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OPTIMIZING SPATIAL ACCESSIBILITY TO PRIMARY HEALTHCARE USING GEOGRAPHICAL INFORMATION SYSTEM: A CASE OF MIGORI COUNTY, KENYA

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Antony Ondiwa OKUNDI

IN PARTIAL FULFILLMENT OF THE REQUIREMENTS
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ETHICAL STATEMENT

I hereby declare that in this thesis study I prepared in accordance with thesis writing rules of Gazi University Graduate School of Natural and Applied Sciences;

- All data, information and documents presented in this thesis have been obtained within the scope of academic rules and ethical conduct,
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Antony Ondiwa OKUNDI

09/08/2023

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(M. Sc. Thesis)

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ABSTRACT

The study aimed to evaluate the level of accessibility to primary healthcare in Migori County, Kenya, and propose interventions to enhance spatial access to healthcare services. The study used the Maximum Covering Location Problem (MCLP) to analyse the availability of healthcare services, taking into account the operating hours of primary healthcare providers. The study found that the overall spatial accessibility of basic healthcare facilities was 84%, with some facilities being non-operational on weekends and 24 hours. The study also found that accessibility declined to 60% on weekends and 49% for 24-hour accessibility. Additionally, the study recommended upgrading strategically situated healthcare facilities to improve access for the local population to primary healthcare services. This upgrading strategy aimed to establish a practical spatial framework that complements the implementation of the Kenya Primary Health Care Strategic Framework (2019-2024) by addressing spatial disparities in Migori County. The study emphasizes the need for sustainable spatial frameworks that promote equitable access to primary healthcare and highlights the importance of policymakers and healthcare providers working together to address geographical disparities in healthcare access.
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COĞRAFİ BİLGİ SİSTEMİ KULLANARAK BİRİNCİL SAĞLIK HİZMETLERİNE MEKANSAL ERİŞİLEBİLİRLİK OPTİMİZASYONU: KENYA, MIGORI BÖLGESI

(Yüksek Lisans Tezi)

Antony Ondiwa OKUNDI

GAZİ ÜNİVERSİTESİ
FEN BİLİMLERİ ENSTİTÜSÜ
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ÖZET

Bu çalışmanın amacı, Kenya'nın Migori İli'nde birinci basamak sağlık hizmetlerine erişilebilirliği değerlendirmek ve sağlık hizmetlerine mekânsal erişimi artırmak için gerekli müdahaleleri önermektir. Çalışmada Maksimum Kapsama Konum Problemi (MKKP) kullanılmış ve birinci basamak sağlık hizmeti sunan kuruluşların çalışma saatleri dikkate alınarak sağlık hizmetlerinin kullanılabilirliği incelenmiştir. Araştırma, bazı tesislerin hafta sonları ve 24 saat boyunca çalışmadığını gözeterek, temel sağlık hizmetlerine mekânsal erişilebilirliğin toplamda %84 olduğunu ortaya koymuştur. Ayrıca, erişilebilirliğin hafta sonları erişilebilenler için %60 ve 24 saat erişilebilenler için %49 değerlerine düştüğü görülmüştür. Bununla beraber çalışma, yerel nüfusun birinci basamak sağlık hizmetlerine erişiminin daha iyi sağlanması için, stratejik olarak konumlandırılmış sağlık tesislerinin bir üst seviyeye getirilmesini önermiştir. Bu iyileştirme stratejisi, Migori İli'ndeki mekânsal eşitsizliklere referansla Kenya Birinci Basamak Sağlık Hizmetleri Stratejik Çerçevesi'nin (2019-2024) uygulanmasını tamamlayacak pratik bir mekânsal çerçeve oluşturmayı amaçlamıştır. Çalışma, birinci basamak sağlık hizmetlerine adil erişimi teşvik eden sürdürülebilir mekânsal çerçevelerin gerekliliğini vurgulamakta ve sağlık hizmetlerine erişimdeki mekansal eşitsizlikleri ele almak için politika yapıcıları ve sağlık hizmeti sağlayıcılarının birlikte çalışmasının önemini vurgulamaktadır.

Bilim Kodu	:	80201
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LIST OF ACRONYMS AND ABBREVIATIONS

The acronyms and abbreviations used in this study are presented below along with their definitions.

Acronyms	**Definitions**
Km^2	Square kilometers
Ha	Hectare
m^2	Square meters
24/7	24 hours a day, seven days a week
2SFCA	Two-step floating catchment area method

Abbreviations	**Definitions**
AMREF	African Medical and Research Foundation
CBO	Community Based Organization
CBS	Central Bureau of Statistics
CDC	Center for Disease Control and Prevention
CDF	Constituency Development Fund
CIDP	County Integrated Development Plan
CRU	Climate Research Unit
DEM	Digital elevation model
ERS	Emergency Response Services
ESRI	Environmental Systems Research Institute
FAO	Food and Agriculture Organization
FBO	Faith Based Organization
FCA	Floating Catchment Area method
GIS	Geographical Information System
HDX	Humanitarian Data Exchange portal
HEP	Hydro-Electric Power
HIV	Human Immunodeficiency Virus
ICCM	Integrated Community Case Management
KDE	Kernel density estimation
KHSSP	Kenya Health Sector Strategic Plan

Abbreviation	**Definitions**
KMHFL	Kenya Master Health Facility List
KNBS	Kenya Bureau of Statistics
KRMA	Kenya Registered Midwives Association
LMs	Lower Midlands
LMIC	Lower-Middle-Income Country
LSCP	Location Set Covering Problem
MCA	Multi-criteria Analysis
MCIDP	Migori County Integrated Development Plan
MCLP	Maximal Coverage Location Problem
MTP	Medium Term Plan
NCAPD	National Coordinating Agency for Population and Development
NGO	Non-Govermental Organization
OD	Origin-Destination
OSM	OpenStreetMap
PHC	Primary Health Care
PPR	Population -Provider Ratios
SGD	Sustainable Development Goals
SOK	Survey of Kenya
UHC	Universal Health Coverage
UM	Upper Midlands
UNOCHA	United Nations Office for the Coordination of Humanitarian Affairs
USGS	United States Geological Survey
UTM	Universal Transverse Mercator
VCT	Voluntary Counselling and Testing
WHO	World Health Organization
WRU	World Resource Unit

1. INTRODUCTION

In developing countries, distance is a significant factor that determines healthy communities (Buor, 2002), and increasing distance from health facilities jeopardizes accessibility especially among the aged and physically disabled. Penchansky and Thomas (1981) posited five main dimensions that demand considerations when contextualizing access to health service: availability, accessibility, accommodation, affordability and acceptability. According to them, accessibility is the interaction or interplay between a patient's location and a target health facility which involves the exploration of different mobility mediums and the incurrence of distance, time, and cost. Accessibility can also be further categorized into two categories: Potential Accessibility (dependency on the usage of physical distance with zero restrictions) and Revealed Accessibility (accountability of geographic and non-geographical impedances such as social, economic, or cultural in services utilization)(Aday and Andersen, 1974; Guagliardo, 2004; Joseph and Phillips, 1984; Luo and Wang, 2003).

Healthcare provision in developing countries is characterized by a dearth or insufficient supply, with urban dominance in their geographical distribution. On the other hand, while developed countries take pride in having robust health service provision frameworks and systems, there are still constraints such as unequal geographical distribution of health infrastructure and accessibility barriers specific to a specific group of the catchment population (Khan, 1992). The quality of access to public goods is a concern not only in developing countries, but also in developed countries such as the United States, where healthcare access issues have been observed among vulnerable groups such as children, ethnic minorities, the poor, and immigrants (Mclafferty, 2003).

Research on the measurement of spatial accessibility has registered evolution in the approaches, evaluations, and applied methodology frameworks. Previous studies have has utilized diverse methodologies to evaluate the geographical accessibility of healthcare facilities. These methods include the provider-population ratio (PPR) (Neutens, 2015) ,Euclidean distance (Guagliardo, 2004; Noor et al., 2009), gravity models such as 2SFCA and M2SFCA (Delamater, 2013; Mcgrail, 2012; Ni et al., 2015; Shaltynov et al., 2022), kernel density estimation (Schuurman et al., 2010), network analysis (Masoodi and Rahimzadeh, 2015; Noor et al., 2009; Owen et al., 2010) and cost-distance analysis (Huerta Munoz and Källestål, 2012; Ouma et al., 2021; Ray and Ebener, 2008).

Over the last 30 years, researchers have attempted to exploring Geographical Information System (GIS) technology as a measurement of spatial accessibility (Gatrell and Elliott, 2014). Usage and applications of GIS has been adopted in the health sector to provide a viable interface for understanding the distribution of health infrastructures and their related areas of service coverage (Delamater et al., 2012). GIS technology has made significant strides in spatially identifying vulnerable populations, determining their accessibility index and status to public goods, and revealing the set of barriers that exacerbate their access to healthcare systems, such as travel time and distance, affordability issues, and lack of social security (Young, 1999).It enables evidence-based identification and justification of gaps attributed to health service provision (Cromley and McLafferty, 2011). GIS also supports the estimation of travel time between a patient's points of origin to the point of health service acquisition and is capable of determining the fastest and shortest routes to the nearest health facility. These capabilities are key to service provision as the probability of a patient mortality is inversely proportional to the time/distance incurred in accessing a health facility (Jones et al., 2014).

This study focuses on the geographical accessibility of primary healthcare services, specifically addressing access to basic healthcare providers such as health centers and hospitals. This study is based on the premise that the ideas of geographical accessibility and availability of healthcare are inextricably linked. In addition to the dynamics of time and distance, geographical accessibility, in terms of service availability, must be evaluated. For example, if a patient has timely access to a nearby health facility but the sort of care requested is unavailable when he or she requires it, it ceases to be spatially accessible. Consequently, a patient in the aforementioned circumstance is vulnerable to "distance decay" while seeking services distant from the closest health facility.

By employing Geographic Information Systems (GIS) for spatial and network analysis, this study aimed to examine disparities in accessibility related to service availability during weekdays, weekends, and 24-hour periods. It also aimed to suggest a spatial strategy to improve the existing situation in Migori County, Kenya. Using the location-allocation model, this study assessed potential accessibility. Location-allocation models include seven major issue types: reduce impedance, maximize coverage, maximize capacitated coverage, minimize facilities, maximize attendance, maximum market share, and target market share

(Rahman and Smith, 2000). The Maximal Coverage Location Problem (MCLP) optimization model is useful to policymakers and researchers as a strategy for allocating resources sustainably and addressing the mystery of regional inequalities in resource allocation and utilization.

Research Problem Statement

Agenda 2063 envisions capacitated coverage of Africans for health services. Additionally, SDG 3 underscores that achieving healthy lifestyles and well-being at all ages is achievable through Universal Healthcare Coverage (UHC) rollout and ensuring quality access to health services for all. However, equal and quality health service provision, particularly in developing countries, remains a major challenge. The geographical distribution of healthcare facilities in a given area influences their efficiency and utilization.

In Migori County, primary healthcare service delivery is organized into four hierarchical tiers, progressing from community health units to dispensaries, health centers, and primary referral hospitals. However, the geographical distribution of healthcare facilities poses challenges to the spatial accessibility of the local population, considering factors such as distance, time, and associated non-medical costs. While the Kenya Primary Healthcare Strategic Framework (2019 – 2024) focuses on enhancing primary healthcare by elevating dispensaries to provide outpatient services, the strategic placement of health centers and hospitals across the county needs thoughtful consideration to ensure equitable access to primary healthcare and streamlined referrals from dispensaries to health centers, sub-county hospitals, and county referral hospitals. Achieving this requires a comprehensive spatial analysis to inform decision-making and optimize the locations of health centers for regional equity and accessibility.

With this context in mind, the objective of this study was to illuminate the regional accessibility of primary healthcare services, specifically provided by health centers and hospitals, to the catchment population of Migori County. Healthcare facility service delivery within the county varies in terms of operational hours and service availability. The operational hours and types of healthcare services offered at a facility significantly influence patients' geographic accessibility. Furthermore, this study proposed an evidence-based approach aimed at mitigating regional disparities in the delivery of primary healthcare services.

Purpose of the Research

The main objective of this research is to contribute technical knowledge on spatial accessibility to health service delivery in health service planning in Migori County. This research aims to investigate and examine the distribution and spatial accessibility of the existing primary healthcare facilities and propose an evidence-based approach that optimizes equitable health service delivery. The research objectives were as follows:

1. To determine the distribution of existing health facilities
2. To ascertain the spatial accessibility of existing primary healthcare facilities.
3. To propose an evidence-based approach that optimizes equitable primary healthcare service delivery.

Importance of the Research

This study simulated the real spatial accessibility of the catchment population of Migori County to primary healthcare services. Through dasymetric modeling, the research predicted population distributions and identified areas with inadequate health infrastructure allocation. Furthermore, this study holds significance, as it offers a planning intervention that could be embraced by policymakers and decision-makers to enhance the current situation, thus improving regional accessibility for all and mitigating spatial inequities in the allocation of healthcare resources.

Conceptual Framework

In particular, the investigation focused on patients' spatial accessibility to primary healthcare services, considering service availability (level of provision) and operational hours of healthcare facilities. Within the analytical framework, access was treated as the dependent variable, while travel impediments, and temporal operations of healthcare facilities were identified as independent variables. Notably, variations in travel impediments and the operational state of primary healthcare facilities were found to have a significant impact on patient access within the catchment area. Additionally, the analysis incorporated the current operational status of healthcare facilities, acknowledging that not all facilities operate around the clock or remain accessible on weekends. This study further proposes planning interventions to address regional spatial disparities in primary healthcare by suggesting healthcare facility upgrades (Figure 1.1).

Limitations

This study has some limitations. The analysis was solely centered on spatial accessibility and did not encompass other facets of access, such as availability, accommodation, affordability, and acceptability, all of which are equally significant. The health facility dataset used in the analysis was acquired on January 5, 2023; therefore, there is a possibility of new health facilities being established or upgrades having been implemented in some existing health facilities since that date. Additionally, examination of spatial accessibility to primary healthcare services was limited to health facilities located exclusively within Migori County, assuming that the population exclusively utilized these healthcare facilities for their medical needs. Finally, the demand points were derived from WorldPop, which provides a spatial population distribution dataset adjusted at a national scale to align with the 2020 United Nations Population Division (UNPD) estimation.

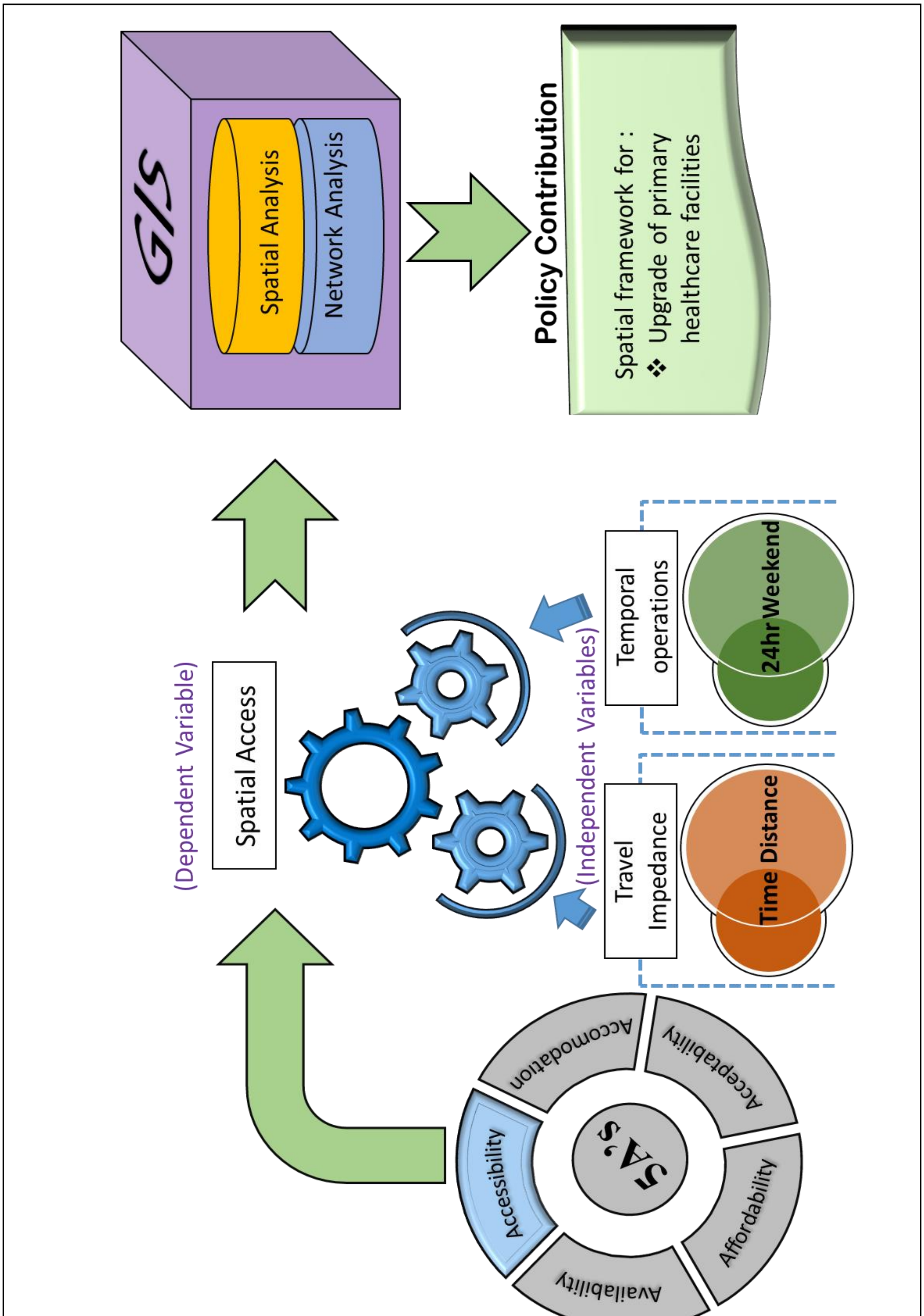


Figure 1.1. Conceptual framework

2. HEALTHCARE ACCESS

2.1. The Spatial Factor of Healthcare Access

2.1.1. Brief historical account

Over the years, scientists and researchers have sought to unravel and establish the relationships between health and spatial location. This implies the continuous contributions to the gaps and panaceas associated with health decision making and policy formation. Normative approaches to emerging concerns in health planning have adopted a technical approach: Geographical Information System. The continuous advancement of Geographical Information System technology has spurred success in public health surveillance, geographical accessibility, and the use of healthcare service centers.

Hippocrates (2400 years ago) pioneered early contributions to spatial health in his works titled "Airs, Waters, Places" (Krieger, 2003). He proposed that disparities in people's geographical locations influenced variations in their public health status. This was further demonstrated by the writings of Al-Razi (1500 years ago), who was entrusted with identifying the optimum location for the establishment of a hospital in Baghdad City, Iraq. He employed a spatial approach, randomly distributing fresh pieces of meat in various areas and then examining the spot where the meat was free of contamination as the healthiest to locate a health facility after a period of time (Geraghty, 2016). Later in 1694, the commencement of spatial health mapping was initiated in Bari, Italy, in response to the outbreak of plague (Koch, 2016). Mapping was useful in identifying disease hotspots, taming, and monitoring movements within disease-infested areas.

Conventionally, the relationship between GIS and spatial health commenced in 1854, with a catastrophic cholera epidemic in London, England (GISGeography, 2022). Dr. Snow, known as the "Father of Modern Epidemiology," addressed the "enigma" by developing a spatial approach for mapping significant spatial elements associated with the disease outbreak, such as hotspot zones, road and water reticulation networks, and property boundaries. His spatial analysis revealed that water pumps were the source of disease transmission, and that subsequent contagion implied that anyone who drank water from the contaminated pumps almost certainly contracted the disease. As a result, the concept of airborne cholera has been debunked. Dr. Snow's embrace of GIS underscores the indelible relationship between geography and public health, as well as the formidable role of GIS as an avatar to address spatial-related problems and make evidence-based decisions.

Dr. Snow's study has influenced future epidemiological research breakthroughs. Alfred Haviland's work in 1875 resulted in the creation of the first Atlas Colour maps utilizing GIS for the spatial risk of Cancer; particularly, to demonstrate that environmental causative agents had hand in Cancer disease in England and Wales (D'Onofrio et al., 2016). Spatial maps created in previous studies were printed on paper. The transition from paper maps to digital maps followed the advent of computer systems, notably between 1960 and 1990, when primary GIS systems, including Esri software, were developed and launched (GISGeography, 2022). During the 1970s, the use of computerized GIS in scientific disciplines permitted faster and easier map generation, suitability analysis, and development and management of spatial databases (Clarke et al., 1996).

The promise of GIS advancement spurred its acceptance by important epidemiology-based institutions such as the Centers for Disease Control and Prevention (CDC) in the 1990s (Croner, 1998). They were able to achieve important improvements in illness surveillance, usage, and allocation of health resources as a result of their subscription to the technology. After 2000, GIS technology and software advancement and development accelerated the sprout of new technological approaches to public health issues such as disease spread patterns and dynamics mapping, disease monitoring, development of health information systems, accessibility, utilization, and allocation of health resources (Briney, 2014).

2.1.2. Accessibility and dimensions of healthcare access

Spatial accessibility is the ability of a catchment population to conveniently patronize a health facility for service within a prescribed or conventional timeframe (Jankowski and Brown, 2014). The concept of spatial accessibility can be viewed through two main analysis lenses: potential accessibility (an estimated percentage of the catchment population that is assumed to be able to conveniently access health facilities within a defined or acceptable time interval) and perceived accessibility (actual percentage of the catchment population that patronizes nearby facilities and consumes health services) (Khan, 1992). This has also spurred the development of spatial accessibility measuring metrics to identify and justify places with inadequate accessibility and determine optimal locations for future health infrastructure. Penchansky and Thomas (1981) proposed five main dimensions of health-care access in their seminal paper: availability, accessibility, accommodation, affordability and acceptability - which are now known as the "Five As of Healthcare Access" (Table 2.1).

Table 2.1. The 5A's of healthcare access (Source: Penchansky and Thomas, 1981)

Dimensions	Description
Availability	It refers to the sufficiency of healthcare professionals, clinics, hospitals, specialized programs, and services. It also encompass the quantity and variety of current services and resources related to the volume and diverse needs of clients.
Accessibility	A crucial factor to consider is the connection between the supply location and the location of clients. This assessment considers the transportation resources available to clients, including factors such as travel time, distance and cost.
Accommodation	The interplay between the configuration of supply resources to accommodate clients, including appointment systems, operating hours, walk-in facilities, and phone services, and the ability of clients to adapt to these aspects.
Affordability	The correlation between clients' income, affordability, existing health insurance coverage, service expenses, and requirements for provider insurance or deposits. Additionally, clients' perceptions of service quality in relation to overall costs, their awareness of pricing, total expenses, and available financing options are important considerations.
Acceptability	It encompasses unique consumer responses to various features of service providers, including factors such as age, gender, ethnicity, type of facility, neighborhood, or religious affiliation of the facility or provider. Conversely, service providers also hold opinions on patient preferences and payment methods.

2.1.3. Measurements of accessibility

Techniques, assessments, and applied methodology frameworks in the field of spatial accessibility have evolved over time. Recent literature on measures of spatial accessibility to healthcare may be categorized into four major categories: “Provider-to-population ratios”, “Travel impedance to the nearest provider", "Average travel impedance to the provider” and “Gravitational models of provider influence” (Rekha et al., 2017). The primary measures used by health researchers to quantify and scale accessibility are listed in the Table 2.2.

Table 2.2. Measures of spatial accessibility

Metrics	Description
Population – provider ratios (PPR)	Use of rudimentary metrics that are easily interpreted, communicated and implemented by health policymakers.
Gravity model	Measurement using gravity model came to light in the seminal work of (Hansen, 1959). Its prominence as a measure of accessibility has been witnessed through its adoption for use in public health .The gravity model takes the following mathematical form: $$A_i = \sum_j \frac{a_j}{f(c_{ij})}$$ where *i* and *j* are the geographical locations of health demand and health service provider, respectively; an is the size or quality of health supply at *j*; *f* is a travel impedance function; and c_{ij} is incurred cost of travel impedance I and j.Gravity models trade off acceptability with spatial accessibility.
Cumulative Opportunity Measure	The cumulative opportunity measure tallies up the number of opportunities such as the number of health personnel or operational beds within a cut-off distance. It is worth noting that gravity model values can only be intepretated by normalizing over a cutoff distance, cumulative opportunity counts consist of relative and absolute values (Batty, 2009). The disadvantage of this measure is the risk of subjectivity in deciding the appropriate travel cutoff distance which can be avoided using average trip length (Paez et al., 2010).

Table 2.2. (Continued): Measures of spatial accessibility

Metrics	Description
Floating Catchment Area method (FCA)	It was developed in 2003 by Luo and Wang (2003), based on the work of Radke and Mu (2000). The 2SFCA metric is calculated in two steps: computing the catchment population for each service provider and assigning service providers to catchment populations based on weighted population-to-provider ratios. This procedure is mathematically expressed as follows: $$R_j = \frac{S_j}{\sum_{k \in \{d_{kj} \leqslant d_r\}} P_k W(d_{kj})}$$ where p_k is the population of zone k whose centroid lies inside the catchment, S_j is the number of healthcare providers at location j, d_{kj} is the distance between k and j, and $W(d_{kj})$ is the distance decay function of d_{kj}. The second step of summing up the weighted provider-to-population ratios of the providers within defined catchments is as follows: $$A_i = \sum_{j \in \{d_{ij} \leqslant d_r\}} R_j W(d_{ij})$$ where A_i denotes the accessibility at residential point i and d_{ij} denotes the distance between i and j. The Floating Catchment Area measure gained popularity among researchers because it allowed for the consideration of capacity constraints, local competition, and patient cross-border concerns. FCA, on the other hand, suffers from three key bottlenecks: static rigidity in analyzing travel impedances, a propensity to overestimate local demand for service, and the assumption that demand is equally dispersed. It is worth mentioning that FCA has made significant progress by incorporating "variable catchment sizes" (Mcgrail and Humphreys, 2009), "distance decay effects" (Luo and Qi, 2009), "age adjustment healthcare demand" (Ngui and Apparicio, 2011), and "multiple transport modes" (Mao and Nekorchuk, 2013).

Table 2.2. (Continued): Measures of spatial accessibility

Metrics	Description
Expansion Method	The expansion method involves the estimation of the average trip lengths in a multivariate spatial modelling framework with socioeconomic,mobility and location characteristics as exploratory variables (Casetti, 1972). This permits the spatial variations of regression coefficients hence the possibility of establishing the "location specific cut-off values". This approach operates on the assumption that the far people travel is a sufficient indicator of their willingness to travel. Accordıngly, relative to reality,this assumption is flawed since the average distance travelled of persons varies with respect to different purposes and modes of transport.
Kernel density estimation (KDE)	KDE is a spatial analysis method that considers the locations of features in relation to one another. The ability to weigh the distribution of destinations based on their proximity to a primary feature is an essential requirements for utilizing KDE. When researchers employ KDE to examine the distribution of destinations in neighborhoods, they may identify where they are sparsely and densely distributed.KDE is employed in the creation of smooth density surfaces from points through the mathematical expresssion below (Silverman, 1986) : $$\hat{\lambda}(s) = \sum_{i=1}^{n} \frac{1}{\pi r^2} k\left(\frac{s - s_i}{r}\right)$$ where $\hat{\lambda}(s)$ denotes the predicted density at position *s, r is* the search radius or bandwidth, k is a kernel weighting function, and s_i is the location of the observed event. This measurement typology also faces some bottlenecks such as subjectivity in the selection of an appropriate bandwidth size, not considering transport networks and unoccupied land and risk factors of distortion espeacially at the boundaries (Okabe et al., 2009).

2.1.4. Factors affecting healthcare inequalities

Geographic access to healthcare facilities and health inequalities are adversely related (Petrie and Tang, 2008). Although traditional health resource allocation aims to ensure equal and reliable access to healthcare services, this goal is rarely realized due to a variety of influential factors, such as population density, socioeconomic status, the urban-rural divide, and the quality of transportation infrastructure.

- In terms of population distribution, health resources are often allocated to regions with high population densities. However, this strategy has resulted in continual rural-urban migration and unequal allocation of healthcare resources. Owing to their smaller population proportions, rural populations confront vulnerability and health inequities (Hart, 1971).

- Socioeconomic standing also affects access to healthcare. Those with lower incomes must travel greater distances and spend more time reaching healthcare services than those with higher incomes (Chang et al., 2019; Liu et al., 2022). Affluent populations, who can afford their own automobiles, have easier access to healthcare, but those with lower socioeconomic standing must rely on unreliable public transit, which can be time-consuming and inefficient. Furthermore, there is a bias in the allocation of private health facilities and resources, with a preference for places hosting wealthier members of society (Chavehpour et al., 2019).

- The urban-rural divide exacerbates health disparities in resource distribution. Urban locations tend to receive a greater share of health resources owing to their higher population density, superior infrastructure, and economic viability. Private healthcare facilities tend to establish themselves in major cities to maximize profits owing to increased demand. Consequently, healthcare accessibility differs between urban and rural populations (Chavehpour et al., 2019; Cinnamon et al., 2008).

- The distribution of health facilities is also greatly impacted by transportation infrastructure. Areas with well-developed transportation networks such as roads and highways are more appealing for the placement of health infrastructure. Such locations are preferred in the distribution of healthcare resources, whereas those lacking a suitable transportation infrastructure are neglected (Liu et al., 2022).

2.2. Situational Analysis of Health Sector in Kenya

2.2.1. Background

Kenya is located in East Africa and occupies an approximate area of 580,367 square kilometers. It is bordered by South Sudan to the northwest, Ethiopia to the north, Somalia to the east, Uganda to the west, Tanzania to the south, and the Indian Ocean to the east. It is divided into 48 governments, with 47 of them being devolved County Governments, each headed by a governor, and one National Government, led by the President.

Kenya comprises of approximately 47.5 million people spread across 12.2 million households, with an average household size of 3.9 people. English and Kiswahili are official languages, although a wide range of native languages are also spoken. The population of Kenya is predominantly young, with a considerable 73% of the population under the age of 30 and a life expectancy of 66 years. It has the most significant economy in East and Central Africa and is classified as a Lower-Middle-Income Country (LMIC). Tea and coffee are the main sources of income and the agricultural sector is flourishing. Tourism is another key industry contributing to the economy.

2.2.2. Legal and policy framework

The provision of primary healthcare in Kenya is regulated by the following policies and regulations:

Table 2.3. Policy and legal framework governing healthcare provision

Policy/Regulations	Description
Health Act 2017	The Health Act 2017 is a legislation passed by Parliament, which creates a unified health system that manages the interaction between health systems operated by the national and county governments and governs the provision of healthcare services (Government of Kenya, 2017).

Table 2.3. (Continued): Policy and legal framework governing healthcare provision

Policy/ Regulations	Description
The Constitution of Kenya 2010	According to Article 174 of the Kenyan constitution, all Kenyans, including children, people with disabilities, minority and marginalized groups, and the elderly are given the right to receive quality healthcare services. It also promotes and encourages social and economic development and the provision of easily accessible healthcare in close proximity. In addition, the 4th Schedule of the Kenyan constitution entrusts county governments with the responsibility of providing healthcare services to the public while also offering policies, guidelines, standards, and technical assistance (Government of Kenya, 2013).
Kenya Vision 2030	Vision 2030 has set an ambitious goal of transforming Kenya into an industrialized nation with a high quality of life and safe environment by the year 2030. To achieve this, the first initiative under the Health pillar of Vision 2030 is to renew community health centers, pushing them towards preventive healthcare rather than curative care, as well as encouraging healthy lifestyles among the population (Government of Kenya, 2008). This is accompanied by devolving money and control to towns and counties to shift the national focus from curing illnesses to preventing them.
Kenya Third Medium Term Plan, 2018 – 2022	The government presented its Medium-Term Plan (MTP III) which listed the most important goals for 2018-2022. MTP III focused on the community health strategy, which was designed to carry out effective measures and extend health insurance coverage. The components of this plan include National Integrated Community Case Management (ICCM), which will facilitate healthcare initiatives and nutrition-based interventions that will be applied at the local level (Government of Kenya, 2018a).
Universal Health Coverage	The Kenyan government has taken a stronger stance on improving healthcare delivery at the local level, which has positively impacted the country's community health system. The National Ministry of Health (MoH) implemented a Universal Health Coverage (UHC) pilot in four counties, setting the stage for further UHC expansion to other counties in Kenya. Additionally, the MoH has been a primary force behind UHC and pushed for primary healthcare and community health by launching the Kenya Primary Healthcare Strategic Framework (2019 – 2024) and the Kenya Community Health Policy (2020 – 2030).

Table 2.3. (Continued): Policy and legal framework governing healthcare provision

Policy/Regulations	Description
Kenya Health Policy (2014 – 2030)	The Kenyan government created a Health Policy to meet all of its Vision 2030 aspirations in the area of health. The main objectives of the Health Policy are to eradicate communicable illnesses, put an end to, and reverse, the growing prevalence of non-communicable diseases and mental health issues, lessen the effect of violence and injuries, provide necessary healthcare, lower the risk of health conditions, and bolster cross-sector collaboration. The policy also includes a four-tiered system of health services: community unit (tier 1), Primary Care (tier 2), Referral (tier 3) and Tertiary Referral (tier 4). Tier 1, which is the Community Unit, is to concentrates on developing demand for services. The policy further states that community units should assist communities in living healthy lifestyles and recognize signs and symptoms of conditions requiring healthcare (Government of Kenya, 2014a).
Kenya Health Sector Strategic Plan 2018 – 2023	Subsequent to the Astana Declaration of 2018 which is focused on bringing primary healthcare to the forefront of attention to ensure that all people have access to the best possible standard of health, the Kenya Health Sector Strategic Plan (KHSSP) of (2018-2023) offers a fundamental structure for investment in primary healthcare. The KHSSP acknowledges the need to build resilient community health systems to respond promptly and vibrantly to public health emergencies and outbreaks(Government of Kenya, 2014b).
Kenya Primary Healthcare Strategic Framework (2019 – 2024)	In accordance with the Kenyan Constitution 2010 and the Kenya Health Policy Framework (2014-2030), this document furnishes proposals for the development and implementation of plans to enhance Kenya's primary healthcare system. One of the main objectives of the framework is to augment primary healthcare services. One of the major proposals made by the framework is to elevate the current duties of dispensaries to the suppliers of primary healthcare services. This implies a clear decentralization of primary healthcare and reliable access at the community level (Government of Kenya, 2020b).

2.2.3. Health finance

Kenya is going through a transformation in the way healthcare is financed, with the government playing a larger role, while support from donors and businesses is diminishing. From 2009/10 to 2018/19, the government's contribution to healthcare costs increased from 27% to 52% of the total expenditure (World Bank, 2022). The most recent data also show that the amount of money the government has devoted to healthcare as a portion of its total spending has gone up from 8% to more than 10% in the past 10 years (World Health Organization, 2017). This is a positive development towards the goal of the Abuja Declaration, which seeks to allocate 15% of the budget to health, although it is still not enough to provide UHC for everyone in the country.

2.2.4. Human resources for health

In Kenya, there are at least nine health personnel per institution, with the majority found in cities (52.7 percent) and 58.1 percent of them employed in public health facilities compared to 41.9 percent in private institutions (Government of Kenya, 2020a). The distribution of health professionals is dependent on population size, number of healthcare establishments and epidemiological situation in the various counties. The vast majority (90%) of health professionals are nurses or clinical officers, resulting in a lack of doctors. The number of physicians per 1,000 people decreased from 0.2 in 2002 to 0.16 in 2018 (World Bank, 2018). The scarcity of health personnel limits the extent to which counties can deliver consistent care and specialist services and is likely to affect the quality of healthcare, the outcomes, and consequently, the efficacy of the healthcare system (Nyawira et al., 2022). Increased investment in training institutions is essential to meet the heightening demand for health personnel.

2.2.5. Health information systems

In 2014, the Kenyan Health Strategic and Investment Plan identified health information as a key area for investment. To address the restrictions of the File Protocol Transfer System, the District Health Information System (DHIS-2) software was developed in 2010 and is a cloud-based platform that collects and stores data on individual facilities. One of the most prominent Health Information System (HIS) projects is the Kenya Health Management

Information Systems project (KeHMIS), which is overseen by palladium and funded by the United States President's Emergency Plan for AIDS Relief (PEPFAR). The KeHMIS project was initiated in 2011 and is currently in its third phase, aiming to deliver "Patient-Centered Care", as well as increasing the "demand and use of individual-level data"(KeHMIS, 2020).

2.2.6. Access to essential medicines

The Kenya Health Service Delivery Indicator Survey of 2018 reported that hospitals were most likely to have a steady availability of necessary medications, with health centers following closely behind, and dispensaries and clinics having the least access to these essential supplies (World Bank, 2019).

2.2.7. Service delivery

The Kenyan government transitioned from six to four tiers with the Constitution of 2010, granting county governments the power to offer services, including those for community health. The Primary Healthcare Strategic Framework (2019-2024) outlines a service provision hierarchy that progresses through various levels, starting from community units (Level 1), dispensaries (Level 2), and health centers (Level 3), then advancing to primary referral hospitals (Level 4), secondary hospitals (Level 5), and tertiary hospitals (Level 6). (Government of Kenya, 2020a) (Figure 2.1).

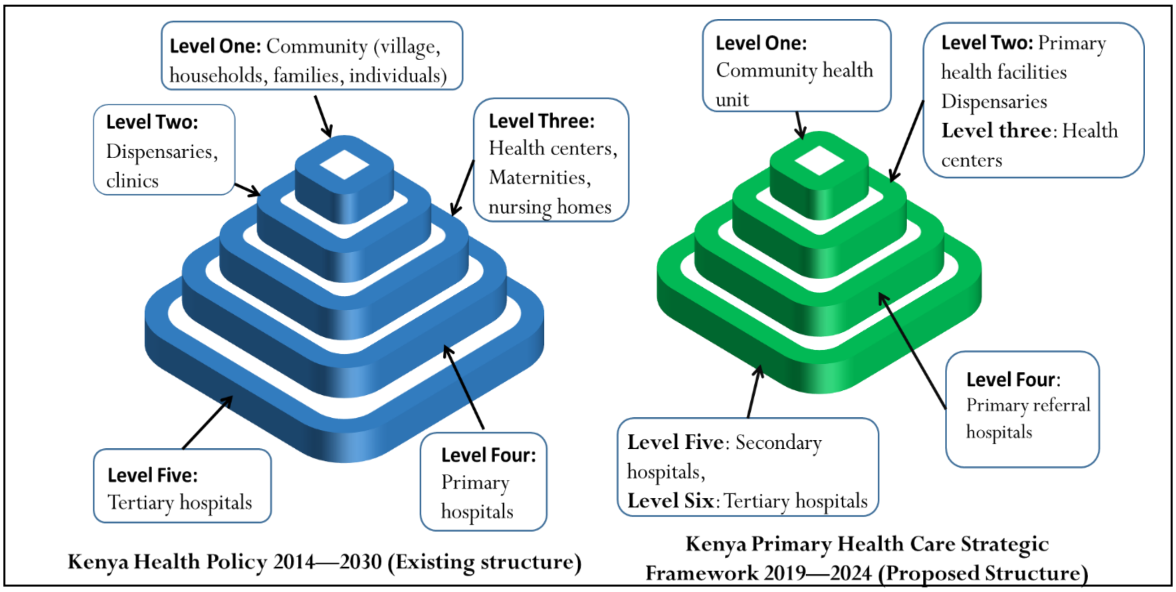


Figure 2.1. Existing and proposed hierarchy of service delivery

3. METHOD

This section covers the overarching research methodology, data collection sources, data collection methods, data processing procedures, and their utilization to address research objectives and questions. The research design was informed by an extensive literature review and encompassed a compilation of datasets and network analysis, leading to the identification of diverse policy implications and recommendations.

3.1. Data Sources

By examining already existing spatial data and obtaining spatial data from satellite imagery, relevant datasets were gathered. Sources such as the Kenya National Bureau of Statistics (KNBS), Kenya Master Health Facility List (KMHFL), Survey of Kenya (SOK), World Resource Institute (WRU), The World Bank Data Catalogue, openstreetmap (OSM) and Climate Research Unit (CRU) were among the sources used. In addition, Google Earth and USGS gave access to digital elevation models (DEM), land use, slope, hydrology, etc. To verify the accuracy of the data, an overlay of all spatial datasets on Google Earth was conducted, which necessitated edits, data cleaning, and rectification of spatial errors.

3.2. Preparation of Health Facility Dataset

The health facility data utilized in this study were derived from an evaluation of the Kenya Master Health Facility List (KMHFL), accessed on January 5, 2023. To augment this dataset, a thorough online searches across various health facility listings was conducted and downloaded datasets from health facility data directories such as the United Nations Office for the Coordination of Humanitarian Affairs' (UNOCHA) Humanitarian Data Exchange (HDX) portal. We also utilized data from online Health Management Information Systems such as Afya 360, along with health information websites of non-governmental organizations (NGOs) operating within the country, such as Life Yangu.

To ensure data accuracy, we geocoded the health facilities and performed analyses using ArcMap, version 10.6. These facilities were clipped to align them with the administrative boundaries of Migori County. To validate the precision of the geographical coordinates, the dataset was overlaid onto Google Earth, correcting any identified spatial inaccuracies.

Additionally, duplicate entries and spatial inaccuracies within the health-facility dataset was rectified and updated appropriately. For the purposes of t study, which concentrated on primary healthcare facilities offering basic healthcare services and operational inpatient and outpatient services, we excluded Level 2 and Level 1 health facilities from the analysis. However, during the planning intervention phase, Level 2 facilities was considered, specifically dispensaries, to identify those that were strategically located and merited consideration for potential upgrades.

3.3. Modelling Demand Points

To assess healthcare accessibility, demand points requiring healthcare services were derived from the WorldPop top-down constrained dataset. This dataset portrays the geographic distribution of the population in 2020, which was refined on a national scale to align with the UNPD estimate for the same year (Bondarenko et al., 2020). It was chosen due to its proven accuracy in constraining population enumeration within settlement areas (Hierink et al., 2022; Nilsen et al., 2021), making it particularly suitable for this purpose. The population dataset was refined by clipping it with the Migori County administrative boundary. Subsequently, the dataset was transformed into a vector format, and a grid of 200m x 200m cells was created. The centroids of these grid cells were then considered as the demand points. Every demand point served as a host for estimating healthcare access to the population.

3.4. Modeling the Operating Hours of Facilities

The Google Map dataset offers information on the operational schedule of primary healthcare facilities on weekdays and weekends. Employing ArcMap version 10.6, the shapefiles of healthcare facilities were classified into three distinct categories: facilities operating exclusively on weekdays, those functioning on both weekdays and weekends, and those providing services continuously throughout the week. Subsequently, a service area analysis was conducted, generating isochrone maps to visualize the geographical reach of primary healthcare facilities individually for weekdays, weekends, and 24/7 operational scenarios.

3.5. Network Analysis

The utilization of network analysis was adopted to model the primary healthcare facilities' service area and to explore alternative scenarios that would facilitate an equitable distribution of health resources. This research made use of the service area model and location-allocation models' capabilities to ascertain the spatial efficiency of the target health facilities and to make evidence-based proposals.

3.5.1. Network dataset configurations

The foundation of any network analysis project is the network dataset. For the assessment, a network dataset was created using the roads dataset developed by Kenya Roads Board (KRB). This was complemented with the road shapefiles obtained from OSM were cross-referenced with satellite images through Google Earth software. The data underwent cleansing in ArcMap version 10.6, eliminating duplicate entries and resolving any digitization errors. The resulting refined dataset was utilized to generate the network dataset used in the network analysis.

3.5.2. Modelling travel time

The study sought to calculate the amount of time it took for patients in need of primary healthcare to go from their home or workplace to the nearest health center. To accomplish this, the mode of transportation, the speed of travel, and the type of roads used were all taken into account. The two modes of transportation examined were walking and motorized transportation, and the speeds of travel were based on findings from prior research (Macharia et al., 2021) (Table 3.1).

Table 3.1. Assigned according to respective road classes

Road Class	Speed (Km/hr)		
	Walking	Motorbike	Vehicle
International trunk road	4	35	65
Primary road	4	30	40
Secondary road	4	30	40
Rural access road	4	20	25

3.5.3. Service area analysis

The service area model was executed by utilizing the network dataset to build isochrones maps of primary healthcare facilities. A time travel impedance of fifteen minutes was adopted to reveal the accessibility dynamics of the residents at diverse locations from the closest health center. The model perceived individuals seeking primary health services commencing their journey from the demand points to the nearest primary healthcare provider.

3.5.4. Location-allocation analysis

The Maximum Covering Location Problem (MCLP) was employed in this study. This model was devised to maximize the placement of pre-determined health service locations within a pre-defined trip impedance cut-off (Church and ReVelle, 1974). This feature has been employed by previous researchers to identify the optimal locations for health services from a list of all proposed locations (Gerrard et al., 1997). Additionally, the MCLP operates under four crucial constraints: allocation of demand to the closest service location within the travel impedance cut-off, specifying the number of service facilities to be chosen (p-service value), and enforcement of an integer restriction property on the model's location and allocation variables.

3.6. Summary of Research Methodology Framework

The research process involves two major components: modeling service coverage and policy recommendations. At the outset, datasets were collected and modified to obtain a better understanding of the distribution of resources throughout the county and how they associated with and impacted the health resources that were the focus of the study. A network dataset was created and then used to analyze the spatial accessibility of the catchment population, taking into account travel dynamics and changes in healthcare facility operations. The second phase of the methodology was composed of two sub-stages: spatial accessibility analysis and planning intervention (Figure 3.1).

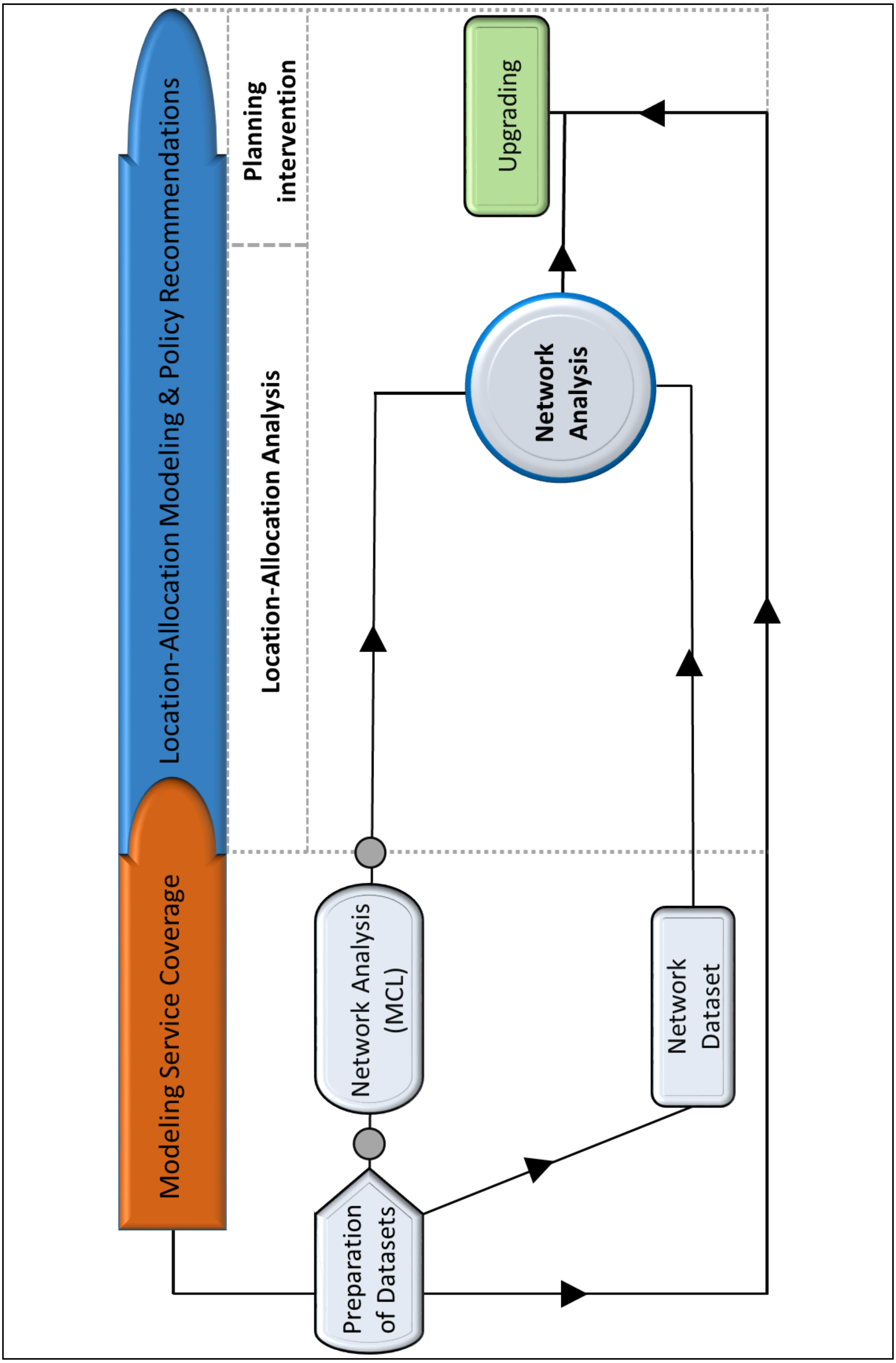


Figure 3.1. Methodology framework

4. STUDY AREA PROFILE

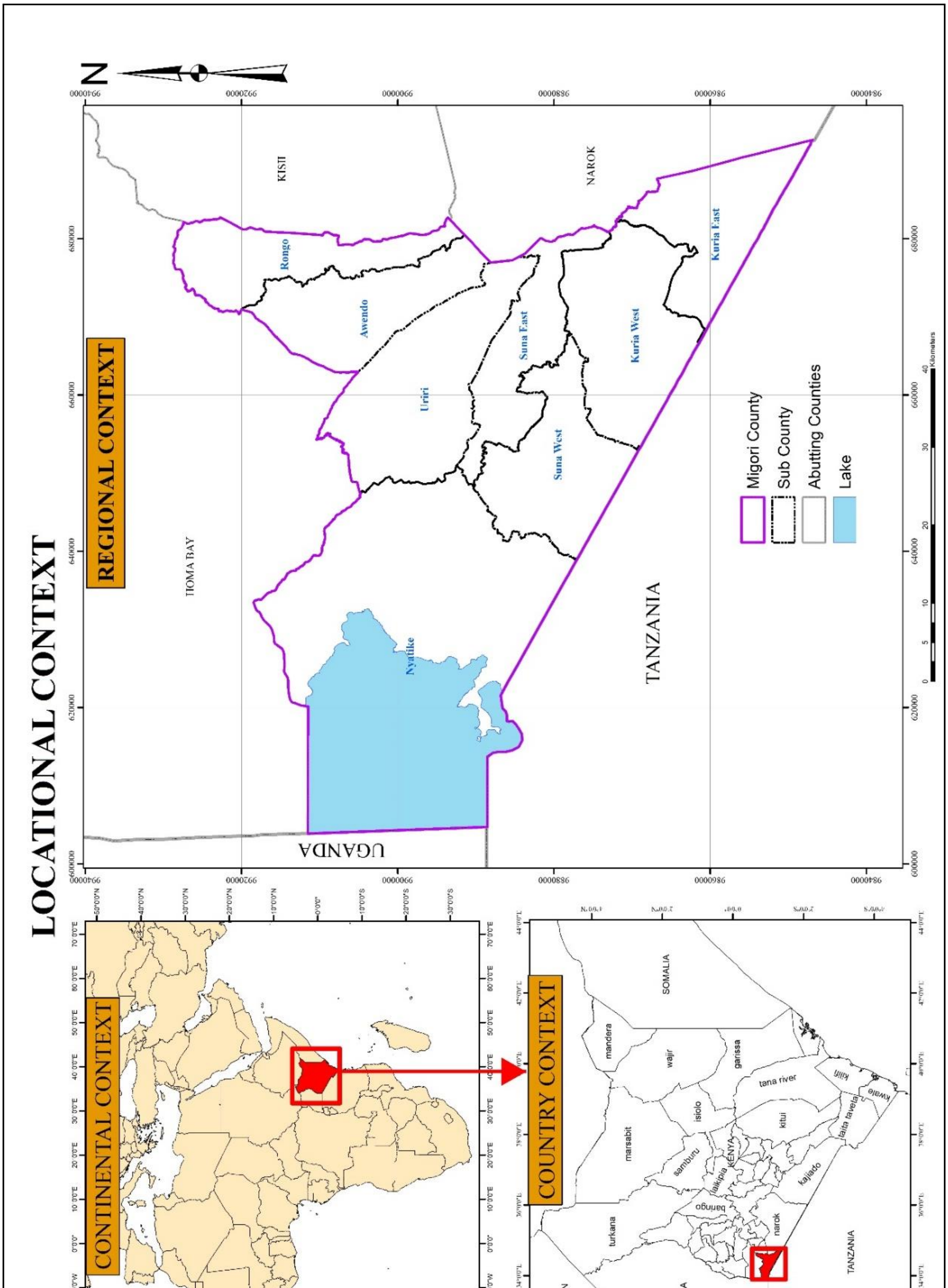
This chapter provides a comprehensive overview of Migori County's physical, ecological, climatic, demographic, and geological environments. It provides an overview of the size, location, administrative hierarchy, terrain typology, hydrological configurations, agro-ecological zoning, climate, urban profiles, population dynamics, and soil and lithological features. The administrative hierarchy of the Migori County offers a foundation for comprehending the geographical variations in physical, climatic, demographic, hydrological, and topographic characteristics. Understanding the endowed resources allows for a better understanding of development issues, orientations and potentials. Additionally, a proper understanding of the geographical elements and dynamics that impact the county's social, economic, and political drivers provides potential entry points from which development may be delivered in an equitable and sustainable manner.

4.1. Geographical Location

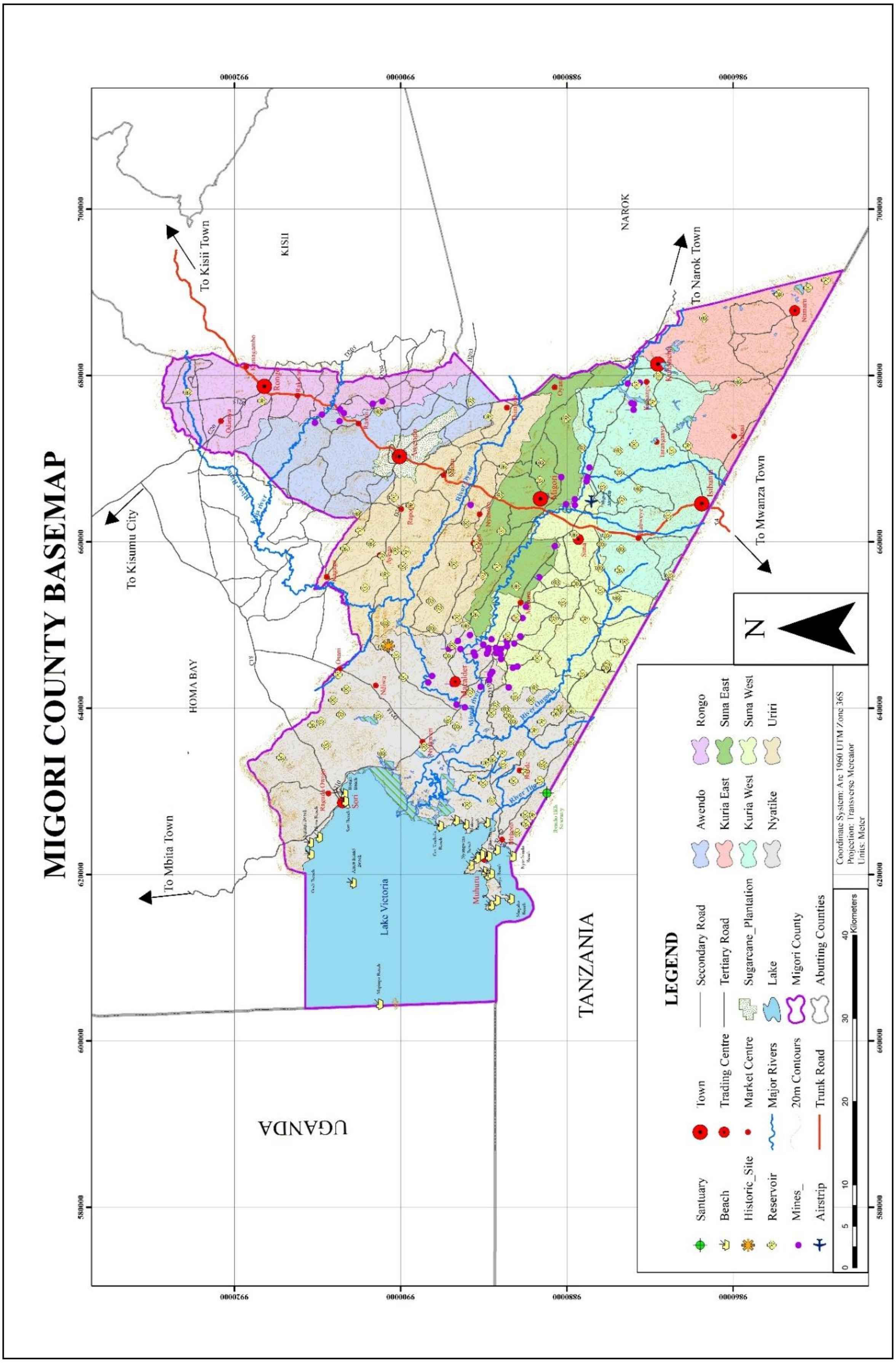
Migori County is one of Kenya's 47 counties, with a total size of 2,596.5 km^2 that includes 478 km^2 of the Lake Victoria Basin. Homa Bay County borders it in the North, Kisii and Narok Counties in the East, the Republic of Tanzania in the South, and the Republic of Uganda in the West. Migori County is divided into eight administrative sub-counties: Nyatike, Rongo, Awendo, Uriri, Suna East, Suna West, Kuria West, and Kuria East. Furthermore, the sub-counties are subsequently divided into 40 electoral wards (Map 4.1-2).

4.2. Physical and Topographical Profile

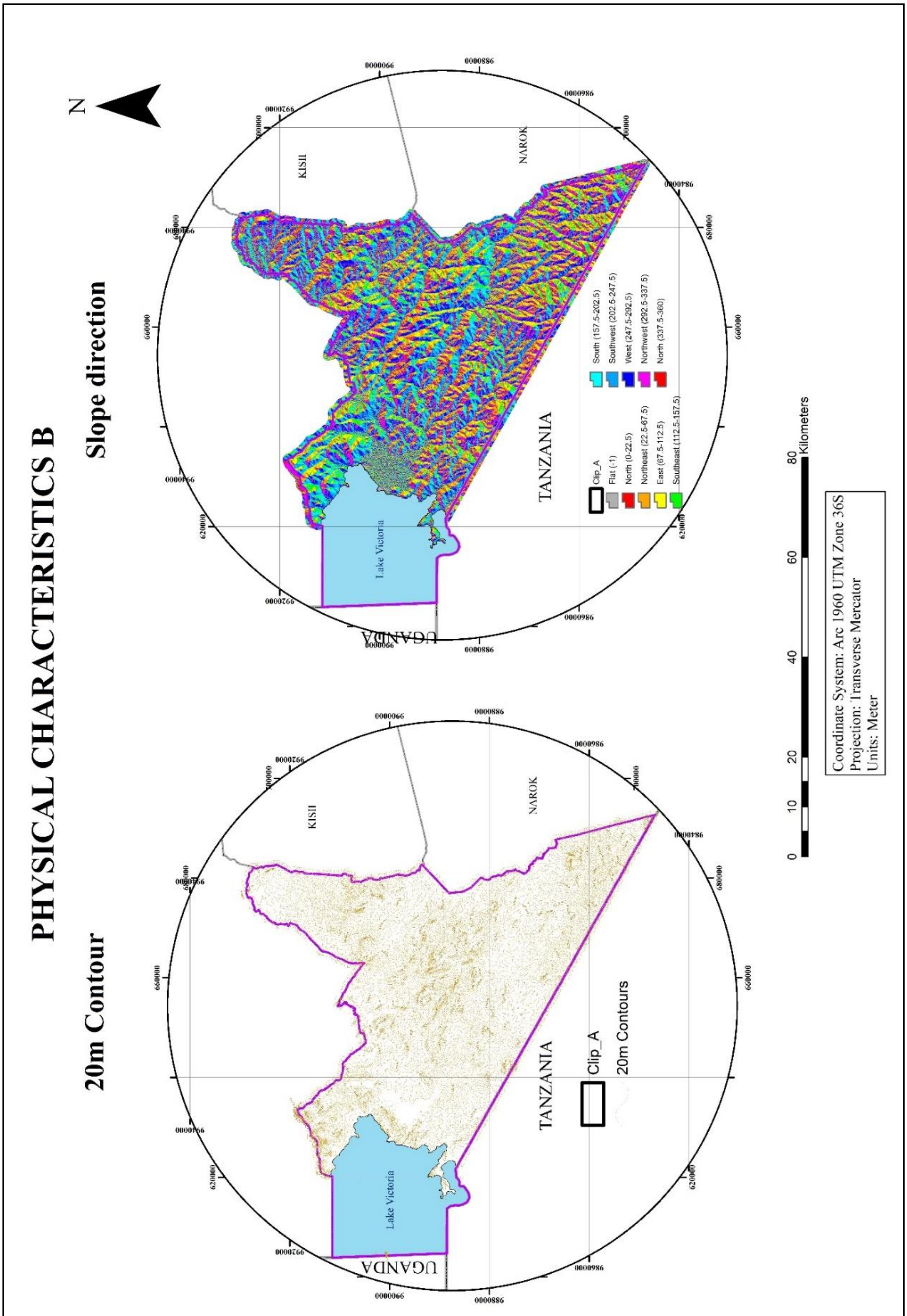
The elevation configuration of the county ranges from 1134m to 1892m. Nyatike and Kuria West Sub-counties have the lowest and highest points, respectively. The natural occurrences of undulating and flat regions displayed slope disparities. Furthermore, the presence of undulating hills such as Nyakune, Ogengo, God Sibwoche, God Kwer, Mukuro and Nyabisawa, God Kwach, Renjoka, and Maeta informs the spatial disparity in altitudes. In the county, the slope percentage ranged from 0% to 36% (Map 4.3). Generally, the county's physical geography slopes from east to west, according to the regional natural terrain that drains into the Lake Victoria Basin (Map 4.3-4).



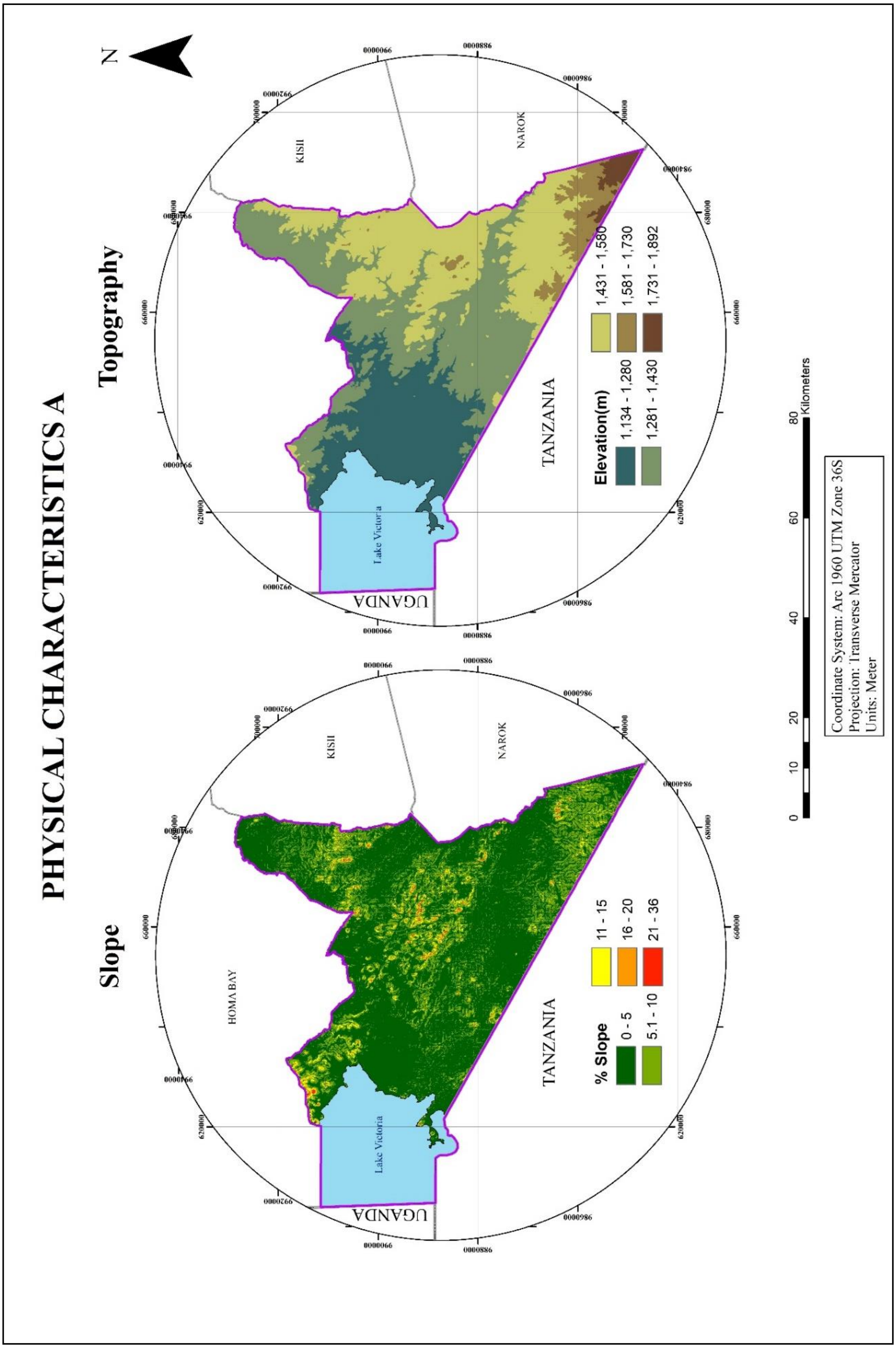
Map 4.1. Locational context of Migori County (Source: SOK)



Map 4.2. Migori County basemap (Source: WRU, Google Earth, OSM)



Map 4.3. The slope and topography of Migori County (Source: USGS)

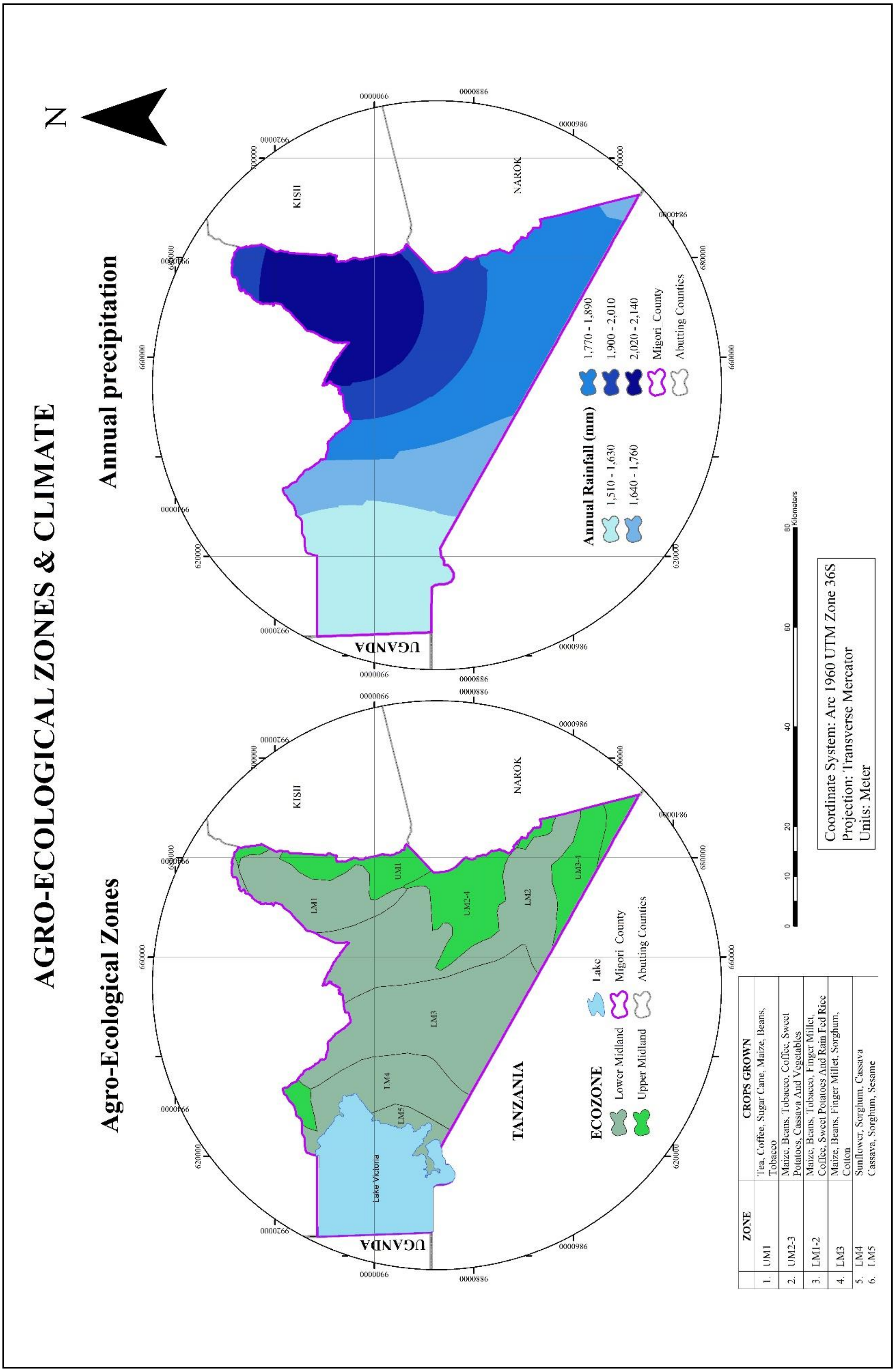


Map 4.4. The contours and aspect of Migori County (Source: USGS)

4.3. Ecological and Climatic Conditions

Successful farming in Kenya is heavily reliant on the FAO's agro-ecological zones. The county is split into two agro-ecological zones: the Upper Midlands (UM) and the Lower Midlands (LM). These zones were further divided into the following six groups: UM1, UM2-3, LM1-2, LM3, LM4, and LM5. These zones describe and map crops with increased agricultural potential based on soil, natural characteristics, and climatic conditions (FAO, 1996).

The county's proximity to the Lake Victoria Basin and undulating terrain impact the climatic conditions encountered. Annually, the area has two seasons: rainy (March to May and September to November) and dry (December to February and June to September) (Government of Kenya, 2018b). The annual rainfall in the previous year ranged from 1,510 mm to 2,140 mm. Annual rainfall of more than 2,000 mm was only experienced in Rongo and Awendo Sub-Counties, whereas Nyatike Sub-County receives low and inconsistent rainfall of as little as 1,510 mm. The region also has an average annual temperature ranges of 24^oC - 31^oC (Government of Kenya, 2018b) (Map 4.5).

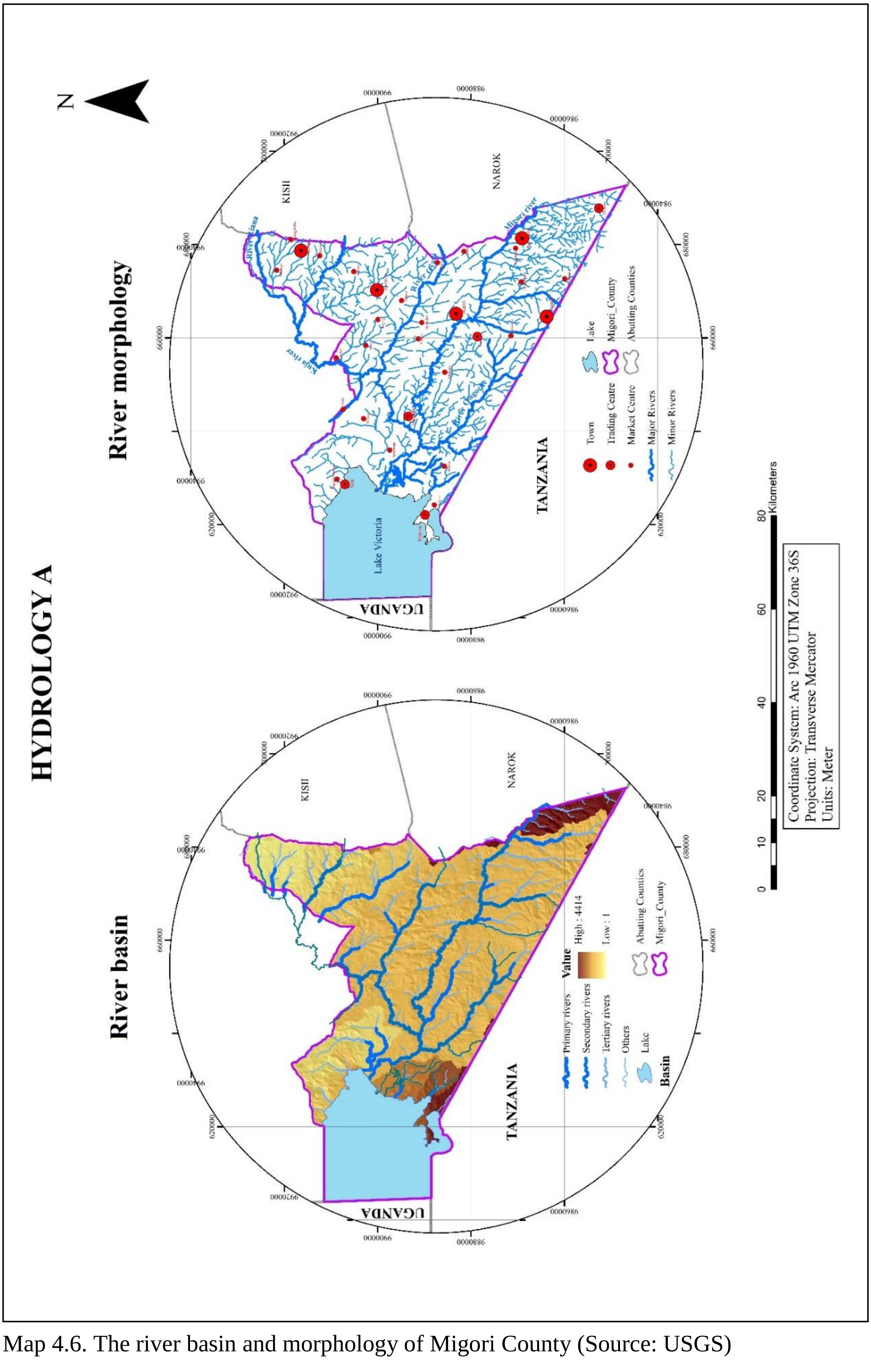


Map 4.5. Agro-ecological zones and climatic conditions (Source: CRU)

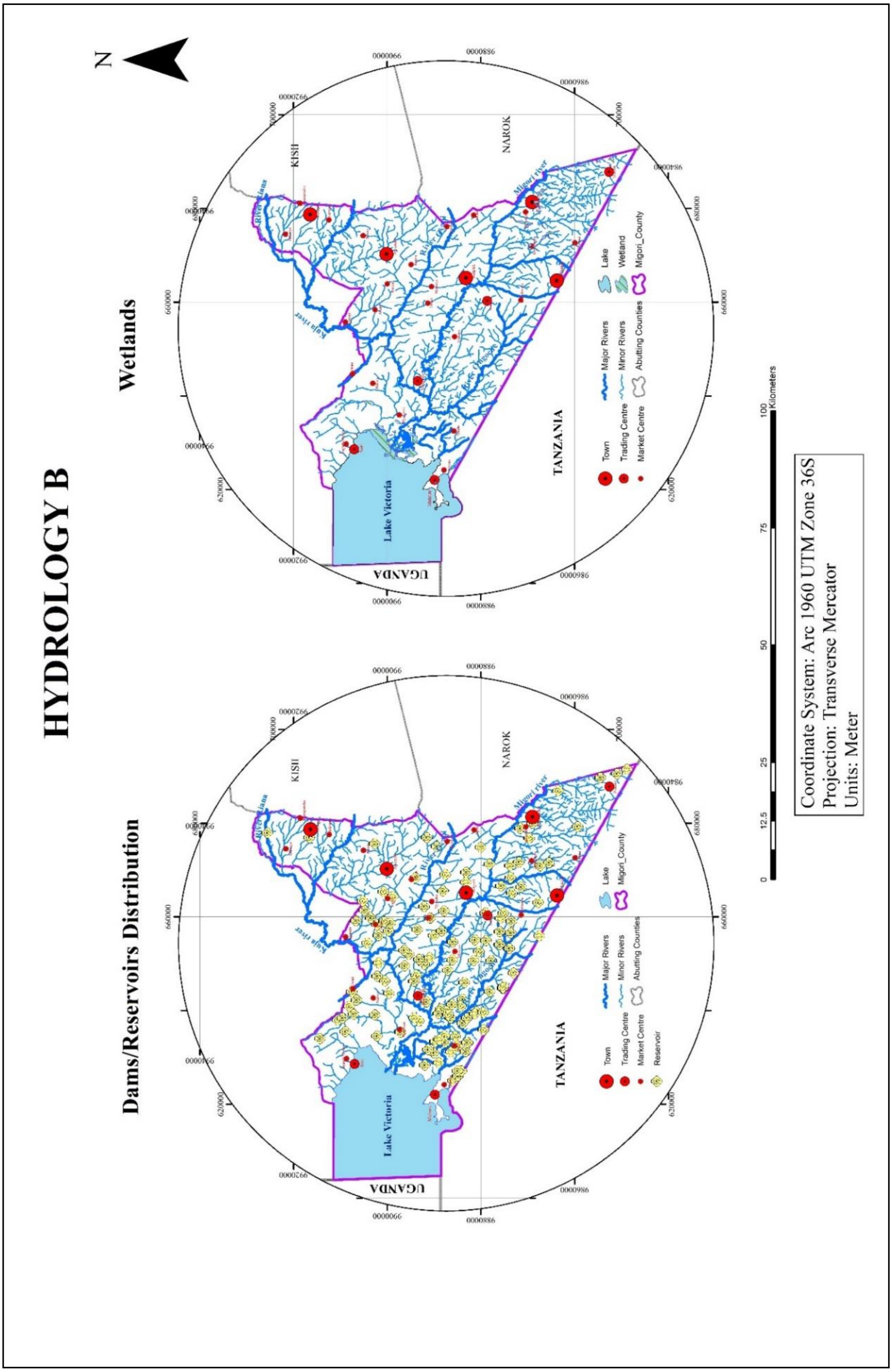
4.4. Hydrology Profile

Migori County's undulating terrain descends structurally and drains into Lake Victoria Basin. The two largest rivers that traverse the county are the Kuja and Migori rivers, which originate in the Kiabonyoru highlands in Nyamira County and the Chepalungu forest in Bomet County, respectively. The two rivers join at a confluence near the Nyandema Market Center (Macalder Ward) to form the Gucha-Migori River Basin, which ultimately drains into the Lake Victoria Basin (Government of Kenya, 1975). Other notable seasonal rivers that feed into the Gucha-Migori River Basin are the Riana, Ongoche, Oyani, and Sare rivers (Map 4.6).

The County has also invested in the construction of infrastructure dams and reservoirs. There are approximately 132 reservoirs installed along the river channels in the county. Some of the dams / reservoirs include but not limited to Gogo, Nyamome, Nyagesese, Nyamweni, Stella, Silanga, Suka, Yao, Mifwadhi, Omamba, Sare, Orarwe, Sanawa etc. The Gogo Dam is located near Gogo Falls along the Kuja River and is primarily used to generate hydroelectric power (HEP), irrigation, and domestic supply of water (Government of Kenya, 1975). The county also registers sites that can be classified as wetlands. These areas are mostly located along large river valleys, particularly the Gucha-Migori River Basin. Wetlands are prominent in Nyatike Sub-county, particularly at the confluence where the Gucha-Migori River feeds into Lake Victoria. The area hosts several meanders and alterations in the river channels, implying the occurrence of wetlands in the earlier river channels (Map 4.7).



Map 4.6. The river basin and morphology of Migori County (Source: USGS)

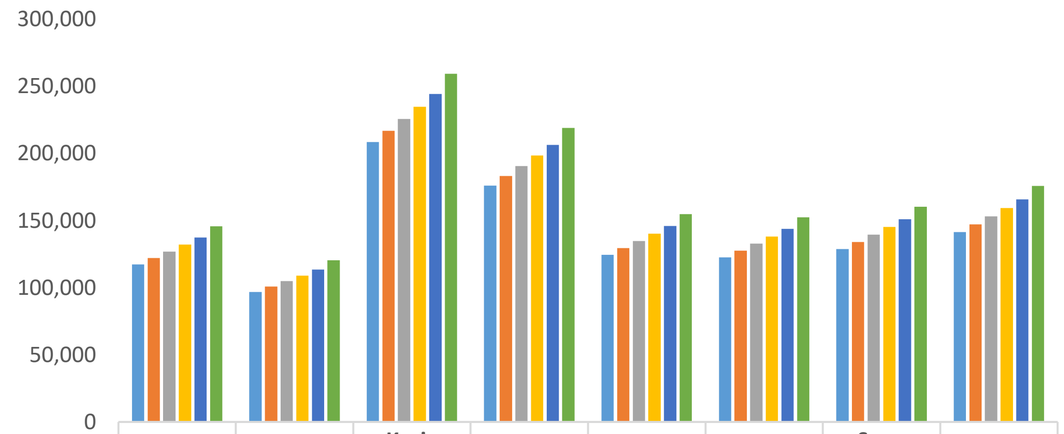


Map 4.7. The reservoirs/dams and wetlands in Migori County (Source: WRU, USGS)

4.5. Demography

4.5.1. Population

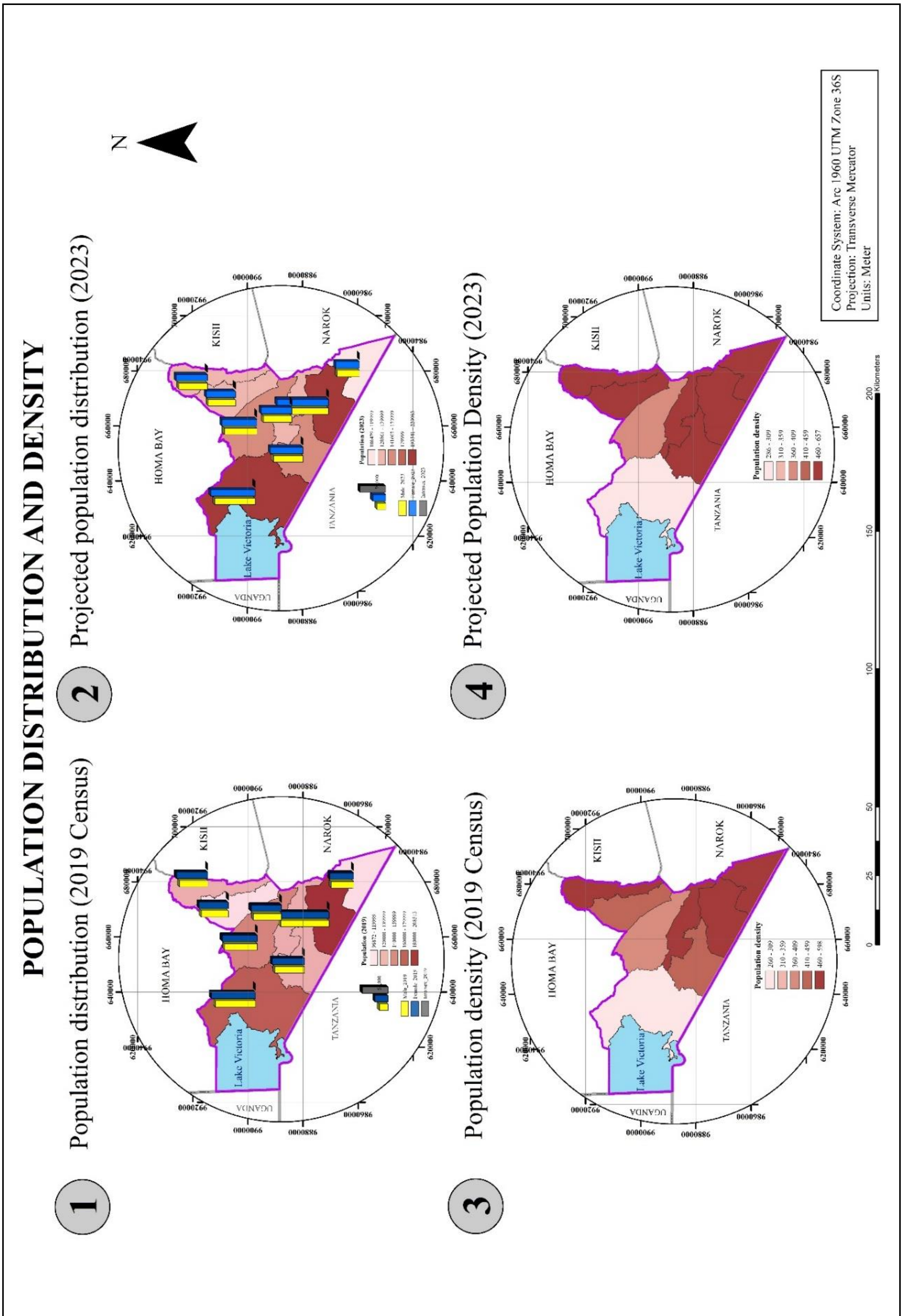
According to the 2019 Population Census, the total population of Migori County was 1,116,436 people, with 536,187 men, 580,214 females, and 35 intersex persons (Government of Kenya, 2019a). The annual population growth rate is 2.38%; thus the current projected population is 1,208,466. Nyatike and Kuria West Sub Counties have a larger population, accounting for 16% and 19% of the county's population, respectively. In 2030, the county is expected to host an extra 179,682 persons which would demand efficient and rational decision making in the distribution and redistribution of County resources (Figure 4.1).



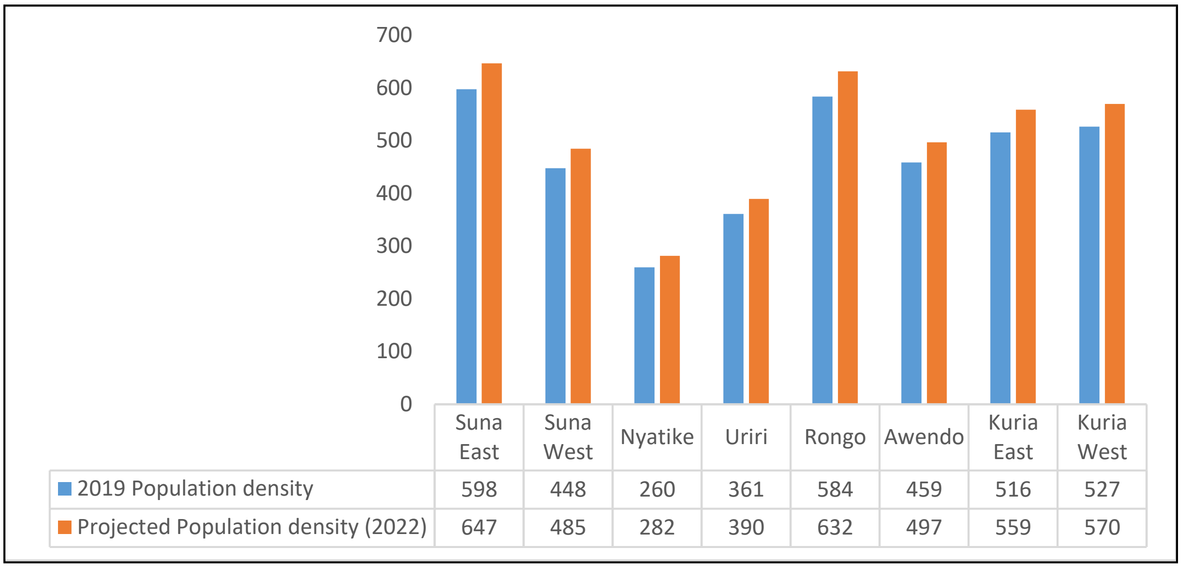
	Awendo	Kuria East	Kuria West	Nyatike	Rongo	Suna East	Suna West	Uriri
Sum of 2019	117,290	96,872	208,513	176,162	124,587	122,674	128,890	141,448
Sum of 2021	122,029	100,786	216,937	183,279	129,620	127,630	134,097	147,162
Sum of 2023	126,958	104,857	225,701	190,683	134,857	132,786	139,515	153,108
Sum of 2025	132,088	109,094	234,820	198,387	140,305	138,151	145,151	159,293
Sum of 2027	137,424	113,501	244,306	206,402	145,974	143,732	151,015	165,729
Sum of 2030	145,835	120,448	259,260	219,035	154,908	152,530	160,259	175,873

Figure 4.1. Population projections of Migori County (Source: KNBS)

According to the 2019 Population Census, the County had a population density of 427.2 people per square kilometer. High population densities of more than 460 persons per square kilometer were exhibited in Suna East, Rongo, Kuria East and Kuria West Sub-Counties. According to the current projected population density, only Nyatike and Uriri Sub-Counties have population densities of less than 460 people per square kilometer (Figure 4.2).



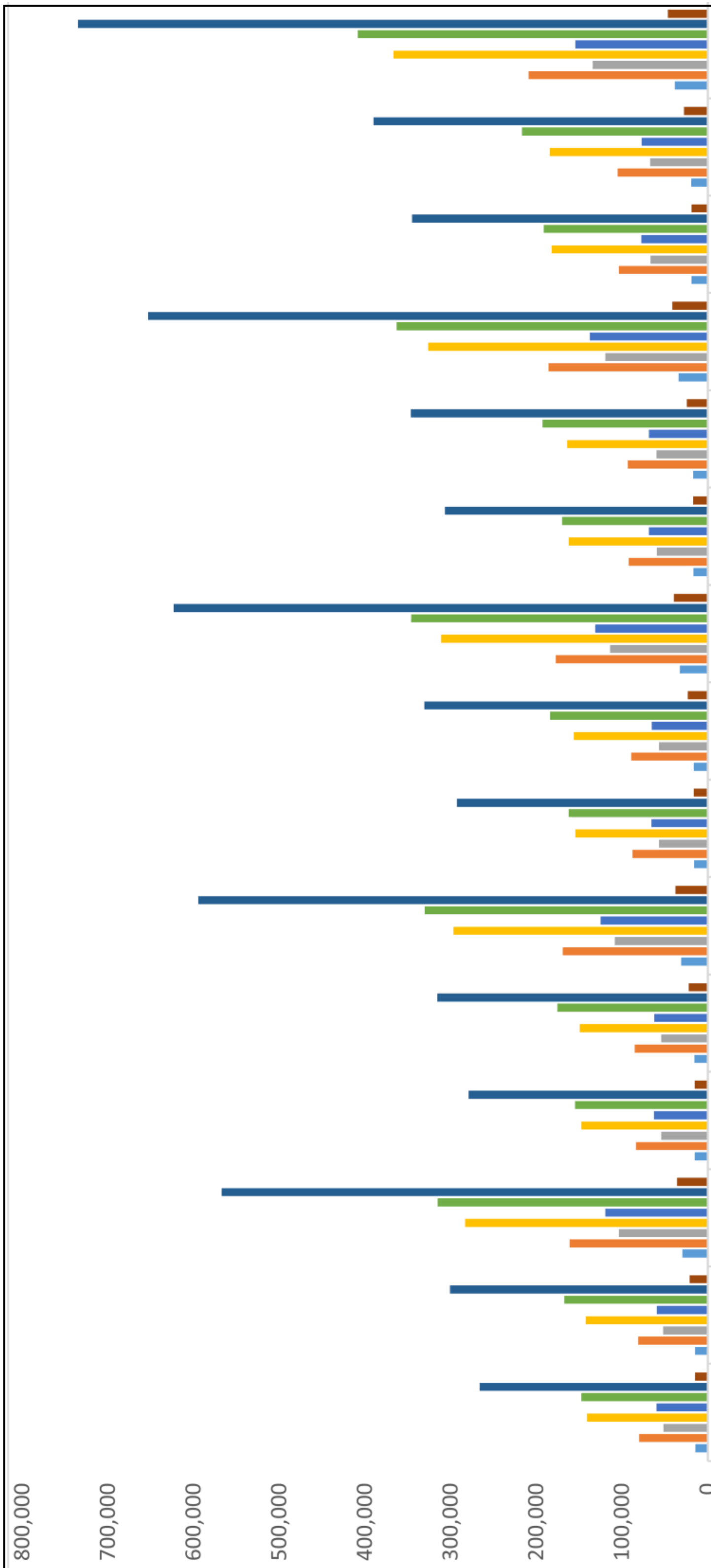
Map 4.8. Population density and distribution in Migori County (Source: KNBS)



	Suna East	Suna West	Nyatike	Uriri	Rongo	Awendo	Kuria East	Kuria West
2019 Population density	598	448	260	361	584	459	516	527
Projected Population density (2022)	647	485	282	390	632	497	559	570

Figure 4.2. County projected population density (Source: KNBS)

74% of the Migori County population comprises persons less than 30 years old and children below 15 years old and the youth population accounts for 46% and 28%, respectively (Government of Kenya, 2019b). The Labour force in the county accounts for 50.8% of the total population, while the dependent population stands at 49.2%. The majority of the county's labour force resides in Kuria West and Nyatike Sub-Counties and accounts for 34% of the total labour force. Additionally, both Kuria West and Nyatike Sub-Counties also registered the highest dependency ratio of 98%.On average, according to the 2019 population Census, Migori County recorded a high dependency ratio of 96.72%, which implies a heavy economic burden on the labour force to support and sustain the needs of the dependent populations. The projected population of the 2023 age cohort below one year is 32,622, which implies the need to invest in improved nutrition and child survival programs to cushion infant mortality. Of the 2023 projected population, 14% comprise children less than five years of age, requiring sufficient access and provision of Early Childhood Development education programs and centers. Moreover, Migori County has a low aged population (3.2%), since the life expectancy in Kenya is estimated to be 63 (World Bank, 2020). Nyatike Sub-County registered the highest projected aged population, amounting to 7,013 persons in 2023 (Figure 4.3-5).



	2019 Male	2019 Female	2019 Total	2,021 Male	2,021 Female	2,021 Total	2023 Male	2023 Female	2023 Total	2025 Male	2025 Female	2025 Total	2030 Male	2030 Female	2030 Total
Under 1	14,715	14,978	29,693	15,424	15,699	31,123	16,167	16,456	32,622	16,945	17,248	34,194	19,060	19,401	38,461
Under 5	80,137	81,289	161,426	83,997	85,204	169,201	88,043	89,308	177,351	92,283	93,610	185,894	103,801	105,293	209,093
Pre-School (3-5)	51,736	52,002	103,738	54,228	54,507	108,735	56,840	57,132	113,972	59,578	59,884	119,462	67,013	67,358	134,371
Primary School (6-13)	140,856	142,531	283,387	147,641	149,396	297,037	154,752	156,592	311,344	162,206	164,135	326,340	182,449	184,619	367,068
Secondary School (14-17)	59,823	59,672	119,495	62,704	62,546	125,251	65,725	65,559	131,284	68,890	68,717	137,607	77,488	77,292	154,780
Youth Population (15-29)	147,788	167,565	315,353	154,906	175,636	330,542	162,368	184,096	346,463	170,188	192,963	363,151	191,428	217,045	408,473
Labour Force (15-64)	266,400	301,093	567,493	279,232	315,596	594,827	292,681	330,797	623,478	306,779	346,730	653,509	345,065	390,002	735,067
Age Population (65+)	14,762	21,351	36,113	15,473	22,379	37,852	16,218	23,457	39,676	16,999	24,587	41,587	19,121	27,656	46,777

Figure 4.3. Population projections of the county by age and sex (Source: KNBS)

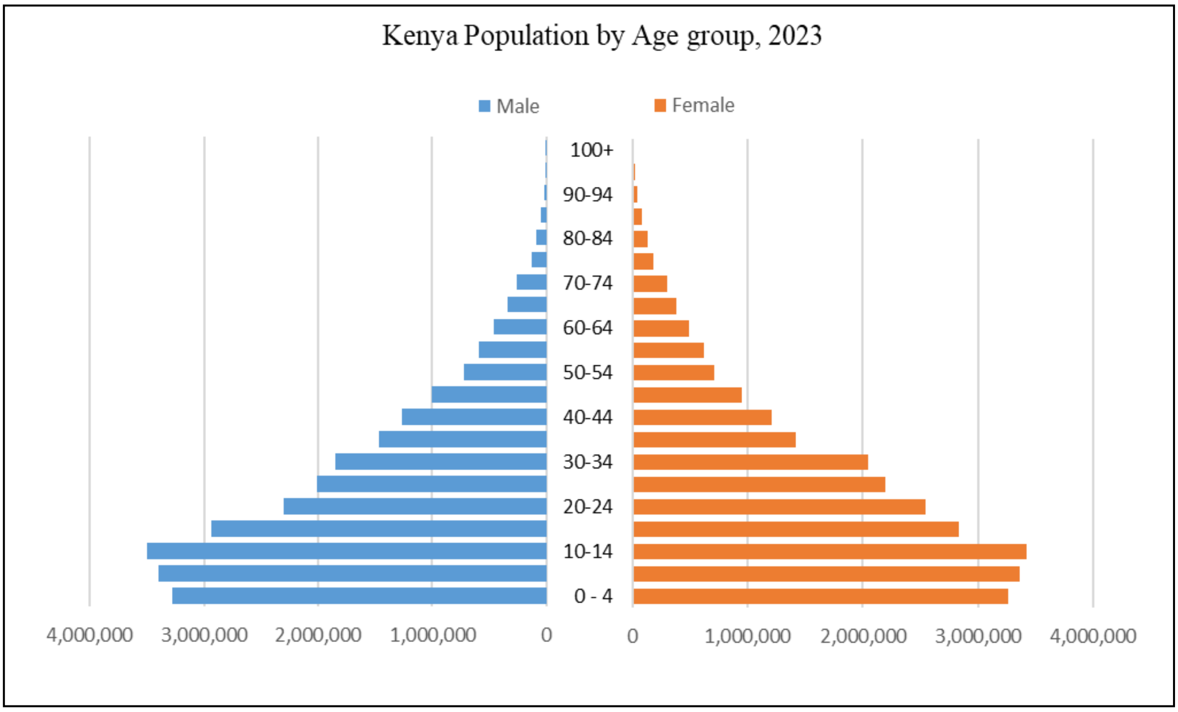


Figure 4.4. 2023 Population distribution of Kenya by age and sex (Source: KNBS)

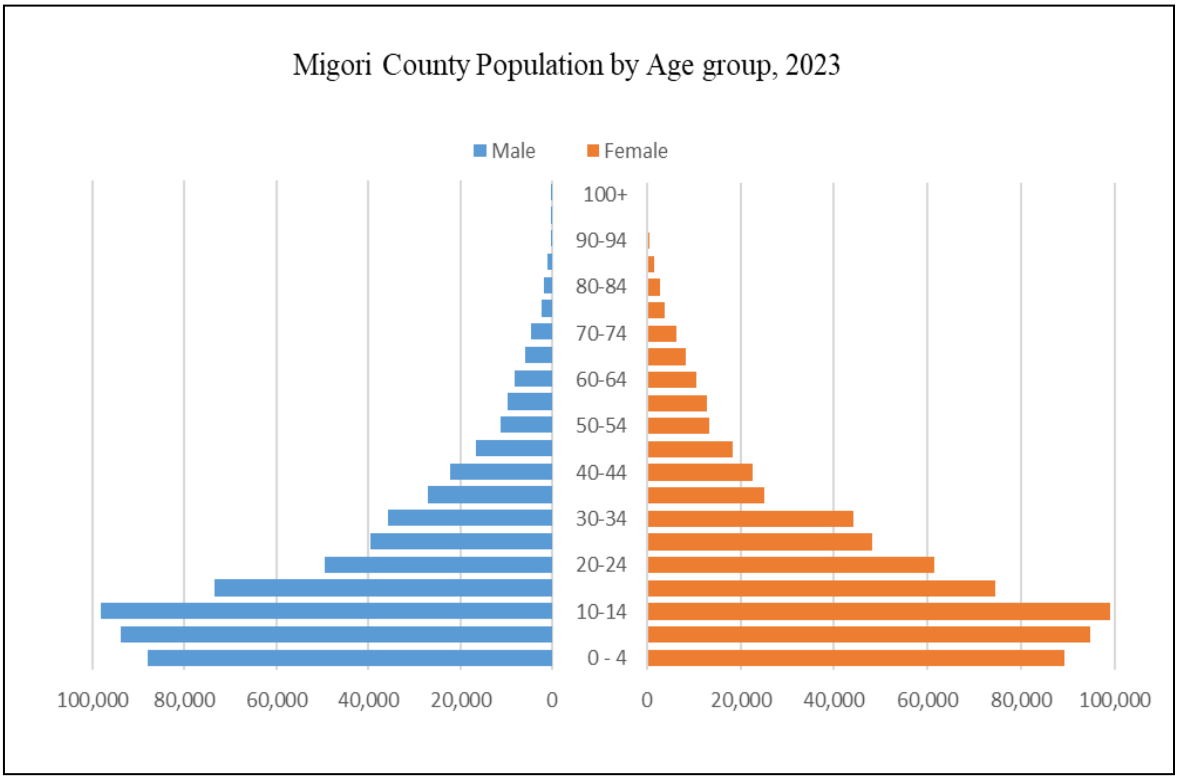
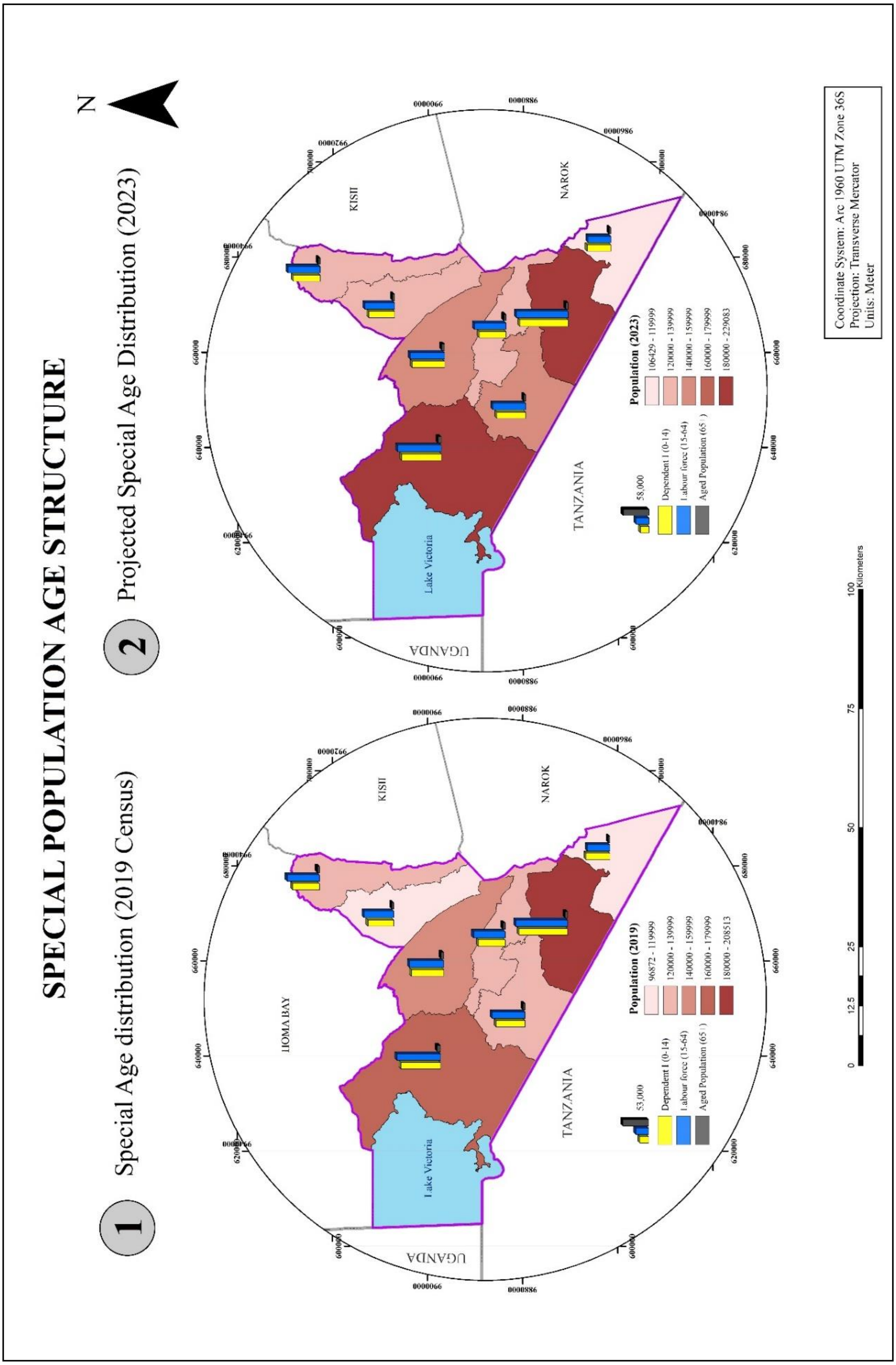


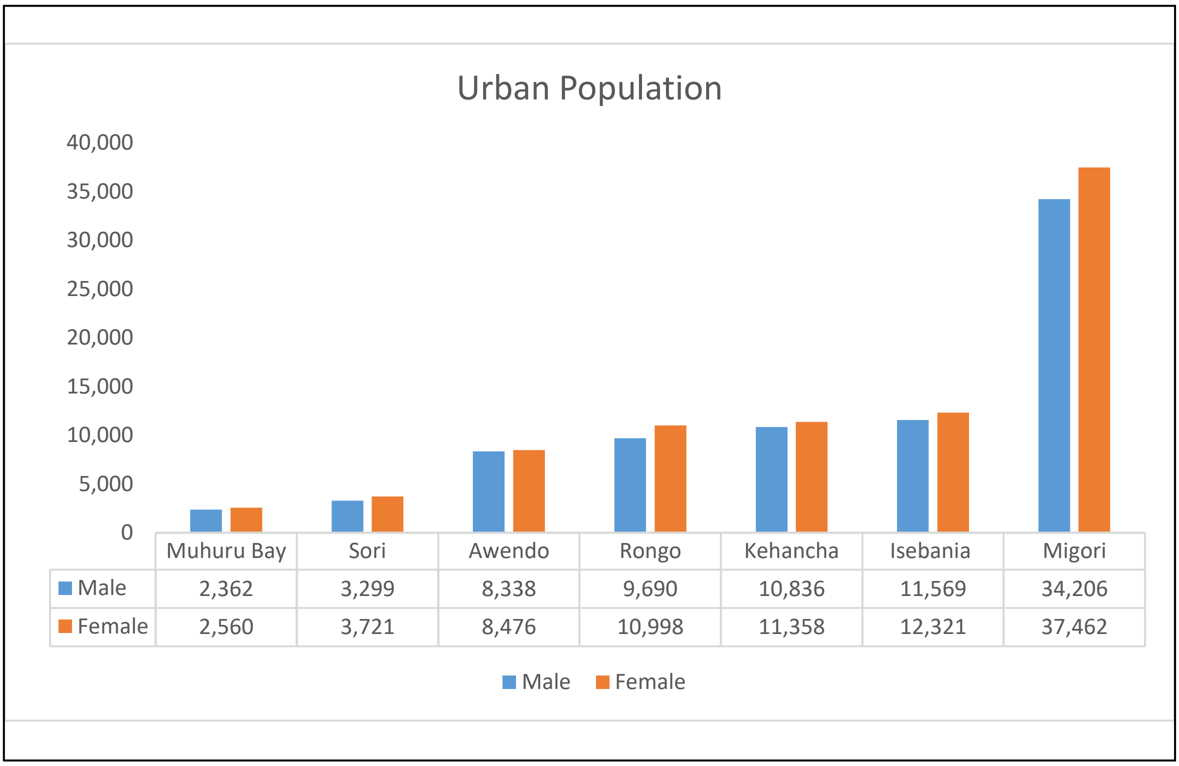
Figure 4.5. 2023 County population distribution by age and sex (Source: KNBS)



Map 4.9. The Population distribution of the special population (Source: KNBS)

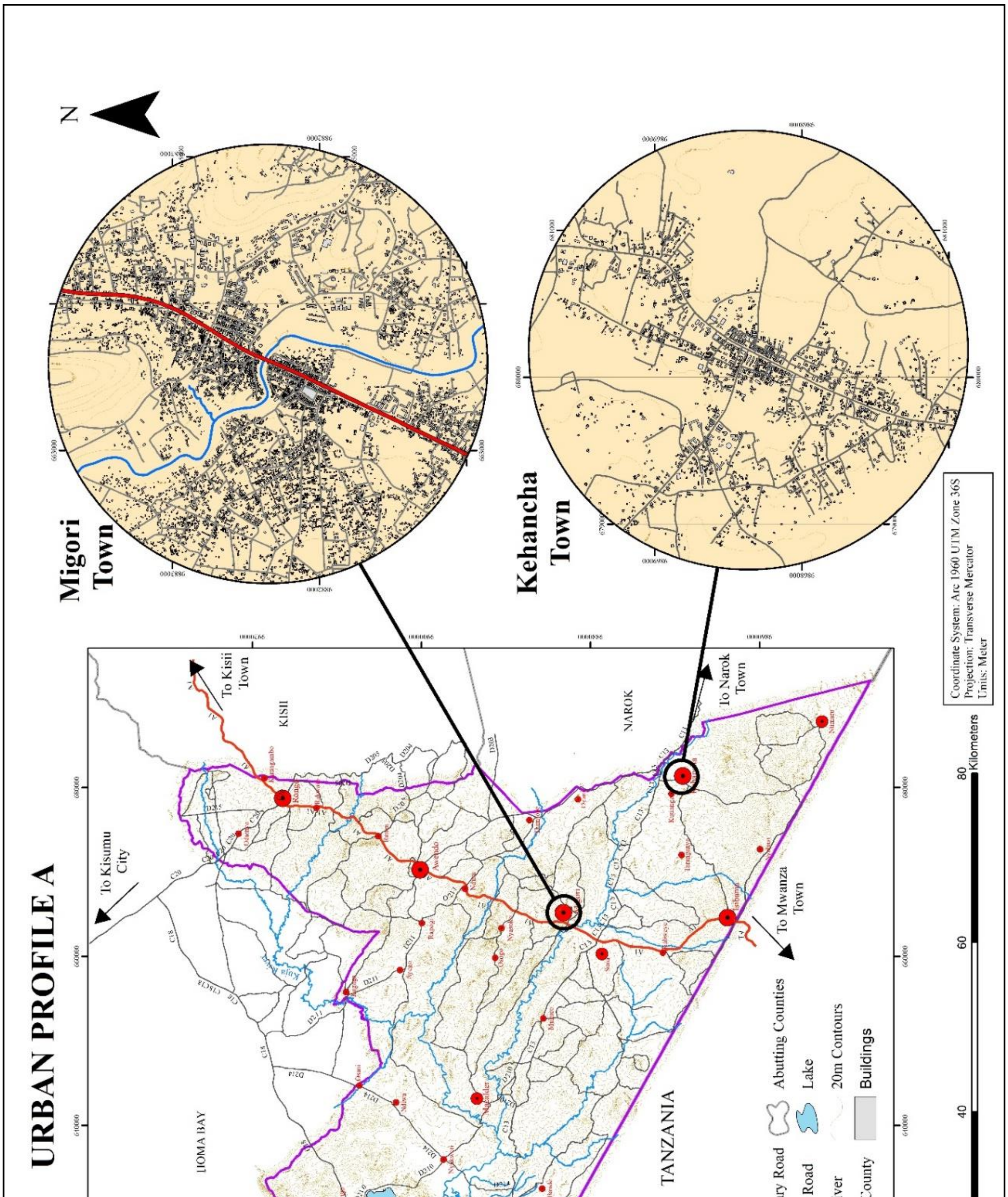
4.5.2. Urban populations

According to the 2019 population census, 85% of the county's population (949,236 people) lived in rural regions, whereas only 167,200 people lived in urban areas. The urban population is dominated by 40% of the labour force and 37% of persons below 15 years of age (Figure 4.6). The County is also experiencing an increase in urban population, particularly in Migori Town, which is considered the county's capital and accounts for 43% of the total urban population. Other notable urban centers include Isebania, Kehancha, Rongo, Awendo, Sori, and Muhuru Bay (Map 4.10-12). According to the 2019 Kenya Census, some towns, such as Muhuru Bay and Awendo, Sori have experienced a decline in population as a result of migration to neighbouring towns. The majority of major towns (Isebania, Migori, Awendo, and Rongo) attribute their growth and economic prosperity to the Isebania–Kisii–Ahero trunk Road. The transport corridor not only improves trade linkages to regional towns and cities, but also creates a favorable business climate with the Republic of Tanzania, Kenya's neighbouring international community. Accordingly, built forms within major towns have naturally been subscribed into transit-oriented developments.

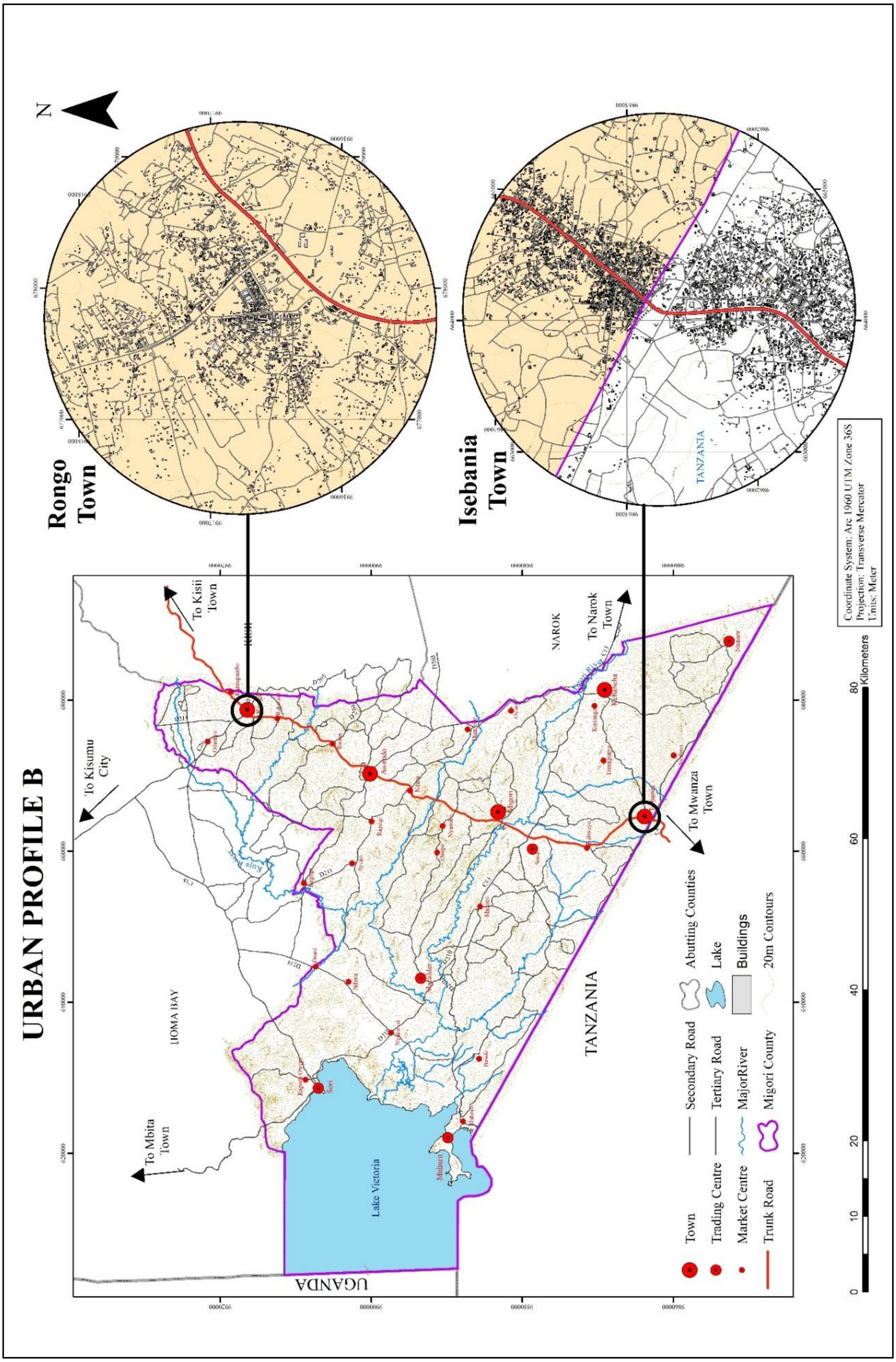


	Muhuru Bay	Sori	Awendo	Rongo	Kehancha	Isebania	Migori
Male	2,362	3,299	8,338	9,690	10,836	11,569	34,206
Female	2,560	3,721	8,476	10,998	11,358	12,321	37,462

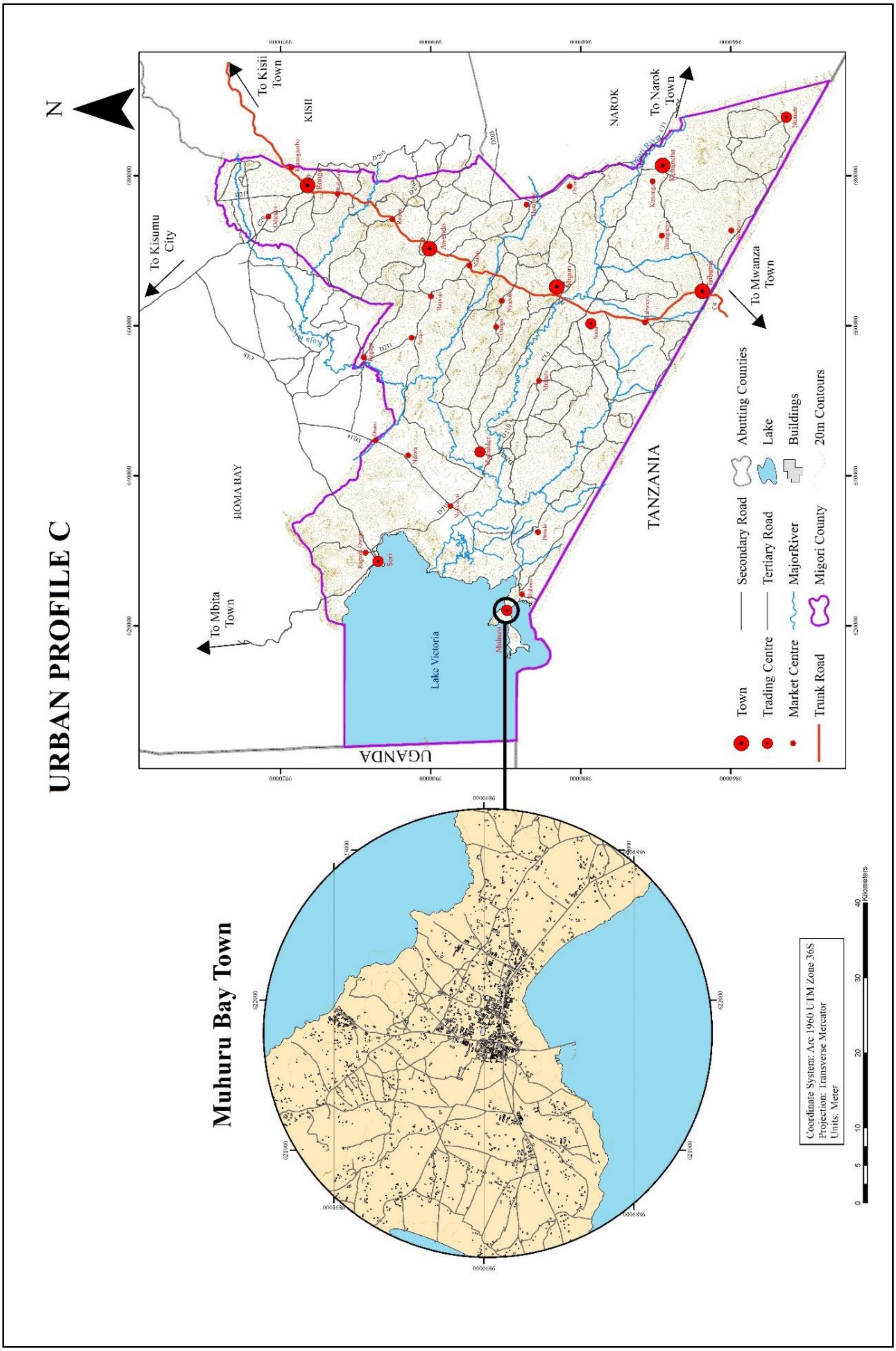
Figure 4.6. Population of urban centers in Migori County (Source: KNBS)



Map 4.10. Structure of built forms within Migori and Kehancha towns (Source: OSM)



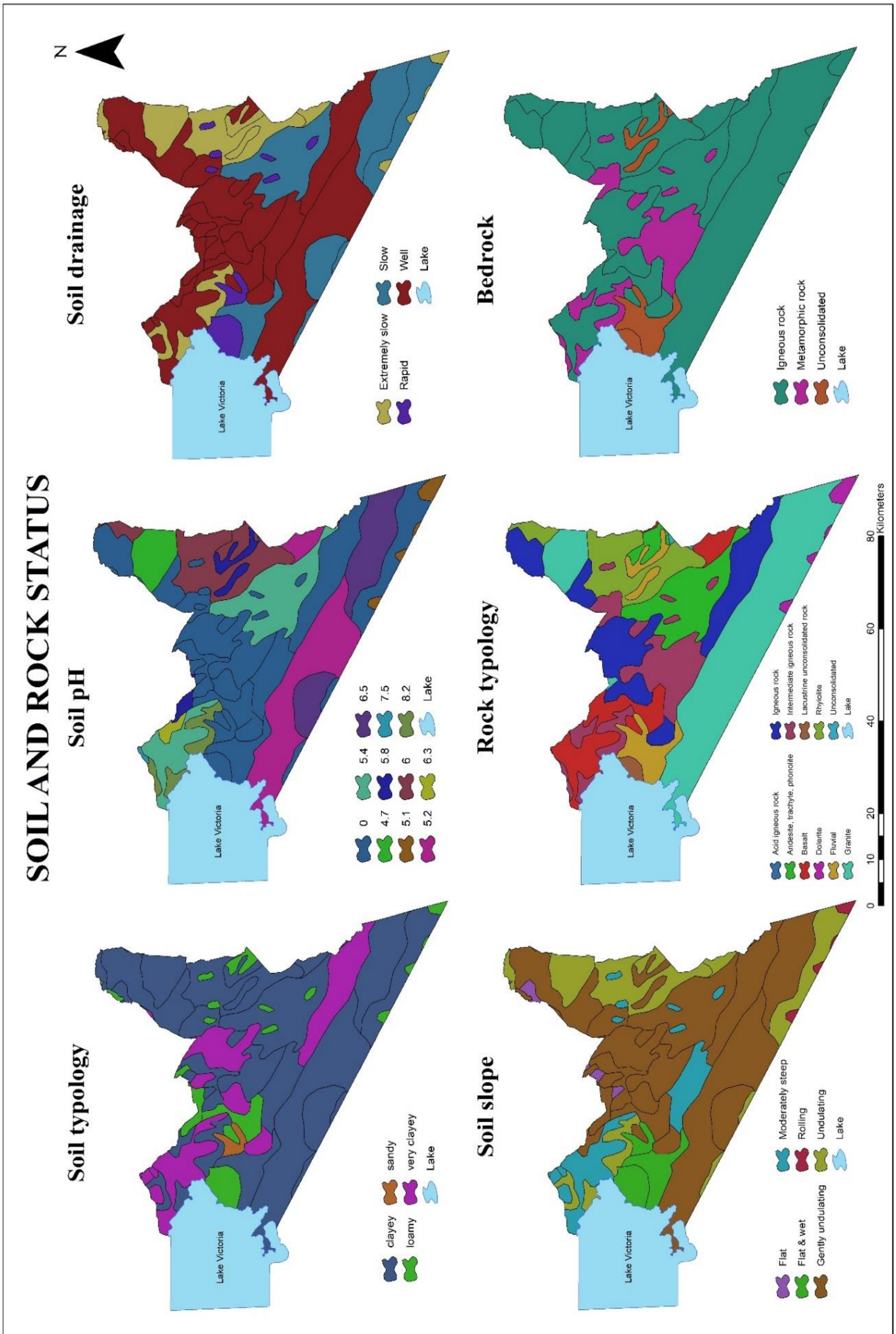
Map 4.11. Structure of built forms within Rongo and Isebania towns (Source: OSM)



Map 4.12. Structure of built forms within Muhuru Bay town (Source: OSM)

4.6. Soils and Geology

Soils found in the county range from Sandy, Clay/Black cotton, to soils. Clay soils are the primary soils, accounting for 91% of the total soil coverage. The county also boasts well-drained fertile soils that have boosted its agricultural potential. However, certain Sub-counties such Rongo, Awendo and Nyatike, are endowed with poor soils with exceedingly sluggish drainage. The geology of the county comprises an inventory of rocks: Nyanzian, Bukoban, granite, quaternary sediments, and tertiary volcanics. They can be further categorized into acid igneous rock, andesite, trachyte, phonolite, Basalt, Dolerite, Fluvial, Granite, Igneous rock, intermediate igneous rock, lacustrine unconsolidated rock, rhyolite, and unconsolidated rocks (Government of Kenya, 2016). Granite is the primary rock, occupying approximately 34% of the total rock composition, and is found in more than half of the sub-counties, namely Nyatike, Suna West, Kuria East,Kuria West, Awendo, and Rongo. Additionally, approximately 82% of the bedrock is chiefly igneous rocks that sit adjacent to other bedrock, such as Metamorphic and Unconsolidated rocks (Map 4.13).



Map 4.13. Soil and bedrock composition (Source: Government of Kenya, 2016)

4.7. Socio-economic Profiles

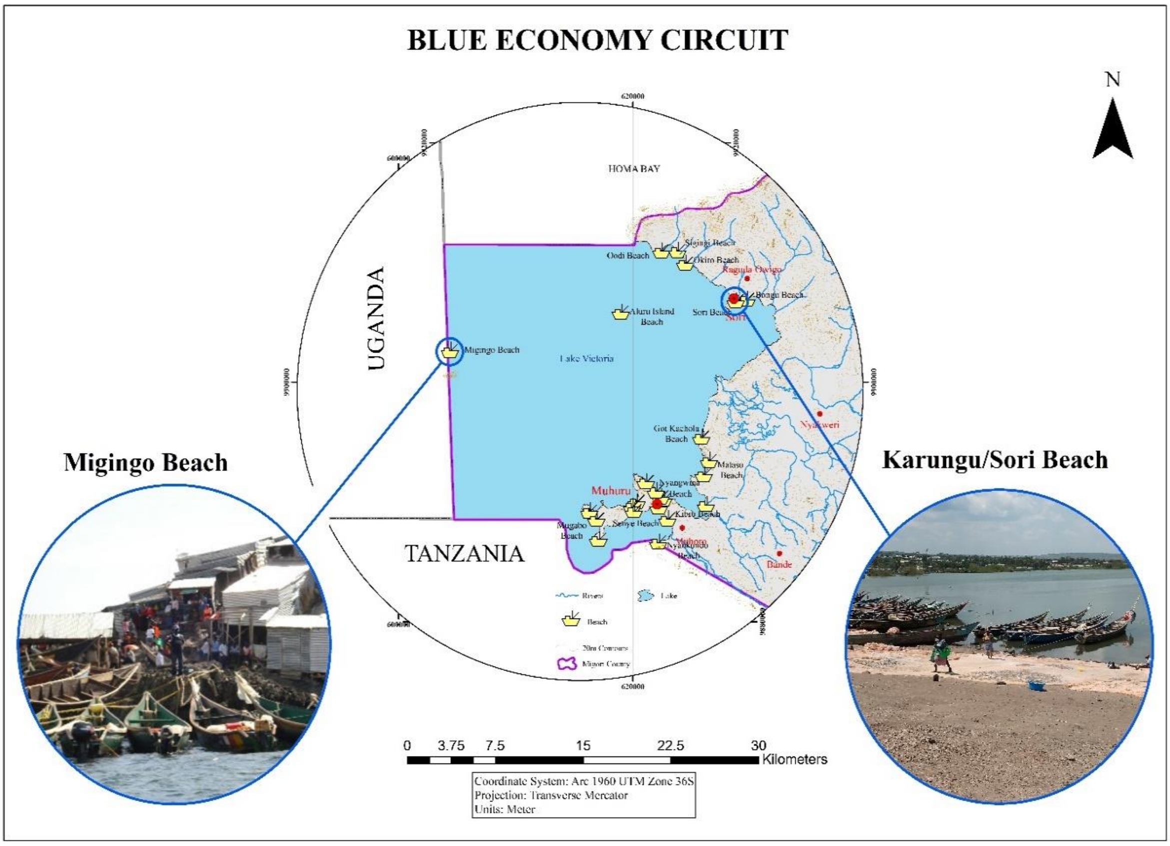
The county has a variety of distinct tourist attractions, allowing it to contribute to the tourism circuit that spans Western Kenya and Northern Tanzania. Some of the well-known tourist attractions include the Crying Stone of Kuria East, God Kweru Religious Shrine, Gogo Falls, Mugabo Caves, Lake Victoria islands, and Thim Lich Ohinga. Despite the absence of a game reserve or animal sanctuary, the county is home to a variety of birds, monkeys, snakes, leopards, gazelles, hyenas, and hippos, which might be utilized as tourism commodities.

The county is a bustling food crop and cash crop producer, supplying both local and regional markets. This is heavily reliant on the favorable climate conditions encountered in most parts of the county. Cereals, legumes, roots, and tubers are the principal food crops farmed in the county, whereas sugarcane, tobacco, and horticulture are the main cash crops. Most livestock farmers in the county farm traditional varieties, a few exotic species, indigenous goats, poultry, and bees. There are more than 47 open-air markets spread across all wards and are equipped with toilets and ablution blocks (Government of Kenya, 2018b). Commercial transactions provide a sizable portion of the county government's revenue. In addition, the county is involved in industrial operations, such as Jua Kali, milk and fish processing, and other associated businesses. Jua Kali sheds are located in Rongo, Awendo, and Migori and specialize in blacksmithing, carpentry, tailoring, food processing and welding. Sony Sugar Limited is a notable industry that operates with the help of over 25,000 cane growers to supply sugar to the country's consumers.

The County hosts 475 km^2 of Lake Victoria, which is spanned by the Gucha-Migori basin. This has offered opportunities to capture the revenues of the blue economy by building dams and establishing 18 beaches along the shoreline of Lake Victoria (Table 4.1). Fishing has long been the main source of income in Nyatike Sub-County, which is home to all 27 landing spots and 18 designated beaches (Government of Kenya, 2018b). The county is endowed with stunning islands, such as Yamburi, Mbaiyo/Aluru, Migingo, Usingo, and Pyramid. Although the tourist potential of visiting and appreciating the islands is underutilized, it offers a significant cash generator if properly reformed and planned.

Table 4.1. Landing sites/ beaches in Migori County (Source:Government of Kenya,2018b)

Sub- County	Landing sites/Beaches
Nyatike	Oodi, Okiro, Siginga, Sori, Aloma, Ngira, Lwanda Konyango, Modi Ngwena, Kao, Aneko, Got Kachola, Matoso, Lidha, Tagache, Ngore, Nyangwina, Aluru Island, Bongu, Kimambra, Ongoro, Bam Got, Sumba Senye, Kithegunga, Makwach, Kibro, Mugabo and Nyankondo (Map 4.14)



Map 4.14. Landing sites/beaches in Migori County (Source: Government of Kenya 2018b)

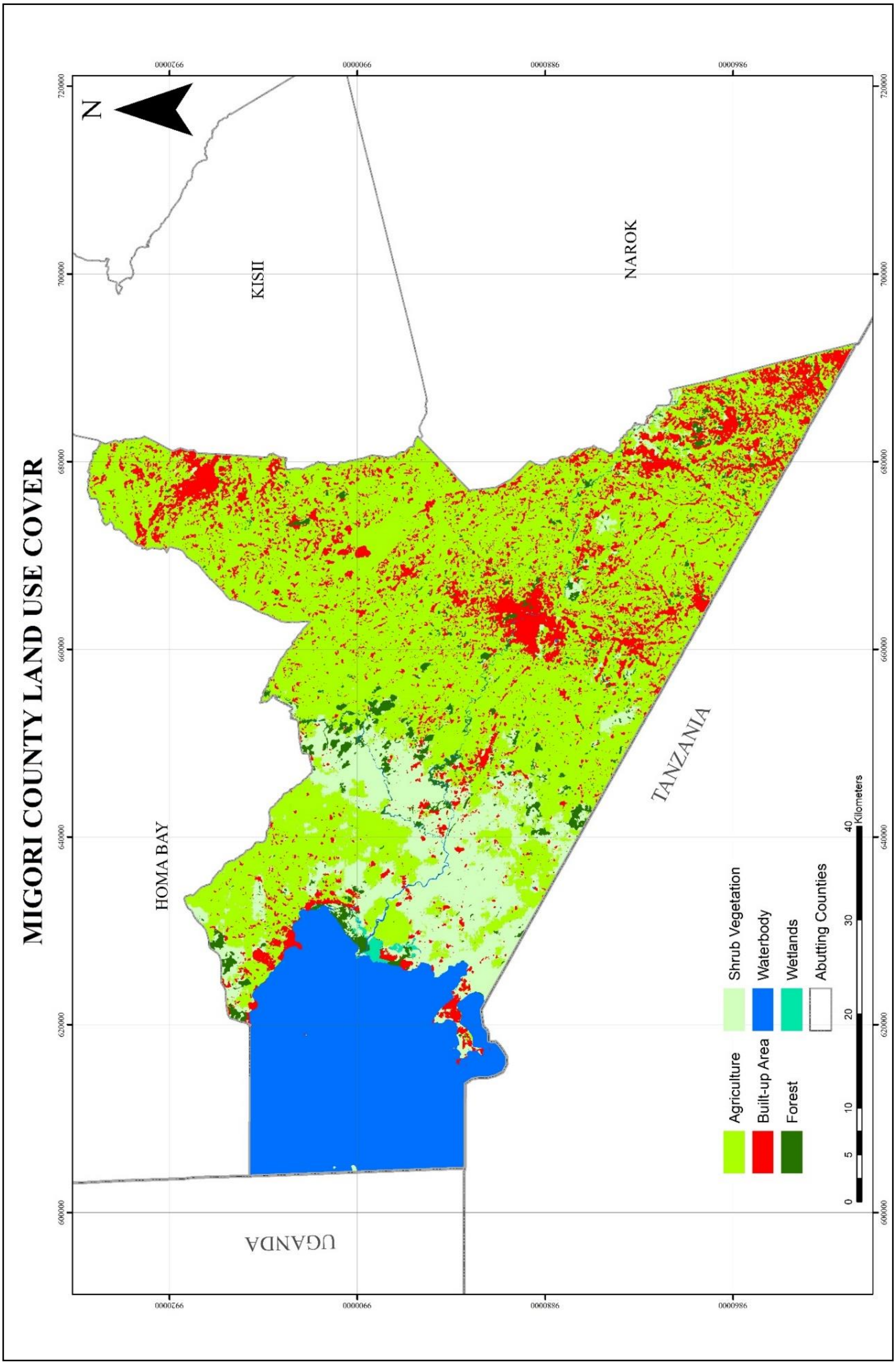
4.8. Land Use

The land use of Migori County is dominated by agriculture-related operations, which account for approximately 55% of the entire area. The western section of the county is mostly engaged in food and cash crop cultivation because of its favorable climatic conditions and rich agricultural soils. Cereals, roots, and tubers are the principal food crops, while sugarcane (grown in Awendo, Rongo, Uriri, Suna East and Suna West Sub-Counties) and tobacco are the main cash crops (grown in Kuria West and Kuria East) (Government of Kenya, 2018b). In the Eastern part of the County (Nyatike Sub county), Livestock keeping is the mainstay of agricultural activity in the eastern part of Nyatike Sub County.

The county also hosts several forests, including Aroso, Giribe, Got Kogalo,Gatambega, Kwa, Magina, Makangwa, Nyamarere, Nyaitara, Nyandiri, Nyasoko, Omange, Ombo, Otacho, Rabuor, Ranen, Sagegi, and Tarakwiti. There are also wetlands along the Gucha-Migori River Basin, especially regions around its confluence with Lake Victoria. This phenomenon has curtailed not only settlement, but also farming and infrastructural developments. Most wetlands are found in Nyatike Sub County and occupy an estimated land cover of 6.23 km^2.Throughout the County, there are 399.14 km^2 of clustered-built forms in market centers, trading centers, urban centers, and rural vicinity. The built forms are particularly visible along the international transportation route of the Isebania-Kisii-Ahero trunk road and the Lake Victoria Blue Economic Corridor. Settlements in rural areas are characterized by scattered, dispersed, and concentrated patterns. Kuria West, Rongo, and Suna East Sub Counties, which have higher population densities of 570, 632, and 647 people per square kilometer respectively, have densely grouped rural settlements. In contrast, Nyatike Sub-County has the lowest projected density of 282 people per square kilometer, indicating sparse/dispersed population patterns (Table 4.2) (Map 4.15).

Table 4.2. Land Cover distribution in Migori County (ESRI, 2022)

Land Cover	Area of Coverage (km^2)	Percentage of Coverage
Agriculture	1,713.52	54.23%
Built up Area	399.14	12.63%
Forest	84.89	2.69%
Shrub Vegetation	400.08	12.66%
Waterbody	555.87	17.59%
Wetlands	6.23	0.20%



Map 4.15. Land use cover in Migori County (Source: ESRI 2022)

5. RESULTS

5.1. Spatial Distribution of Health Facilities

This section describes the spatial distribution of health facilities in Migori County. It recognizes the ownership diversity of health facilities by examining the locations of various healthcare service providers. A comparative analytical approach was employed to shed light on regional differences in the distribution of public and private healthcare facilities.

5.1.1. Distribution of health facilities

In Migori County, there are two primary healthcare service systems: the public system, which includes the Ministry of Health (MOH), Non-Governmental Organizations (NGOs), and faith-based organizations (FBOs) and the private system, which include private practitioners, Migori County's health demands and needs were met by approximately 249 health facilities spread across the county (Map 5.1). These health infrastructures vary in terms of ownership, operating time, capacity, and the level or nature of services rendered.

The healthcare delivery system is organized into a hierarchical framework comprising six tiers: Community Health Unit at the first level, Dispensary at the second level, Health center at the third level, primary referral hospital at the fourth level, secondary hospital at the fifth level, and tertiary hospital at the sixth level. This service delivery is constrained by their operating hours; some are set to provide services 24 hours a day, while others only operate during standard business hours (8am-5pm/8pm). Furthermore, because certain health facilities are not scheduled to function on weekends and others are not operational, equitable access to service provision has been curtailed.

5.1.2. Distribution of public health facilities

The operation of public health facilities is controlled and managed by the Ministry of Health. There is seamless coordination of activities and programs between County Health departments and the National Ministry of Health. The hierarchy of public healthcare service provision has evolved, with the current program advocating for a four-tiered level hierarchy of service provision.

Table 5.1. Hierarchy of public health facilities

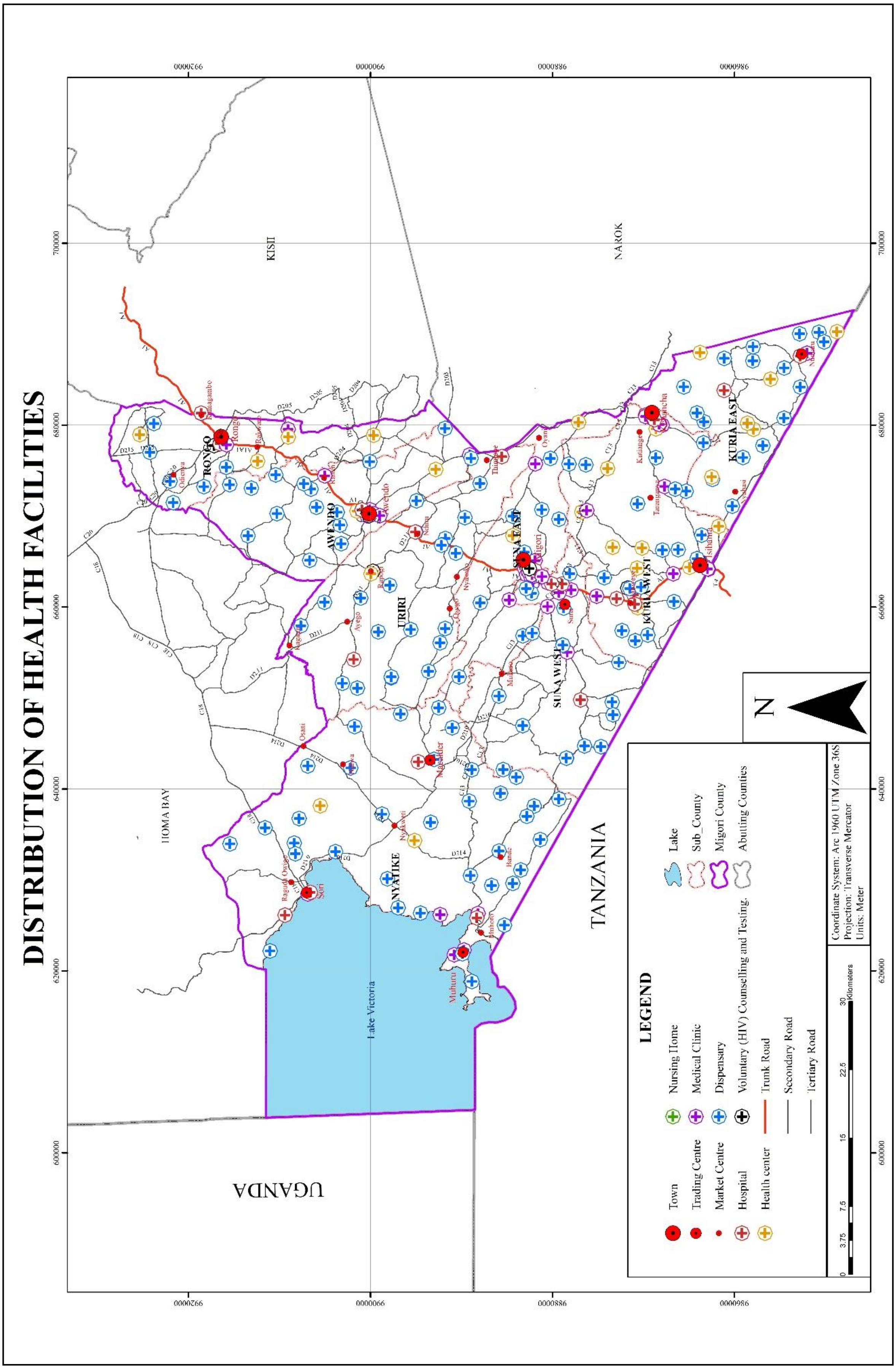
Health facility	Description
Hospitals	These healthcare institutions are classified as primary, secondary, or tertiary. They serve as referral centers at the Sub-County and County levels. Hospitals are in charge of delivering curative and preventative care, surgical and clinical services, inpatient and outpatient healthcare services, referral and emergency services, technical training and supervision of health facilities throughout the county, and so on. Surgeons, general medical physicians, pediatricians, nurses, midwives, and public health workers typically staff these patients (NCAPD et al., 2004). There were approximately 16 public hospitals serving counties, with at least one hospital in every sub-county.
Health centers	Its principal functions include but are not limited to the provision of curative and preventative healthcare, reproductive health services, and minor surgical procedures (NCAPD et al., 2004). Health demands that exceed their technical capabilities are forwarded to higher-tier healthcare providers—hospitalsin the area. There were approximately 26 public health centers in Migori County. Midwives, nurses, clinical officers, and doctors are among those who work in health centers.
Medical clinics	The medical clinics render curative care (NCAPD et al., 2004). Curative healthcare services were offered by 3 FBO clinics, and 12 NGO clinics.
Dispensaries	According to Kenya Health Policy (2014-2030), dispensaries are at the bottom of the healthcare service delivery hierarchy and are the initial point of contact for patients. They provide preventative, prenatal, and basic curative services aided by nurses and public health specialists (NCAPD et al., 2004). The county registered approximately 137 operational public dispensaries spread across eight sub-counties.
Voluntary Counselling and Testing (VCTs) facilities	There were six standalone public human immunodeficiency virus (HIV) Counseling and Testing sites stations.

5.1.3. Distribution of private health facilities

There were approximately 48 private health service providers (Map 5.1). Their contribution is critical in supplementing or complementing the Ministry of Health's healthcare service hands in increasing adequate and high-quality access to healthcare coverage (NCAPD et al., 2004).

Table 5.2. Hierarchy of private health facilities

Health facility	Description
Hospital	Private hospitals, like public hospitals, also provide a variety of health services, including curative and preventative treatment as well as inpatient and outpatient care, and are staffed by surgeons, general medical physicians, pediatricians, nurses, midwives, and public health personnel (NCAPD et al., 2004). There were seven private health facilities are managed and owned by private practitioners.
Private Maternity and Nursing Homes	The Kenya Registered Midwives Association (KRMA) controls and manages the operations of these health institutions, which are mostly handled by private doctors and clinical officers (NCAPD et al., 2004). Maternity and nursing facilities provide reproductive healthcare services, family planning services, and child welfare programs in collaboration with and support from the Ministry of Health. There were six Maternity and nursing homes operated by private practitioners.
Private clinic	Clinics' healthcare services are primarily designed to offer curative care (NCAPD et al., 2004). Medical clinics providing curative healthcare services were available through the operation of 34 private practitioner-led facilities.
Voluntary Counselling and Testing (VCTs) facilities	There was one standalone station in Rongo town under the management of a private practitioner.



Map 5.1. The distribution of Health facilities in Migori County (Source: KMHFL)

5.2. Spatial Accessibility of Primary Healthcare

This section presents the spatial efficiency of the Migori County's primary healthcare facilities. In general, the distribution of public-use facilities should be guided by the principles of equity, maximum access, and resource utilization. Each facility has a sphere of influence/operation and its catchment population. The redistribution of public resources and infrastructure is informed by rational and evidence-based decision making to ensure communal ownership, facility operating efficiency, and optimal usage. Conventionally, regional development plans are vulnerable to the manipulative influences of the market economy and political injustices in laisse-faire scenarios. To explore health accessibility in Migori County in depth, three spatial access models for public health facilities, private health facilities, and all target health facilities were developed. The accessibility and availability of health facilities' service coverage were evaluated using the lens of facility operation time. This allowed for a more comprehensive assessment of geographical accessibility and situational dynamics encountered by Migori County inhabitants in their pursuit of primary healthcare services.

5.2.1. Weekday spatial accessibility

There were 43 public and 13 private health facilities capacitated for basic healthcare in Migori County. Kuria West Sub-County has the highest number of health facilities (11), and every county has at least one public primary healthcare provider.

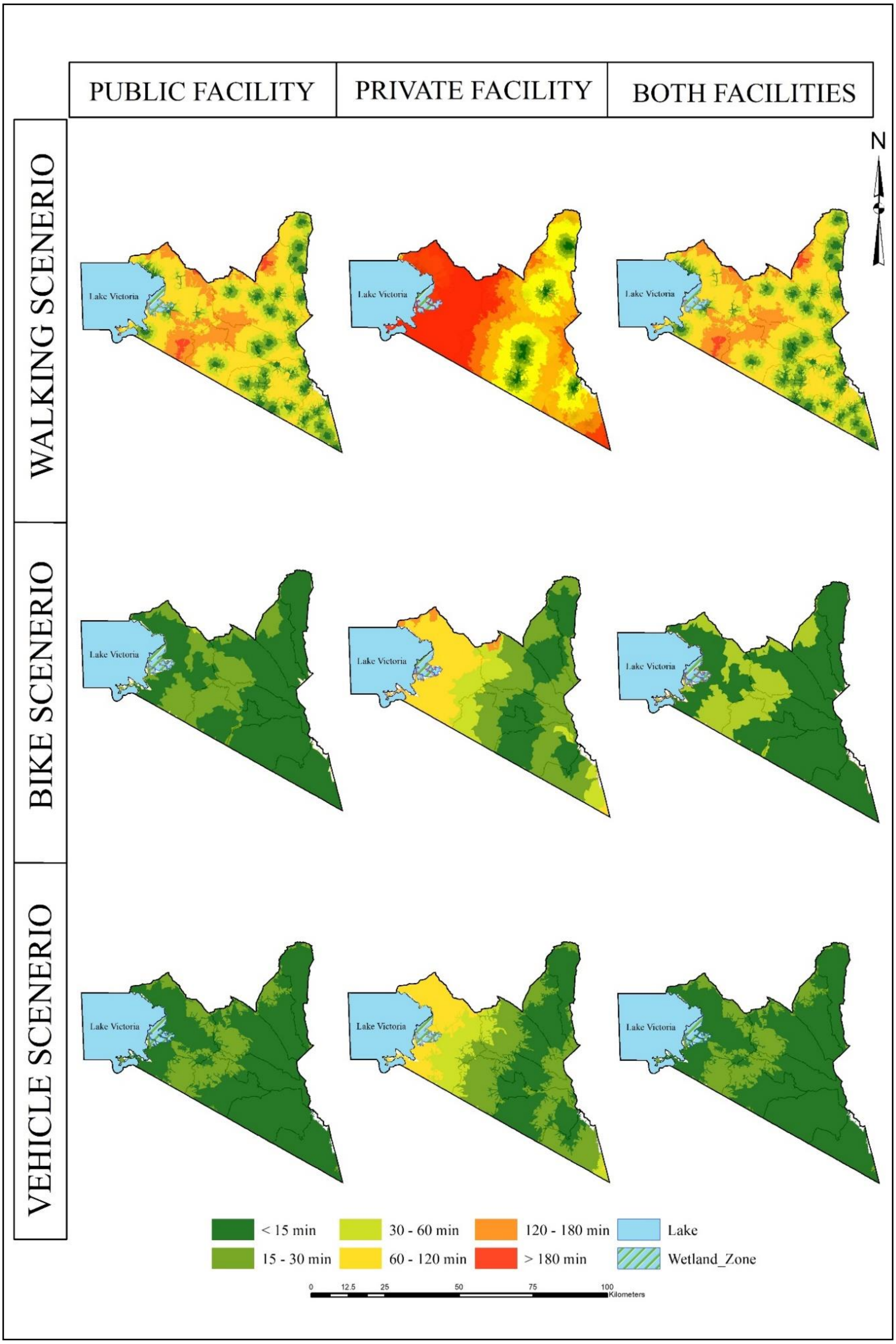
In terms of accessibility by walking on weekdays, 8% of the population was able to incur a walking time of 20 min to reach the nearest private health facility, whereas 16% of the population was able to access the nearest public health facilities. Additionally, it was estimated that spatial accessibility of 19% was achieved within 20 min when considering both types of facilities.

Regarding accessibility by motorbikes, within a 20-minute travel time, the spatial accessibility of the population to the nearest health facility was 84%. Consequently, 83% of the population can travel to the nearest public health facility, whereas 40% can reach the nearest private health facility within 20 min of travel. Kuria East Sub-County has the highest spatial accessibility to public facilities, reaching 99.69%. In contrast, Nyatike Sub-County had the lowest spatial accessibility to public facilities, with only 64% of the population able to access the facility within 20 min. Regarding private facilities, the highest spatial accessibility of 68% was observed in Kuria West Sub-County.

For access by vehicle, the basic healthcare spatial accessibility by public facilities was relatively high at 92%, with Kuria East,Kuria West, and Rongo Sub-counties having the highest spatial accessibility of 99%. On the other hand, a spatial accessibility of 57% was registered by private facilities, with the highest coverage of 91% in the Kuria West and Rongo Sub-Counties. The basic healthcare spatial accessibility of both public and private health facilities was 92% (as shown in Table 5.1 and Map 5.2).

Table 5.3. Spatial accessibility of primary healthcare facilities on weekdays

Transport model		Spatial accessibility within 20 minutes							
		Awendo	Kuria East	Kuria West	Nyatike	Rongo	Suna East	Suna West	Uriri
Walking	Public facility	14,685	25,139	64,888	177,18	28,415	21,902	9,414	10,700
	Private facility	14,158	0	22,768	0	18,943	4,741	27,882	0
	Both	16,744	25,139	71,160	17,718	31,316	22,375	3,0291	10,700
Motorbike	Public facility	108,916	133,838	188,060	118,398	129,107	101,930	80,709	110,041
	Private facility	78,556	14,399	134,932	0	89,698	70,300	54,097	30,107
	Both	110,210	133,838	188,244	118,398	129,212	105,384	83,313	110,041
Vehicle	Public facility	125,856	134,240	191,982	149,624	130,911	117,730	100,952	128,034
	Private facility	111,391	29,951	175,571	0	120,710	100,084	63,394	64,323
	Both	125,948	134,240	191,982	149,624	130,911	120,150	101,501	128,034



Map 5.2. Weekday spatial accessibility of primary healthcare facilities

5.2.2. Weekend spatial accessibility

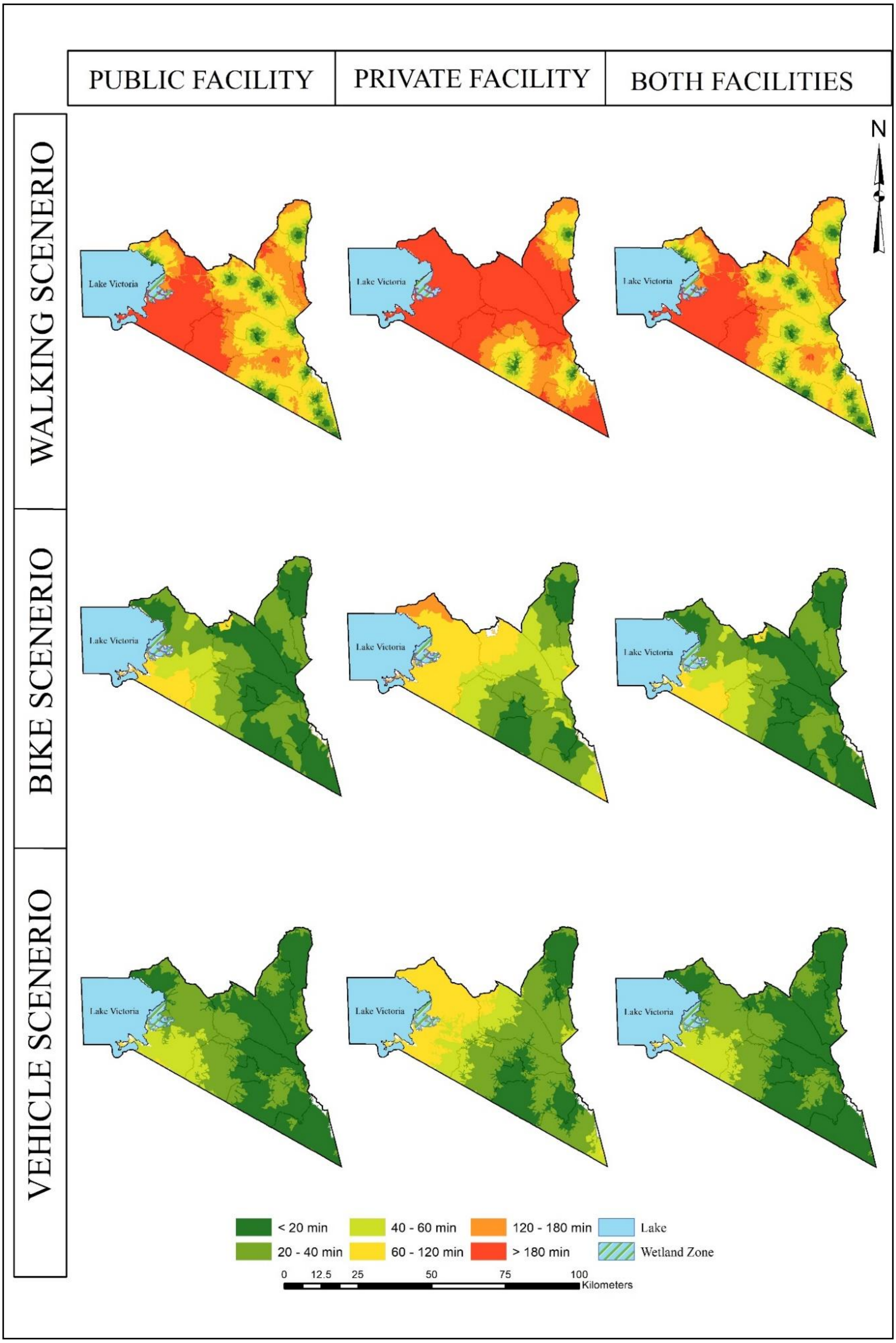
On weekends, basic healthcare in the county is provided by a limited number of operational facilities, including four private facilities and 17 public health facilities. When considering spatial accessibility by walking, it was estimated that only 2% and 9% of the population were able to travel 20 minutes to the nearest private and public facilities, respectively. Overall, 11% of the population could reach the nearest public or private health facility within 20 min of walking (Map 5.3).

Regarding accessibility by motorcycle taxis, within a 20-minute travel time, 60% of the population was able to reach the nearest public or private facility. The spatial accessibility of public facilities was 58%, whereas that of private facilities was 23%. Public facilities had the highest service coverage (85%) in Kuria East Sub-County on weekends. Private facilities had an adequate spatial accessibility of 67% in Kuria West sub-county, which hosts the town of Isebania and is serviced by three private facilities that are operational on weekends.

In terms of vehicle access, within a 20-minute travel time, 75% of the population was able to reach the nearest public and private health facilities. Kuria East Sub-County has the highest spatial accessibility (99%). Public health facilities had a spatial coverage of 74%, with Kuria East Sub-county having the highest spatial accessibility (99 %). Private health facilities had greater spatial coverage of 87% in Kuria West Sub-County (Table 5.2).

Table 5.4. Spatial accessibility of primary healthcare facilities on weekends

Transport model		Spatial accessibility within 20 minutes							
		Awendo	Kuria East	Kuria West	Nyatike	Rongo	Suna East	Suna West	Uriri
Walking	Public facility	0	16,847	29,610	10,605	17,509	16,454	8,024	10,700
	Private facility	0	10	19,920	0	8,618	0	0	0
	Both	0	16,857	45,903	10,605	19,440	16,454	8,024	10,700
Motorbike	Public facility	59,947	114,114	135,210	36,270	88,155	90,538	45,883	107,097
	Private facility	7,396	11,812	128,687	0	77,401	12,253	37,651	0
	Both	59,947	115,157	156,574	36,270	88,278	90,538	49,171	107,097
Vehicle	Public facility	115,146	132,652	172,729	45,975	113,996	113,592	55,710	122,858
	Private facility	38,232	27,142	167,806	0	106,916	65,270	58,466	5,778
	Both	115,146	133,353	178,291	45,975	113,996	113,592	59,145	122,858



Map 5.3. Weekend spatial accessibility of primary healthcare facilities

5.2.3. 24-Hour spatial accessibility

In Migori County, the provision of basic healthcare services round the clock is rendered by only four private facilities, and 12 public facilities offer these services. Private health facilities that were operational on a 24/7 basis were available only in Kuria West and Rongo Sub-County. Additionally, an operational public health center or hospital around the clock was not available in Awendo Sub-County.

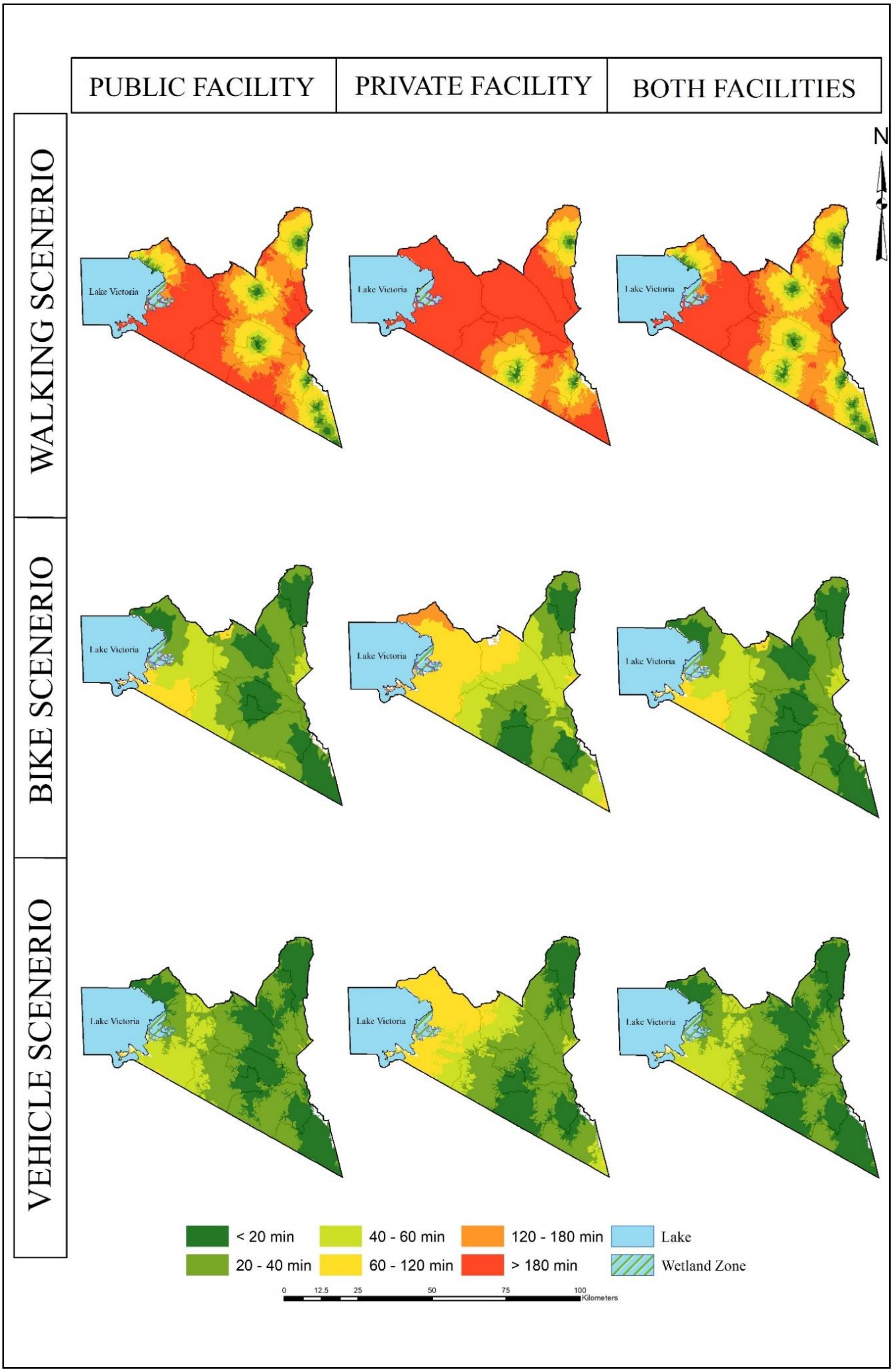
Regarding accessibility by walking, only 2% and 9% of the population could walk within 20-minutes to reach the nearest private and public health facilities, respectively. In Rongo Sub-County, 15% of the population could walk to the nearest public and private health facility within 20 minutes.

Using a motorbike, the spatial coverage of public health facilities within a 20-minute ride was 41%, whereas private health facilities had a coverage of 23%. Public facilities had the highest spatial accessibility (73 %) in Kuria East Sub-County. On the other hand, private facilities had higher spatial coverage in Kuria West Sub-County (67%). On average, both facilities cover 49% of the population within a 20-minute ride.

Regarding accessibility by vehicle, 66% of the population could reach the nearest private or public health facility within 20 min. Private facilities had the highest coverage in Kuria West Sub-County (87%) and lowest coverage in Uriri Sub-County (4%).On the other hand, only Rongo and Kuria West Sub-counties had more than 80% of their population accessible to the nearest 24/7 operational public facilities (Table 5.3) (Map 5.4).

Table 5.5. 24-Hour spatial accessibility of primary healthcare facilities

Transport model		Spatial accessibility within 20 minutes							
		Awendo	Kuria East	Kuria West	Nyatike	Rongo	Suna East	Suna West	Uriri
Walking	Public facility	0	161,47	4,676	10,605	17,509	16,454	8,024	3,113
	Private facility	0	10	19,920	0	8,618	0	0	0
	Both	0	16,157	20,970	10,605	19,440	16,454	8,024	3,113
Motorbike	Public facility	40,563	97,964	40,444	35,322	88,155	78,663	45,883	55,207
	Private facility	7,396	11,812	128,687	0	77,401	12,253	37,651	0
	Both	40,563	99,006	129,838	35,322	88,278	78,663	49,172	55,207
Vehicle	Public facility	86,014	108,919	88,339	42,942	11,0720	102,890	55,710	92,135
	Private facility	38,232	27,141	167,806	0	106,916	65,271	58,466	5,778
	Both	86,014	111,754	170,703	42,942	110,720	102,890	59,142	92,135



Map 5.4. 24-Hour spatial accessibility of primary healthcare facilities

5.3. Planning Intervention

This section presents recommendations for addressing the significant gap in the spatial accessibility of basic healthcare in Migori County. The government has established public health facilities to serve the collective well-being of the population. However, if their distribution lacks prudence and rationality, it can lead to issues such as public exploitation owing to market forces, service area overlaps, wastage of healthcare resources, and regional impoverishment. Effective decision-making based on logic and evidence is essential at both national and county levels of the government. This ensures that taxpayers' funds are allocated wisely and efficiently to redistribute resources to the common good. This study aimed to formulate an optimal spatial strategy for improving community access to basic healthcare services at public facilities. This was achieved by adopting a widely accepted and utilized transportation model.

5.3.1. Choice and justification of the transport model

Owing to weak road network configurations, particularly in rural regions, commercial motorcycle taxis have been increasingly used in Africa as reliable penetration vehicles to address transportation challenges (Bolbol and Zalat, 2018; Gamberini, 2014). In Migori County, rural hinterlands house 85% of the overall population, while urban centers house only 15%. According to Obudho (2020), motorbikes are the primary and most preferred means of travel because they are readily available, economical, and convenient, and they allow for easier penetration of impassable roads into the county’s rural hinterland. He also acknowledges that the use of private cars or public transportation is limited by factors such as impassable roads, fixed transportation schedules (particularly for public transportation vehicles), affordability issues, and the exclusive operation of public service vehicles on major roads connecting urban areas. On the other hand, the usage of motorcycle taxis ensures convenient and reliable access to public services because it does not have fixed schedules, is prompt, and may have personalized services (Jenkins et al., 2020). Therefore, the motorcycle transportation model is employed to make proposals in the subsequent sections.

5.3.2. Choice and justification of the travel time

In Migori County, the healthcare service delivery system comprises four tiers: the community health unit, dispensary, health center, and primary referral hospital. The implementation of the Kenya Primary Healthcare Strategic Framework (2019-2024) prompted the elevation of dispensary functions to a level 3 status (health centers), allowing them to provide outpatient services. To evaluate the spatial accessibility of primary healthcare, particularly focusing on basic healthcare providers offering both inpatient and outpatient services, a travel time of 20 minutes was used. It has been established that a motorized travel time exceeding 20 minutes to a hospital is associated with an elevated risk of mortality (Ravelli et al., 2011). Hence, this study utilized a 20-minute threshold for spatial accessibility to existing primary healthcare providers (health centers and hospitals). This approach was employed to assess the current level of spatial accessibility and to guide planning for the enhancement of spatial accessibility.

5.3.3. Enhancing spatial accessibility on weekdays

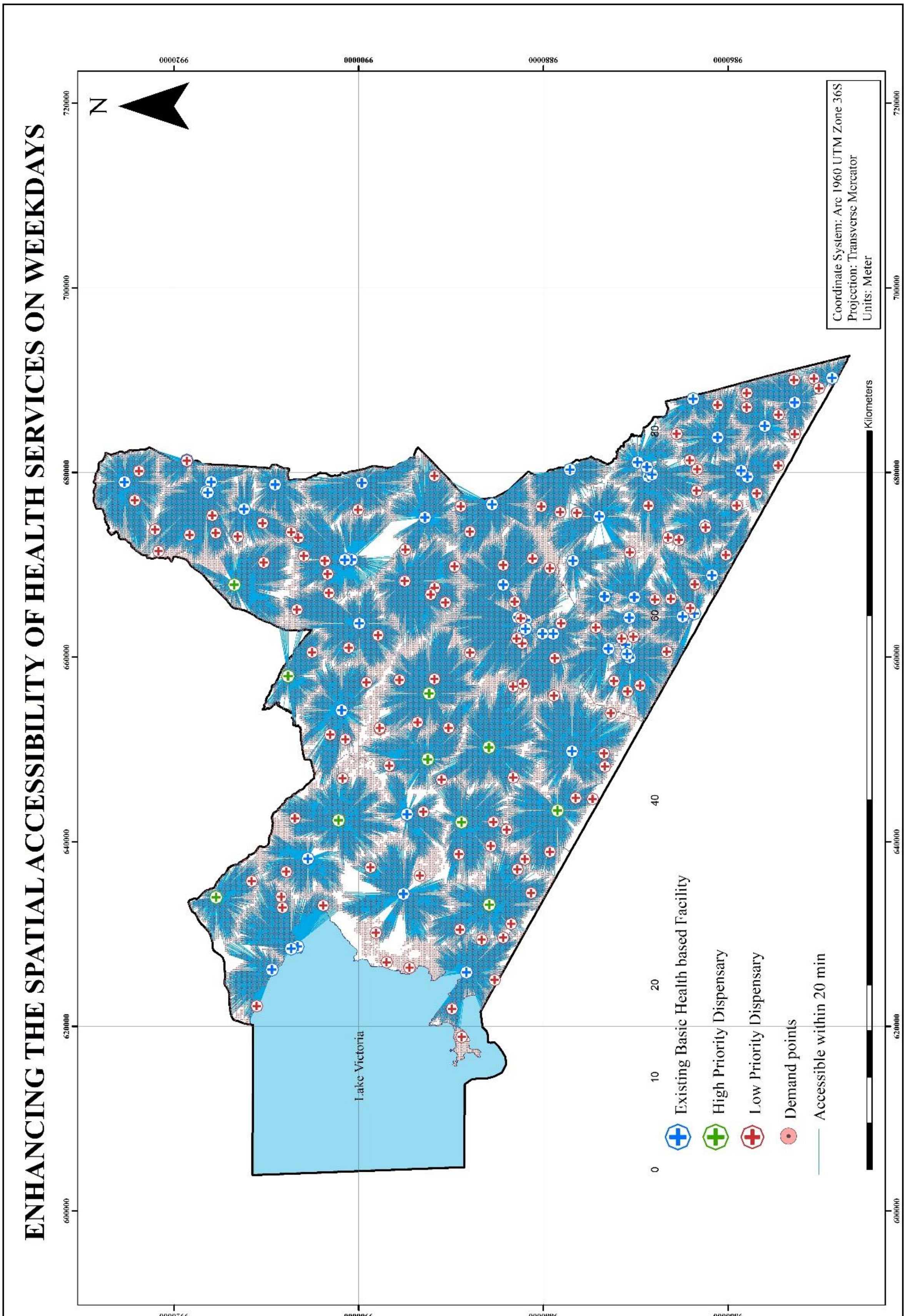
This proposal focused on enhancing the accessibility of fundamental healthcare services in Migori County. Recognizing dispensaries as immediate points of contact for communities, the upgrade of selected dispensaries to level three status was targeted to alleviate travel demands for community health. The available network of basic healthcare service providers ensures 84% spatial accessibility for the population within a 20-minute ride. Nevertheless, disparities in spatial accessibility were evident in Nyatike, Suna West, and Uriri Sub-Counties. By leveraging location-allocation models, 137 public dispensaries were evaluated for potential upgrades to function as basic healthcare providers- health centers or hospitals. Through this process, the model pinpointed ten optimal dispensaries that would enhance spatial access for the county's population across different demand points. As a result, the chosen dispensaries augmented spatial access to primary healthcare, elevating it from 84% to 96% within a 20-minute timeframe. Every sub-county achieved spatial accessibility exceeding 90%. The location-allocation model specifically identified Suna West Sub-County as experiencing the greatest increase in spatial coverage, from 71% to 98%. Kuria East Sub-County displayed the highest spatial accessibility of 99.69% (see Table 5.4-5) (Map 5.5). Notably, the model's use of current road networks implies that a more substantial enhancement in spatial accessibility could be attained by revamping rural road infrastructure.

Table 5.6. Enhancing spatial accessibility on the weekdays

Sub county	Population Coverage	% Coverage
Awendo	131,847	96%
Kuria East	133,838	99.69%
Kuria West	188,244	98%
Nyatike	165,252	90%
Rongo	129,212	98%
Suna East	119,964	96%
Suna West	115,041	98%
Uriri	146,897	99%

Table 5.7. Proposed dispensaries for upgrade to health centers

MFL Code	High priority dispensary
13486	Arombe Dispensary
13494	Bande Dispensary
16270	Kombato Dispensary
16273	Namba Kodero Dispensary
13844	Ndiwa Dispensary
13885	Nyakuru Dispensary
13960	Ogada Dispensary
13999	Otati Dispensary
22348	Nyamage Dispensary
25182	Rae Kondiala Dispensary



Map 5.5. Planning Intervention for weekday spatial accessibility

5.3.4. Enhancing spatial accessibility on weekends

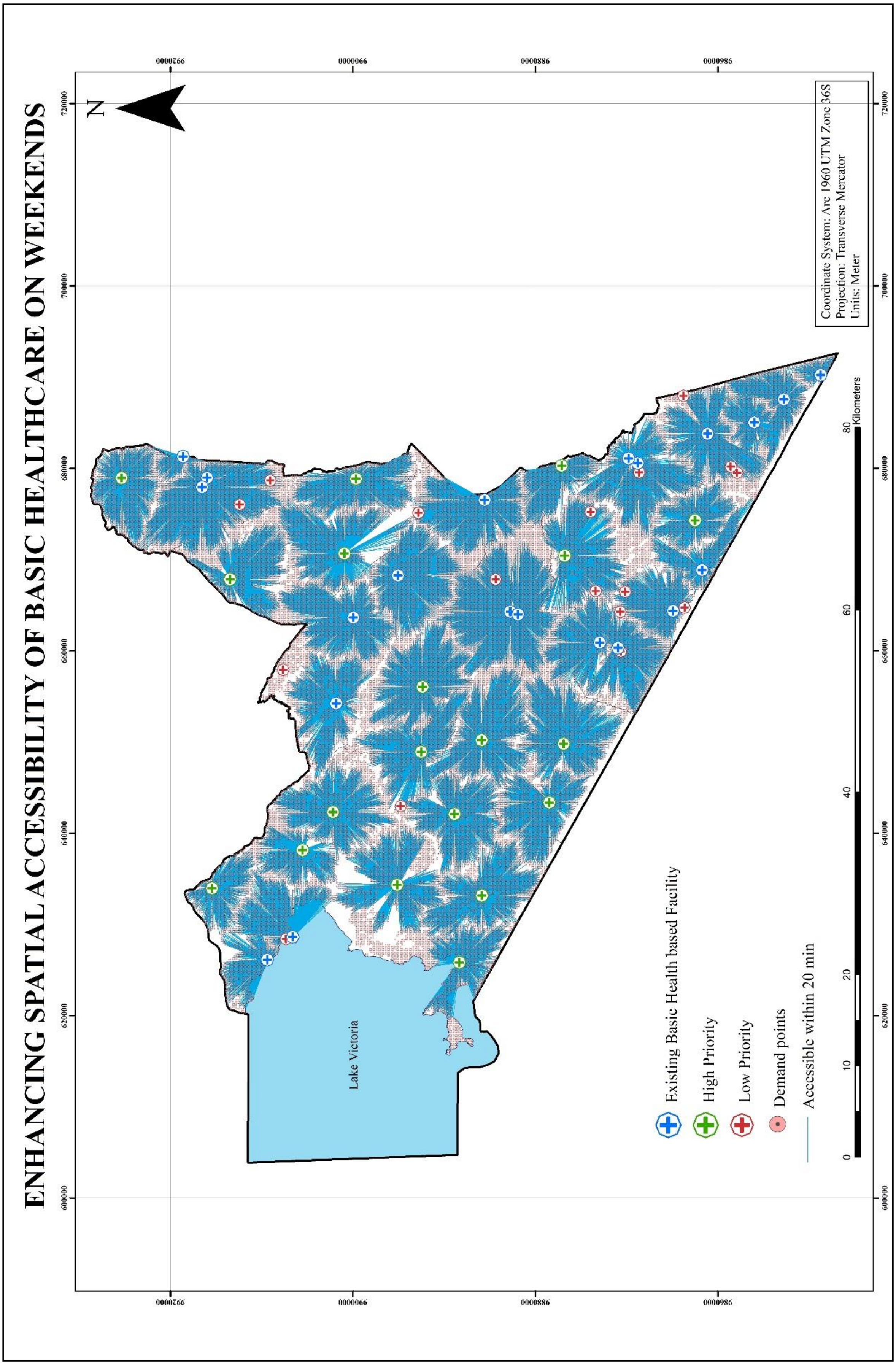
On weekends, spatial accessibility to basic healthcare by both public and private health facilities was 60%. Enhancing the spatial coverage of the population implies the rational and evidence-based selection of existing health facilities that can be considered for upgrading to be operational during weekends. Two inputs were considered as candidates for selection in the location-allocation model: existing non-operational public health facilities during the weekends and dispensaries that were considered for upgrades in the previous location-allocation analysis during the weekdays. The location-allocation analysis revealed that upgrading optimally located candidate facilities would improve spatial accessibility to basic healthcare from 60% to 92%. The highest spatial accessibility of 97% was achieved in Suna West Sub-County (Table 5.6). Eight dispensaries recommended for upgrades to enhance weekday spatial accessibility were considered for operation during weekends. Additionally, six health centers and five sub-county hospitals were recommended by location-allocation analysis to upgrade facility capabilities to include weekend operations (Table 5.7) (Map 5.6).

Table 5.8. Enhancing spatial accessibility on the weekends

Sub county	Population Coverage	% Coverage
Awendo	125,161	91%
Kuria East	126,072	94%
Kuria West	183,363	95%
Nyatike	161,361	88%
Rongo	126,038	95%
Suna East	114,118	91%
Suna West	113,610	97%
Uriri	133,405	89%

Table 5.9. Proposed health facilities for upgrading to operate on weekends

MFL Code	High priority dispensary	MFL Code	High priority dispensary
13486	Arombe Dispensary	22348	Nyamage Dispensary
13492	Awendo Sub-County Hospital	13897	Nyamaraga Sub County Hospital
13494	Bande Dispensary	20568	Obware Health Centre
16270	Kombato Dispensary	13960	Ogada Dispensary
13740	Lwala Community Hospital	13969	Ogwedhi Health Centre
13779	Masaba Health Centre	13989	Ongo Health Centre
13833	Muhuru Sub County Hospital	13999	Otati Dispensary
16273	Namba Kodero Dispensary	14149	Tisinye Health Center
13844	Ndiwa Dispensary	14170	Wath Onger Health Center
13885	Nyakuru Dispensary		



Map 5.6. Planning Intervention for weekend spatial accessibility

5.3.5. Enhancing 24-hour spatial accessibility

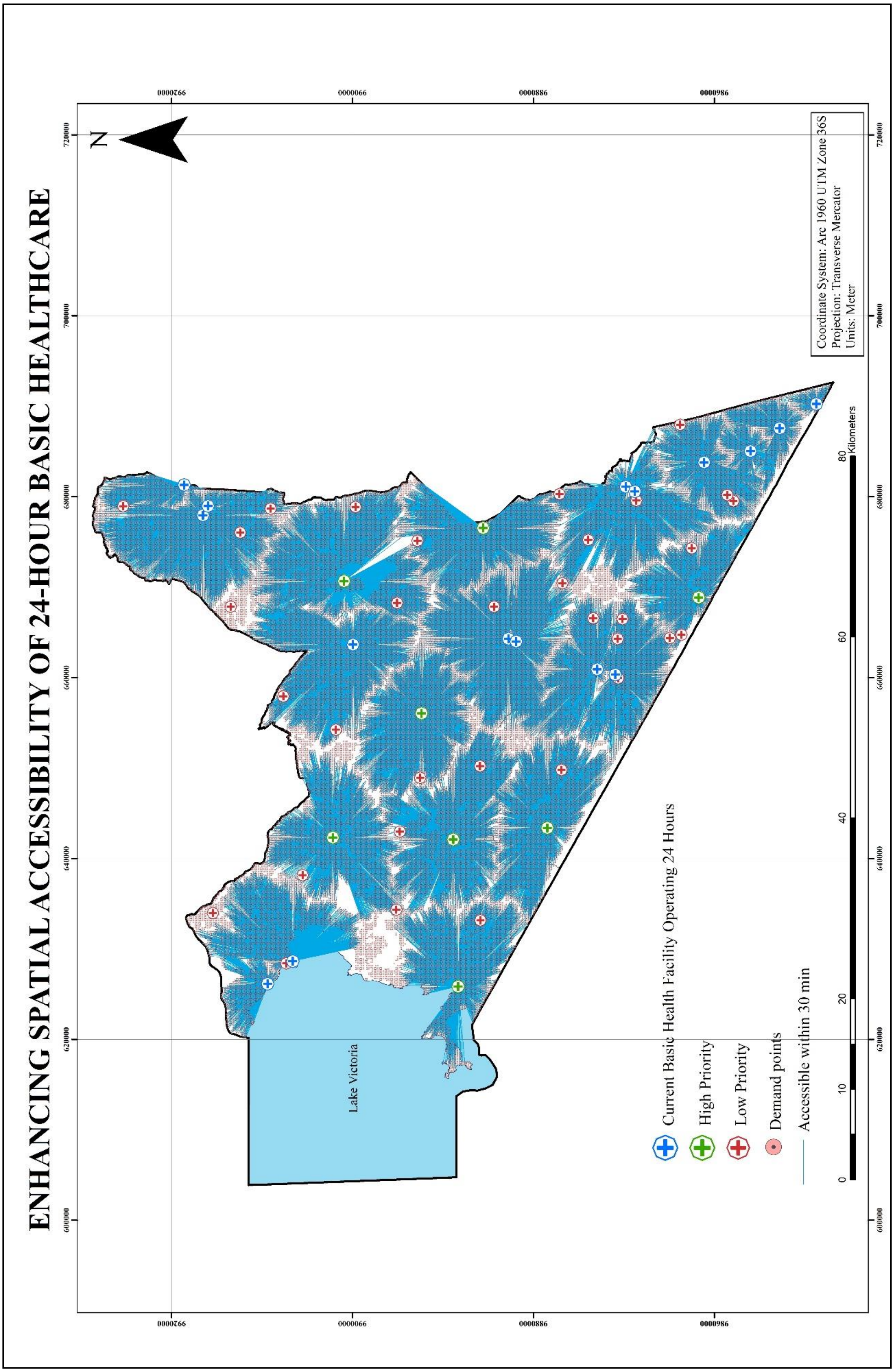
The capacity of a healthcare facility to operate continuously throughout the day ensures prompt responses to medical needs within the community, regardless of the time. Although some basic healthcare facilities operate on weekdays and weekends, they lack the capability to provide services around the clock. To identify strategically positioned healthcare facilities that could potentially offer 24-hour services, location-allocation analysis was conducted. Two inputs were evaluated as potential candidates for inclusion in the location-allocation model: existing non-operational public health facilities for continuous operation, and dispensaries previously considered for upgrades in the weekday-focused locational analysis. The proposed enhancement of 24 hour spatial accessibility to basic healthcare involved the addition of three hospitals, one health center, and four dispensaries, facilitated by motorcycle taxis for travel within a 30-minute timeframe (Table 5.9). This resulted in the spatial accessibility of 97% of the population to the nearest round-the-clock operational health facility (Table 5.8).

Table 5.10. Enhancing 24hour spatial accessibility

Sub county	Population Coverage	% Coverage
Awendo	129,722	94%
Kuria East	134,251	100%
Kuria West	184,857	96%
Nyatike	171,859	93%
Rongo	128,880	97%
Suna East	123,455	99%
Suna West	113,982	97%
Uriri	144,552	97%

Table 5.11. Proposed health facilities for upgrading to operate round the clock

MFL Code	High priority dispensary
13492	Awendo Sub-County Hospital
13833	Muhuru Sub County Hospital
16273	Namba Kodero Dispensary
13844	Ndiwa Dispensary
22348	Nyamage Dispensary
13909	Nyametaburo Health Centre
13960	Ogada Dispensary
14009	Oyani Sub County Hospital



Map 5.7. Planning intervention for 24 hour spatial accessibility

6. DISCUSSIONS

This study highlights the influence of organizational obstacles on the accessibility of primary healthcare in Migori County, specifically focusing on facility operating hours. For example, despite the prevalent use of motorcycle taxis by residents to access community healthcare facilities, the current spatial accessibility to health facilities providing basic healthcare stands at 84% on weekdays, but declines to 60% on weekends. Additionally, the limited number of health facilities operating around the clock poses a considerable challenge to spatial accessibility, with only 49% of the population residing within a 20-minute distance from the nearest health center or hospital. If unaddressed, this situation can further worsen the overall quality of life and health outcomes of the community (Gulliford et al., 2002).

The spatial accessibility analysis also highlights disparities in different regions within Migori County, revealing issues related to spatial injustice and distance decay. Sub-counties in the eastern region exhibit better access to primary healthcare due to the presence of an adequate number of health centers and hospitals compared to sub-counties in the western region. For instance, in Nyatike Sub-County, during weekends, only 20% of the population can reach the nearest health center or hospital within a 20-minute travel time, which equates to approximately 7 km of travel. While the Kenya Primary Healthcare Strategic Framework aims to strengthen dispensaries for outpatient services, there remains a need for proximate health centers or hospitals capable of providing both inpatient and outpatient services to complement their operations.

Regarding road infrastructure quality, rural areas in Migori County, where the majority of the population resides, suffer from poor and deteriorating road conditions (Government of Kenya, 2018b). Motorcycle taxis have become the preferred mode of transportation because of their cost-effectiveness, availability, and ability to effectively navigate the rural landscape, which would be challenging for vehicles (Obudho et al., 2020). Efficient transportation infrastructure plays a pivotal role in ensuring that the population can promptly access healthcare facilities. Therefore, it is essential for county governments to invest in road infrastructure to diversify mobility options and reduce travel times to services, consequently enhancing spatial access to primary healthcare services.

In conclusion, this study offers recommendations to improve healthcare accessibility in the county, including upgrading selected dispensaries to health centers with level three status and ensuring 24/7 healthcare facility operations, which would help mitigate regional spatial disparities. These recommendations are based on a comprehensive location-allocation analysis aimed at enhancing the spatial accessibility of a county's population. Therefore, policymakers and decision-makers should use GIS-based spatial analysis to identify underserved areas and prioritize resource allocation accordingly.

This study had some caveats. First, accessibility to a healthcare facility was assessed only by travel impedances, availability of primary healthcare facilities, and duration of healthcare facility operations. Second, the focus of assessment and planning for regional access to primary healthcare services was on health centers and hospitals, which is due to their role in providing both inpatient and outpatient care and their contribution to referral services through their strategic distribution. It is important to mention that the healthcare facilities utilized in the analysis were accessed from KMHFL on January 5, 2023. Third, owing to the unavailability of household-level population data within the county, the population data were limited to the county, sub-county, and ward levels. Consequently, to enhance the precision of healthcare accessibility modeling, demand points were derived from the WorldPop top-down constrained dataset (Bondarenko et al., 2020). This dataset portrays the geographic distribution of the population in 2020, which has been refined on a national scale to align with the UNPD estimate for the same year. Fourth, the motorbike travel model was incorporated in the planning intervention because the regional landscape of Migori County is predominantly rural-based (Government of Kenya, 2018b) , and the primary mode of transport in accessing public services within the county is through the use of motorbikes (Obudho et al., 2020). Finally, A 20-minute time limit was imposed during the planning intervention to evaluate the healthcare facilities that were strategically located and eligible for upgrade to enhance their spatial accessibility. Subject to the poor road network configurations in the county (Government of Kenya, 2018b) and adoption of motorbike speeds employed in previous studies (Macharia et al., 2021), a 20 minute travel by a patient is equated to a minimum of 6 km from the nearest healthcare facility. Increasing the acceptable travel time implies a cumulative increase in additional distance and strain in access if a patient opts to explore other modes of transport, such as walking.

7. CONCLUSION AND RECOMMENDATION

In Migori County, evidence-based decision making is underutilized in the distribution of public health resources. Most of the private service providers have concentrated their service efforts on urban areas, neglecting rural hinterlands. Evidently, this has resulted in an overlap in healthcare service coverage, exposing the majority of rural patients to distance decay. In addition, because of inadequate coordination between public and private service providers, there are serious instances of regional imbalances: the eastern area of the county has more health infrastructure, while the western region lags behind in spatial accessibility to basic healthcare. Access to existing primary healthcare facilities was also curtailed by variations in service hours during weekdays and weekends. The implication is that a patient must incur additional distance and time in situations where their nearest primary healthcare service provider is closed. Therefore, inadequate and uneven distribution of primary healthcare facilities (basic healthcare based), variations in facility time operations, and overlap of service areas of health facilities had a significant influence on regional access to primary healthcare.

The planning intervention aimed to tackle spatial accessibility issues identified in specific areas by suggesting strategic upgrading of healthcare facilities. Notably, the western regions of the county have demonstrated a deficiency in the allocation of primary healthcare resources. Prioritizing spatial justice in resource allocation is crucial to alleviate regional disparities. In summary, these findings hold great importance for healthcare planning and policy formulation as they illuminate the disparities in accessibility among sub-counties and the influence of different transportation modes on healthcare service access.

Several prior research papers used administrative or census blocks or residential addresses to account for catchment population when evaluating access to healthcare (Guagliardo, 2004; Higgs, 2004; Wang, 2012). Such approaches have been criticized for failing to adequately accommodate the dynamics of health seeking behavior within a community: health service demand locations vary within human activity-based systems (Allan, 2014; Rainham et al., 2010; Vallée and Chauvin, 2012). This study recognized the dynamic nature of population distribution when modeling catchment populations for healthcare facilities. Therefore, the locations of the building footprints within Migori County, as estimated by the UNPD, were considered as the locations of the catchment population.

The application of location-allocation models in the redistribution of resources has been hailed for its evidence-based spatial intelligence, which is necessary for the efficient allocation of resources and services. A strong relationship exists between the deliverables of location-allocation models and Central Place theory, which was first postulated by Walter Christaller in 1933. The location-allocation models in contemporary times are conceived of as the operationalization of the Central Place theory. Central place theory is a theoretical framework focused on establishing spatial correlations between settlements and services (Christaller, 1966). These models go beyond the conventional central place theory by facilitating the identification of underserved central places. This research also in its employment of location-allocation models massively informs the planning intervention to optimize primary healthcare accessibility in Migori County: a spatial framework for identifying optimally located dispensaries to be considered for upgrade. Location-allocation models have become essential tools in regional planning for governmental authorities and decision makers. They aid in making informed placement decisions, optimizing the distribution of resources and services, and improving the cost-effectiveness and efficiency of service delivery (Polo et al., 2015; Rahman and Smith, 2000; Yousefi et al., 2020).

As a result of this study, the following recommendations are proposed:

- The County government should prioritize the improvement of transport infrastructure, especially in rural areas, to facilitate easier access and movement through various mobility options. This will significantly reduce travel impedances and enhance the accessibility of primary healthcare service providers.
- Health policymakers should utilize location-allocation models to effectively allocate and reallocate health resources.

Previous studies have focused on measuring accessibility to healthcare facilities, with little research assessing the efficiency of healthcare facilities. A profound focus of research needs to illuminate the capacity of healthcare facilities to adequately service the nearest catchment population. Specifically, the question of whether a healthcare facility is adequately capacitated to provide services to its assigned population should be addressed.

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Gazili olmak ayrıcalıktır