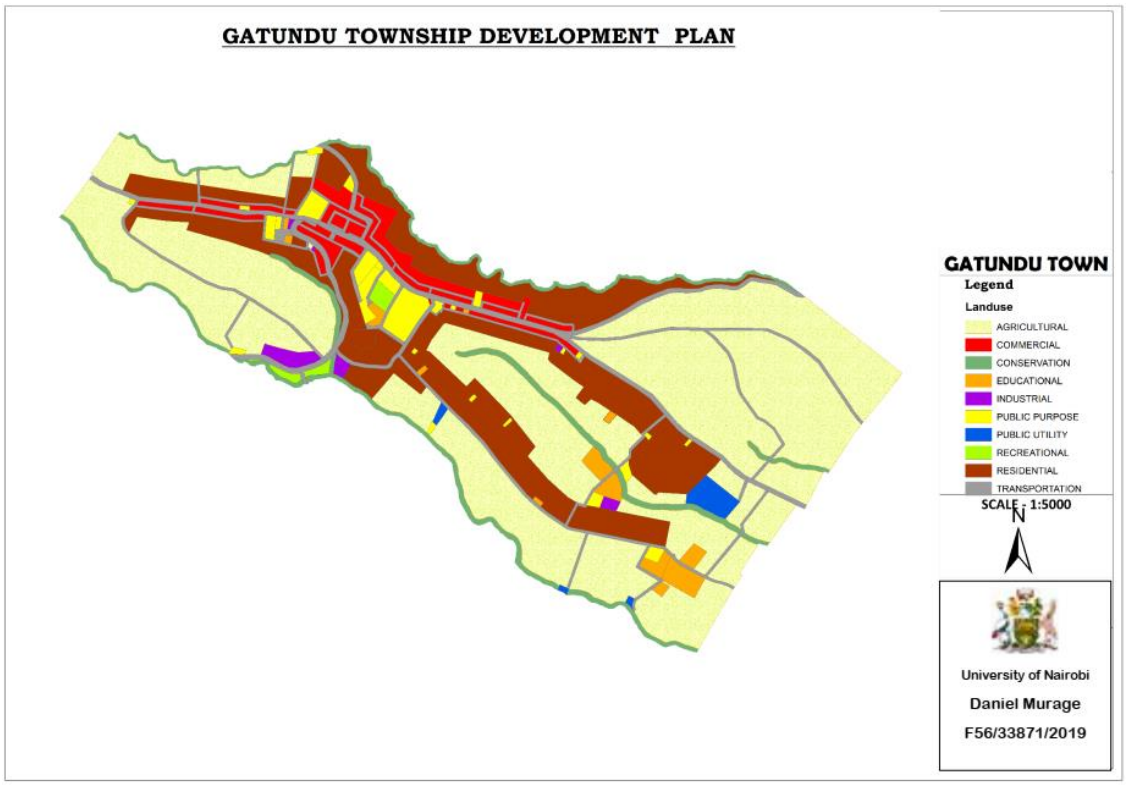


Plate 2: Problems in Gatundu

Like in many towns in Kenya, the main problems facing Gatundu town are uncontrolled land use changes and urban drift. The area surrounding the town is mainly agricultural, but in the recent past, the agricultural land has been converted to urban use and subjected to uneconomical subdivisions.

Urban sprawl in the town has led to overloading of the sewer line, road reserve encroachment, water wayleave encroachment, riparian land encroachment, and uneconomical land subdivision. The town lacks sustainable development plans to guide development, giving room to haphazard development that does not conform to any planning standard.

A more effective approach to achieving sustainable and efficient physical planning is the use of GIS and remote sensing both in the development of physical plans as well as their monitoring and implementation so as to provide a good basis for constructive decision-making both nationally and within the county level.



Map 1: Previous planning attempt map of the Study Area

Incompatible land uses are also a challenge in the town. GIS-based physical and land use development plans will resolve this challenge and guide the development of zones. Due to the lack of comprehensive rezoning guidelines as well as the current state of affairs, it is challenging for a designer to distribute such areas without overlooking certain critical variables that must be considered. GIS is advantageous for coordinating such activities and determining the ideal location for allocating multiple services per their particular requirements.

1.3. Study Objectives

1.3.1 Main Objective

The main study objective was to apply GIS to the development of a proposed physical and land use development plan for Gatundu town.

1.3.2 Specific objectives

The specific study objectives were

1. To produce a Land Use / Land Cover map of Gatundu Town.
2. To prepare a proposed Physical and Land use development plan for Gatundu Town.

3. To assess the conformity or otherwise of the existing physical development of Gatundu to the proposed physical and Land use development plan.
4. To make recommendations on the implementation of the proposed plan.

1.4. Study Justification

The purpose of this project is to use GIS to create a proposed Physical and Land use development plan for Gatundu Town (*The Physical and Land Use Planning Act*, 2019).

This suggested development plan will demonstrate how geographic information systems (GIS) can be integrated into Physical and Land use planning. It is also aimed to benefit the County Government of Kiambu in the development control and urban management of the Gatundu town. It also aims to benefit the entire metropolitan being part of the larger Nairobi metropolitan region.

The residents of Gatundu south stand to benefit from well-controlled development, which will be more productive. The plan will align with the Physical and Land Use Planning Act, which requires that all counties prepare a GIS-based Physical and Land use development plan every ten years *(The Physical and Land Use Planning Act*, 2019).

The GIS-based development plan is also in line with the requirement of Kenya Vision 2030, the National Spatial Plan (2015-2045), the National Land use Policy (2018), and the National Land Policy (2019).

1.5. The scope of work

This research has covered the town core of Gatundu together with its environs. That is where the urban has sprawled towards. The size of the study area is about 9.91 square Kilometers per the urban boundaries done by Kenya Urban support programs (KUSP, 2020).

In this project, GIS has been used in supporting, informing decisions in planning for Gatundu town and preparing maps that will guide the future growth and management of the town; the maps will be the reference tools for development control.

Since modern planning methodologies require multi-sectoral analysis, it requires a broad, up-to-date database. A GIS-based physical and land use development plan will ensure improvement of the quality of information supplied to the planners, policy, and decision-makers. This will, in turn, improve the quality of planning and implementation of development plans.

In conclusion, this study has provided a practical and adaptable proposed physical and land use development plan for Gatundu Town.

1.6. Report organization

The following chapters comprise the structure and organization of this study report.

Chapter 1: Introduction. The section gives a summary of the background to the application of GIS to physical planning, highlighting its evaluation problem in terms of efficiency and completeness. Secondly, it dwells on the study's aims, rationale, methodology, as well as hypotheses.

Chapter 2: Overview of relevant literature. This section has capitalized on the use of GIS in planning trends focusing on the Global Context, African Context, and Regional Context. The chapter covers an examination of literature relevant to the theories and emerging issues for sustainable physical planning. The chapter culminates with the design of a conceptual framework to ensure sustainable physical development plans in Gatundu town, Kiambu County.

Chapter 3: Materials and Methodology. This section has discussed the original study information sourcing strategy, methods, and geographical approaches.

Chapter 4: Research findings, analysis, and discussion. This section involves the presentation and interpretation of the findings. The presentation involves the use of visual presentation such as the generated maps and the display of data in tabular format. This is followed by using spatial thinking to identify patterns and interpret the output.

Chapter 5: Conclusion and recommendations. This chapter concludes the report by providing the summary of this research findings and later provides suggestions for further study.

CHAPTER 2: LITERATURE REVIEW

2.1. Issues Definitions

2.1.1. Physical and Land Use Planning

When defining what physical and Land Use planning is, one can take the literal meaning of the term and actually grasp the meaning the term. However, several studies have been conducted, and different scholars have defined this term in their own words.

GEMET's (2021) article defines Physical and Land Use Planning as a kind of land use planning in an urban setup that tries to realize an ideal spatial organization of various human activities to enhance one's standard of living.

Vallabhaneni (2014) gives a more detailed definition in his article, Physical Planning in Town Planning. He defines physical planning as the overall design of land use, the distribution of public buildings and structures, street design, and other facilities necessary to promote economic growth (Vallabhaneni, 2014).

2.1.2. Definition of Land Use planning

Cendrero et al. (2021) define Land use planning as a means for managing a variety of important human activities by controlling and designing which man uses land and the resources available.

Another adaptable definition given to land use planning is given by GEMET (2021) article, which labels it as a crucial element of an integrated plan that designates the location and intensity of development for public, and private land uses.

2.1.3. Definition of Geographical Information Systems (GIS)

Bareth (2009) defines GIS as a device-based information system that offers multiple capabilities for geographically referenced, land-related data and information, including input data, system integration, analysis techniques, selection and data output, and distribution.

In yet another news piece by Burrough (1986), the terminology is defined as an effective toolset for accumulating, recording, fetching at will, converting, to divide real-world data in line with a specific variety of reasons Cowen (1988). Furthermore, Cowen (1988) defines a scheme for facilitating strategic planning which incorporates spatial data in dilemma surroundings.

2.2. Conceptual perspective

Dhanabalan (2008) explains that land use planning and physical development are related and are an important combination. Various urban planning issues lie in poor planning and hence unequal resource distribution. Traditional methods of physical planning and land use cannot solve or cannot be used in solving today's urban crises. This is because people and technology keep changing with time Dhanabalan (2008).

2.2.1. Sustainable Development Concept

Sustainable development is a concept that, at its core, is revolutionary but still hard to define (Anon, 2011) rationally. Blewitt (2018) defines sustainable development as the act of sustaining productivity by substituting used resources with those of the same or even greater worth without negatively affecting the natural biotic systems (UNESCO, 2015).

Chemin et al. (2006) explore various ways GIS can be applied to achieve sustainable development. He explains that GIS is a tool in planning for sustainable development, which is done by maintaining an up-to-date database that will ensure monitoring of land and land resources as well as the implementation of the developments.

2.2.2. Spatial Planning Concept

Acheampong (2018) explains that the spatial planning concept originates in Europe, where it has been used to mean the creation of systems used by governments to affect the supply of activities in space. It expands on this notion by defining it as "a collection of administrative methods for establishing as well as implementing initiatives, budgets, programs, including undertakings, as well as for controlling the place as well as the pace of growth."

According to Morphet (2010), the notion incorporates social, financial, but also sustainability problems across multiple spatial scales. In summary, spatial planning implies a growing organizing ideology and a shift in the institution's mindset, as it is all-inclusive in character and highlights the importance of collaborative working, cooperation, and collaboration across various actors.

2.2.3. Integrated planning concept

Integrated planning as a concept is an approach to planning that aligns the organization and emphasizes preparedness (Niemelä, 1999). It is an iterative cross-functional process that ensures all stakeholders are involved in the planning process. This ensures that the resulting development

plan represents the needs and suggestions or the needs of all these stakeholders. Therefore, an integrated planning approach is achieved through public participation, which is an important part of making physical plans.

2.2.4. **Conceptual framework**

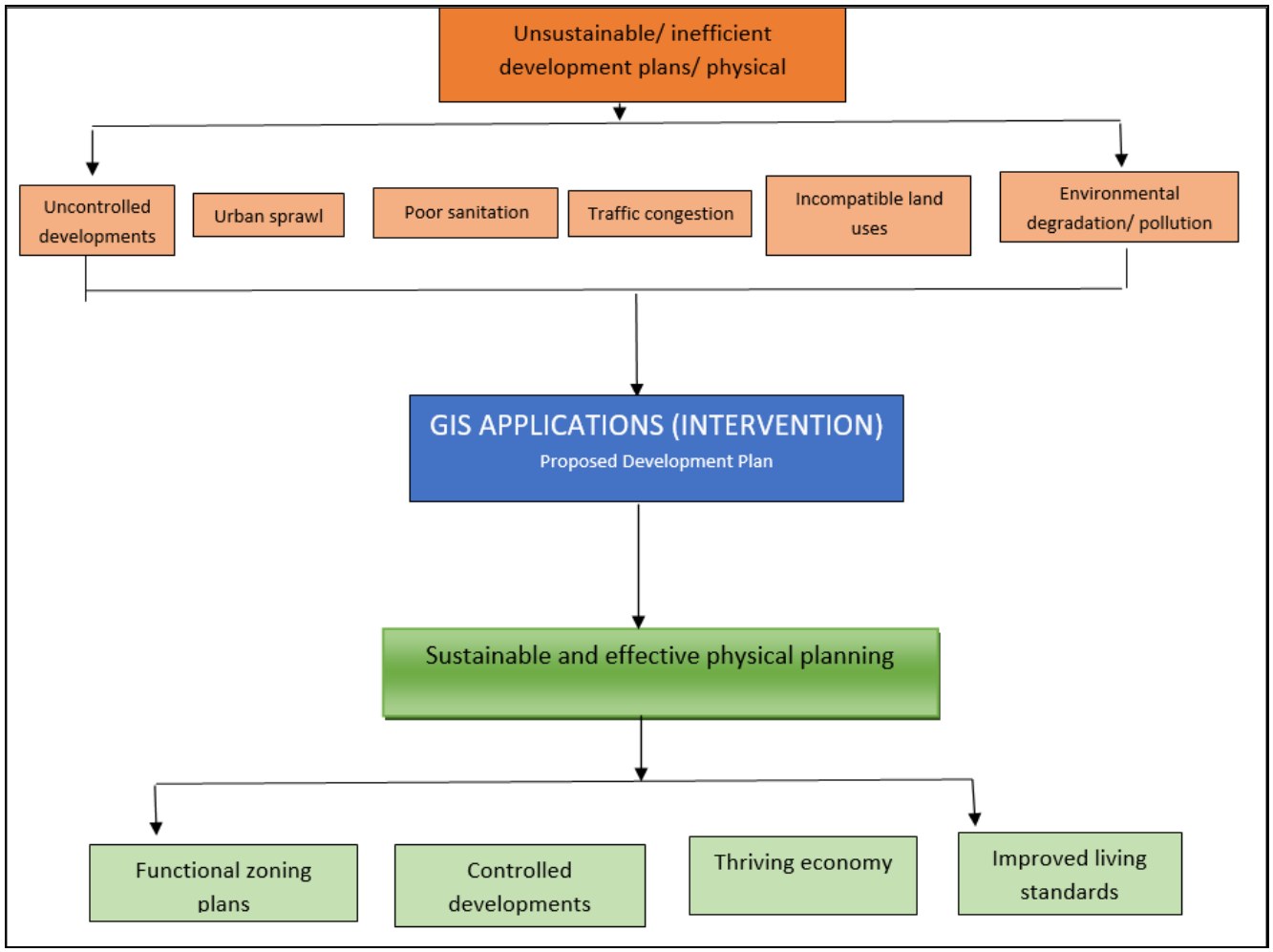


Figure 1: Conceptual Framework.

2.3. Theoretical Perspective

Throughout history, considerable focus has been given to the necessity for the planning system to enlarge its boundaries, both conceptual and practically. For example, between the 1960s and 2000, the rebirth of strategy and governance reemphasized the tactical as well as geographical components of design (Albrechts, 2001).

2.3.1. The Rational-Comprehensive theory.

According to Sandercock (1998), this theory proposes a systematic judgment approach that aims at enhancing the attainment of intended objectives by a rigorous understanding of the possible repercussions of accessible options. Sandercock (1998) bases his argument on the theory's emphasis on technological experience and skills, including its unwavering conviction in the ability of technological and human sciences to address issues. Like technical expertise, GIS is overwhelmingly backed by this notion, as its integration with structure plan results in more fact-based making decisions. Because of the actual judgment procedure, this concept has been dubbed the operational management concept (Faludi, 2000). Continues by stating that the organizer relies on first-hand knowledge, which he or she thinks about and contextualizes.

2.3.2. Modernization theory

According to an adaptation of the modernization theory by Rostow (1962), Least Developed countries should follow the path developed and industrialized societies take in their pursuit of moderation. This includes integrating modern ways of dealing with the current problems facing society, such as the use of modern technology and, in this case, GIS.

2.3.3 The advocacy theory

This theory was given by Davidoff (2007), who identified three kinds of groups involved in planning that is the political parties in power or opposition, the special interest groups, and Ad-hoc associations protesting against existing policies. This theory, therefore, gives importance to public participation in planning which ensures the interests of everyone are represented. Davidoff (2007), as an activist lawyer and planner who believed in advocacy, further identified this theory as a diverse theory where planners aim to represent the interests of several groups.

2.3.4 Urbanization

Perceptions in urbanization shift the focus of inequality to dis-articulation between urban and rural communities (Lipton, 1977). The main argument, pushed by theorists such as Bradshaw

(1987), argues that development favors urban communities where economic elites amass political power and compose policies to their advantage, disadvantaging the underdeveloped rural communities (Bradshaw, 1987). Weede (1996) further explains how benefiting urbanized setups increases the disparity between urbanized and hinterland areas that keep rural communities poor and powerless. It is important to recognize how unequal development may stem from such patterns, mainly due to the significance of urbanization to social evolution.

2.4 Introduction of GIS in Urban and Regional Planning

Kheir (1995) states that "preparation of physical development plan, as well as GIS, owns a lengthy tradition of collaboration." Experts highlight how GIS has its origins in initial 1912 urban planning for regions like Dusseldorf, Germany, as well as Billerica, Massachusetts, in which information was pulled from one chart and then transferred to others in the form of separate zones. GIS started spreading further on the consumer scale in the late 1980s and early 1990s. When GIS became accessible on laptops, it became increasingly significant to a wider variety of commercial customers (Castle, 1993).

Harris & Elmes (1993) reported that, as early as 1993, North America began experiencing a transformation in the integration of machine GIS into development. Geographic Information Systems (GIS) have been used for scheduling and resource control around the globe since the mid-1960s. Additionally, it was noted that inculcating GIS into organizing was likely due to growing consciousness, organizational acceptance, declining system costs, product variety, the emergence of microprocessors, and the accessibility of Personal Computers (PC) based GIS operating system during the early 1990s. Nour (2011) adds that in the early 1960s, a university professor of Washington produced a few of the earliest computer geographic information system, which was used in a program to survey Canada's national environment.

2.5 Geographic Information Systems (GIS) in Physical and Land Use Planning

As indicated by Dhanabalan (2008), GIS plays a major role in Physical and Land use planning. This is by the fact that GIS has the capacity to integrate different data sources and analyze different data to get results. It also makes it easy for data storage, retrieval, and flexibility in data updating. This plays a huge role in monitoring changes in Physical and land use planning, with the development and invention of easy-to-use and establishment of GIS and related software and the price reduction of GIS hardware (ESRI, 2006).

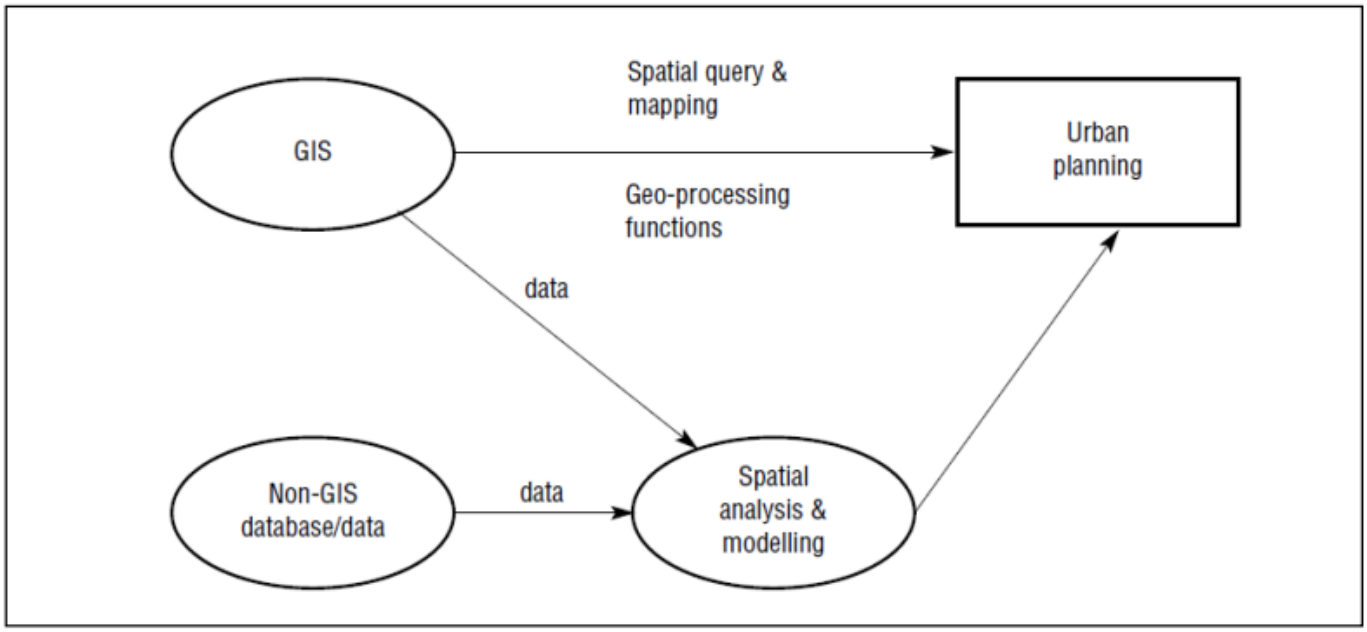


Figure 2:Involvement of GIS and Urban and Regional Planning

GIS is applied in many disciplines of physical and land use planning Figure 2 Indicates how GIS is combined with other functions to spice up functional physical and land use planning (ESRI, 2006).

Another GIS application in planning is the case of New Delhi, India, where the city is expanding outside the unplanned areas of the National Capital Territory (Diwakar, 2021).

With the exception of expanding urban centers, cities have other difficulties like random and uncontrolled development in all dimensions, leading to issues with basic facilities like water systems, sewerage, transportation, accommodation, and solid waste disposal.

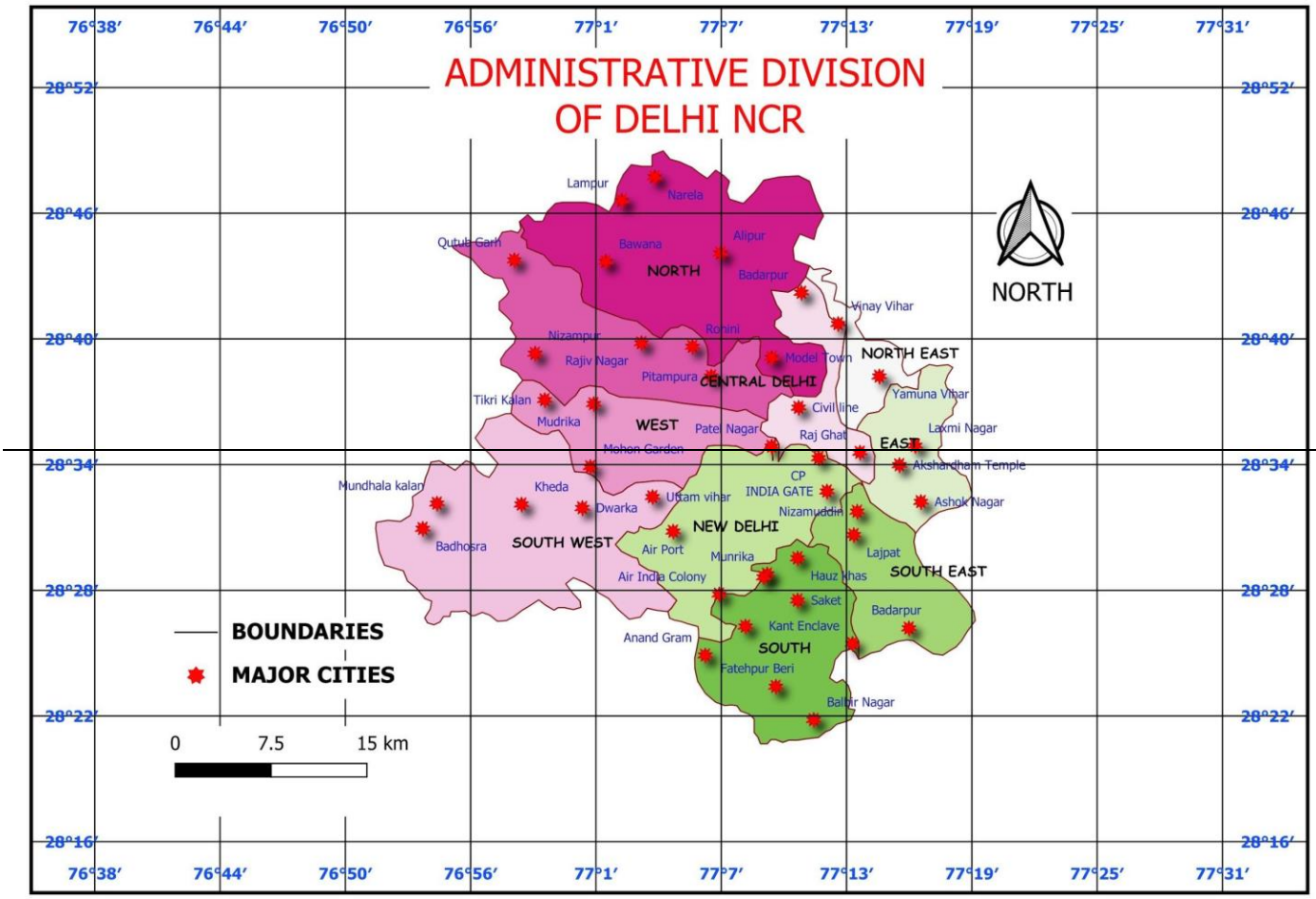


Figure 3: Use of GIS in controlling urbanization (Diwakar, 2021).

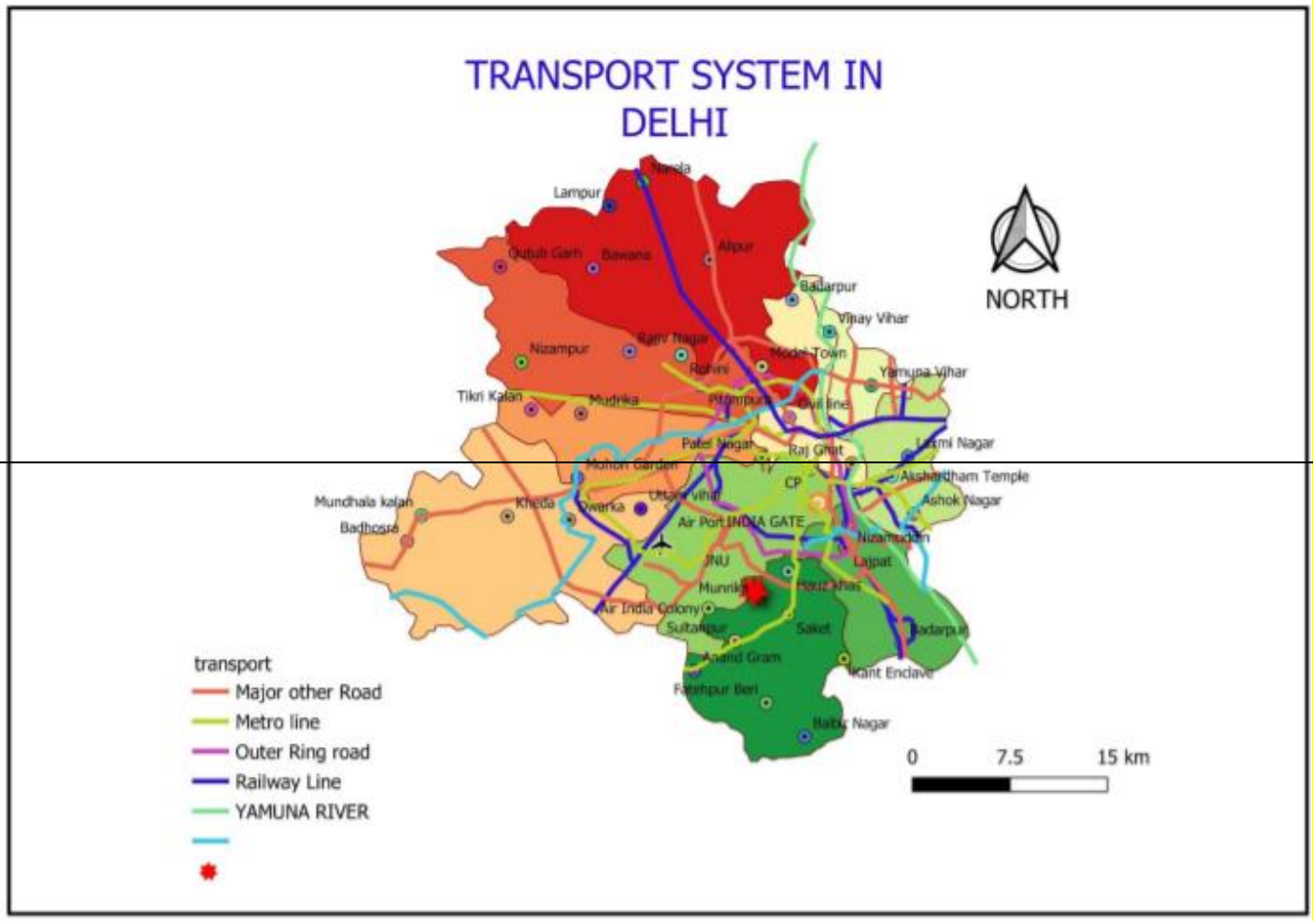


Figure 4: Use of GIS in controlling urbanization (Diwakar, 2021).

CHAPTER 3: MATERIALS AND METHODOLOGY

3.1. Introduction

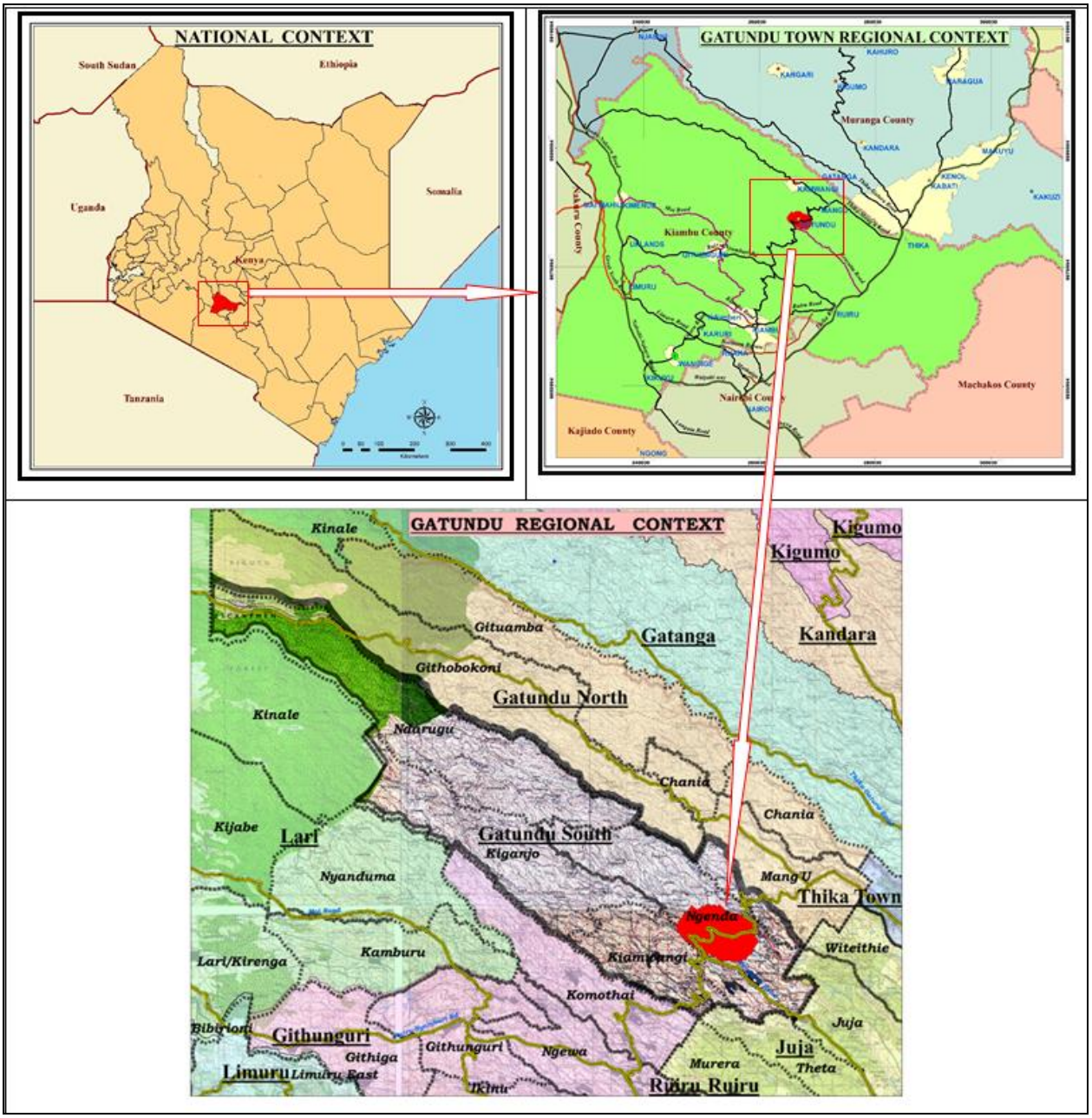
In this research study, GIS application in physical and land use planning has been used in beefing up elements over the previous physical and land use planning techniques. A physical and land use development plan is intended to guide development in a defined area over a certain given duration, such as a 10-year plan. This helps in attaining optimal growth and sustainable development. The plan helps in guiding development and other activities in an area.

This study used a quantitative approach to research. GIS was the main tool used to analyze spatial data obtained as one of this study's objectives is to look into the existing developing plans and consider whether they follow the set planning guidelines. It, therefore, revolved around collecting, evaluating, and analyzing relevant data and information that was used to answer questions posed by the research's objectives.

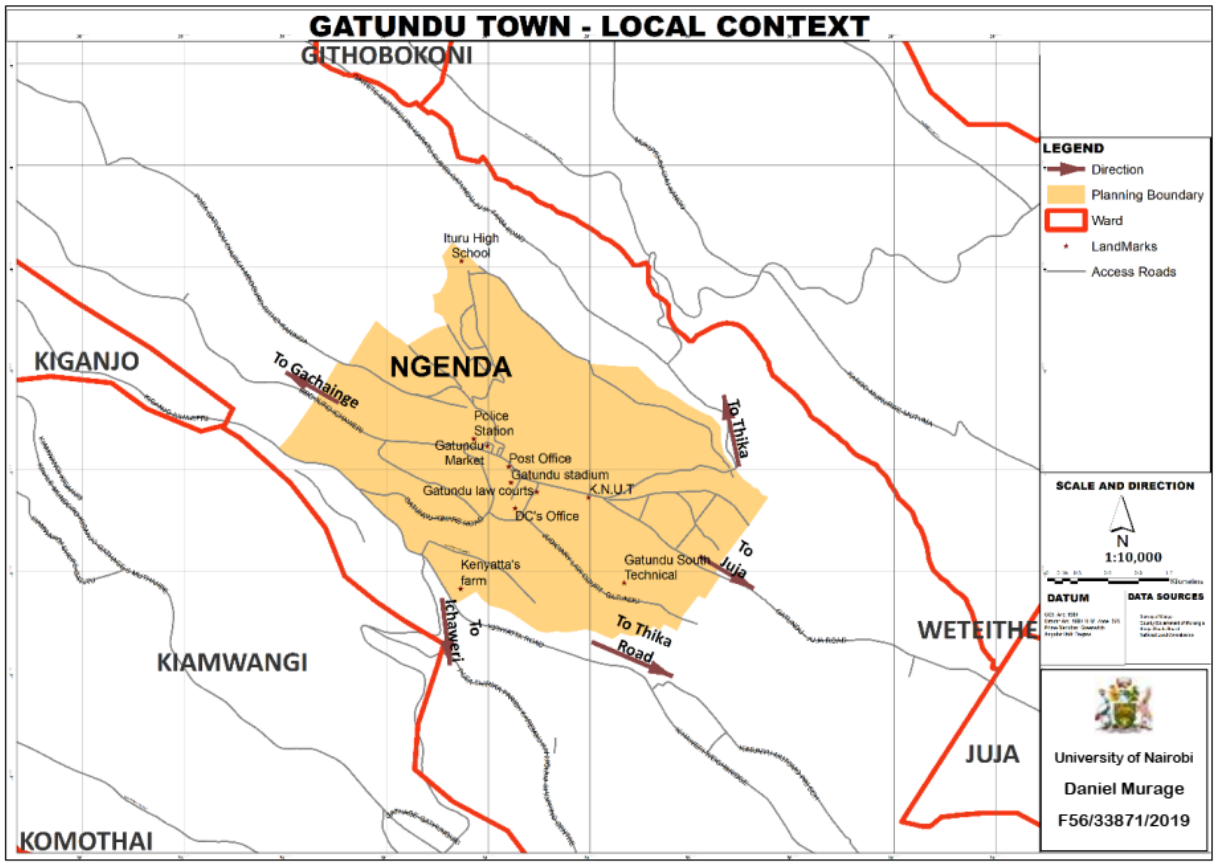
3.2. Study Area

The study area covers an area of 990 hectares and falls within Ngenda ward, covering parts of 4 sub-locations: Githunguchu, Ituru, Kirangani, and Kimunyu. Gatundu township serves as the administrative town of the larger Gatundu South sub-County in Kiambu County.

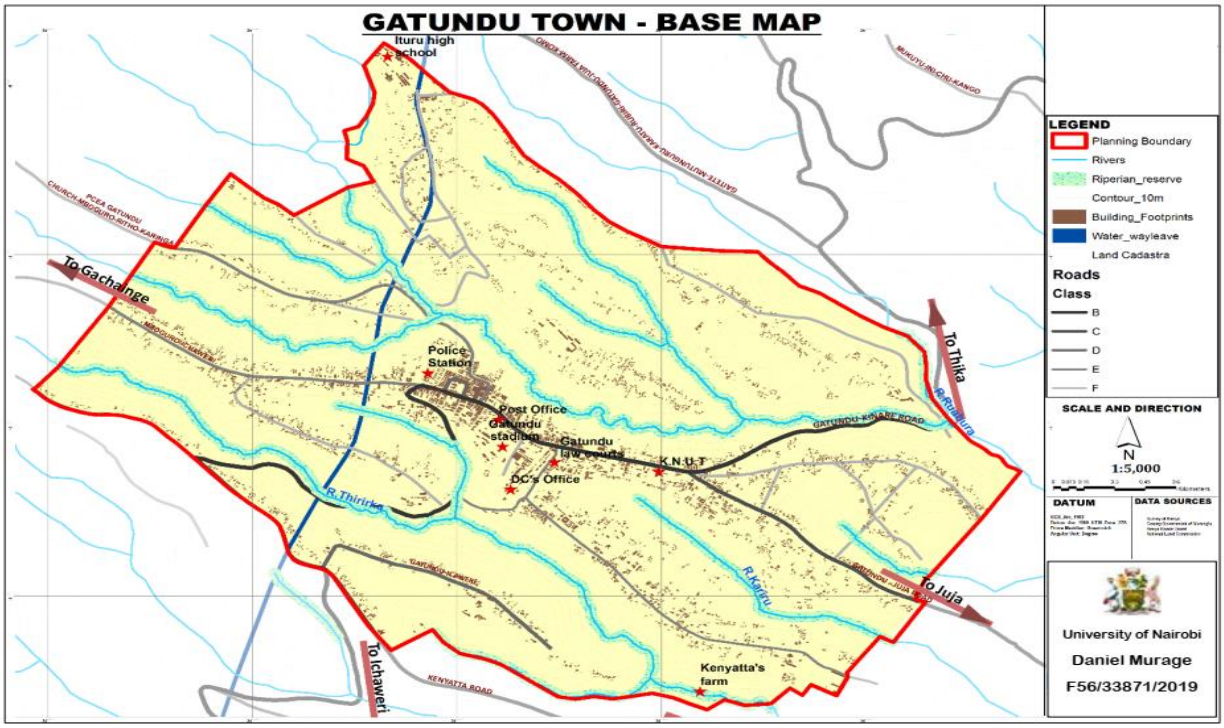
The main road cutting through the town is Gatundu – Juja Road. The town is connected to the Thika Super Highway through Kenyatta Road. The maps below, i.e., map 3 and map 4, show the location of the study area in relation to the national and regional context.



Map 2: Location Context of the Gatundu Town (Kenya, 2022)



Map 3:Local Context Map of Gatundu Town



Map 4:Base Map of the Study Area

3.3. Project considerations

3.3.1. Current Land use

The study area is about 990 Ha and covers enough area, which includes almost all land use zones apart from conservation/protected areas. So, various land uses are well shown in the study. Gatundu town is experiencing unplanned rapid urban growth. This has been evidenced by converting agricultural use to commercial and residential multi-dwelling uses and also uneconomical land subdivisions. This growth has occurred in the absence of a plan or planning regulations to guide the development. Reasons being:

a) Gatundu town lacks established development control tools, for example, the GIS-based integrated Physical and Land Use Development plan, which is current.

b) The main land use in Gatundu is an agricultural area. The dominant land tenure is freehold. This tenure is subject to misuse since the owner reserves absolute rights.

c) Uneconomical land subdivisions without a recommendation from physical planners.

d) Absence of updated physical and land use development plan for Gatundu.

e) 6M roads all over the town ignoring planning standards and guidelines

Modern-day land use has come about evidently through the compelled capitalistic market and agglomeration economics (Butler et al., 2010).

3.3.2. Standards of Land use in Physical Planning.

In line with the Ministry of Lands and Physical Planning (2007), a plan has nine different land uses. These land uses are presented in a plan using the stipulated color and codes. The area is shown below;

Table 1:Land use color codes and zone numbers (planning, 2007)

Zone Number	Land Use	Color Name	Color
00	Residential	Brown	
01	Industrial	Purple	
02	Educational	Orange	

03	Recreational	Green	
04	Public Purpose	Yellow	
05	Commercial	Red	
06	Public Utility	Blue	
07	Transport	Grey	
08	Differed	-	
09	Agricultural	Pale yellow	

3.3.3. Land Use Allocation

Allocation for various Land Use and size is determined by considering various factors, some being;

The intended use of land- Land uses like agricultural use needs a large area to achieve the intended results from their activities. Other land uses also dictates the size in line with the requirements; educational use requires a bigger size than residential(Butler et al., 2010).

Availability of land- Land Use allocation has been done in order of priority in case of land scarcity. Auxiliary uses are not prioritized example, recreational facilities.

Catchment Population- Land Uses such as schools and hospitals are largely influenced by the population they are serving and the distance from one institution to another. For example, the public primary school has to serve within a radius of 2km. This also influences the location of the land use.

This guides the planning process when it comes to developing the proposed physical and land use development plan for Gatundu.

3.4. Spatial and Non-Spatial Data

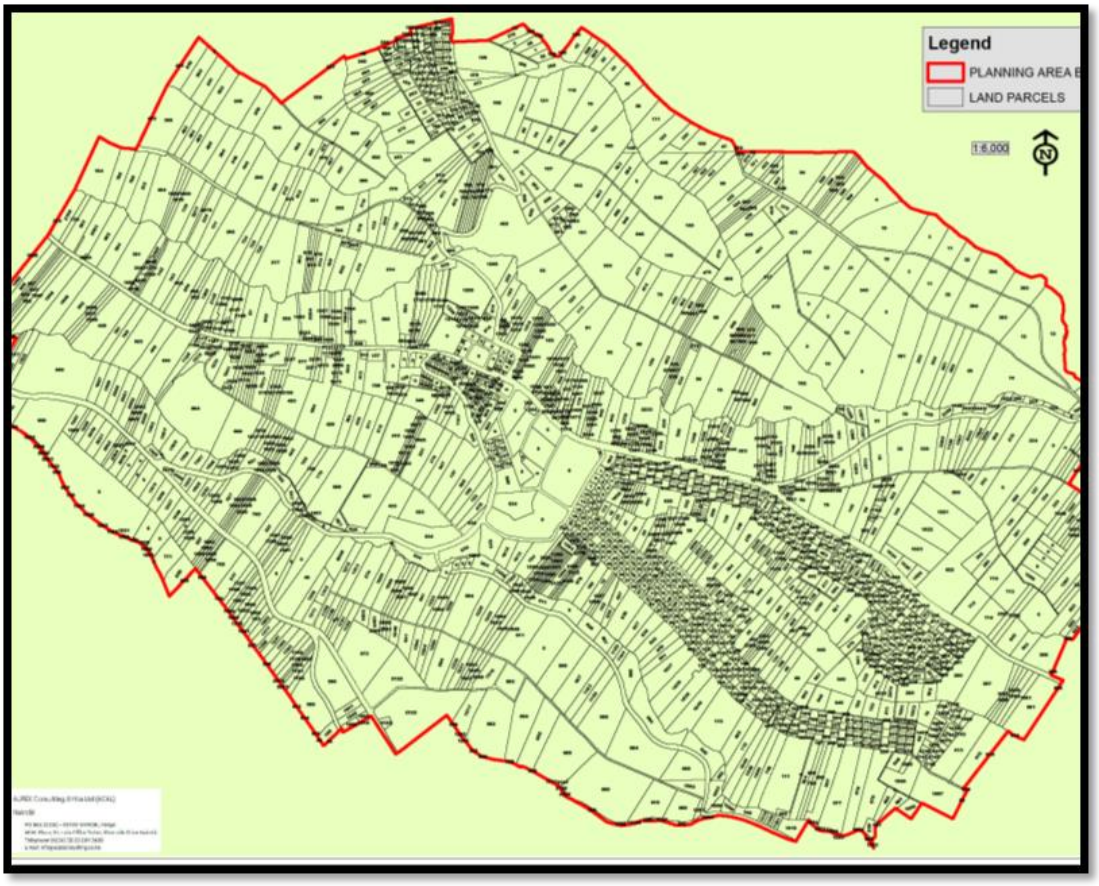
3.4.1. Spatial Data

Spatial data is data that gives the geo-position of a feature. Spatial data is the same as geographic data or spatial information. The data can be captured, analyzed, manipulated, and stored using GIS to make maps and inform planning decisions (Ormsby, 2001).

For this study, geographic data was obtained from georeferencing the area Registration section maps-RIM obtained from the survey of Kenya, Google earth image, and various data sets all georeferenced.

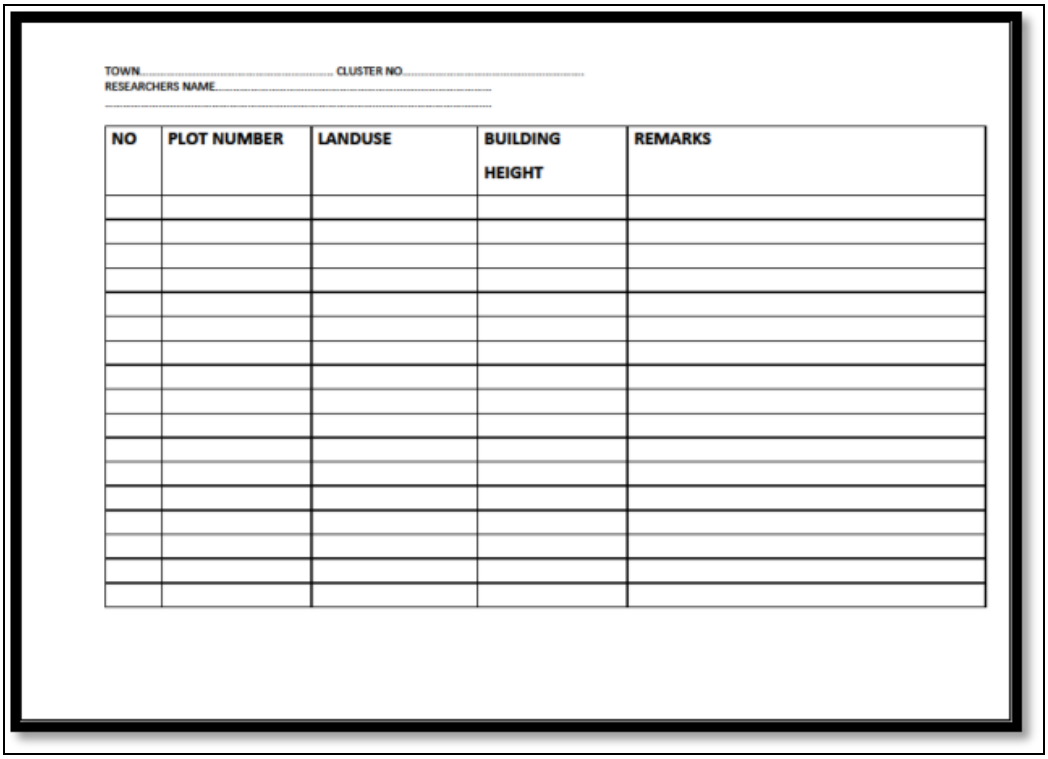
The physical collection of spatial data was done by use of submeters accuracy GPS and also filling the field mapping sheet, which informs the base map to capture the current land use;

The Submetres GPS, mapping sheet, and field map are as shown below;



Map 5:Cadaster map showing plot numbers for easier reference when capturing the current land use

Plate 3: GPS used during data collection



TOWN..... CLUSTER NO.....
RESEARCHERS NAME.....
.....

NO	PLOT NUMBER	LANDUSE	BUILDING HEIGHT	REMARKS

Plate 4: Data Sheet used during Data collection

3.4.2. Non-Spatial data (Attribute data sets)

This type of data describes a feature without the aspect of geo-location. The data is saved in tables and connected to the cited functions by using a particular identifier. Some of the non-spatial data are Dominant Land Use, Building Height, Plot owner, and zone code (Ormsby, 2001).

It's also called attribute or characteristic data. This is information that was independent of all Geometric considerations. Non-spatial data of the town included its name, population, land uses, road names, proposed land uses, and existing institutions. Of importance to note is that, this data was not dependent on their location identity. This kind of data was stored in GIS tables having rows and columns where each row shows a spatial feature, and each column represents a certain characteristic.

Table 2: Data and their Sources

No.	Data	Source
1.	Roads	ArcGIS online KRB
2.	Contours	Kenya Data
3.	Rivers	I'll website
4	Buildings	Mappable
5.	Cadastral boundaries	Survey of Kenya
6.	Land use zones	Mappable and fieldwork

3.5. Software and equipment

Tables 3 and 4 show the equipment and software used to complete the project.

Table 3:Equipments used during data collection

Device	Type	Function
Laptop	HP ENVY x360 • Operating System- Windows 10 • CPU- Intel Core i3/i5/i7 U series • Memory-8GB	Data analysis and manipulation using GIS Report typing Storage of data

GPS	Sub-meter GPS • Accuracy of 1m	Collection of ground points for various landmarks and control points
Printer	HP T525 • Plotter Large format • Sharp and True-color prints • Wi-Fi printer	Printing large format maps for field work, A1 size Printing report
Camera	Samsung S21 Ultra • 512GB 12GB RAM	Taking photos during fieldwork in the study area

Table 4: Software/Program used during data collection

Software/program	**Model**	**Function**
ArcGIS	ESRI10.5	Creating Maps. Analysis and manipulation of data.
Office Word	2016	Word for typing the report.
Office Publisher	2016	flow chats creation
Office excel	2016	Pie charts creation
Google earth pro	2018	Obtaining aerial satellite images

3.6. Methodology

This research study utilized both primary and secondary sources of data collection. The data collection entailed both qualitative and quantitative techniques. The research study was guided by the below methodology steps.

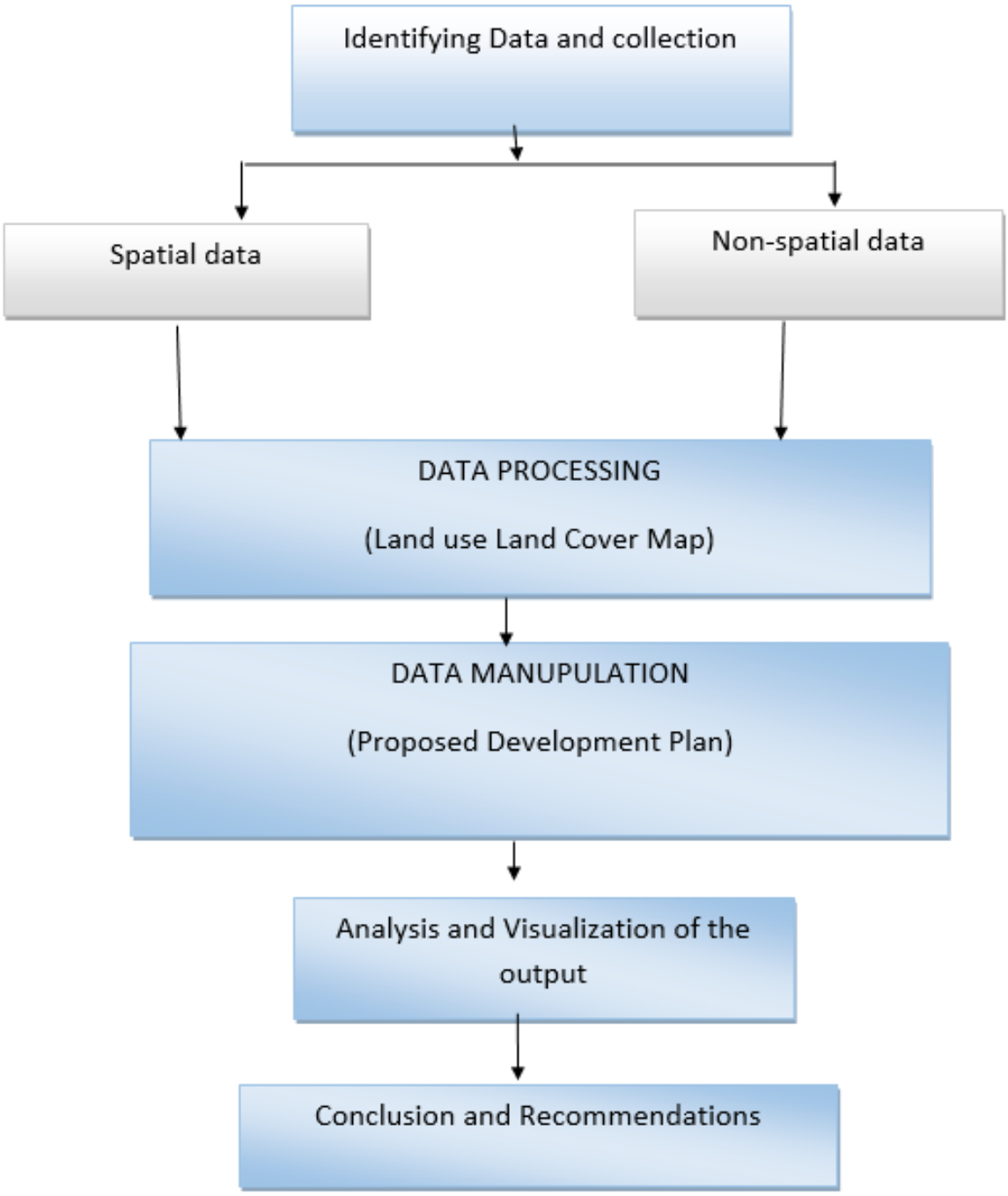


Figure 5: Methodology framework

3.7. Data preparation

This is the process of assigning data (raster/vector) to a specific location in relation to earth's The coordinate system contains a latitude and longitude). The township maps were scanned and they were georeferenced in the ArcGIS environment. The sheet was digitized, and the table of contents had features like plot number, Dominant Land Use this is the land use in a plot which

takes over 50% of the use, Landmarks. This was per polygon being the plot format georeferencing was done using the following parameters UTM Arc 1960 zone 37 M.

3.8. Identifying the Study Area

Gatundu Town boundary was deduced from the existing ward boundary, i.e., Ngenda ward. The google image of the area was downloaded from google search using a universal map downloader, then loaded to ArcMap 10.5 and georeferenced in line with the registred index maps for the Ngenda/Kimunyu registration section.

Then from the RIM sheets, cadaster boundaries were digitized for easier capturing of dominant land use on each parcel.

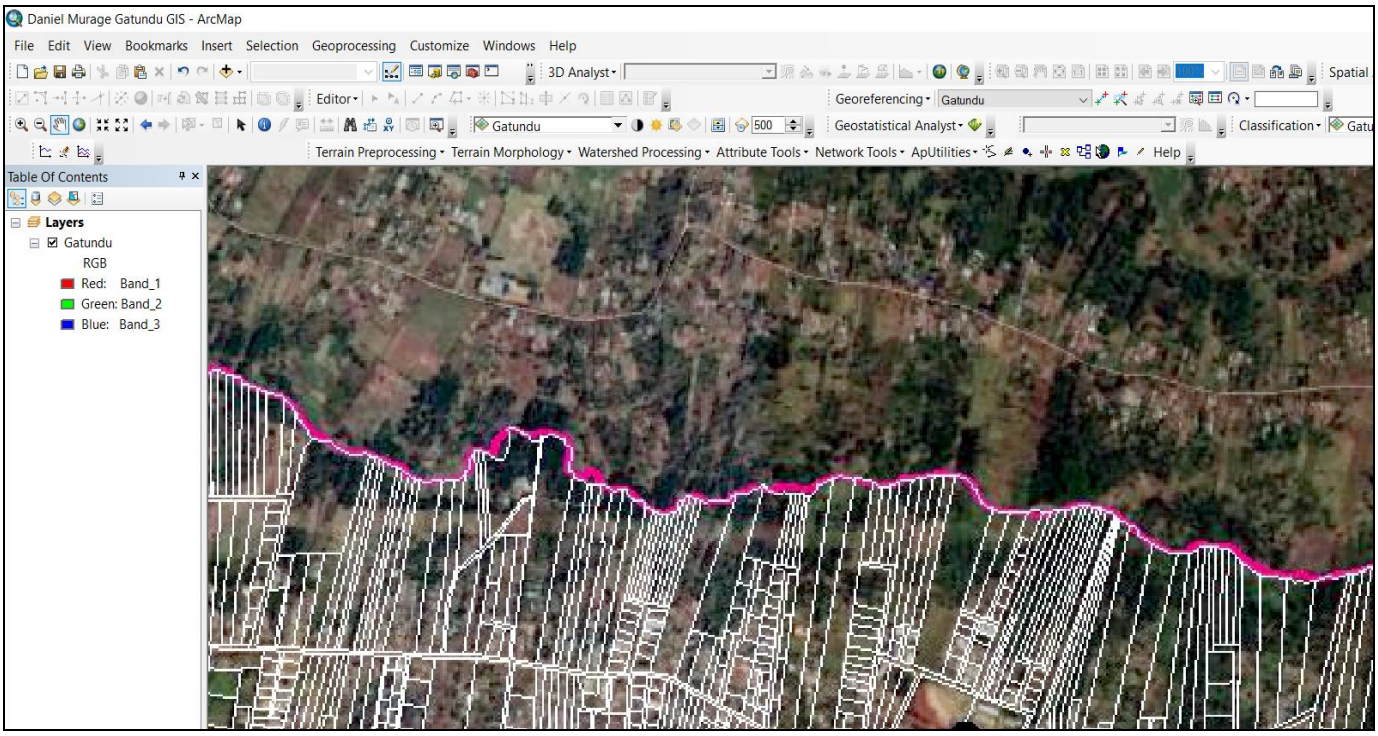


Figure 6: Creation of Land Use Land Cover shapefiles

The shapefiles were designed to capture the spatial and non-spatial data from the RIM, the google satellite image, and the land cover data from different sources. This data was stored in a geo File called "Gatundu Digitization" in this File Geodatabase.

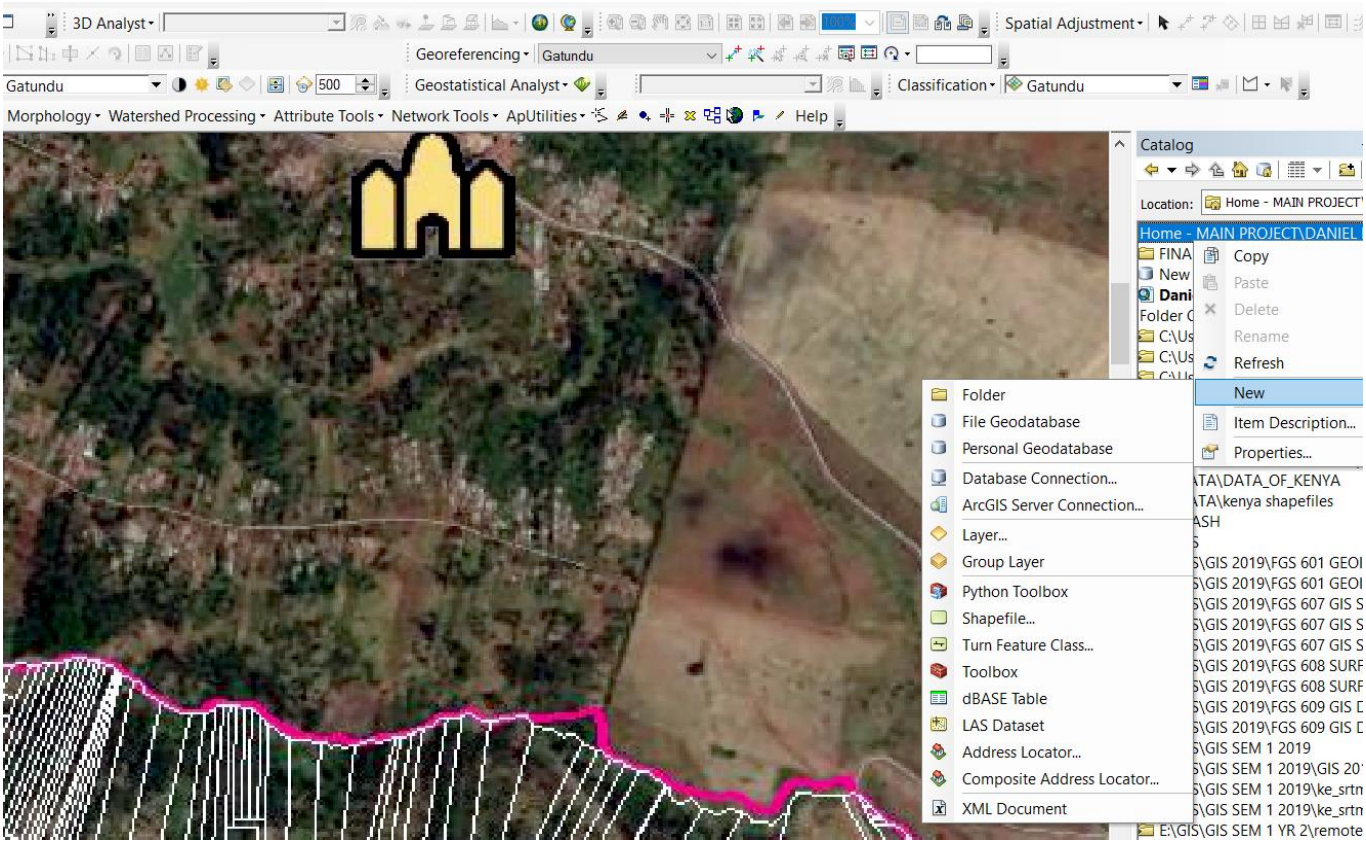


Figure 7: Creation of file geodatabase

3.9. File geodatabase creation

In GIS Arc Catalogue, a new file geodatabase was created, which held all data for the research project. The figure below shows how the file geodatabase was created.

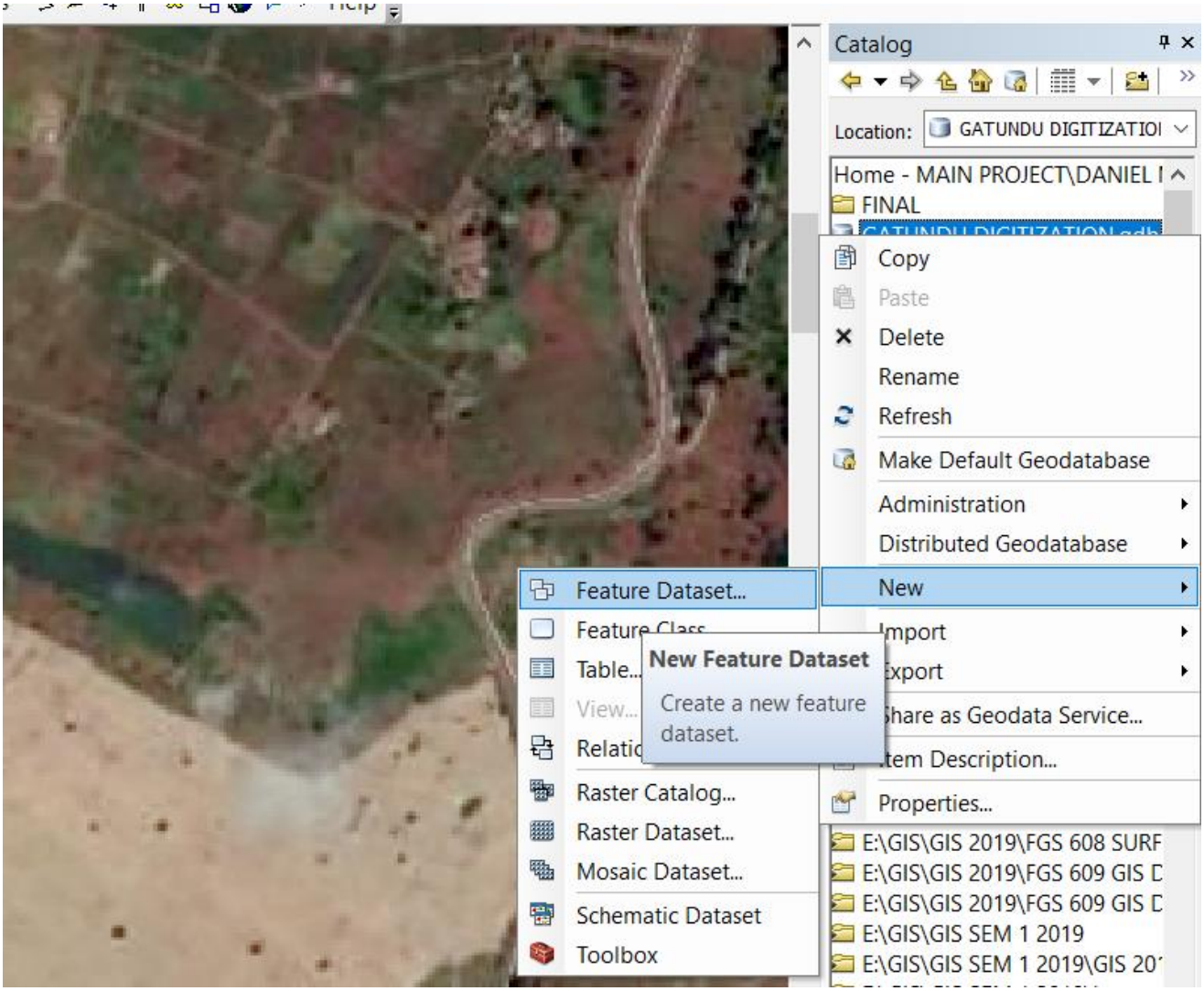


Figure 8:Shows how the file geodatabase was created

Feature database creation

Land use shapefiles Attributes are;

1. Dominant Land use
2. Land use code
3. Plot Number
4. Landmark

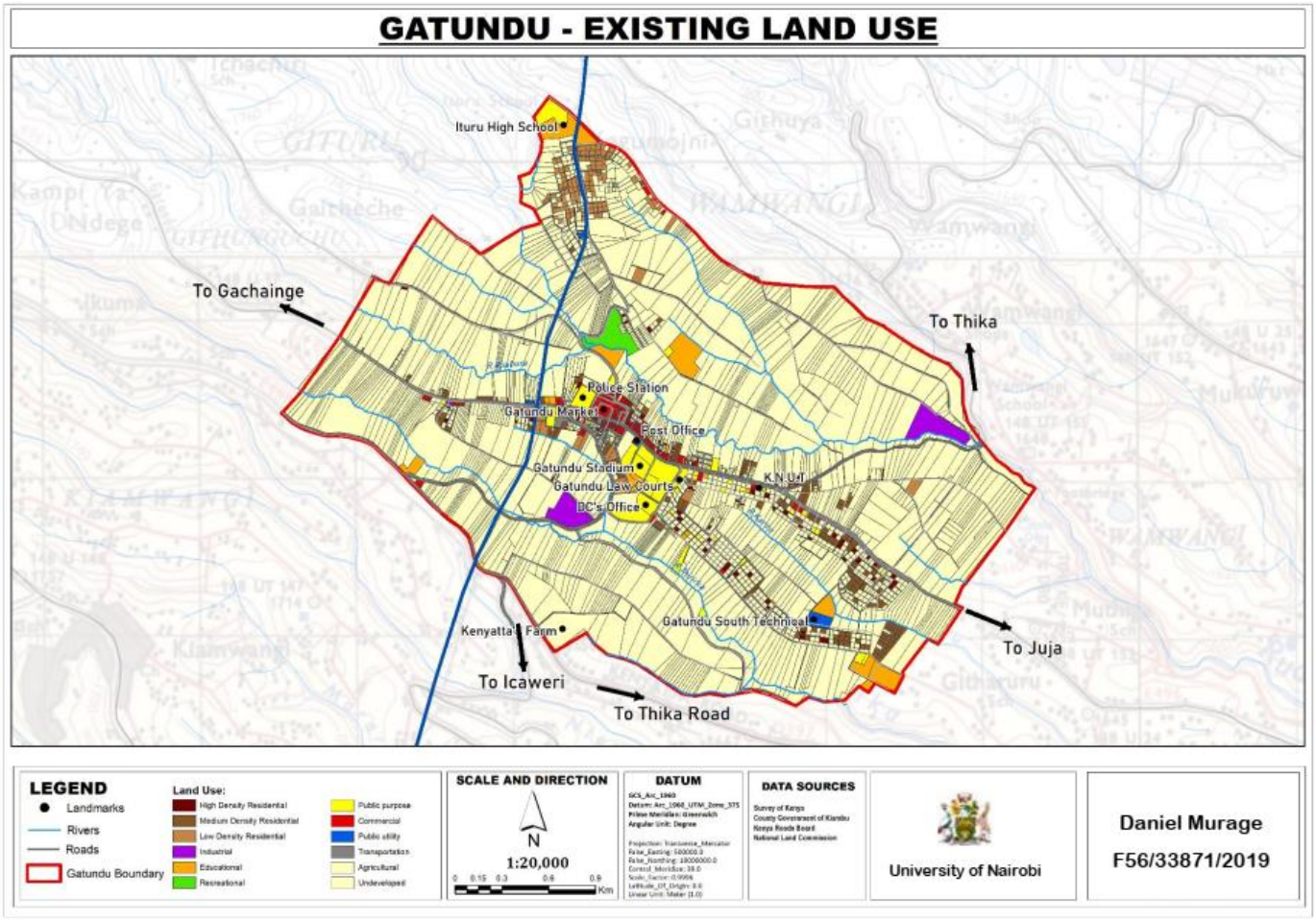
Attributes of land cover shapefiles are

1. Building footprints
2. Land cover type
3. Vegetation

CHAPTER 4: RESEARCH FINDINGS, ANALYSIS, AND DISCUSSION

4.1. Gatundu town Existing Land Use Map

Digitization of existing land use for Gatundu town was done for the whole town showing the existing dominant Land Use for every plot. Only the dominant land use was captured, i.e., over 50% use. Below is the existing land use map for Gatundu town.



Map 6:Existing land use map for Gatundu town.

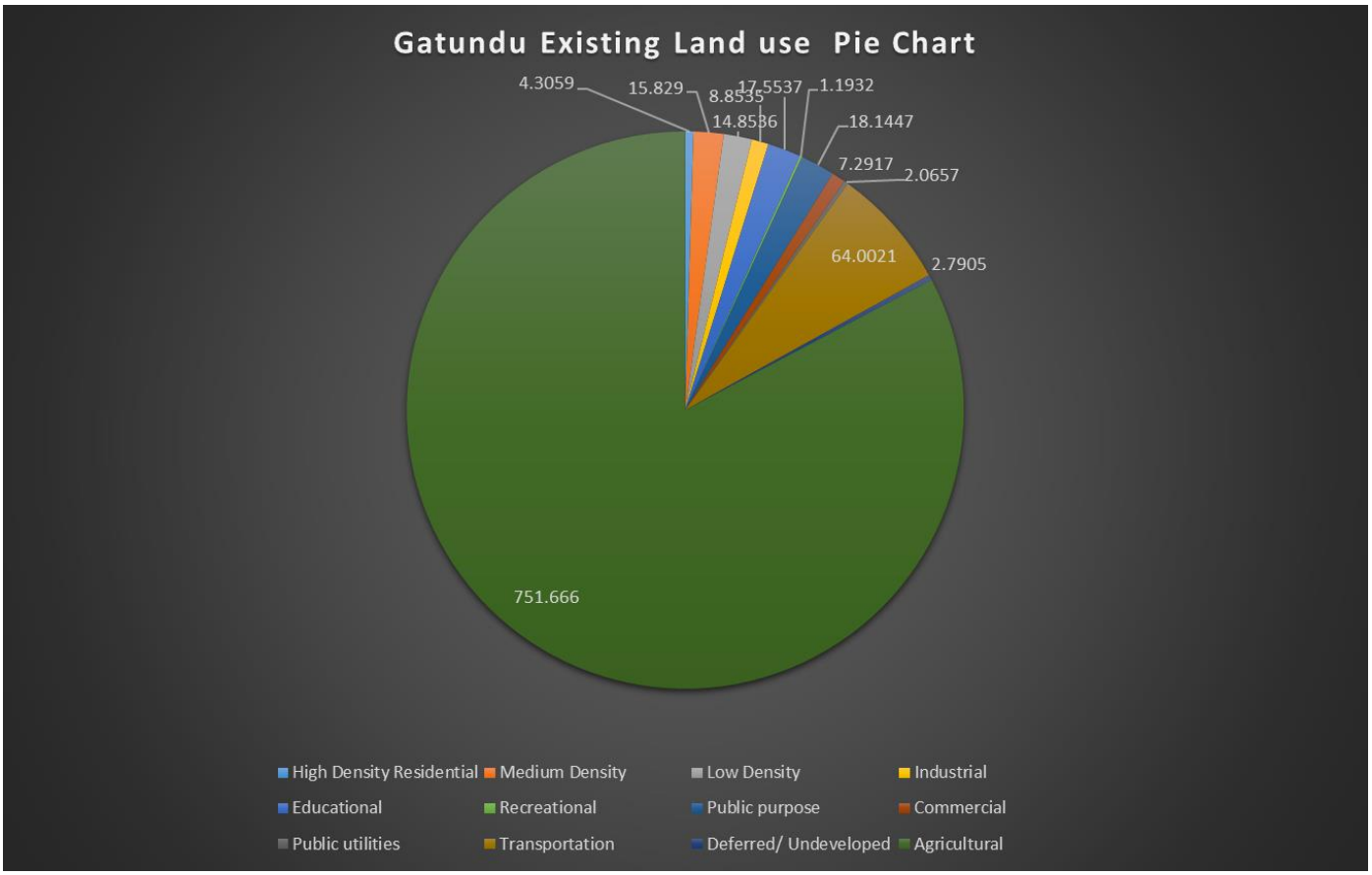


Figure 9: Existing Land use chart

Table 5: Existing land use map for Gatundu town.

Code	**Land use**	**Existing Land Use**	
		Existing area (ha)	Existing Percentage (%)
0	High-Density Residential	4.3059	2
	Medium Density	15.8290	1
	Low Density	14.8536	1
1	Industrial	8.8535	0.1
2	Educational	17.5537	2.1

3	Recreational	1.1932	0.13
4	Public purpose	18.1447	1.03
5	Commercial	7.2917	0.53
6	Public utilities	2.0657	0.6
7	Transportation	64.0021	3.98
8	Deferred/ Undeveloped	2.7905	1.27
9	Agricultural	751.666	86.27
	TOTAL	991.2395	100.00

4.2. Proposed Physical and Land use development plan for Gatundu town.

Gatundu town has no development plan in place guiding the development of the town; hence there was a need to have the town's proposed physical and land use development plan to guide future developments. A situation whereby the area's urban structure is not tampered with but left to continue evolving with no planning improvement measures being put in place. Urban growth will adapt to the current development trend, spearheaded by haphazard developments, poor accessibility, inadequate basic facilities, and inharmonious land use organization. There being no planning interventions, the end product will be a much worse situation than the existing one.

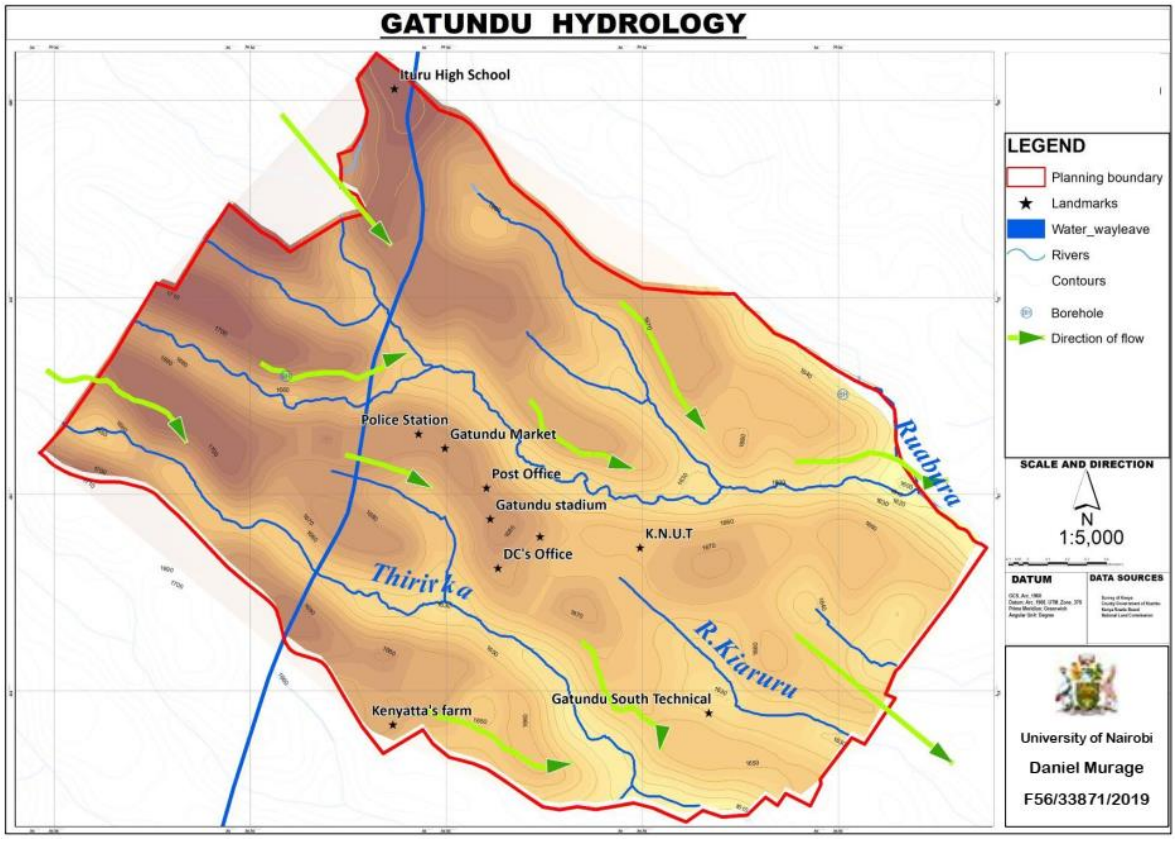
Various aspects have a hand while preparing Gatundu's Proposed physical and land use development plan. These factors are well complemented by GIS technology to achieve the ideal development plan.

4.3. Physiographic Characteristics

Several physiographic characteristics had an influence on the study area, i.e., Gatundu Town.

4.3.1. Hydrology and Drainage

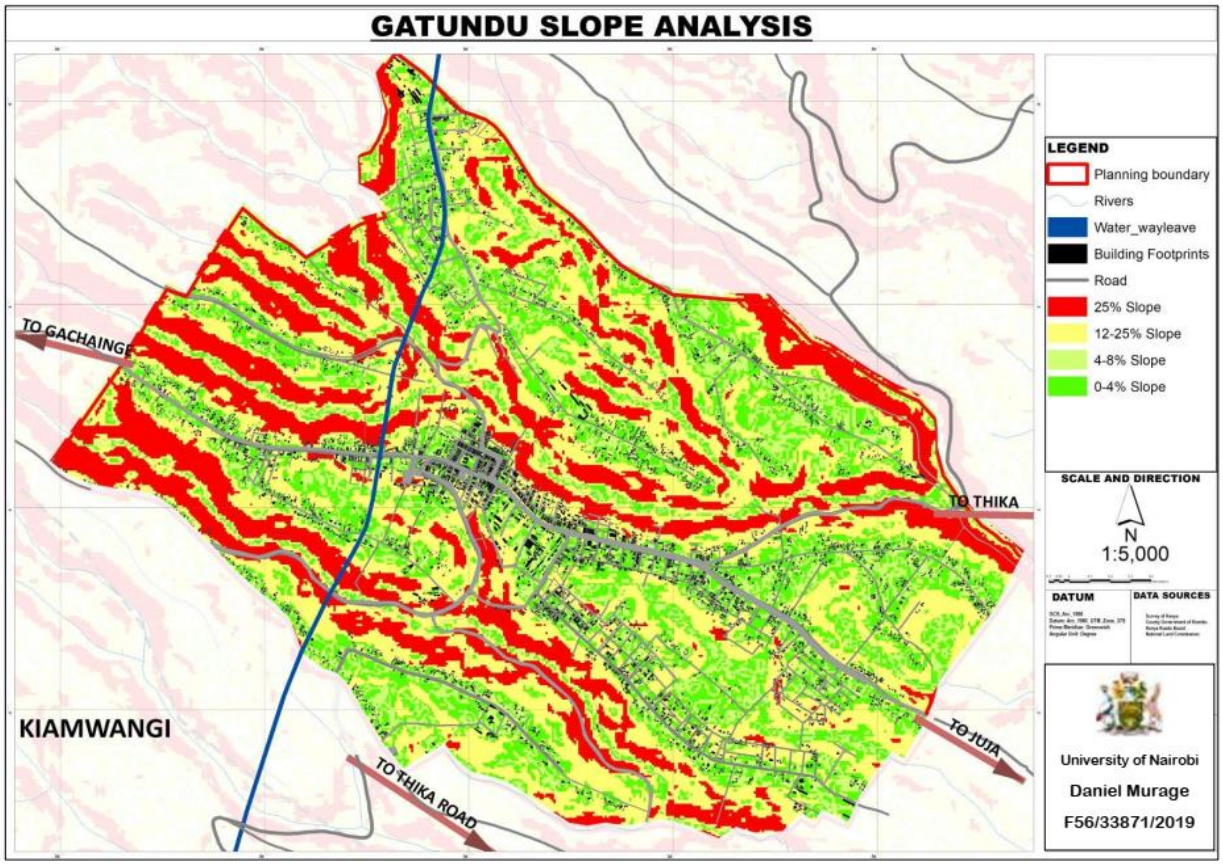
This included various rivers-Thiririka river, the muthurumbi river, water bodies, and different categories of boreholes.



Map 7:Gatundu Hydrology map

4.3.2. Topography

This also influences the study area. This is analyzed using GIS in terms of Slope analysis, determining areas suitable for development and those unsafe for human settlement, i.e., areas whose slope exceeds 25%.



Map 8:Gatundu slope analysis map

4.4. Population size and distribution

All development plans are done for the people. The urban population growth is 3.4%, with the Gatundu population projected to be about 18000 by the year 2030.

Various population analysis is done using GIS to inform the preparation of the proposed Physical and Landuse development plan for Gatundu.

This includes –

4.4.1. Population structure

This summarises the structure of age cohorts' distribution within Gatundu town.

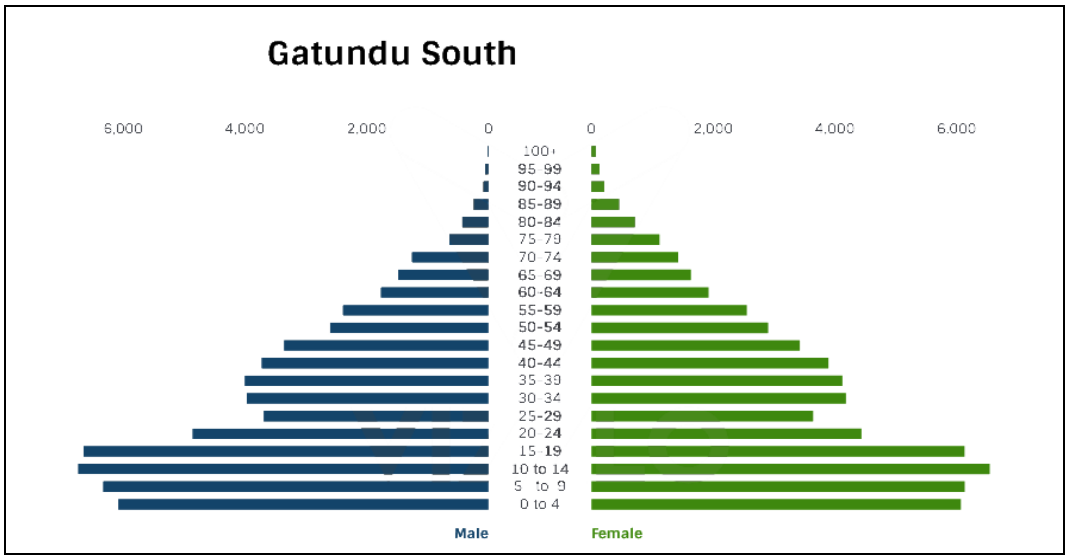


Figure 10:Distribution of Age Cohorts within Gatundu

4.4.2. Population Projection

The urban population growth rate for the county is 3.4% projecting the population to about 18000 by the year 2030. This has to be factored in when planning.

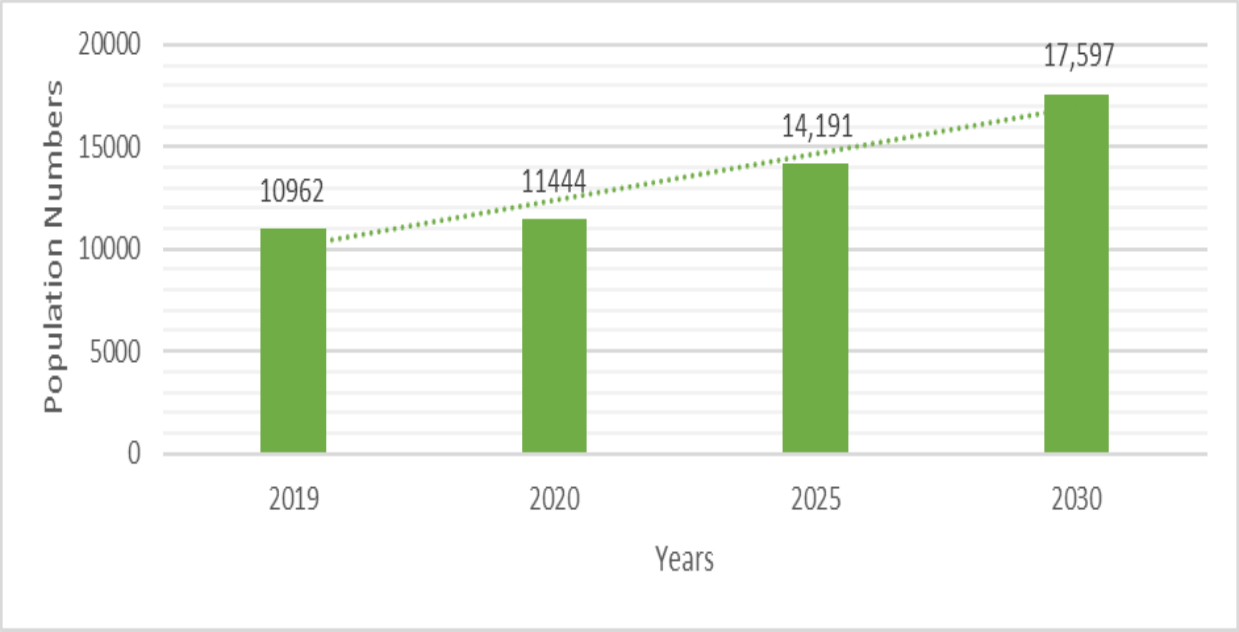


Figure 11:Population projection (KNBS 2019)

4.4.3. Population Demography

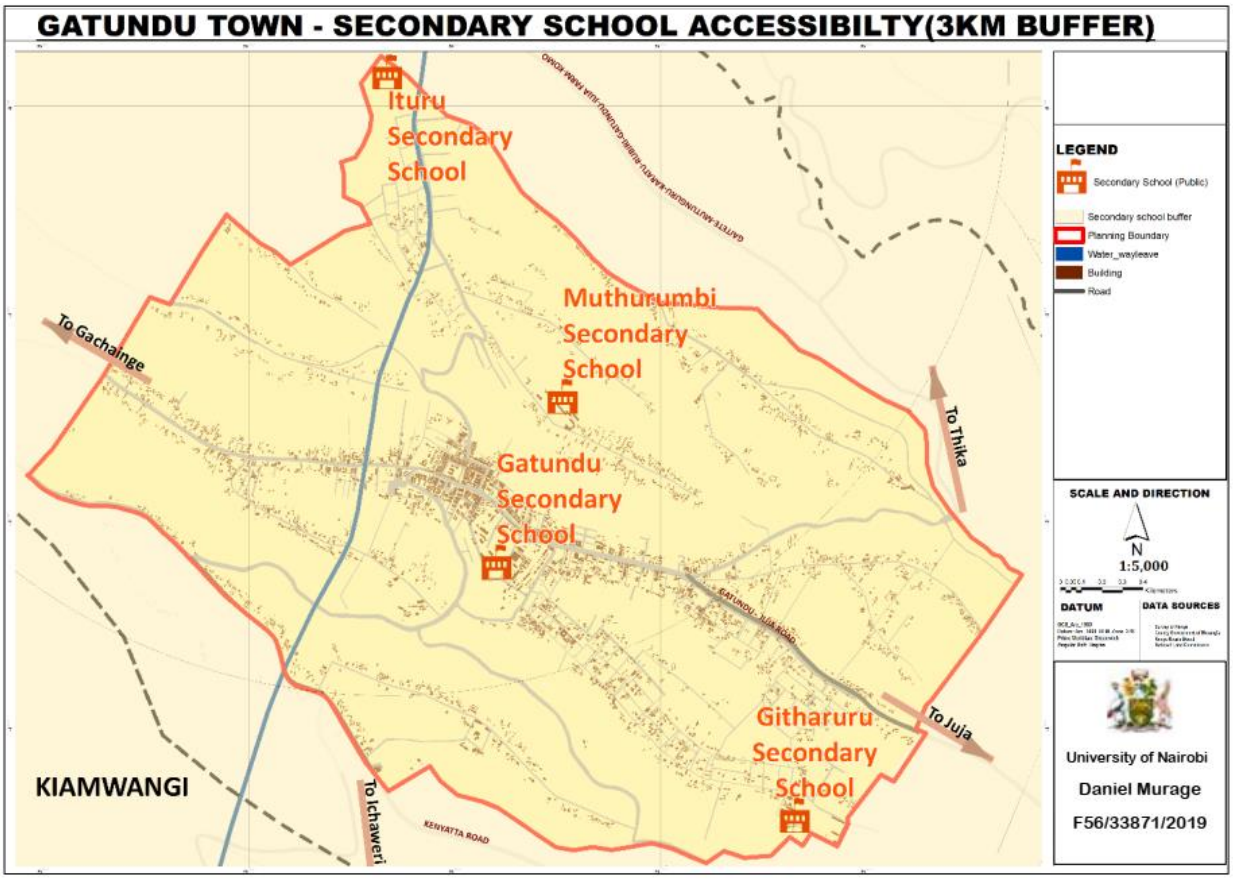
This analysis was done using GIS technology and other analysis methods to consider; Household size, well-being, education, poverty levels, and employment.

4.5. Social Infrastructure

In preparing the proposed physical and land use development plan, social infrastructures are also vital considerations to make sure the plan is all around.

4.5.1. Education facilities

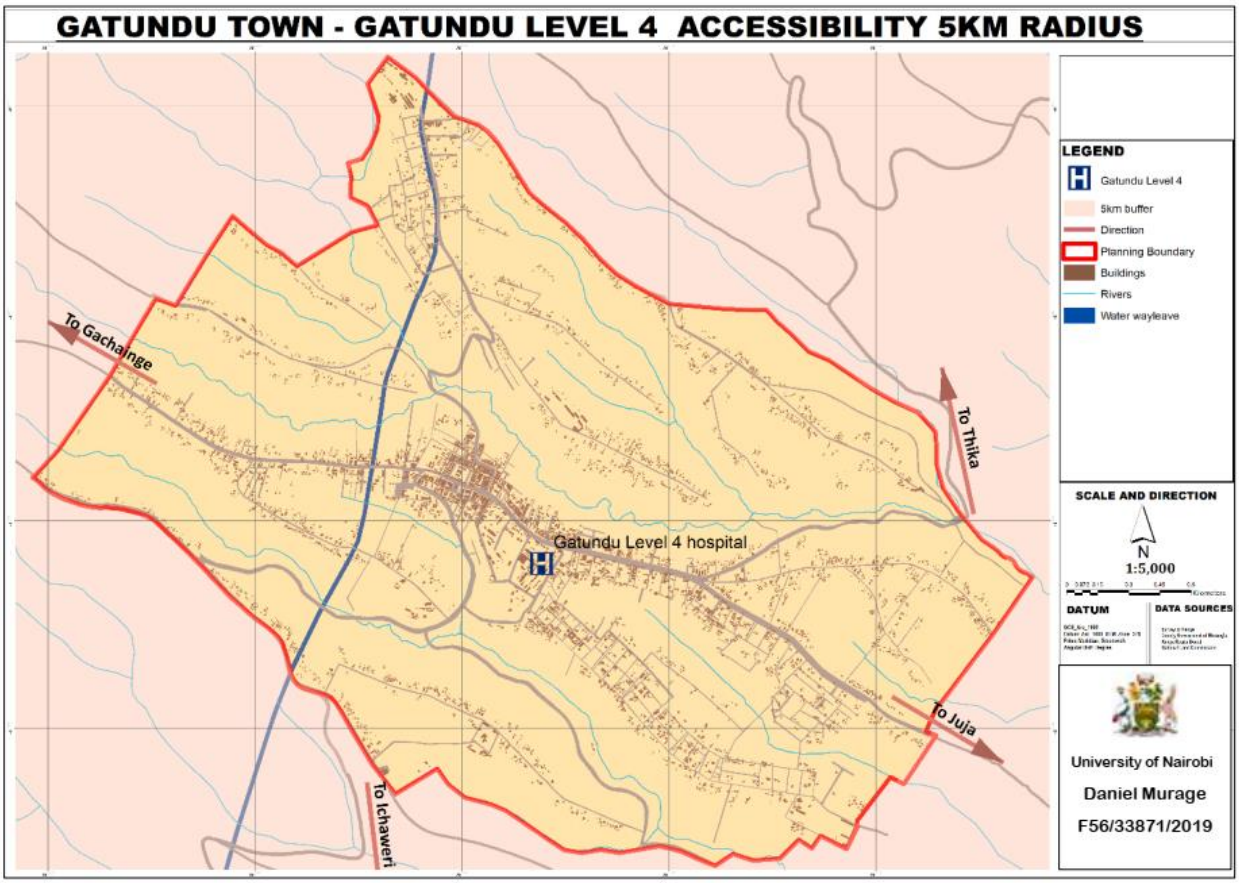
These include Primary schools, secondary schools, and tertiary institutions. In line with the physical planning handbook (2007), primary school catmint is 2KM radius and secondary school 3km radius.



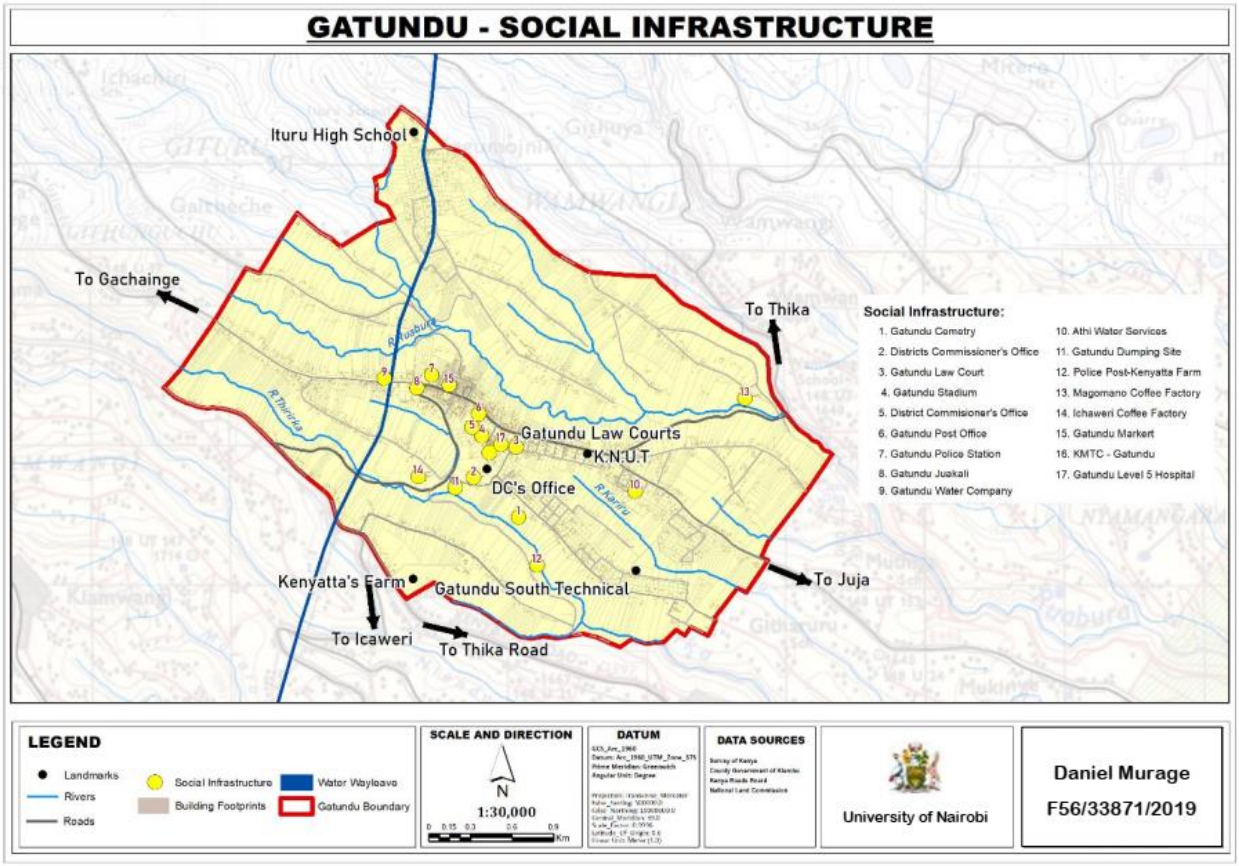
Map 9; Gatundu town Secondary schools Accessibility map (3km buffer).

4.5.2. Health facilities

Gatundu town has a level 4 hospital within a 5km radius, meaning the study area is well covered. Hence in the proposed physical and land use development plan no need to provide for another health facility.



Map 10: Gatundu Level 4 Hospital Accessibility 5KM Radius



Map 11:Gatundu social infrastructure map

The table below shows a summary of all social infrastructure in Gatundu

Table 5:Summary of other social infrastructure

NO.	**Facility:**	**Name/ Number:**
1.	Recreational Facilities	None
2.	Government Offices	Present
3.	Sports Facilities	Gatundu stadium
4.	Social Hall	None
5.	Public Library	None
6.	Post Office	Gatundu Post Office
7.	Fire Station	None
8.	Police Stations	Gatundu Police Station
9.	Religious Institutions	Many

10.	Slaughterhouses	Gatundu South (Near Gatundu Polytechnic)
11.	Cattle dip	3

4.6. Physical infrastructure

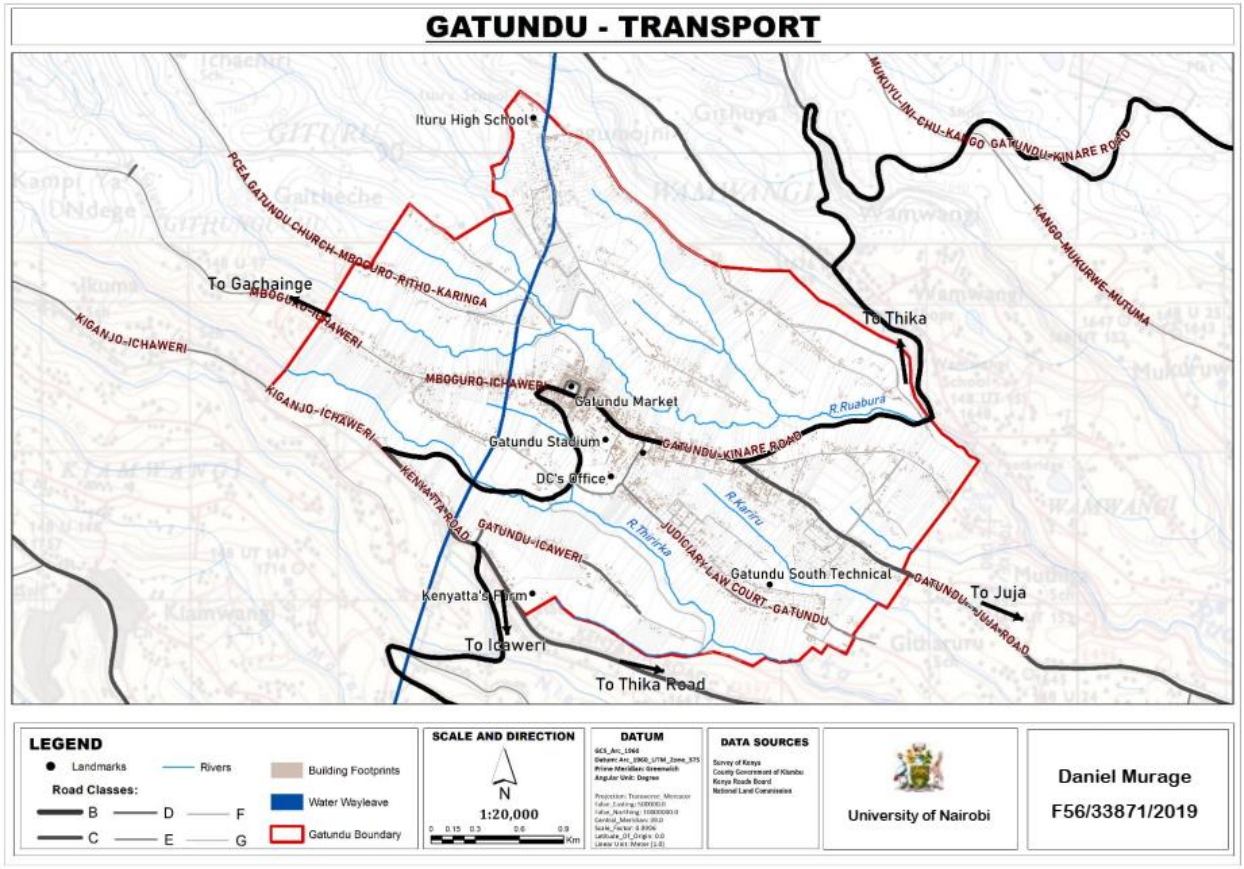
Physical infrastructure has an influence on the study area. This had to be factored in when preparing the proposed physical and land use development plan. They included;

4.6.1. Regional Connectivity

Gatundu enjoys good connectivity to surrounding hubs in the region. The area is well linked to 2 Class A roads (A 104 – Nairobi - Naivasha Highway and A2- Thika road). The linkage to A2 is through Kenyatta Road and also through C66. Thika road serves as the main cargo route and an important metropolitan, regional and international transit link.

4.6.1. Road Networks

The study area has five classes of roads, the majority being of reasonably good standards. The map below shows the road network in the study area.



Map 12:Transportation Network in Gatundu

Table 6: Showing various roads and their standards

Road	Class	Carriage Way	Road Reserve	Length	Carriage Way Surface Type	Condition
Gatundu-Kinare Road	B30	7 Metres	40	6.1km	Paved	Good
Kenyatta Road	C565	12 Metres	8	3.7 Kms	Paved	Good
Githioro-Kiganjo	E2209	12 Metres	8	3	Paved	Good
Gatundu - Juja	F2127	12 Metres	8	1.8 Kms	Gravel	Good
Muhara Rd	G9666	3 Metres	6	1.1 Km	Gravel	Fair

4.7. Water

The primary source of water in Gatundu South, where the planning area lies, is piped water (50.9%), while 16.6% of the households get water from rivers and streams (KNBS 2019). Gatundu Water and Sewerage Co Ltd serve Gatundu Town.

4.8. Storm Water Drainage

Stormwater infrastructure in the town is poorly developed and missing in most parts. Some of them are also clogged by siltation and solid waste, thus reducing their efficiency. This is a challenge to the management of stormwater, leading to the pooling of water, destruction of roads, and increased erosion risks. The stormwater system further contributes to the siltation and pollution of water rivers and streams.

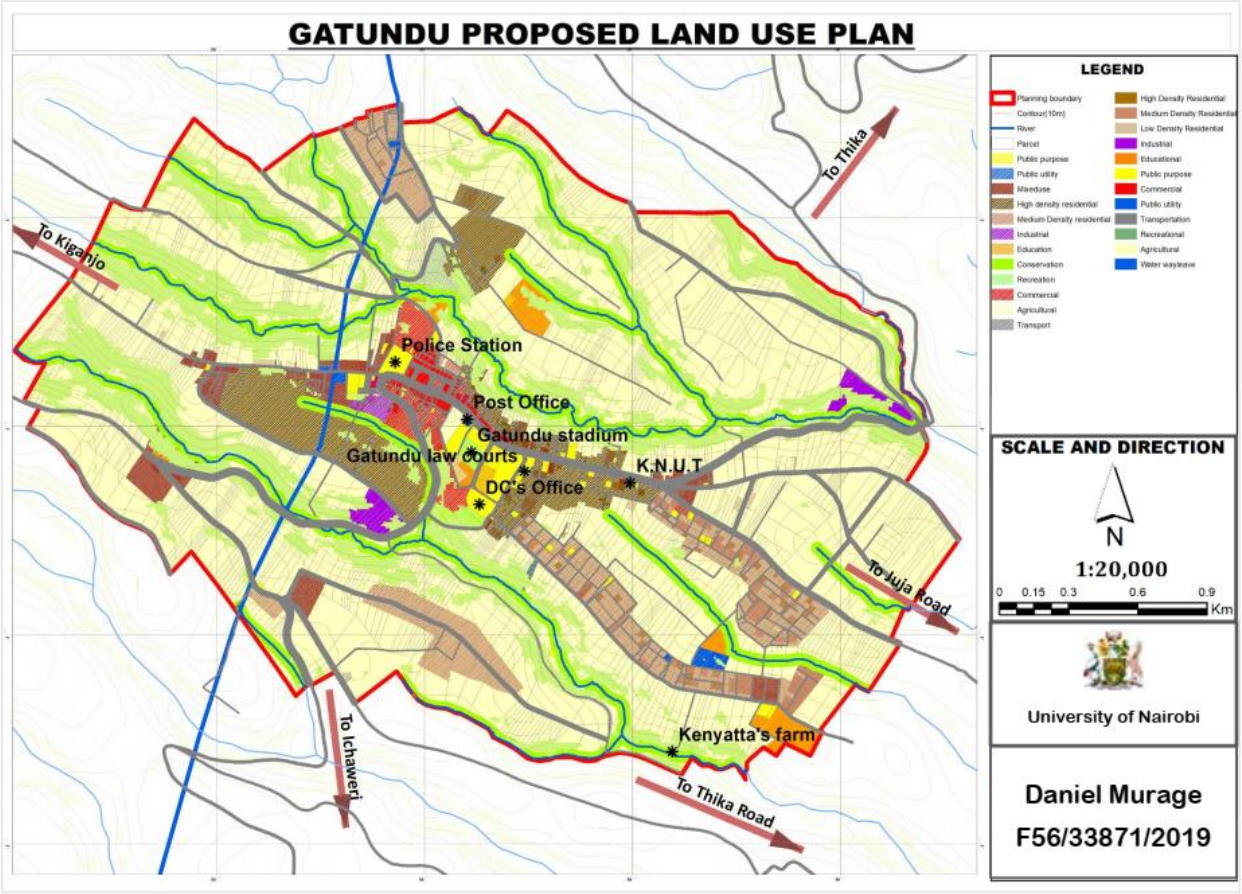
Plate 5: Existing drainage channel in poor condition

4.9. Land Use requirements

The population of Gatundu is expected to grow to about 18000 people by 2030, creating more demand for land to support the different uses. This may lead to shifts in percentage land uses to accommodate change based on the trend. The biggest demand will be on land for residential, commercial, and transportation purposes. Using GIS analysis tools, below is the proposed physical and land use development plan for Gatundu.

Table 7; Summary of School Land Sizes Vis a Vis Required Standards

EDUCATIONAL FACILITY	COVERAGE IN Ha	Guidelines	Deficit/Surplus
Githaruru Secondary School	1.6191	3.25	0.19
Muthurumbi primary and sec school	3.9877	4.25	-0.35
Ituru primary and secondary	3.778	4.25	-0.472



Map 13:Proposed physical and land use development plan

The Gatundu physical and land use development plan is developed with a consideration of land demand for various principal uses and the prospective need in 2030. The preparation of the plan has been guided by the identified development challenges in Gatundu as well as the analysis of the opportunities and strengths in the area. An analysis of development suitability has been undertaken, which has provided a basis for the location of various land uses in multiple areas.

4.10. Comparison in terms of conformity between the existing physical development in Gatundu and the proposed development plan.

After analysis of land use requirements shows that key land use allocation fall below the threshold required. The most affected are residential, education, public purpose, and recreation. This deficit has been catered for in the proposed physical and land use development plan for Gatundu town. The geographical location of various land uses has not changed, but more control and organization have been realized and densified on the proposed physical and land use plan.

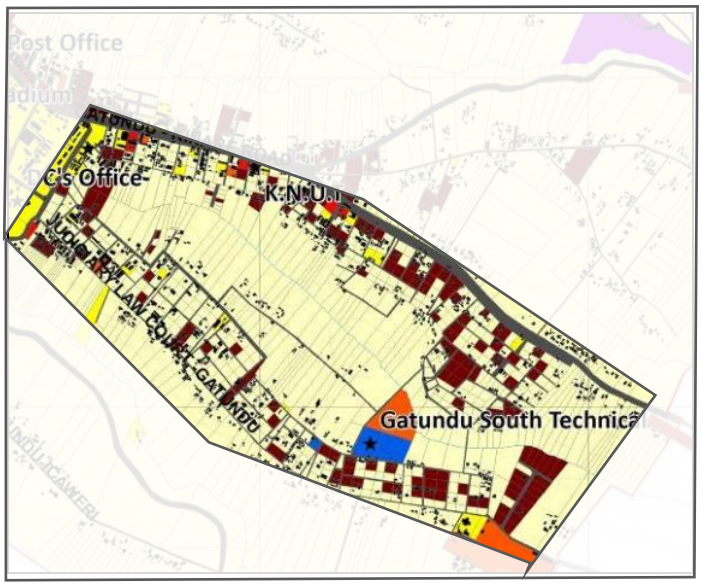


Figure 12: Existing residential land use near Gatundu Level 5 hospital

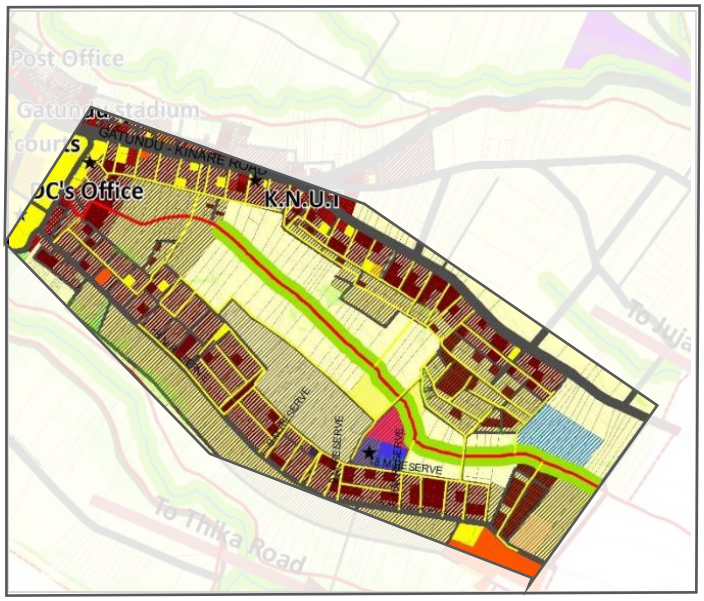
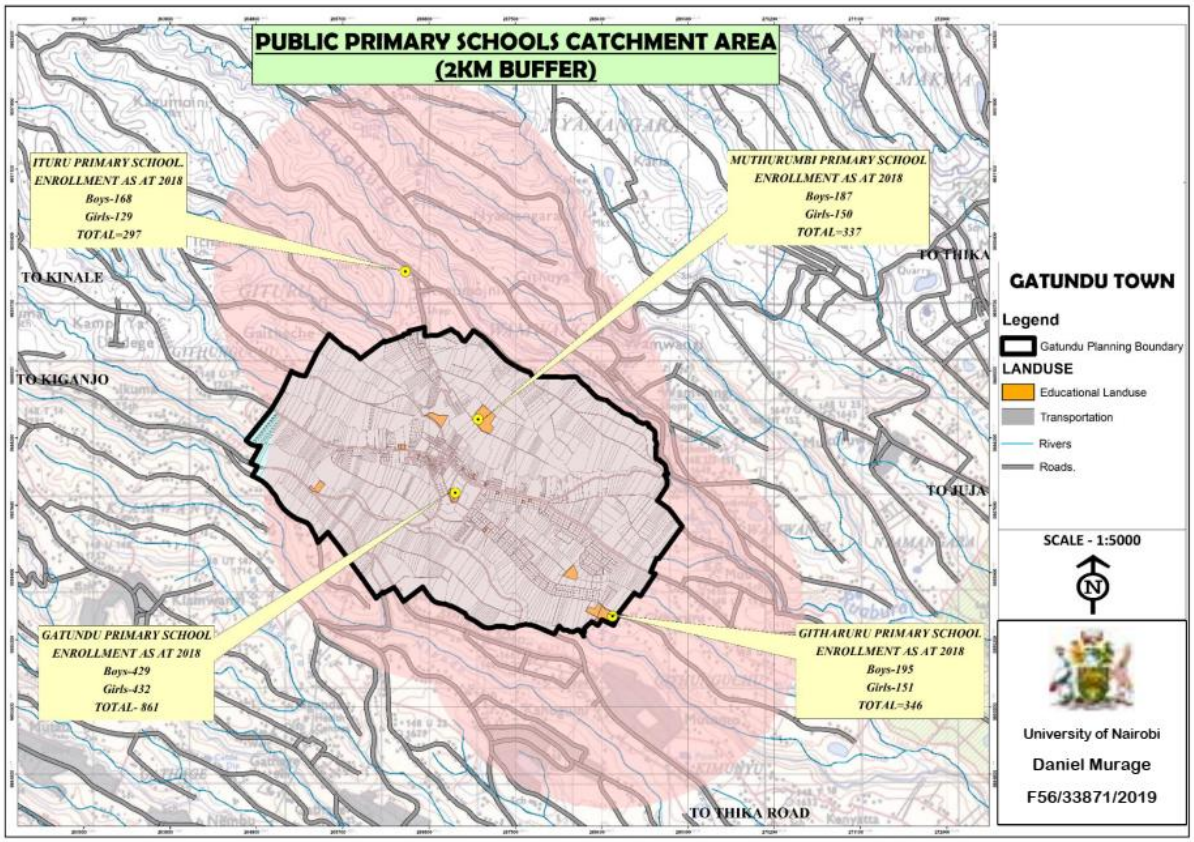


Figure 13: Proposed residential land use categories near Gatundu Level 5 hospital. Residential high, medium, and low density

The human settlement pattern in the town, which ranges from linear and nucleated, has not changed much, but various categories have been realized, ranging from low density, medium density, and high density.

The proposed plan has enhanced the distribution of amenities and public institutions. This is by the fact of following various recommendations from the physical and land use. This is by using a GIS buffer example 2km walking distance buffer for Public primary schools as required by the physical planning handbook.



Map 14: Gatundu public primary schools 2km buffer.

Planning and redesigning the existing transport infrastructure is needed even though there is no change of location; this in the new proposed physical and land use development plan will be treated as an action area plan.

Also, the existing situation has a deficit in the provision of public parks. The proposed plan has created a few urban pocket parks integrated with the existing bus park, as shown in the action area below.

Map 15: Gatundu town bus park action area

4.11. Implementation recommendations for the proposed physical and land use development plan for Gatundu town.

Establish clear planning guidelines and regulations in line with the town's proposed physical and land use development plan. This will include zoning guidelines and regulations to regulate developments in the town.

Capacity building- The existing staff at the physical planning department have to be trained in line with the proposed GIS-based development plan to lead the implementation process.

Establish a town GIS lab to have a day-to-day GIS-based update on the levels of compliance and implementation.

Public Awareness-Members of the public have to be informed about the plan. This includes public notices and stakeholder meetings from notice of intention to plan up to the final proposal or draft. This is in line with public participation provisions in the constitution of Kenya 2010.

Having a clear guide on those who defy the set planning regulations, be it penalties or regularization processes as per the planning laws in Kenya.

To be clear on the main plan goals such as;

1. Transport efficiency improvement
2. Social infrastructure Development-Water, sanitation, and drainage
3. Environment conservation and management

Establishment of County Spatial data infrastructure for easier referencing and updated spatial data.

CHAPTER 5: CONCLUSION AND RECOMMENDATIONS

5.1. Conclusions

This study brings out the support of GIS in different Physical and Land use planning approaches or levels ranging from national plans, inter-county or regional plans, County plans, local plans special, and sectoral plans.

In physical and Land Use Planning, GIS helps analyze, store, and spatial process data to bring out the desired plan, which will guide development in a given area for a stipulated period, mostly ten years.

Also, GIS is vital in evaluating the implementation of a given Physical and Land Use Development Plan to monitor whether the objectives of the plan are realized or which improvements can be made to achieve the said objectives.

GIS has proved to be a strong tool in physical and Land Use Planning.

5.2. Recommendations

To achieve the optimum utilization of GIS in planning, several things have to be met:

- Include the GIS unit in the physical planning curriculum to equip physical planners with GIS skills.
- Development of a stable and reliable spatial data infrastructure for easier reference
- Have a stable and reliable National Spatial Data Infrastructure (NSDI).

Since unplanned towns are a general issue across the country, counties should prioritize planning preparation to salvage urban centers' uncoordinated growth.

All Counties should adhere to section 110 of the constitution through enforcement to ensure the preparation of GIS-based development plans within the first two years of any county government being in office.

Moreover, it is very important to fast-track digitization of the maps, physical and land use plans, and all previous planning attempts to track an area's planning milestones.

There is a need to plan using GIS for current and emerging issues such as the COVID 19 pandemic.

5.3. Area for further research

The proposed physical and land use development plan for Gatundu town has met the intended objectives, although there is a need for more research and input.

There is a need to have temporary development control measures which are in place to control developments when the long-term plan is being prepared. Some plans take more than 2 or 3 years.

During that period, a lot is happening on the ground, which will make the final plan look like it's outdated.

Also physical and land use planning process is heavily influenced politically. This is evident when making various land use an example, landfills. This has to be reviewed in terms of policies to caution planning exercise.

REFERENCES

Acheampong, R. A. (2018). The Concept of Spatial Planning and the Planning System. *The Urban Book Series*, 11–27. https://doi.org/10.1007/978-3-030-02011-8_2

Albrechts, L. (2001). The revival of strategic spatial planning. *Sociale Geografie*, 385–386.

Anon. (2011, July 27). *The Concept of Sustainable Development*. E-International Relations. https://www.e-ir.info/2011/07/27/the-concept-of-sustainable-development/

Bareth, G. (2009). GIS- and RS-based spatial decision support: structure of a spatial environmental information system (SEIS). *International Journal of Digital Earth*, *2*(2), 134–154. https://doi.org/10.1080/17538940902736315

Barofsky, J., Siba, E., & Grabinsky, J. (2016, September 7). *Can rapid urbanization in Africa reduce poverty? Causes, opportunities, and policy recommendations*. Brookings. https://www.brookings.edu/blog/africa-in-focus/2016/09/07/can-rapid-urbanization-in-africa-reduce-poverty-causes-opportunities-and-policy-recommendations/

Blewitt, J. (2018). *Understanding sustainable development*. Routledge.

Bradshaw, Y. W. (1987). Urbanization and Underdevelopment: A Global Study of Modernization, Urban Bias, and Economic Dependency. *American Sociological Review*, *52*(2), 224. https://doi.org/10.2307/2095451

Bryman, A. (2015). *Analyzing qualitative data*. London Routledge.

Burrough, P. A. (1986). Principles of geographical information systems for land resources assessment. *Geocarto International*, *1*(3), 54–54. https://doi.org/10.1080/10106048609354060

Butler, S. J., Boccaccio, L., Gregory, R. D., Vorisek, P., & Norris, K. (2010). Quantifying the impact of land-use change to European farmland bird populations. *Agriculture, Ecosystems & Environment*, *137*(3-4), 348–357. https://doi.org/10.1016/j.agee.2010.03.005

Castle, G. H. (1993). *Profiting from a Geographic Information System.* John Wiley & Sons.

Cendrero, A., LüttigG., & Wolff, F. C. (2021). *Planning the use of the earth's surface*. Springer-Verlag.

Chemin, Y., Abeykoon, M., Jayasekara, J. M. L., & Ratnayake, J. (2006). Use of GIS in preparation of the National Physical Plan for Sri Lanka. *National Physical Planning Department*.

https://www.academia.edu/1430202/Use_of_GIS_in_preparation_of_the_National_Physical_Plan_for_Sri_Lanka

Cowen. (1988). *GIS and Geography: Elements of a Debate*.

Davidoff, P. (2007). Advocacy and pluralism in planning. *Journal of the American Institute of Planners*, *31*(4), 331–338. https://doi.org/10.1080/01944366508978187

Dhanabalan, M. (2008). GIS Applications in Urban Planning. *Proceedings of International Conference on Emerging Scenarios in Space Technology and Applications*, *1*. https://doi.org/DOI:10.13140/RG.2.2.26901.78562

Diwakar Kr. (2021). App. of GIS and RS in Urban Planning. *ResearchGate*. https://doi.org/10.13140/RG.2.2.28603.75041

ESRI. (2006). *GIS Solutions for Urban and Regional Planning Designing and Mapping the Future of Your Community with GIS*. https://www.esri.com/~/media/Files/Pdfs/library/brochures/pdfs/gis-sols-for-urban-planning.pdf

Faludi, A. (2000). The performance of spatial planning. *Planning Practice and Research*, *15*(4), 299–318. https://doi.org/10.1080/713691907

Forester, J. (1999). Reflections on the future understanding of planning practice. *International Planning Studies*, *4*(2), 175–193. https://doi.org/10.1080/13563479908721734

Friedmann, J. (1987). *Planning in the public domain: from knowledge to action*. Princeton University Press.

Friedmann, J. (1998). Planning theory revisited*. *European Planning Studies*, *6*(3), 245–253. https://doi.org/10.1080/09654319808720459

Friend, J., & Hickling, A. (1987). *Planning under pressure: the strategic choice approach*. Pergamon.

Fukuyama, F. (1992). *The End of History and the Last Man*. Penguin.

Gellner, E. (1985). *Relativism and the social sciences*. Cambridge University Press.

GEMET. (2021). *Spatial data themes*. https://www.eionet.europa.eu/gemet/en/inspire-themes/

Hall, P. (1988). *Cities of tomorrow an intellectual history of urban planning and design since 1880*. Chichester Wiley Blackwell.

Hanson, S. (2006). Imagine. *Journal of Transport Geography*, *14*(3), 232–233. https://doi.org/10.1016/j.jtrangeo.2006.02.007

Harris, T. M., & Elmes, G. A. (1993). The application of GIS in urban and regional planning: a review of the North American experience. *Applied Geography*, *13*(1), 9–27. https://doi.org/10.1016/0143-6228(93)90077-e

Jiang, H., & Eastman, J. R. (2000). application of fuzzy measures in multi-criteria evaluation in GIS. *International Journal of Geographical Information Science*, *14*(2), 173–184. https://doi.org/10.1080/136588100240903

Judith, V. (1994). Analyzing qualitative data. Routledge

Khan, R. E. A., Azid, T., & Toseef, M. U. (2012). Determinants of food security in rural areas of Pakistan. *International Journal of Social Economics*, *39*(12), 951–964. https://ideas.repec.org/a/eme/ijsepp/v39y2012i12p951-964.html

Kenya, S. O. (2022). *Topographical Maps.* Gorvernment Of Kenya.

Kheir A., K. B. (1995). *GIS for Planning Prospectus.* Indiana State University.

KNBS. (2019). *National Census*.

Lipton, M. (1977). Why poor people stay poor: a study of urban bias in world development. In *openresearch-repository.anu.edu.au*. Temple Smith ; Australian National University Press. https://openresearch-repository.anu.edu.au/handle/1885/114902

Lwasa, S., & Njenga, C. K. (2012). Reappraising Urban Planning and Urban Sustainability in East Africa. *Urban Development*. https://doi.org/10.5772/35133

Madhavan, K. (2008). Remote Sensing and GIS applications in urban planning and management. *Advances in Remote Sensing Technology with Special Emphasis on Microwave Remote Sensing*.

Ministry of Lands and Physical Planning. (2007). *Physical Planning Handbook of 2007*. Government Press.

Morphet, J. (2011). *Effective practice in spatial planning*. Routledge.

Mutua, F. (2017). *GIS Needs Assessment in Kenya. A National and County Level Analysis of the State of GIS. and its Application for Spatial Planning in Kenya*. Council of Governors.

Niemelä, J. (1999). Ecology and urban planning. *Biodiversity and Conservation*, *8*(1), 119–131. https://doi.org/10.1023/a:1008817325994

Nour, A. M. (2011). The potential of GIS tools in strategic urban planning process; as an approach for sustainable development in Egypt. *Journal of Sustainable Development*, *4*(1). https://doi.org/10.5539/jsd.v4n1p284

Ormsby, T. (2001). *Getting to know ArcGIS desktop: basics of ArcView, ArcEditor, and ArcInfo*. Esri Press.

Pieterse, P. (2014). *Africa's urban revolution*. Zed Books.

Reddy, P. S. (2021). Implication of GIS on sustainable urban planning and management in Uganda. *International Journal of Technology and Systems*, *6*(1), 15–27. https://doi.org/10.47604/ijts.1268

Rostow, W. W. (1962). *Stages of economic growth.* Cambridge University Press.

Sandercock, L. (1998). *Towards cosmopolis: planning for multicultural cities*. Wiley.

The County Government Act. (2012). Goverment Press.

The Physical and Land Use Planning Act. (2019). Government Press.

UNESCO. (2015). *Issues and trends in education for sustainable development.*

UN-Habitat. (2007). Enhancing Urban Safety and Security. *Global Report on Human Settlements 2007 - Enhancing Urban Safety and Security*, 448.

Urban areas and Cities Act. (2011). Goverment Press.

Vallabhaneni, A. (2014, October 16). *Physical planning in town planning*. https://www.slideshare.net/neni009/physical-planning-in-town-planning

Van Maarseveen, M., Martinez, J., & Flacke, J. (2019). *GIS in sustainable urban planning and management*. Boca Raton, Fl CRC Press, Taylor & Francis Group.

Weede, E. (1996). *Economic development, social order, and world politics: with special emphasis on war, freedom, the rise and decline of the West, and the future of East Asia*. L. Rienner Publishers.