IMPACT OF MIGRATION AND CLIMATE CHANGE ON LAND USE AND LAND COVER TRANSFORMATION OF NORTH-EASTERN NIGERIA

By

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PhD/SPS/FT/2021/13008

WEST AFRICA SCIENCE SERVICE CENTRE ON CLIMATE CHANGE AND ADAPTED LAND USE - CLIMATE CHANGE AND HUMAN HABITAT
FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA

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A THESIS SUBMITTED TO THE POSTGRADUATE SCHOOL FEDERAL UNIVERSITY OF TECHNOLOGY, MINNA, NIGERIA IN PARTIAL FULFILLMENT OF THE REQUIREMENTS FOR THE AWARD OF DEGREE OF DOCTOR OF PHILOSOPHY (PhD) IN CLIMATE CHANGE AND HUMAN HABITAT

APRIL, 2025

DECLARATION

I declare that this thesis titled ''**Impact of Migration and Climate Change on Land Use and Land Cover Transformation of North-Eastern Nigeria**'' is a collection of my original research work and it has not been presented for any other qualification anywhere. Information from other sources (published and unpublished) has been duly acknowledged.

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CERTIFICATION

The thesis titled "**Impact of Migration and Climate Change on Land Use and Land Cover Transformation of North-Eastern Nigeria**" by: ISHAKU Deborah (PhD/SPS/FT/2021/13008) meets the regulations governing the award of the degree of PhD of the Federal University of Technology, Minna and it is approved for its contribution to scientific knowledge and literary presentation.

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ABSTRACT

Migration and climate change form a nexus having significant consequences on the Land use and land cover change of North-Eastern Nigeria. This research investigated the impact of migration and climate change on land use and land cover transformation of Northeastern Nigeria, targeting Adamawa, Borno and Gombe States between 1981 and 2021. The study used NASA POWER data (rainfall and air temperature), questionnaire, net migration data and multispectral satellite images, which were combined to analyze the correlation between the study variables. Modified Mann-Kendall trend analysis, IDW interpolation, questionnaire analysis, Landsat images analysis and Spearman's rank correlation analysis were carried out using R Studio, SPSS, Arc GIS 10.8, Google Earth Engine and TerrSet 18.31 and Python. Results of the study revealed that rainfall is decreasing ($z = -0.442$), maximum temperature is increasing ($z = 0.046$) while minimum temperature is on a marginal decline ($z = -0.005$). Higher precipitation was observed during the wet season (100.95mm), maximum temperatures peaked during the dry season (38.09 ^{o}C), while minimum temperatures were higher during the wet season (20.94 ^{o}C). Transformation in the land use and land cover was observed, especially in the increasing trend in built-up (720.61 km^2 in 1991 to 1725.67 km^2 in 2021). Urban expansion was particularly pronounced in state capitals, corresponding with a reduction in cultivated land (41.14 percent to 30.75 percent), forest (6.64 percent to 4.92 percent), bare/sparse land (0.54 percent to 0.48 percent) and water bodies (3.86 percent to 3.64 percent) and projected to increase to 3385.27 km^2 in 2040. The accuracy assessment result exceeds 80 percent. The result from the questionnaire administered showed 55.5 percent of migrants tend to converge more into the state capital from neighboring surrounding rural communities (rural-urban migration) and migration in the study area is predominantly driven by job opportunities (33.5 percent), education (30.3 percent) and insecurity (28.8 percent). Complex interactions were observed between climatic variables (rainfall and temperature), net migration, and LULC classes. Variations suggest how climatic factors and migration influence land use and land cover changes. Increasing urbanization, deforestation, increased competition of water resources, loss of biodiversity, increased land fragmentation, land degradation, loss of cultural heritage and spread of diseases were identified as the impacts of migration and climate change on land use and land cover transformation of North-Eastern Nigeria. The study advocates for proactive dissemination of climate information, integrating climate change and migration policies into national and developmental plans, providing support to migrants, especially Internally Displaced Persons (IDPs), encouraging climate-smart agriculture, enhancing access to education, health care, social services and peaceful co-existence.

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LIST OF ABBREVIATIONS AND ACRONYMS

CBD	Central Business District
CH_4	Methane
CMIP5	Coupled Model Intercomparison Project
CO_2	Carbon Dioxide
GCMs	Global Climate Models
GGWSAP	Great Green Wall Policy for Sahara and Sahel Initiative National Strategic Action Plan
GHGs	Greenhouse Gases
GIS	Geographic Information System
IPCC	Intergovernmental Panel on Climate Change
LGAs	Local Government Areas
LST	Land Surface Temperature
LULC	Land Use and Land Cover
LULCC	Land Use and Land Cover Change
NASA	National Aeronautics and Space Administration
NASPA-CCN	National Adaptation Strategy and Plan of Action on Climate Change for Nigeria
NDC	Nationally Determined Contribution
NIMET	Nigeria Meteorological Agency
OCHA	Office for the Coordination of Humanitarian Affairs
RCPs	Representative Concentration Pathways
SDGs	Sustainable Development Goals
SPSS	Statistical Package for Social Science
Tmax	Maximum Temperature

Tmin	Minimum Temperature
UK	United Kingdom
UN	United Nations
UNHCR	United Nations High Commission for Refugees

CHAPTER ONE

1.0 INTRODUCTION

1.1 Background to the Study

Migration and climate change are among the most powerful forces shaping our world today. They influence where and how people live, how land is used, and the sustainability of the ecosystems that support life. Migration, at its core, reflects humanity's ability to adapt and respond to environmental and social pressures. Similarly, climate change reminds us of how interconnected and fragile our natural systems are, as shifting weather patterns and extreme events alter the landscapes we depend on. Together, these forces create a complex relationship that addresses every aspect of human and environmental systems.

This study focuses on understanding how climate change—marked by fluctuations in rainfall, temperature, and extreme weather (Massey, 2015; Kolstad and Moore, 2020), —impacts of migration patterns on Land use and Land cover transformation. Climate-induced migration often leads to changes in settlement locations, farming methods, and the use of natural resources, making it a clear outcome of shifting environmental conditions (Olagunju *et al*., 2021).

On a global scale, the effects of climate change and migration are already visible (Timmermann and Friedrich, 2016). Europe, North America, and Oceania serve as the primary destinations for migrants, with Europe and Asia experiencing the highest influx of migrants in recent years (Internal Displacement Monitoring Centre, 2018). This has attracted global attention in policy circles and contemporary literature (Baldwine and Fornale, 2017). For example, in Bangladesh, Pakistan, the Philippines, China, India, Brazil, Colombia, Syria and Türkiye, repeated climate- and weather-related disasters have forced millions of people to leave their homes and rebuild their lives elsewhere (McAuliffe and Oucho, 2024). Sleeter *et al.* (2018) highlighted how human activity in the United States impacts land cover, with 28 percent of 3.1 million square miles of land undergoing major alteration for cultivated farmland or settlements. These cases illustrate how climate variability can uproot communities and how migration can alter livelihoods and reshape an entire region (Semenza and Ebi, 2019; Akinbami, 2021).

In Africa, the story is no different but often more pronounced. The Sahel region, with its fragile ecosystem, is a stark example of how desertification and unpredictable rainfall force communities to move in search of fertile land and water. In Southern Zambia, for instance, the Tonga-speaking people rely on migration as a strategy to adapt to the lack of water for farming and livestock rearing (International Organization for Migration, 2018).

In Northeastern Nigeria, climate change presents a unique set of challenges. Rising temperatures, recurring floods, encroaching deserts, and dwindling water supplies have significantly disrupted livelihoods (Nwokeoma and Chinedu, 2017). For instance, a recent flood in Maiduguri displaced over 300,000 people, leaving communities struggling to rebuild while grappling with land use and land cover challenges (Adamu and Lawal, 2024). Compounding these issues are socio-political crises like banditry, herder-farmer conflicts, and terrorism, all of which drive displacement and migration, further straining the land and its resources (Lenshie *et al*., 2021).

The key challenge lies in understanding how climate change and migration interact and what this means for land use and land cover sustainability. While global and regional trends offer valuable lessons, the local dynamics in Northeastern Nigeria remain understudied, leaving critical gaps in our understanding of how to address these issues effectively.

This study aims to identify the intricate relationship between climate change, migration, land use and land cover in Northeastern Nigeria. It seeks to uncover patterns, identify the drivers of these changes, and provide insights that can guide sustainable land management and adaptation strategies. The research stems from a pressing need to address the environmental and social challenges facing this vulnerable region. By exploring these dynamics, this study seeks to fill knowledge gaps and empower communities and policymakers with the necessary information to build resilience. Ultimately, it is fueled by a vision of a more sustainable and equitable future for the people of Northeastern Nigeria.

1.2 Statement of the Research Problem

Northeastern Nigeria has long been a region where agriculture flourished, supported by stable environmental conditions. The availability of fertile land and favorable weather allowed rural communities to thrive, providing food security and economic prosperity. People relied on farming and livestock rearing as sustainable livelihoods, fostering a harmonious balance between human activities and the natural environment (Lesmore, 2022; Lahsen and Ribot, 2022).

Today, this ideal reality has been significantly disrupted. Unstable rainfall, desert encroachment, and shrinking water resources have severely impacted agricultural productivity. Additionally, insecurity driven by the Boko Haram insurgency and banditry has rendered many farmlands inaccessible, forcing farmers to abandon their livelihoods. By 2023, over 2.3 million people in the region, mostly women and children, had been displaced (International Organization for Migration, 2023). Many of these individuals now live in overcrowded camps or with host communities, where resources are stretched thin (Sani and Kemaw, 2019; Olagunju *et al*., 2021). This forced migration has led to unplanned urbanization, unsustainable land use practices, and heightened stress on limited urban infrastructure, deepening the region's socio-economic and environmental challenges (National Bureau of Statistics, 2018).

Pandey *et al.* (2018), Omerkhil *et al*. (2020), and Giri *et al*. (2021) explored the profound effects of climate change in India, Ethiopia, and other highly vulnerable regions. Their studies highlighted its influence on land use and land cover, human health, and livelihoods, while also noting the lack of effective adaptation strategies. Similarly, Hermans-Neumann *et al.* (2017) investigated the link between human migration, climate variability, and land degradation, emphasizing the resulting socio-ecological pressures in Ethiopia.

In Nigeria, Ragatoa *et al*. (2019) report how Southern Nigeria's vegetation changes due to fluctuations in the rainfall sequence, while the savanna vegetation zone is seriously confronted with severe heat waves. In the Sahel region, hectares of cropland are at risk of being lost to desertification each year. Similarly, climate variability has significantly affected Nigeria's water and wetland resources, leading to a decline in the flow rate and network length of major water bodies. This reduction is largely attributed to decreased rainfall and increased evapotranspiration, which have directly and indirectly impacted both crop and livestock productivity (Fitton *et al*., 2019).

Environmental changes continue to threaten livelihoods, serving as a key driver of both internal and international migration. The Intergovernmental Panel on Climate Change (IPCC, 2021) warns that human migration could become one of the most profound consequences of climate change. Millions of people are expected to be displaced due to shoreline erosion, flooding from intensified rainfall, prolonged droughts, and significant shifts in land use and land cover patterns.

Despite the severity of these issues, there is limited research exploring the interconnected impacts of climate change, migration, and land use transformation in Northeastern Nigeria. While these topics have been examined globally, the region's unique challenges—such as the interplay of insecurity, environmental degradation, and forced migration—remain underexplored. Furthermore, the lack of effective adaptive strategies leaves vulnerable communities struggling to cope with these challenges (Conte, 2022). This gap in understanding and intervention underscores the need for localized, in-depth research to address the complex dynamics at play.

This study seeks to bridge these gaps by investigating how climate change and migration transform land use and land cover in Northeastern Nigeria. By analyzing these interactions and identifying key drivers and outcomes, the research aims to provide practical recommendations for sustainable land management and climate adaptation strategies. Ultimately, this work strives to empower policymakers and stakeholders with actionable insights to build resilience and secure a more sustainable future for the region's vulnerable populations.

1.3 Research Questions

1. How have rainfall and temperature trends changed in the study area between 1981 and 2021?
2. Which factors contribute to influencing migration?
3. What is the nature of the Land use and Land cover in the study area between 1981 and 2021?
4. How might the study area's land use and cover appear in 2040?
5. What are the impacts of Migration and Climate on Land use and Land cover?

1.4 Aim and Objectives of the Study

The study aims to investigate the significant implications of migration and climate change on land use land cover transformation in northeast Nigeria. The following objectives were considered:

i. examine the trend in rainfall and temperature between 1981 and 2021 in the study area;
ii. evaluate the factors that influence Migration;

iii. analyze the Land use and Land cover dynamics between 1991 and 2021;
iv. model the Land use and land cover of the study area to 2040;
v. evaluate the impact of Migration and Climate on Land use and Land cover;

1.5 Justification for the Study

As a member of the Global South, Nigeria has implemented various policies to address environmental challenges and the impacts of climate change. Key initiatives include the Nigeria Climate Change Policy Response and Strategy (NCCPRS), the Great Green Wall Policy for Sahara and Sahel Initiative National Strategic Action Plan (GGWSAP), the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN), and the National Policy on Environment. These frameworks are designed to promote climate resilience and sustainability across the country.

Additionally, policies such as the World Population Policy and the Migration Policy emphasize sustainable resource management, environmental conservation, and orderly migration, aligning with Nigeria's constitutional mandate to protect the environment. The findings of this research contribute valuable insights that can help refine and enhance these existing policies for more effective climate action and environmental governance.

This study is essential for aligning these policies with current socio-economic and environmental realities. By addressing gaps in existing frameworks it will help ensure that policies on land use, climate adaptation, and migration are coherent and relevant. Furthermore, it supports Nigeria's commitment to the Nationally Determined Contribution (NDC) by contributing actionable insights to mitigate greenhouse gas emissions and reduce the socio-economic impacts of climate change.

The research supports the design and refinement of policies that promote sustainable land use, migration management, and climate action. It will benefit policymakers at all levels of government, particularly in ministries such as Agriculture, Environment, Culture and Tourism, Works and Housing and Humanitarian Affairs. These findings can inform strategies that address Sustainable Development Goals (SDGs) 13 and 11, focusing on climate action and sustainable cities and communities. The study's outcome is valuable to organizations working in urban planning, agriculture, and humanitarian assistance. By providing data-driven insights into land use and climate dynamics, it will help these entities optimize resource management, improve agricultural practices, and enhance urban infrastructure planning. For instance, NGOs and development agencies can adopt the recommendations to improve ecological sustainability and socio-economic resilience in affected regions.

This research contributes a foundational framework for academics and researchers investigating the relationships between climate change, migration, and land use. By highlighting the unique challenges of Northeastern Nigeria, it will stimulate future studies that examine these dynamics in other contexts. The high-resolution data and methodologies used in this study will serve as a valuable reference for advancing research in this field.

The study fills a critical gap in understanding the interplay between climate change, migration, land use and land cover transformation in Northeastern Nigeria. Previous studies (Lambin *et al.,* 2001; Mwaniki *et al.,* 2015; Pipitpukdee, 2020; Brewer *et al.,* 2024; Arizapana-Almonacid *et al.,* 2024) explored similar dynamics in other regions but did not address the localized complexities of this study area. By focusing on the "source" and "sink" zones of migration, this research offers clear insights into how environmental changes influence land use and land cover changes (Ma *et* *al*., 2021; Yabe *et al.*, 2022). These findings expand the academic discourse on sustainable land management and rural-urban dynamics, offering practical solutions to global challenges.

Ultimately, this study presents an in-depth exploration of the intricate relationship between climate change, migration, and land use transformation in Northeastern Nigeria. By highlighting these interconnected impacts, it provides a strong foundation for developing evidence-based policies and sustainable practices aimed at enhancing resilience and fostering long-term development in the region.

1.6 Description of Study Area

1.6.1 Geographical location

The northeast has a total landmass of about 279,203 Km^2 (situated within Latitudes 6° 30'N to 14° 00'N and Longitudes 8° 30'E to 15° 00'E). It comprises six states namely Adamawa, Bauchi Borno, Gombe, Taraba, and Yobe that were at one time collectively called and administered as one state (North Eastern State); The northeast geo-political zone has a total of 112 local government areas (Tukur, 2015). Three states Borno, Adamawa and Gombe have been purposively chosen as the study area as shown in Figure 1.1.

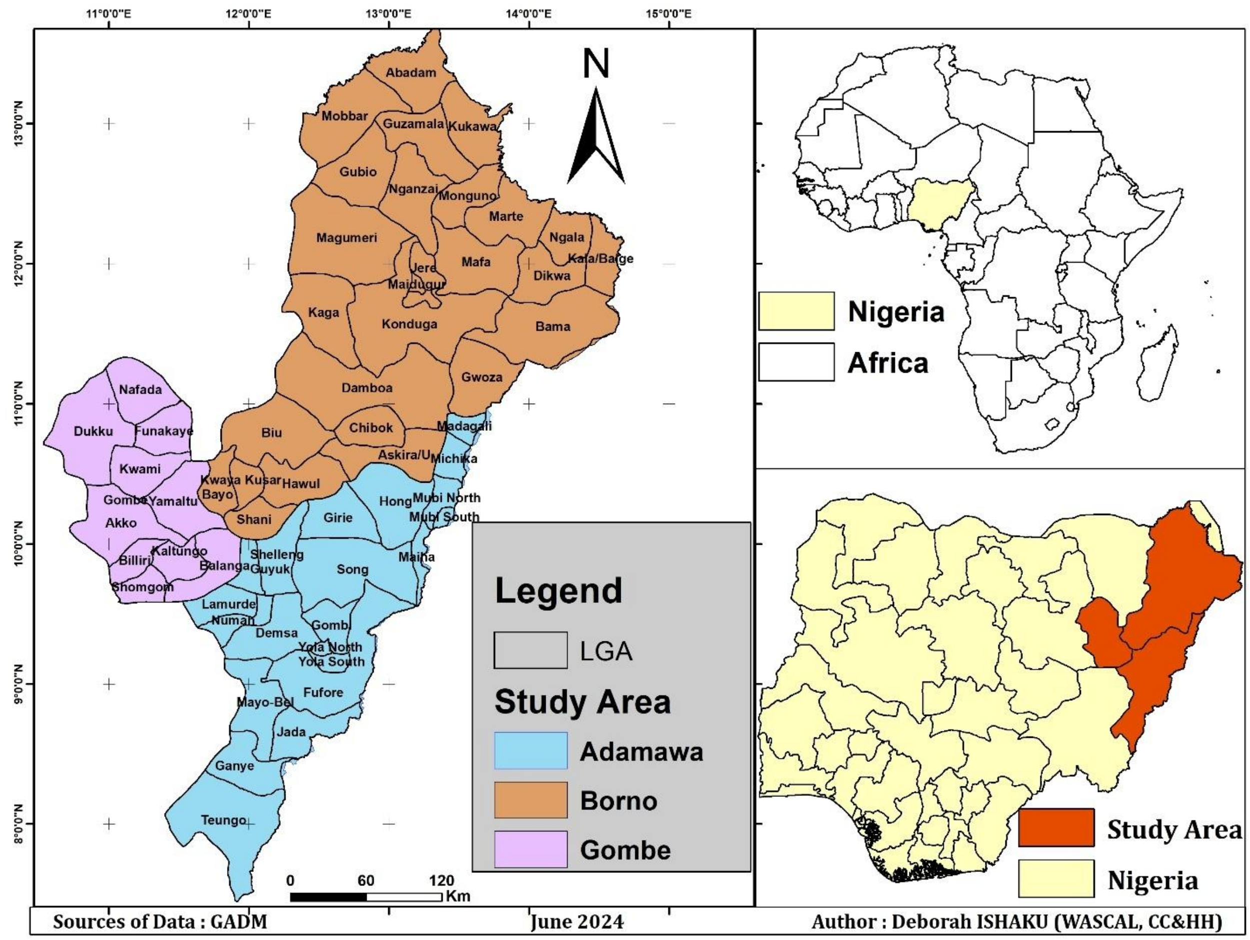

Figure. 1.1: The Study Area

1.6.2 Climate

It has a tropical continental climate marked by a distinct wet and dry season. The rainy season begins in May and ends in October while the dry season lasts mainly from November to April. The mean length of the rainy season ranges from 120 to 210 days, while the mean annual rainfall in the region ranges from 300mm in the extreme north to over 2000 mm in the extreme south. Thus, mean annual rainfall decreases in a south-north direction following the latitude (Adebayo, 2002). The temperature in this climatic region is high throughout the year; however, there is usually a seasonal change. The seasonal maxima usually occur in April with a maximum temperature of 40 °C while the minimum can be as low as 18°C between December and January.

1.6.3 Soil, vegetation and hydrology

The area is characterized by broadly flat topography with gentle undulating hill ranges. The soils comprise sandy, silty clays, loamy, nitisols, regosols, leptosols, cambisols, luvisols, regosols, leptosols, regosols, Luvisols vertisols (Bello and Msheliza, 2019). River Benue is the major river in the area, it rises from the highlands of the Cameroon Republic and flows southwards into Nigeria joining the river Niger at Lokoja where it forms a confluence. River Benue, which is the main river with many tributaries, flows all year round with the peak in the months of August-October in the Wet season (Tukur and Barde, 2014; Ladu, 2015). The vegetation is characterized by two vegetation zone (Guinea and Sudan Savanna) which is predominantly wooded shrubland with a plant community comprising Anogeissus/ Combretum and a mosaic of shrubbed grassland with the preponderance of Acacia, Affrormosia, and Detarium (Bello and Msheliza, 2019).

1.6.4 Socio-economic activities

The northeast geopolitical zone has a total population of 18,971,965 (according to the 2006 Nigerian Population census returns) with a projected population of about 26 million people segmented into more than 100 ethnic/language groups. Abundant agricultural lands are found in the many morphological units within the state, making the growth of various crops, vegetables, and livestock management possible. The major socio-economic activities are farming, fishing, animal rearing, hunting, and trading (Bello and Msheliza, 2019).

1.7 Scope and Limitation of the Study

The study has a time boundary of forty-one (41) years, 1981-2021. This was chosen purposively to cover a long period that includes pre- and post-Boko haram terrorism experiences, which resulted in the migration of many people. Majorly, three states were considered as the study sample, which are Borno, Adamawa, and Gombe States. Borno and Adamawa states were mostly affected by out-migration due to terrorism while Gombe state, which is relatively peaceful, has hosted people from the terrorized states (OCHA, 2021). Issues to be addressed are an examination of the trend in rainfall and temperature, an analysis of Land use and Land cover dynamics, an evaluation of the factors that influence migration, a projection of land use and land cover changes, and an analysis of the relationship between migration and climate parameters on Land use and Land cover.

Some limitations experienced are restrictions due to one's masculinity or femininity in some parts of the study area, hostility due to previous research in an area without visible results, unavailability of migration data at state level hence net migration data for Nigeria was used and inaccessibility to communities in northern Borno due to restrictions caused by unrest and terrorist attacks.

CHAPTER TWO

2.0 LITERATURE REVIEW

2.1 Conceptual Framework

2.1.1 Migration

The history of humanity and civilization is deeply intertwined with migration, making it a fundamental aspect of societal development. Migration refers to the movement of people from one location to another, either within their own country (internal migration) or across international borders (external migration). This movement can be temporary or permanent, depending on various social, economic, and environmental factors. History has shown that people migrate for various reasons. Some migrate voluntarily in search of high-paying jobs or better living conditions, while others are forced out of their homes by natural disasters. In some cases, people flee their home countries due to fear of being arrested and persecuted for their religious and political beliefs, or membership in a particular social group (Carletto *et al*., 2006).

The desire to move from one territory to another has made people to apply any means possible to achieve that as such, some can follow the legal means to migrate while others migrate illegally. In legitimate Migration, the Migrants are accepted either for employment, humanitarian reasons or visa lottery. In illegal migration, people enter the country via the borders in a variety of ways without government approval (Ghanbari and Rezazadeh, 2022).

Hu (2020) highlighted two factors (push and pull) that encourage people to vacate their homes and to settle in another location. Push factors represent the factors existing in the migrants' origin country and seem to be the reasons that persuade and sometimes oblige people to abandon their country. The factors existing in the modern country, which encourage people to migrate to that country, are considered the pull factors. Safety, environmental, economic, social, and political factors are examples of push and pull factors. Among the safety factors, war is the most significant factor causing forced migration around the world. Persecution and harassment based on political beliefs and religion encourage people to migrate to a country where they can have freedom and safety in their lives (Hintermeier *et al.*, 2021).

Environmental factors are the other substantial factors that have caused migration in recent years, significantly. Water shortage, which leads to crop failure, food leakage, and reduction of agricultural jobs, abet people to relocate to other places with better environmental conditions where they can find more job positions. Water, air, and soil pollution create considerable health risks and can cause people to escape to locations with better air quality. Natural disasters such as earthquakes and tsunamis are other environmental factors that may lead to the migration of people. The main reasons for the human movement in economic migration are mostly a lack of job positions and inadequate wages. The mentioned reasons cause people to migrate to areas where they can find jobs with higher wages. Social factors that encourage migration originate from a human need to ensure better opportunities for themselves and their families (Ghanbari and Rezazadeh, 2022).

Hermans-Neumann *et al*. (2017) in their study on Human migration, climate variability, and land degradation attested that deteriorating environmental conditions, including land cover transformations, can be both the cause and the effect of migration. Therefore, Migration in its real form, whether in or out, has varying impacts on land use and land cover transformation of an area.

2.1.2 Climate change

The increasing concerns over climate change and its far-reaching consequences have sparked a global outcry. This is due to its widespread impact, affecting individuals and communities regardless of geographical location or socioeconomic status. The Intergovernmental Panel on Climate Change (IPCC, 2007) defines climate change as a long-term shift in the state of the climate, identifiable through statistical analysis of changes in mean climate conditions and variability. These changes persist for extended periods, typically decades or longer, and may result from natural internal processes, external influences, or sustained anthropogenic alterations in atmospheric composition and land use. In contrast, the United Nations Framework Convention on Climate Change (UNFCCC, 1992) defines climate change as climate alterations directly or indirectly caused by human activities that modify the composition of the global atmosphere, beyond the natural variability observed over comparable periods.

For this study, the IPCC definition is adopted, as there is statistically significant evidence of long-term climatic shifts in the study area, exemplified by the persistent shrinking of Lake Chad (Elisha *et al*., 2017). Vulnerability assessments indicate that northern states, particularly those in the Northeast, experience a higher degree of climate vulnerability compared to southern states (Madu, 2016; Federal Ministry of Environment, 2012). In the North, declining precipitation poses a major threat to rain-fed agriculture, whereas in the Southeast, water loss due to high soil porosity is a significant concern (Okon *et al*., 2021).

Several case studies have demonstrated that migration can serve as an essential adaptation strategy to climate change, enabling individuals and communities in dryland regions to enhance their livelihoods (McLeman and Smit, 2006; McLeman and Hunter, 2010; Scheffran *et al.,* 2012; Brockhaus *et al*., 2013). As such, the interconnection between climate change and migration has profound implications for land use and land cover, with the potential to drive widespread environmental and socio-economic transformations.

2.1.3 Land use and land cover change

Land use and land cover are two fundamental aspects of the Earth's surface that are significantly influenced by human activities. Although often used interchangeably, these concepts have distinct meanings. Land use refers to how humans utilize land for various purposes, such as agriculture, urban development, or conservation, while land cover describes the physical and biological characteristics of the land, such as forests, wetlands, or open water bodies (NOAA, 2024).

The understanding of Land Use and Land Cover Change (LULCC) has evolved. Initially, research on LULCC was largely focused on physical changes in the landscape. However, in recent decades, attention has shifted to include the broader implications of global environmental change (Parveen *et al*., 2018). In disaster-prone regions, deforestation, landslides, and the rapid conversion of forests into agricultural and horticultural lands have significantly altered land use and land cover, often exacerbating environmental degradation (Khan *et al*., 2017).

Historically, humans have modified land to meet their survival needs, but the rate of land exploitation today is unprecedented, leading to extensive transformations in ecosystems and environmental processes at local, regional, and global scales. Contemporary concerns regarding LULCC now encompass issues such as climate change, biodiversity loss, and pollution of air, water, and soil (Parveen *et al*., 2018). Consequently, monitoring and mitigating the adverse impacts of LULCC while ensuring the sustainable use of natural resources has become a key priority for researchers and policymakers worldwide.

The transition of land from a relatively undisturbed state to more intensive uses—such as farming, livestock grazing, and selective tree harvesting—has numerous ecological consequences. These include the loss of native species, contamination of water, soil, and air (Girma and Hassan, 2014), increased risks of natural disasters such as droughts and floods, greenhouse gas emissions, and disruptions to ecosystem structures and functions. Such alterations undermine the ability of ecosystems to sustain human life (Nel *et al*., 2014).

2.2 Theoretical Framework

2.2.1 Land use and land cover theories

2.2.1.1 Concentric theory- by Ernest Burgess (Geographer)

In 1925, Ernest Burgess proposed the concentric zone theory to explain how cities grow and organize their land use. Based on his study of Chicago, he suggested that cities expand outwards from a central core in a series of concentric rings. This idea was influenced by Von Thunen's model of rural land use and the layout of ancient villages. Burgess argued that the city center or the Central Business District (CBD) would have high-value land uses, such as office buildings, retail stores, and financial institutions.

The area surrounding the central district would feature a mix of uses, including affordable housing for workers employed in the CBD, and spaces for manufacturing, wholesaling, storage, and other activities directly or indirectly linked to the central zone’s operations. Further out in the urban hierarchy, the areas would be allocated to low-cost housing for wage earners, middle-class housing, and, at the rural-urban fringe, higher-cost housing for upper-income residents. This surrounding area is referred to as a transitional zone, characterized by older homes—some converted into flats—along with high-density housing, where factories and other businesses are starting to encroach. Beyond the central and transitional zones lies the inner ring of residential areas, primarily inhabited by the wageworkers from these zones.

In this inner residential area, the housing is typically small, high-density, or in some cases, former higher-end properties now converted into flats or apartments. Residents of this area are drawn to its lower rent and property values, and its proximity to the Central Business District (CBD) and their places of employment. Further development of this theory is the "ripple effect," which describes how land uses spread outward from a central point of high density to progressively lower densities, much like ripples radiating from a stone dropped into water (Burgess, 1925).

Some critics attest that cities do not conform to an ideal circular spatial pattern. Also, mobility channels with the reality of land use extension are more common in the multi-nuclei model. The increasing growth of cities and urbanization is making settlements more of a multiple-nuclei model.

2.2.1.2 Sector theory by C.D. Harris and Homer Hoyt (Economist) based on 34 American cities in the U.S.A. in 1939.

The sector theory, developed by Harris and Hoyt in the 1930s, emerged from analyzing over 200,000 neighborhood blocks across approximately 70 American cities. The theory suggests that in a city without natural geographic boundaries, land uses will spread outward in a pie-slice pattern from the central business district to the outskirts. Each "sector" or slice will consist of similar types of land uses and people from similar social backgrounds, with urban growth extending outward from the city center rather than encroaching upon neighboring sectors. This outward expansion is influenced by transportation routes that radiate from the center of the city.

These transportation routes not only facilitate the expansion of specific land uses but also act as natural boundaries between sectors. They provide a clear path of least resistance, guiding the growth of particular land uses, such as commercial or residential areas. This dynamic helps explain the development of ribbon-like street frontages and the expansion of commercial districts, often followed by infill development between extended street frontages. The Radial Corridor Theory later evolved from this idea, reflecting a shift in emphasis within the sector theory.

Hoyt's theory also highlights the synergistic relationship between land uses, suggesting that similar uses benefit from being located near one another. For example, industrial areas tend to cluster with other industrial properties, while residential areas are often located next to other residential zones. This clustering creates a positive exchange between compatible land uses while reducing the negative impact of incompatible uses being situated too close to one another (Barlowe, 1978).

The model has faced criticism for considering only railway lines as the primary factor driving sector growth, without accounting for the influence of private cars. It is a monocentric representation of cities; the model does not account for multiple business centers. In addition, physical features may restrict or direct growth along specific wedges no reference has been made to out-of-town development.

2.2.1.3 Multi-nuclei model by Edward L. Ullman and C.D. Harris in 1845

The multiple nuclei theory of 1945 by Harris and Ullman. This expands Hoyt's theory, stating that cities and other metropolitan areas often emerge with more than one CBD. This is particularly the case in huge cities. As cities grow, the traditional Central Business District (CBD) or downtown core remains central, but additional business districts often emerge along major transportation routes, some distance away from the original CBD. These new districts develop their own hierarchy of land uses, similar to the pattern observed in the CBD, as described by the Burgess or

Hoyt theories. For this to happen, there must be areas of vacant or low-intensity land between these new centers, allowing space for their emergence and growth.

The rise of multiple business districts, or nuclei, can occur for several reasons. One key factor is that expanding cities may outgrow existing commercial centers, which continue to function as smaller nuclei within the broader urban landscape. Additionally, the increasing distance and time required for commuting to the CBD can create opportunities for subsidiary nuclei to provide some of the common functions traditionally performed by the central business area.

This trend has become especially evident since World War II, with the widespread use of motor vehicles and the expansion of new streets contributing to urban congestion in the CBD. Furthermore, this pattern is more likely to emerge in areas where public transportation systems are less developed, as the strength of the CBD is less dependent on efficient transit systems (McDonagh, 2007).

According to critics of the theory, the height of buildings was neglected, and instead of having clear-cut, rigid boundaries between zones, each zone tends to show considerable internal diversity, rather than uniformity. The term multiple nuclei alone and the nature of its land use formation diagram seem not very clear enough to explain the complexity of the multi-nuclei model, unlike concentric, residential, succession, and sector models, which were easy to comprehend.

2.2.1.4 Succession theory

All of the aforementioned theories propose that urban growth over time leads to a "succession" of changing land uses as the concept of "highest and best use" evolves. For instance, commercial areas, once limited by the surrounding land uses in a particular zone or sector, will eventually expand by acquiring and redeveloping neighboring properties, transforming their character to align with that of the commercial zone. The theory of succession is also applicable to the residential property market, where change often occurs even before external pressure from other land uses pushes for redevelopment.

In practice, this can be seen when residents of older, once-high-cost housing near expanding commercial areas consider modernizing their homes but ultimately choose to sell. This initiates a filtering process, where higher-cost and mid-range homes gradually deteriorate, being occupied by lower-income residents over time. Eventually, these homes may be converted into apartments or flats, and ultimately demolished to make way for commercial or industrial developments.

The succession theory, therefore, provides a valuable framework for understanding the transitional areas that often arise between different land uses, complementing the broader land use theories and offering insight into how urban landscapes evolve (Barlowe, 1978). However, in criticism of the theory, many people are emotionally attached to their family household and may not want to change their location no matter the height of development.

2.2.1.5 Residential theory

The theory of residential location suggests that homebuyers typically seek a combination of convenience, adequate space, and a pleasant environment. In addition to the economic factors that influence industrial and commercial spaces, personal preferences play a significant role in residential choices. These preferences can vary greatly, as what is desirable to one individual may be less appealing to another. Furthermore, "fashion" and trends often influence residential choices.

Historically, before the widespread availability of modern transportation, residential locations were closely tied to proximity to a worker's place of employment, with convenience being a primary factor in choosing a home. However, in contemporary urban settings, housing can be located virtually anywhere within a large commuting zone. Today, the location, style, and amenities of a home are largely determined by the individual's personal preferences, or "trade-offs," which balance factors like distance from work, lifestyle desires, and the financial capacity to pay (McDonagh, 2007). Critics see the importance of the availability of land used for transportation routes as a key factor for residential use.

2.2.1.6 Cause-cover relationship concept of LULCC

This study adopts the Cause-Cover Relationship Concept of Land Use and Land Cover Change (LULCC) shown in Figure 2.1 as proposed by Turner (1994) and later modified by Turner *et al*. (2021). This framework examines the driving forces behind land cover change, providing insights into how environmental transformations occur from local to global scales. LULCC occurs primarily through conversion (complete transformation from one cover type to another) and modification (gradual alteration of existing land cover), both of which result from complex interactions between climatic variables and human activities (Turner, 1994; Lambin *et al*., 2003).

Turner (1994) emphasized that the causes of LULCC vary across different socio-economic, political, cultural, and technological contexts. Consequently, the notion that only a few drivers influence land cover change has been replaced with a more intricate understanding of multiple interacting factors (Turner *et al*., 2021). This study applies this framework to examine the relationship between migration, climate change, and their subsequent impacts on land use and land cover transformation in Northeastern Nigeria.

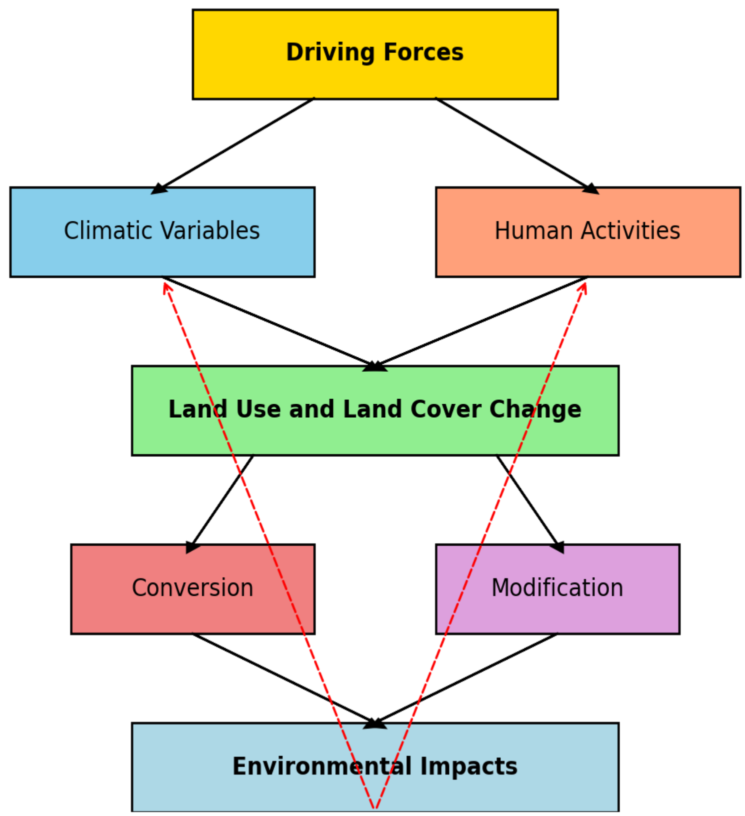

Figure 2.1: Cause-Cover Relationship Concept of LULCC
Source: Turner, 1994 and Turner *et al.,* 2021

2.2.2 Climate change theories

2.2.2.1 Anthropogenic global warming theory

Anthropogenic global warming results from human activities that release greenhouse gases (GHGs) into the atmosphere, intensifying climate change. Since the Industrial Revolution, the concentration of key GHGs—carbon dioxide (CO_2), methane (CH_4), chlorofluorocarbons (CFCs), and nitrous oxide—has risen significantly. For instance, CO_2 levels have increased by 31 percent, while CH_4 has surged by 149 percent. This accumulation has led to a measurable warming of the

Earth's surface, with global temperatures rising by approximately 0.74°C between 1906 and 2005. NASA's records from 1880 to 2007 confirm this ongoing trend.

The Intergovernmental Panel on Climate Change (IPCC, 2013) attributes most of this warming to human-induced GHG emissions, primarily from burning fossil fuels. Climate models predict that, depending on future emissions and climate sensitivity, global temperatures could rise between 1.1°C and 6.4°C by the end of the 21st century. Research by John Cook and the Global Change Institute supports this, showing that climate models incorporating human-driven CO_2 emissions align most accurately with observed temperature trends. These models have successfully predicted past and future warming, reinforcing the consensus that human activities are the primary driver of climate change (IPCC, 2007; Washington, 2013).

2.2.2.2 Global bio-thermostat theory

The Global Bio-Thermostat theory suggests that natural biological and chemical feedback mechanisms counteract the warming effects of increased atmospheric CO_2, maintaining a balance in global temperatures. According to this theory, various processes—such as carbon sequestration, carbonyl sulfide production, diffuse light effects, iodo compounds, dimethyl sulfide emissions, aerosols, and cloud formation—help regulate the Earth's climate. One key argument is that higher CO_2 levels enhance plant growth, increasing carbon uptake and contributing to climate stabilization. As a result, proponents of this theory assert that neither CO_2 emissions nor biological processes pose a significant threat to the environment (Bast, 2010; Cookey and Sigah, 2020).

However, recent research challenges this perspective by suggesting that during past periods of global warming, extreme heat in the tropics may have exceeded the tolerance limits of some organisms, leading to disruptions in ecosystems and biodiversity loss. This finding indicates that while natural feedback mechanisms exist, they may not be sufficient to fully counteract human-induced climate change.

2.2.2.3 The planetary motion theory

The Planetary Motion Theory attributes climate change to natural gravitational and magnetic oscillations within the solar system, influenced by planetary movements through space. These oscillations are believed to regulate solar activity and other extraterrestrial forces that impact Earth's climate. The concept of extraterrestrial influences on long-term climate variations was first proposed by Serbian astrophysicist Milutin Milankovitch in 1941. Advances in research have since allowed scientists to measure these effects with greater accuracy (Bast, 2010; Agu and Ogbeide, 2016).

Scafetta (2009) tested this theory by analyzing the Sun's motion relative to the solar system's center of mass, known as the barycenter. His findings suggest that natural oscillations in the solar system align closely with observed climate patterns, successfully replicating warming and cooling trends since 1860. He further applied this model to project future climate changes, reinforcing the potential role of planetary influences in shaping Earth's climate.

2.2.3 Migration theories

2.2.3.1 Network theory

Network theory conceptualizes international migration as a decision-making process at the individual or household level. It is widely employed in migration studies to explain patterns and volumes of human mobility, as well as the mechanisms that sustain international migration over time. Migrant networks are composed of interpersonal connections that link individuals through shared community origins, friendships, and family ties in both origin and destination regions.

When the number of migrants reaches a critical threshold, the expansion of these networks reduces the costs and risks associated with migration while increasing the potential benefits. As a result, the likelihood of international migration rises, fostering chain migration and further reinforcing the network effect (Massey *et al*., 1993; Kesici, 2021).

While much of the literature emphasizes the role of kinship and community ties in facilitating migration—where migrants in destination areas provide support to prospective migrants from their countries of origin—this perspective often overlooks alternative sources of assistance. Institutional and online resources, for instance, can also play significant roles in shaping migration decisions. Additionally, assuming a universal role for migrant networks, without considering contextual factors such as the scale and history of migration or the specific immigration regimes in place, can be misleading (Van Meeteren and Pereira, 2018). A more nuanced approach is therefore required to account for the varying influences of migrant networks across different migration contexts.

2.2.3.2 The Conflict model of migration

This model, which was originally derived from Dahrendorf (1959) and later developed by Sirkeci (2009) as well as Sirkeci and Cohen (2016). It posits that conflict is a key driver of migration, influencing individuals' decisions to move across borders. Conflict situations—ranging from social tensions to outright violence—play a crucial role at various stages of the migration process, as they contribute to an environment of human insecurity (Sirkeci, 2009).

However, critics argue that conflicts at the individual, household, community, and state levels are not isolated phenomena but are interconnected, influencing one another in complex ways. Within this framework, transnational mobility can be understood as a movement from a state of human insecurity toward greater human security. This perspective highlights migration not only as a response to conflict but also as a means of seeking safety, stability, and improved living conditions.

2.2.3.3 Dual labor market hypothesis

The dual labor market hypothesis, rooted in the economic division between labor and capital, is extensively discussed in Piore's seminal work, Birds of Passage. This theory posits that international labor migration is primarily driven by pull factors, as developed economies—such as Germany and the United Kingdom (UK)—require migrant labor to sustain their industries. Labor markets are divided into two distinct sectors: the primary sector, which offers stable employment, higher wages, and opportunities for advancement, and the secondary sector, characterized by low wages, precarious conditions, and limited mobility. While native workers predominantly occupy positions in the primary sector, migrants often find themselves in the secondary sector, filling low-status jobs that are essential but unattractive to the local workforce (Grimshaw *et al*., 2017).

By the mid-1970s, the economies of industrialized nations such as West Germany and the UK had become increasingly reliant on standardized, repetitive production processes. With labor shortages in the secondary sector and minimal skill requirements for many industrial jobs, unskilled workers from countries such as Turkey and Cyprus were seen as ideal candidates for employment in these roles. This demand-driven migration perpetuated inequalities between the advanced economies of the UK and Germany (the primary labor markets) and the labor-exporting countries (the secondary labor markets). These inequalities were shaped not only by economic conditions but also by employers and policymakers, who controlled access to occupational opportunities and reinforced labor market segmentation (Grimshaw *et al*., 2017).

However, the dual labor market hypothesis has been criticized for overlooking individual decision-making processes, such as the cost-benefit analyses migrants undertake before relocating. Instead, it frames migration as a structural necessity—an inevitable outcome of economic globalization and market expansion across national borders (Massey *et al*., 1993). Rather than focusing on the personal motivations behind migration, this perspective emphasizes the systemic forces that pull migrant labor into developed economies, viewing migration as an inherent response to labor market demands in modern industrial societies.

2.2.3.4 World-system theory

World-systems theory is based on the premise of a sustained demand for low-skilled foreign labor in developed economies. This perspective situates migration within the broader context of a global capitalist economy, in which wealthier, industrialized nations expand their economic dominance over less-developed, peripheral societies. As capital flows from core countries into these regions, migration flows emerge in the opposite direction, with workers from the global periphery moving toward developed economies in search of better opportunities. Within this framework, international migration—alongside large-scale rural-to-urban migration—contributes to demographic shifts, as younger workers leave less-developed areas, exacerbating aging trends among those left behind (Triandafyllidou, 2019).

Despite its influence, world-systems theory has faced significant critique from various theoretical perspectives. According to Wallerstein (1979), criticism arises from four main directions: positivists, orthodox Marxists, state autonomists, and culturalists. Positivists argue that the theory relies too heavily on broad generalizations, lacks sufficient empirical data, and does not present a falsifiable hypothesis. Orthodox Marxists contend that world-systems theory departs too far from classical Marxist principles, particularly by failing to emphasize the role of social class in structuring global economic relations. State autonomists critique the approach for obscuring the distinction between state power and corporate influence, arguing that the state should remain the primary unit of analysis. Meanwhile, culturalists challenge the theory's heavy emphasis on economic structures, asserting that it neglects the role of cultural factors in shaping migration patterns.

While world-systems theory provides a compelling macro-level explanation for migration flows, its limitations highlight the need for more nuanced, multidimensional approaches that incorporate both economic and sociopolitical dynamics. Understanding migration requires not only examining global economic structures but also considering localized factors that shape individual migration decisions.

2.2.3.5 New economics of labor migration (NELM) theory

The New Economics of Labor Migration (NELM) theory builds upon the neoclassical perspective, offering a more refined and comprehensive approach to understanding migration. Unlike traditional economic models that view migration as an individual decision driven by wage differentials, NELM conceptualizes migration as a household or family strategy. This perspective suggests that migration serves as a means of diversifying household income sources, reducing vulnerability to local economic instability. In this framework, family members who remain in the country of origin—particularly older relatives—benefit from remittances, which play a crucial role in ensuring household well-being. This is particularly significant in developing countries where institutional welfare support may be limited (Massey *et al*., 1993).

NELM also offers insights into the broader consequences of migration for sending countries. For instance, migration is often linked to anthropogenic factors such as land use and land cover transformation, as families adjust their economic activities in response to changing environmental and livelihood conditions (Kesici, 2021). Migration, therefore, is not only an economic phenomenon but also a driver of social and environmental change.

Despite its contributions, the NELM theory has been criticized for being a revised version of the neoclassical framework rather than a fundamentally new paradigm. Some scholars argue that its development coincided with the "information-theoretic revolution" in economics, which emphasized the role of information asymmetry in decision-making. Critics advocate for a more comprehensive "historical-structural synthesis" that moves beyond both NELM and traditional neoclassical approaches to offer a more nuanced understanding of migration dynamics.

More broadly, migration theories have often been challenged for their narrow focus on why some individuals choose to migrate while overlooking the reasons others remain in place. Additionally, these theories have been critiqued for their limited engagement with the role of state policies in shaping migration patterns (Karakoulaki *et al*., 2018). To accurately describe migration in the 21st century, these traditional frameworks must be expanded beyond economic "push and pull" factors to incorporate broader societal influences and social transformations (Arango, 2000). In response to these gaps, recent theoretical advancements have adopted interdisciplinary approaches that integrate economic, political, and social dimensions of migration (Massey *et al*., 1993; Favell, 2008).

2.3 Review of Related Studies

Migration, climate change, land use and land cover change are burning issues in the 21st century and the consequences on different environmental components cannot be overemphasized. This study focuses on the impact of migration and climate change on land use and land cover transformation in North-Eastern Nigeria. Therefore, a range of related literature has been reviewed to establish the findings of previous scholars on the subject matter.

2.3.1 Climate change and migration

The concepts of climate change and migration have gotten the attention of scholars. In a recent study, Michael (2024) explored how climate change influences the migration of women in the waterlogged areas in Bayelsa State, Nigeria. Adopting an exploratory research design, the study employed purposive and snowball sampling techniques to select 51 female participants. Data were collected through 24 in-depth interviews and 3 focus group discussions, capturing the experiences of women who are struggling with the challenges posed by climate change. The Findings revealed that climate change shapes the migration decisions of women, often forcing them to relocate due to issues such as flooding and soil erosion. The study advocates for the implementation of gender-responsive policies and community-based strategies to address the relationship between climate change and women's migration in the region.

While Michael (2024) viewed climate change and migration from a gender perspective, Bewul e*t al.* (2024) highlighted how the two concepts can influence crime (homicides, robberies, herder-farmer conflicts, and burglaries) in the country. Using secondary data from academic and news sources, the study examines the relationship between climate change and crime in Nigeria. The analysis draws upon the ecological theory of crime, emphasizing how environmental transformations shape crime patterns. The study recommends incorporating climate change mitigation strategies within Nigeria's criminal justice system and broader policy landscape. Madu and Nwankwo (2021), in their study Spatial Pattern of Climate Change and Farmer-Herder Conflict Vulnerabilities in Nigeria, examine the relationship between climate change and farmer-herder conflicts. Their findings reveal that while farmer-herder conflicts are widespread across

Nigeria, they exhibit significant spatial clustering, with the Middle Belt—particularly Benue State—emerging as a conflict hotspot. The results of their regression model indicate that climate change vulnerability is the strongest predictor of farmer-herder conflicts in Nigeria. However, the relationship is negative, suggesting that areas with higher climate change vulnerability do not necessarily experience higher levels of conflict. This result implies that regions that are more vulnerable to climate change experience lesser farmer-herder conflict.

The paper demonstrated that climate change could influence herders' migration patterns as the herders now move southward due to deteriorating environmental conditions, partly caused by the changing climate in the northern regions. Thus, it argues that climate change is not necessarily the cause of the conflict because the change in the pattern of herders' migration does not automatically lead to climate change causing conflict. Migration is important, but the mechanism establishing the migration–conflict has to be explained.

Lenshie *et al.* (2021) argue that migration driven by desertification, combined with the state's failure to ensure effective security governance, exacerbates herder-farmer conflicts in Nigeria. Their research emphasizes how these conflicts endanger livelihoods, fuel population displacements, and undermine human security. The study concludes that effective security governance amidst increased desertification in Northern Nigeria presents an opportunity for regulating the southward migration of herders, mitigating herder-farmer conflicts, and promoting human security in Nigeria.

Nenger *et al*. (2024) reviewed the Impact of Climate Change on Forced Migration in the Sahel region from a Human Rights Viewpoint. Findings reveal that environmental factors like droughts, desertification, and erratic rainfall patterns act as potent "push" factors, forcing communities to migrate. Climate change severely impacts livelihoods and food security, raising critical human rights concerns regarding food, water, health, and education, particularly among vulnerable groups. For solutions, a comprehensive approach is needed, encompassing mitigation and adaptation efforts, strengthening legal frameworks for climate migrants, providing humanitarian aid, and investing in sustainable development initiatives. The study recommends improvement of collaboration and policy action among stakeholders to address root causes and protect human rights.

Cattaneo and Peri (2016) analyzed data from 115 countries between 1960 and 2000 to examine the relationship between rising temperatures and migration. Their findings indicate that temperature increases lead to higher migration rates from middle-income countries but lower migration rates from low-income countries. In middle-income communities, migration can enhance economic stability by improving income levels and average worker wages. In contrast, low-income populations face greater financial constraints exacerbated by climate change, making migration unaffordable and pushing them further into poverty.

While investigating the extent to which climate change causes international migration, Backhaus *et al.* (2015) identified three key findings in their study. First, they established a positive causal relationship between temperature increases and migration. Second, they found that drastic changes in precipitation contribute to forced migration. Lastly, their research revealed that regions more reliant on agriculture experience a higher number of forced migrants compared to less agriculture-dependent areas. They estimated a panel data set of 142 sending countries for the period 1995 to 2006 using a gravity model of migration augmented with average temperature and precipitation in the country of origin.

2.3.2 Climate Change and LULCC

Other researchers have explored the relationship between climate, land use and land cover change in Nigeria. Ojolowo *et al.* (2024), examined how remote sensing reveals the variability of LST and LULC to assess climate variation in Osun State. Similarly, Salaudeen *et al*. (2023) investigated adaptation measures for the impacts of climate change on land use and land cover in the Gongola River Basin. Employing a process-based watershed modeling approach, they quantified the effectiveness of five management options as adaptation measures for the impacts of the stressors, showing that climate impact could cause a peak discharge rise compared to historical levels.

Bernard and Bilal's (2023) analysis of the spatiotemporal variations in LULCC in Kano urban areas indicated an increase from 7 percent in 1984 to 32 percent in 2022, while bare land decreased from 82 percent in 1984 to 49 percent in 2022. This urban expansion was associated with a significant rise in Land Surface Temperature (LST), which increased from a mean value of 16°C in 1984 to 30.5°C in 2022. The study reveals a negative correlation between vegetation health and LST, where declines in vegetation health led to higher LST due to reduced cooling effects from transpiration. On the contrary, a positive correlation is observed between the built-up index and LST, indicating that urban expansion worsens the urban heat island effect.

Njoku and Tenenbaum (2022) examined the relationship between land use and land cover, altitude and land surface temperature (LST) in Ilorin from 2002 to 2020. Using remote sensing data and spatial analysis tools such as Moran's I spatial autocorrelation and Geographically Weighted Regression (GWR), they found significant changes in LULC patterns. Urban areas increased by over 11 percent, while forested areas decreased. The study showed a clustering of LST values with higher temperatures concentrated in built-up areas.

Koko *et al.* (2021) examined the spatiotemporal impact of land use and land cover (LULC) changes on surface Urban Heat Islands (UHI) in the Abuja metropolis. Their study documented significant urban expansion, with 358.3 sq. km of natural surfaces converted into built-up areas. This transformation led to an increase in mean land surface temperature (LST) from 30.65°C in 1990 to 32.69°C in 2019, with a notable rise of 2.53°C between 2009 and 2019. The findings further confirmed an inverse relationship between LST and the Normalized Difference Vegetation Index (NDVI), while demonstrating a positive correlation between LST and the Normalized Difference Built-up Index (NDBI).

In the derived savannah of Nigeria, Akintuyi *et al*. (2021) used remote sensing and GIS tools to evaluate the interaction between LULC and climate change. Their study revealed an increase in urban areas, water bodies, woodland, and farmlands between 1972 and 2019, accompanied by a decrease in forest cover. Future predictions for 2020 to 2050 suggest further reductions in forested areas, with rainfall identified as the primary driver of LULCC in the study area.

Olagunju *et al*. (2021) highlighted the impact of climate change on rainfall patterns in northern Nigeria, leading to a loss of vegetation, affecting water availability and land-carrying capacity. This has contributed to drought, desertification, and migration of youth to the southern regions for better living conditions. Okon *et al*. (2021) carried out a systematic review of research on the impacts of climate change in Nigeria, highlighting the importance of knowledge-driven approaches in developing effective mitigation and adaptation strategies. The review identified research gaps in the study of climate change impacts on the aquatic environment and limited attention to adaptation in Northern Nigeria.

Dale (2019) argued that while land-use changes are influenced by anthropogenic activities, climate change can affect land management practices, alter crop yields, and shift agricultural potential. Changes in temperature or rainfall can necessitate irrigation or change the suitability of certain crops. Garba and Brewer (2013) examined land cover changes in North-Eastern Nigeria from 1986 to 2005 using NigeriaSat-1 and Landsat images. Their findings showed that 60 percent of the study area remained unchanged during this period, while 11 percent transitioned between shrub, grass and bare ground. Shrub and grassland were found to be the most unstable category, reflecting the vulnerability of vegetation types to environmental changes. All these studies highlighted the interaction between climate and LULCC.

2.3.3 Migration and LULCC

Migration patterns equally influence land use and land cover. Gilbert and Shi (2024) investigated the driving forces behind urban spatial evolution in Lagos, Nigeria, from 2000 to 2020. Using Pearson correlation coefficients, they found that population growth and economic activities are the primary drivers of urban spatial changes in Lagos, with high correlations between LULCC and factors such as population, economic indicators, transport infrastructure, demographic trends, and urbanization rate. Aweda *et al.* (2024) found that migration significantly contributes to land degradation. Supported by spatiotemporal patterns of the Normalized Difference Vegetation Index (NDVI) and the Normalized Difference Built-Up Index (NDBI), showing increasing NDBI values and a slight decrease in NDVI.

Okeleye *et al*. (2023) focused on the impacts of LULCC on migration and food security in the North Central region of Nigeria. By employing multispectral satellite remote sensing, net migration data, household surveys, stakeholder meetings, focus group discussions, and expert interviews, they identified significant LULCC between 1990 and 2020 in Niger, Kwara, and Benue

States. Their findings revealed that vegetation, agricultural land, and water bodies in Kwara and Benue States were increasingly converted into built-up areas and barren land. Meanwhile, Niger State saw an increase in agricultural land and built-up areas. Continuous migration of young farmers to urban areas was observed, leaving previously cultivated agricultural lands unused, with potential negative impacts on food security.

Nnaji *et al*. (2022) explored the spatiotemporal effects of LULCC on the hydrology of Enugu State using the Soil and Water Assessment Tool (SWAT). They demarcated the watershed into 17 sub-basins and analyzed LULC trends over two decades. Their results showed a significant conversion of rangeland to residential and agricultural areas, driven by aggressive urbanization and the need for increased food production to support the growing population.

In a similar study, Obiahu *et al.* (2021) employed remote sensing tools, Landsat images, and GIS techniques to quantify LULCC and built-up expansion in Ebonyi State from 1996 to 2018. They classified five LULC types: forest area, built-up area, bare land, farmland, and water bodies. The analysis revealed a significant increase in built-up areas (+1461 km^2), bare land (+284 ha), and farmland (+349 km^2), while forest areas declined by 2094 km^2 (28.1 percent). Regression analysis confirms that population growth contributed significantly to built-up expansion, with Abakaliki and Ezza North identified as critical hotspots for intense land conversion.

Koko *et al*. (2020) used an integrated Cellular Automata-Markov chain model along with remotely sensed data and GIS techniques to monitor LULC changes in Zaria City, between 1990 and 2020. Their results show a substantial expansion in built-up areas (65.88 percent) and vegetation (28.95 percent), leading to a significant reduction in barren land by 63.06 percent. Predictions for 2035 and 2050 indicate that these patterns of LULC changes will likely continue due to urban growth, reforestation, and agricultural development.

Nébié and West (2019) explored migration and LULCC dynamics in Burkina Faso through a comparative case study between two provinces: Bam, a long-time zone of departure, and Sissili, a destination zone. Using a regional political ecology framework and a time series of LULCC data, the study reveals that in-migration correlated with substantial LULCC, whereas out-migration was associated with moderate LULCC. This suggests a dynamic interaction between local LULCC and migration, where migration patterns stabilize or reverse based on changes in environmental conditions.

In India, Kathwas and Patel (2019) examined the effects of LULC dynamics on migration and demographic patterns of tribal populations in the Subarnarekha watershed, Jharkhand State. The study used geospatial techniques to assess the impact of urbanization on LULC and demographic characteristics between 1987–2000 and 2000–2010. Their analyses revealed a considerable increase in the built-up area during the post-state period and a distinct relationship between demographic parameters like population density, household density, tribal population and different LULC categories. These findings suggest that demographic trends are a major influencing factor on LULC changes, which can lead to ecological degradation and affect livelihoods.

2.4 Examples from Other Regions/Countries:

Globally, issues of climate change, migration, land use and land cover transformation are of paramount importance due to their implications on environmental sustainability and human livelihoods. A review by Chetto *et al*. (2024) on climate change-related drivers of migration in East Africa analyzed 22 research articles focusing on Tanzania, Kenya, and Uganda indicated that climate change effects, such as frequent droughts, floods, livestock pests, and crop diseases, significantly influence migration and displacement in the region. Additionally, rising sea levels pose imminent risks that can trigger migration if adaptation measures are not taken. The study revealed that responses to drought or crop and livestock diseases, whether through localized adjustments or out-migration, are determined by households' adaptive capacities. For rapid-onset climate events like floods, the most vulnerable groups are often those living in poorly constructed structures within flood-prone areas. The review suggested mainstreaming climate change-induced migration in East African nations' adaptation plans and promoting alternative livelihoods to mitigate forced migration.

Arizapana-Almonacid *et al.* (2024) examined land cover changes in a region of the Central Andes impacted by population migration. The study focused on the districts of Huanta and Luricocha, where human population dynamics shifted due to armed conflict with Peruvian authorities between 1980 and 1990, followed by a gradual return from 1990 to 2020. Using satellite imagery from multiple sources, including Landsat and Sentinel, the study assesses temporal changes in land cover. Results showed that high Andean grasslands and scrublands decreased over time, while lagoons and nearby wetlands expanded due to increased demand for water for human consumption and agriculture. The findings highlighted how abandoned agricultural lands did not recover quickly, suggesting a need for more research and actions to restore the high-mountain ecosystems.

Sambieni *et al*. (2024) investigated 60-year rainfall and temperature variability (1960–2019) and land cover changes in the Sota catchment, North Benin, West Africa. The study employed a standardized anomaly index, breakpoints, trend analysis, and Thiessen's polygon techniques to analyze climate data and satellite images for Land use and land cover assessments from 1990, 2005, and 2020. Results revealed distinct climate periods: a wet period (1960–1972), a dry period

(1973–1987), and another wet period (1988–2019). Despite non-significant rainfall trends at the catchment scale, temperatures show significant increases. Land use and land cover analysis from 1990 to 2020 indicates substantial increases in various areas. These changes have implications for the region's environmental stability, necessitating adaptation measures such as Integrated Water Resources Management and afforestation.

In Nepal, Wang *et al*. (2020) explored Land use and land cover detection and prediction in the Kathmandu district, revealing a 9.28 percent decrease in forests, 9.80 percent loss in agricultural land, and a 77 percent reduction in water bodies due to rapid urbanization and changing climate. These losses were absorbed by expanding urban areas, which grew by 52.47 percent. Projections for 2030 predict further declines in forest cover, agriculture, and water bodies by 14.43 percent, 16.67 percent, and 25.83 percent.

Bhawana and Race (2020) examined the effects of outmigration on land management practices in rural communities in the middle hills of Nepal. Through household surveys, in-depth interviews, and group discussions, the study finds that underutilization of farmland is a more prominent phenomenon than land abandonment. Outmigration has led to less intensive farming and decreased food security. The study noted that this issue is not confined to migrant households but is influenced by a complex range of factors. A high risk of food insecurity looms if underutilization and abandonment of farmland persist.

Similarly, Bhawana *et al*. (2017) used geospatial and social research methods to explore internal migration impacts on LULC patterns in the western mountain district of Nepal between 1998 and 2013. Results showed a decreasing number of households at high elevations (above 1400 m), where an increase in forest cover coincided with a decline in agricultural land and shrub or grassland areas, suggesting that internal migration significantly influences LULC dynamics and resource management in the region.

2.5 The Overview and Key Issues of the Study

Migration presents both opportunities and challenges for both the areas of origin and destination. Archaeological evidence shows that human settlement patterns have consistently adapted to climate change. For instance, the rise of some of the first large urban societies appears to have been driven by a combination of climatic shifts and environmental drying. Studies suggest that regions like Egypt and Mesopotamia became centers of early civilization as people migrated from arid rangelands to more hospitable riverine areas. The need to organize densely packed populations and manage scarce resources in these restricted spaces is often cited as a key factor in the development of these early civilizations (McLeman, 2006; Brooks, 2006).

Looking ahead, projections indicate that by 2099, global temperatures may rise by 1.8ºC to 4ºC on average (Black *et al*., 2011). This warming is expected to make large areas drier, with the proportion of land experiencing continuous drought increasing from 2 percent to 10 percent by 2050. Furthermore, areas suffering from extreme drought could rise from 1 percent today to 30 percent by the end of the century. Alterations in rainfall patterns and intensifying hydrological cycles are also anticipated, leading to more intense rainfall that could erode topsoil and cause floods (Burke *et al.*, 2006).

Migration has played a central role in shaping societies throughout history and remains a critical factor in the present day. The reasons behind migration are complex and multifaceted, influenced by various push and pull factors (Cattaneo and Peri, 2016). While some individuals migrate due to conflict or poverty, others do so under conditions of peace, political stability, and development. A significant proportion of international migrants originates from rural areas, and both international and internal migration—especially movement from rural to urban areas—are integral to the structural transformation of economies. These movements bring both opportunities and challenges to rural economies, often leading to social, economic, and environmental changes.

The emergence of Policies aimed at maximizing the benefits of migration and minimizing the risks associated with it, supporting for instance, the National Policy on Environment, whose overall goal is a low-carbon, climate-resilient Nigeria and the World Population Policy which covers 92 indicators including immigration, emigration, age structure, mortality, internal migration, and facilitates orderly, safe, regular and responsible migration and mobility of people is paramount.

CHAPTER THREE

3.0 MATERIALS AND METHODS

3.1 Description of Materials

3.1.1 Types of data

The data used in this study includes

i. Rainfall data for 41 years (1981-2021) for Adamawa, Borno and Gombe states.
ii. Temperature data for 41 years for Adamawa, Borno and Gombe State.
iii. Land use and land cover maps for 31 years for Adamawa, Borno and Yobe States.
iv. Projected Land use and Land cover maps of 2040 for Adamawa, Borno and Gombe states.
v. Questionnaire Survey data.
vi. Net Migration data.

3.1.2 Sources of data

The study used data from both primary and secondary sources. Primary data was acquired through questionnaire and camera recordings, while secondary data was sourced from NASA POWER, Satellite imageries, the World Banks' website, GPS data, and various publications.

i. National Aeronautics and Space Administration Prediction of Worldwide Energy Resources (NASA POWER) for 1981 to 2021.
ii. TerrSet 18.31, Arc GIS 10.8 and Google Earth Engine
iii. Global Positioning System for ground truthing.
iv. Questionnaire Survey using Kobo tool box
v. The World Banks' website

vi. Others include camera and publications.

3.2 Methods of Data Collection

i. **Climate Data**: Gridded monthly rainfall and temperature data acquired from the National Aeronautics and Space Administration Prediction of Worldwide Energy Resources (NASA POWER) for the period 1981 to 2021. Monthly rainfall and temperature (maximum and minimum air temperature at 2 meters above the ground level) data with a spatial resolution of $0.05^{o} \times 0.05^{o}$ was obtained for nine selected stations— (Akko, Billiri, Gombe, Abadam, Biu, Maiduguri, Mubi, Numan and Yola) used for Mann Kendall test and Sens Innovative trend analysis and fifty-nine points/station representing all the Local Government Areas (LGAs) in the study location which was for IDW interpolation and Sen's slope estimator.

ii. **GIS and Remote Sensing Data**: Multispectral satellite images were obtained from the Landsat series (Landsat 5, 7, and 8) for the years 1991, 2001, 2011, and 2021. Google Earth Engine (GEE) was utilized to access, download and pre-process these images (Table 3.1), ensuring that the data was both consistent and comprehensive across the study period. Additionally, ancillary data such as topographic maps and historical land cover data were used to support the classification process and improve the accuracy of the analysis (Table 3.2). The images were selected based on cloud cover, preferring scenes with less than 10 percent cloudiness to ensure clear and accurate data. GEE was also used to perform atmospheric correction and image calibration, standardizing the images across different years for a consistent analysis. The pre-processed images were then exported for further analysis in Arc GIS 10.8 and TerrSet 18.31. Global Positioning System was used for picking coordinates.

Table 3.1: Characteristics of Landsat Images Used for The Study

Date of Acquisition	Sensor	Path	Row	Multispectral Band	Thermal Band	Spectral Range (micrometres)	Spatial Resolution (pixel spacing)	Source
1991	TM	185, 186, 187	51,52,53,54	1 to 5 and 7	6	10.45-12.45	30	Google Earth Engine (GEE)
2001	TM	185, 186, 187	51,52,53,54	1 to 5 and 7	6	10.45-12.45	30	
2011	ETM+	185, 186, 187	51,52,53,54	1 to 5 and 7	6	10.45-12.45	30	
2021	OLI and TIRS	185, 186, 187	51,52,53,54	1 to 7 and 9	10 and 11	10.60-12.51	30	

Source: Author, 2024

Table 3.2: LULC Types Description

LULC Types	Description
Grassland	Areas covered by grasses
Built up	Urban, rural settlements, commercial and industrial areas
Water bodies	Rivers, lakes, dams and streams
Cultivated land	Cropland, irrigated land, commercial farms
Bare soil	Eroded areas, sand dunes
Forest	Areas covered by dense trees

Source, Author, 2024

iii. **Questionnaire Survey**: Convenience sampling was used to choose 3 states for the study. Then, using the 2019 projected population of the 3 states from the National Bureau of Statistics (NBS), the sample size calculator (calculator.net) calculated three hundred and eighty-five (385) questionnaires to be administered in each state. Purposive sampling targeted at people with a migration background was used to administer the questionnaire, which was prepared in English and interpreted in Hausa (a language that is well spoken and understood by the majority of respondents) during interviews using Kobotool box (Table 3.3 and 3.4).

Table 3.3: The Sample size and Questionnaire to be Administered

State	Estimated Population in 2019	No. of Households
Adamawa	4,536,948	385
Borno	5,751,590	385
Gombe	3,623,462	385
Total	13,912,000	1,155

Source: National Bureau of Statistics, (2019)

Table 3.4 Local Governments Sampled

Adamawa	Borno	Gombe
Girei	Biu	Akko
Mubi	Jere	Billiri
Numan	Maiduguri	Gombe
Yola North		
Yola South		

Source: Author, 2022

iv. **Migration Data**: Net Migration data from the World Banks' website (http://data.worldbank.org accessed 27th August, 2024) by the United Nations was downloaded for the years spanning from 1991 – 2021.

3.3 Method of Data Analysis

3.3.1. The trend in rainfall and temperature between 1981 and 2021 in the study area;

a) Auto-correlation Test

Prior to trend analysis, a test for the existence of autocorrelation or serial correlation in the rainfall and temperature dataset was done using the Autocorrelation Function (ACF) in R Studio. The autocorrelation represents the degree of correlation of the same variables between two successive time intervals. Serial correlation, if present, modifies the estimate of the Mann-Kendall statistics (Yue *et al*., 2002).

b) Sen Innovative Trend Analysis (Sen_ITA)

Sen_ITA yields more reliable results by complementing the Mann-Kendall trend test with the Sen_ITA method. Serial correlation does not affect the Sen_ITA method, and this robust property is attempted to be implanted into the Kendall test. The method of Sen Slope Estimator - SSE is adopted for improving the Mann-Kendall test by computing the trend matrix based on the median value, it decreases the impact of the outliers on the trend component (Sen, 2012). Equation (3.1) represents the slope of the trend, $^{s}{}_{ITA}$, in which n is the length of the principal time-series data and $\bar{x}(\bar{y})$ is the average of the first (second) half-time series. The trend line can be derived from equation (3.2). The Confidence Limit (CL) for Sen_ITA can be estimated by using the trend slope. Standard Deviation (SD) of two half series, given that ($\sigma_x = \sigma_y = \sigma/\sqrt{n}$), where σ is the SD of the parent time series, the $^{s}{}_{ITA}$ expectation provided by ($E(^{s}{}_{ITA}) = 0$) for no trend. Equation (3.3) provides the SD of the slope of the trend σ_s where $\rho\overline{xy}$ is the cross-correlation coefficient between the first and second phases. Equation (3.4) provides CL. In that direction, scri=standardized time series critical standard deviation at 95 percent and 90 percent significance levels (α) at ±1.96 and 1.65 respectively. (Alashan, 2020).

$$^{s}{}_{ITA} = \frac{2(\bar{x}-\bar{y})}{n} \tag{3.1}$$

$$y = x + s, \tag{3.2}$$

$$\sigma_s = \frac{2\sqrt{2}}{n\sqrt{n}}\sigma\sqrt{1-\rho}\overline{xy}, \tag{3.3}$$

$$CL_{(1-\propto)} = 0 \pm s_{cri\sigma_s}, \tag{3.4}$$

c) Modified Mann-Kendall Test

The effect of serial correlation can be excluded from a given time series through pre-whitening, variance correction, or over-whitening processes as contained in the modified Mann-Kendall procedure. Note that the pre-whitening process removes some of the current trends, together with the serial correlation. In the present study, the modified Mann-Kendall technique is augmented with the Sen innovative trend analysis instead of using Sen's slope estimator. First, the trend is calculated with the help of the Sen slope estimator Equation (3.5), which is subtracted from the time series according to Equations (3.6) and (3.7). Then, the lag-1 autocorrelation coefficient is estimated and subtracted from the trendless time series (Equation (3.8)), where the trend is added to the independent time series (Equations (3.9) and (3.10)), while the trend of the independent time series is calculated by the Mann-Kendall method. $^{s}{}_{\mathrm{SSE}}$ and $^{s}{}_{\mathrm{ITA}}$ are the trend values calculated by using SSE and Sen_ITA methods, respectively (Alashan, 2020). Z_{SSE}^{d} and Z_{ITA}^{d} shows the time series with no trend. Z^{i} indicates the independent time series, whose correlation effect is removed. The Z_{SSE}^{t} and Z_{ITA}^{t} indicates an independent time series, where the trend values are analyzed according to the SSE and Sen_ITA methods (Alashan, 2020).

$$^{s}{}_{\mathrm{SSE}} = median\left(\frac{Z_j - Z_i}{j - i}\right) \text{ for } j > i\text{: } i = 1 : n - 1 \text{ and } j = 2 : n, \tag{3.5}$$

$$Z_{\mathrm{SSE}}^{d} = Z_k - {}^{s}{}_{\mathrm{SSE.}}\,\mathrm{k}; \text{ for k} = 1\text{: n}, \tag{3.6}$$

$$Z_{\mathrm{ITA}}^{d} = Z_k - {}^{s}{}_{\mathrm{ITA.}}\,\mathrm{k}, \tag{3.7}$$

$$Z^{\mathrm{i}} = Z_k - {}^{\mathrm{p}}{}_{1.}\,z_{k-1}, \tag{3.8}$$

$$Z_{\mathrm{SSE}}^{t} = z_{\mathrm{k}}^{i} + {}^{s}{}_{\mathrm{SSE.}}\,\mathrm{k}, \tag{3.9}$$

$$Z_{\mathrm{ITA}}^{t} = z_{\mathrm{k}}^{i} - {}^{s}{}_{\mathrm{ITA.}}\,\mathrm{k}, \tag{3.10}$$

The data length and variation in a timeseries may change the S parameter too much, with plus and minus differences. However, climate change is a long process and does not change much from 1 year to the next. For this reason, moving z values are calculated in this study. To calculate these values, the final value is subtracted in a timeseries with the greatest climate change effect due to the increased carbon level. This process is repeated until the series has a minimum data length. Thus, the different series are derived by subtracting the last time values from the main time series (Equation (3.11)). Here, Z is the parent time series with elements of $z_{1,}^{t} z_{2,}^{t}\ z_{3,}^{t}\ \ldots z_{\mathrm{n}-\mathrm{m},}^{t}$ is the independent moving time series, but has trend and m is the number of extracted values from the parent time series. Herein, m varies from 1 to the acceptable minimum data length (a). It is selected as 20 for statistical requirements. Similarly, moving Sm and zm values can be calculated using respective Equations (3.12) to (3.14) (Alashan, 2020).

$$Z_{\mathrm{m}}^{t} = z_{1,}^{t} z_{2,}^{t}\ z_{3,}^{t}\ \ldots\ z_{\mathrm{n}-\mathrm{m},}^{t} \tag{3.11}$$

$$S_m = \sum_{i=1}^{n-m} \sum_{j=i+1}^{n-m+1} sign\,(z_{\mathrm{j}}^{t} - z_{\mathrm{j}}^{t}), \tag{3.12}$$

$$Var(S_m) = \frac{(n-m)(n-M-1)-(2(n-m)+5)}{18}, \tag{3.13}$$

$$z_m = \begin{cases} \frac{S_m - 1}{Var(S_m)} & if\ S_m > 0 \\ 0 & if\ \ S_m = 0 \\ \frac{S_m + 1}{Var(S_m)} & if\ S_m < 0 \end{cases} \tag{3.14}$$

d) Inverse Distance Weighting Interpolation of Rainfall and Maximum/Minimum temperature (including seasonal variations) for Adamawa, Borno and Gombe States.

The mean annual rainfall and mean annual maximum/minimum temperatures for four distinct periods: a) 1981–1990, b) 1991–2000, c) 2001–2010, and d) 2011–2021 and the seasonal variation for wet (April – October) and dry season (November to March) were calculated showing the average monthly rainfall in wet and dry seasons, average monthly maximum temperature in wet and dry seasons and average monthly minimum temperature in wet and dry seasons. These datasets were then interpolated from their native grids onto a 0.05° x 0.05° resolution, aligning with the grid of the observed data. To map the spatial distribution of mean annual rainfall, mean annual maximum and minimum temperatures, average monthly rainfall in wet and dry seasons, average monthly maximum temperature in wet and dry seasons and average monthly minimum temperature in wet and dry seasons across the study area, the Inverse Distance Weighting (IDW) interpolation method was employed using ArcGIS 10.8. This method allowed the generation of spatial estimates of climate variables, highlighting localized trends. The Sen's slope value was then calculated for each grid point to quantify the rate of change (increase or decrease) in these climatic variables over the study period.

IDW, a deterministic interpolation technique, predicts values at unknown locations by averaging known values from nearby locations with varying weights based on their distance (Collins and Fred, 1995; Tomczak, 1998). This method assumes that closer values are more similar than those farther apart (Johnston *et al*., 2001). As distance increases, the influence of known values decreases. Therefore, IDW utilizes nearby known data to estimate values at unsampled locations, with closer observations carrying more weight (Apaydin *et al*., 2004; Abdulkadir, 2021; Hossain *et al*., 2021). While interpolation methods like IDW have demonstrated effectiveness, there is no universally preferred method. The choice of interpolation largely depends on the dataset's characteristics, required precision, and available resources (Ozelkan *et al*., 2015).

e) Sen's Slope Estimator (SSE)

Sen's slope estimator is applied in calculating the magnitude of trends in time series data. The technique is preferred as compared to a simple linear regression because it provides a better estimation of the trend. It is often used for estimating the significant linear trends in the time series data which is used in research studies. The slope T_i between two points of time series x calculated by Equation (3.15) (Sen, 1968);

$$T_i = \frac{x_j - x_k}{j - 1} \quad \text{for } i = 1,2,3, \ldots, n \tag{3.15}$$

k=1 to n-1, j = 2 to n, x_j *and* x_k are data values at a time j and k (j >k), respectively. If the time series x has n point observations, there will be N = n (n - 1)/2 slope values. Sen's method estimates the slope as median N values of Q. The Q as slope estimator can be calculated by (Equation (3.16))

$$Q = \begin{cases} T_{(N+1)/2}, N\ odd \\ \frac{T_{N-2} + T_{(N+2)/2}}{2} \quad , N\ even \end{cases} \tag{3.16}$$

3.3.2 The factors that influence migration.

Direct interviews targeted at migrants was employed. A structured questionnaire was administered to the residents of the study locations. The results generated from the questionnaire be subjected to statistical treatment using descriptive statistics due to the nature of the data and the target objective, and presented in tables, figures and charts to demonstrate the effectiveness of the responses when analyzing comments.

3.3.3 The land use and land cover dynamics between 1991 and 2021;

The data analysis for LULC involved several key steps. First, the pre-processed images were imported into ArcGIS 10.8, where supervised classification was conducted using the Maximum Likelihood Classification (MLC) algorithm (Sisodia, 2014). Training samples for each land cover category—Bare/Sparse Vegetation, Built-up areas, Cultivated Land, Forest, Grassland/Shrubs, and Water Bodies—were selected based on field knowledge, historical data, and visual interpretation of the satellite images. Post-classification, accuracy assessments were conducted to validate the results using metrics such as User's Accuracy, Producer's Accuracy, Overall Accuracy, and the Kappa Coefficient were calculated (Li *et al.*, 2023; Dash *et al.*, 2023; Upadhyaya *et al.*, 2024)

Accuracy assessment is a crucial step in processing remotely sensed data. The classified points and ground truth data were combined into a confusion matrix. From this matrix, the user's accuracy, the producer's accuracy, and overall accuracy were calculated. User's accuracy measures how often a class assigned by the classification algorithm is correctly present on the ground (Equation 3.17). Producer's accuracy evaluates how often real features on the ground are accurately represented in the classified map (Equation 3.18) while the Overall accuracy assesses the overall reliability and effectiveness of the classification process (Equation 3.19), (Rwanga and Ndambuki, 2017; Upadyaya *et al.*, 2024).

Kappa statistics (Equation 3.20) calculates the agreement between the classified image and the reference data, accounting for chance agreement. A kappa coefficient of 0 suggests no agreement beyond chance, while a value of 1 indicates perfect agreement (Li *et al.*, 2023).

$$User's\ Accuracy = \frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Classified Pixels in that category Row total}} \text{ x } 100 \qquad (3.17)$$

$$Producer's\ Accuracy = \frac{\text{Number of Correctly Classified Pixels in each Category}}{\text{Total Number of Reference Pixels in that Category Column Total}} \text{ x } 100 \qquad (3.18)$$

$$Overall\ Accuracy = \ Total\ Number\ of \frac{\text{Correctly Classified Pixels diagonal}}{\text{Correctly Classified Pixels diagonal}} \text{ x } 100 \qquad (3.19)$$

$$\kappa\ =\ (Po\ -\ Pe)\ /\ (1\ -\ Pe) \qquad (3.20)$$

Where:

κ = Kappa coefficient

Po = Observed agreement

Pe = Expected agreement by chance

3.3.4 The land use and land cover of the study area in 2040

Land use and land cover change models analyze landscape transformations by comparing an initial state at time t_0 with a later state at t_1 then projecting changes to a future point t_2. The accuracy of these projections is assessed by comparing the predicted map t_2 with an observed reference map. A close match suggests a well-performing simulation model (Gilmore *et al*., 2004; Ahmad *et al*., 2015).

Modeling involves replicating real-world processes over time, capturing key characteristics and behaviors of physical or abstract systems. Understanding historical LULCC patterns enhances predictions of future changes, as past trends often inform future trajectories. Urbanization, for example, typically expands outward from existing urban areas, a pattern leveraged by many predictive models (Briassoulis and Straaten, 2000; Gaur and Singh, 2023).

For projecting LULC changes up to 2040, the classified images were imported into TerrSet 18.31. The Land Change Modeler (LCM) within TerrSet was employed, utilizing the Markov Chain Procedure. This method analyzed the transitions between different land cover types over the study periods and projected future changes based on historical trends. The Markov Chain model incorporated factors such as population growth, urbanization, and agricultural expansion to produce a reliable projection of land cover for the year 2040. The resulting projection map was then validated and analyzed to assess potential future land use dynamics in the study area.

CA-Markov model

Cellular Automata has a spatial database, which is dynamic and can perform simulations that can simulate land use in subsequent years. Markov-CA method is very helpful in making Spatio-temporal projections by taking into account the trend of land use change and the desired scenario. This method provides the basic information for managing the protection, preservation and recognizing the impact of LULCC, policy, management and spatial planning (Mujiono *et al*., 2017) Land use change map of 1991 was defined as input data to validate the 2021 land use map and thereafter used to simulate 2040 land-use scenario. Here the researcher was used two methods to verify and forecast accuracy. One method will be spatial raster contrast to verify whether the land cover type in the spatial location was the same as the actual map.

The two techniques used to model land use change are Markov Chain Analysis and CA Analysis. The Markov Chain Analysis is mainly in terms of the quantity of prediction of land use change and is unable to obtain the change degree of the land use types from a spatial view; while the CA model has a strong dynamic simulation ability to present spatial and temporal changes. CA-Markov model absorbs the advantages of Markov and CA model about space and time series prediction and can be applied in land use change simulation. Using known land use datasets for two different periods for the study area, 1981 and 1991, CA Markov model was used to model and predict land use types for 2040 using TerrSet 18.31 and ArcGIS 10.8. The model analysis was carried out after the integration of the various data into the model, through the following major aspects that will be taken into consideration:

(A). The Markov module was used to predict land use change based purely on the state of land use in 2021 and on land use change in the preceding 20 years between 1991 and 2001. Then output a transition probability matrix, a transition areas matrix, and a set of conditional probability images.

(B). The CA-Markov module utilized the transition areas table and conditional probability images to project land cover changes over the specified period in the Markov chain analysis. To refine this projection, a 5×5 contiguity filter was applied, creating a spatially explicit weighting factor that adjusted cell states based on their neighboring cells. This filter helped enhance the accuracy of the model by identifying suitable areas for each land cover type through a series of suitability maps.

(C). Sub-model was used on the menu "Transition Potential", in this case, to identify the largest land use in the study area. Then, compute the power of each driving factor and record the value on Cramer's V. Input three driving factors into the submenu "Transition Sub Model Structure". The influence of the parameters was quantitatively assessed using Cramer's V. A high Cramer's V value suggests that a variable has strong explanatory potential; however, this does not necessarily ensure robust performance, as it does not account for the mathematical constraints of the modeling approach or the complexity of the relationships involved. Nonetheless, Cramer's V serves as a useful indicator for variable selection—variables with very low values can be discarded, while those with high values can be retained for further analysis (Beltrán-Przekurat *et al*., 2012).

(D). Run sub-model "urban areas" using Multilayer Perceptron (MLP) Neural Network. Then iterate in the range 1000 – 10,000 with RMS Error 0.3. The expected result of the accuracy rate is > 65 percent.

(E). Specify the year of the model on the menu "Change Prediction", which is 2040, using the Markov Chain. Lastly, run the model on the sub-menu "Change Allocation".

This integrated approach overcomes the limitations of using either method alone, as the Markov Chain handles temporal transitions while the CA component addresses spatial dynamics and neighborhood effects, resulting in more realistic and spatially explicit LULC change projections.

3.3.5 The impact of migration and climate change on land use and land cover.

To determine the impact of migration and climate change on land use and land cover, a correlation coefficient analysis was conducted. Prior to that the Shapiro-Wilk Normality test was performed.

(a). Shapira-Wilk Normality Test of data

The Shapira-Wilk Normality test indicates whether each column's data is normally distributed. The test is more frequently employed for lower sample sizes ($n < 50$). It's important because many statistical methods assume normality, and knowing if the data is normally distributed helps in choosing appropriate analytical techniques (Fiandini *et al.*, 2024). A p-value greater than 0.05 suggests normality, while a p-value less than 0.05 suggests non-normality. The test was carried out using various packages in Python software using functions like pandas, numpy and scipy.

(b). Spearman's Rank Correlation Coefficient Analysis

Spearman's Rank correlation analysis was used to establish the correlation between the independent variable (LULC) and dependent variables (Migration and Climate parameters) (Equation 3.21) in the study location to detect the relationship between migration, climate and LULC transformation using various packages in Python software using functions like pandas, numpy, scipy, matplotlib.pyplot and seaborn.

Spearman's Rank Correlation is a non-parametric measure of the strength and direction of association between two ranked variables. It evaluates monotonic relationships and it can capture both linear and non-linear associations (Astivia and Zumbo, 2017). The Spearman correlation coefficient is denoted as ρ_s (Equation 3.21). The formula for is:

$$\rho_s = 1 - \frac{6\Sigma\, d_i^2}{n(n^2-1)} \tag{3.21}$$

Where d_i is the difference between the ranks of corresponding variables and n is the number of observations. The Spearman correlation coefficient, ranges from -1 to 1. A value of 1 indicates a perfect positive relationship, -1 indicates a perfect negative relationship, and 0 indicates no relationship. It is widely used where data may not be normally distributed or where the relationship between variables is not linear (Song and Park, 2020; Fadilah *et al*., 2023).

Due to the violation of normality in one of the variables as indicated by the Shapiro-Wilk test, Spearman's rank correlation coefficient was selected as the appropriate statistical method. This non-parametric alternative is particularly suitable because it does not assume normality in the underlying data distribution, It assesses monotonic relationships rather than strictly linear ones, it is robust against outliers as it operates on ranked data rather than raw values, it transforms the actual values to ranks, making it resistant to non-normal distributions and it maintains statistical validity even when dealing with non-normally distributed variables.

3.4 Method of Data Presentation

The study showcases a comprehensive array of resources, including high-resolution maps, detailed questionnaire survey reports, stunning images, and informative charts that will give a proper understanding of our environmental system. This information will be useful for government agencies, researchers, and the general public, empowering them to make strategic planning and decisions for environmental protection and sustainable development (Figure 3.1).

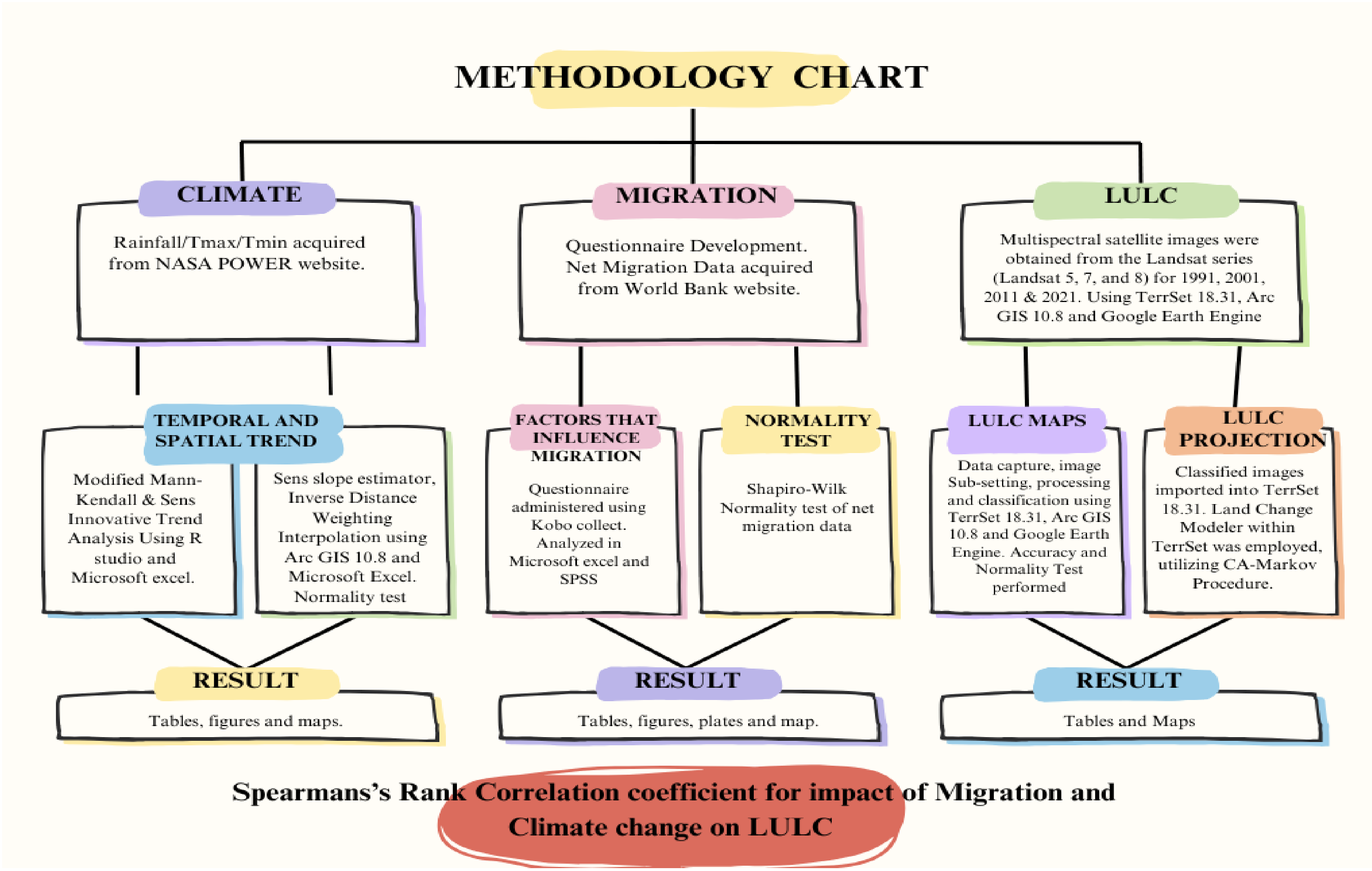

Figure 3.1: Methodology Flowchart

CHAPTER FOUR

4.0 RESULTS AND DISCUSSION

4.1 Presentation and Analysis of Results

4.1.1 Trend in rainfall and temperature between 1981 and 2021 in the study area

4.1.1.1 Trend analysis of rainfall and temperature patterns in nine (9) stations

(a). Result of autocorrelation test

The outcome of this test revealed that there is a serial correlation in the total annual rainfall, maximum and minimum temperature series as all the vertical bars tend beyond the upper and lower limits.

(b). Rainfall Trend in some selected stations in the Northeast, Nigeria

The result of the Modified Mann-Kendall test and Sen's innovative trend analysis for the rainfall in all stations is presented in Tables 4.1 and 4.2. Five (5) stations, namely Akko, Billiri, Maiduguri, Numan and Yola with Sen's slope value (-0.96658333, -0.96658333, -2.542410, -10.280865, -5.273333, respectively) show a decreasing trend. The decreasing trend is statistically significant with a P-value less than 0.05 in Numan, Maiduguri and Yola and not significant in Akko and Billiri. The result also shows an increasing rainfall trend in Gombe, Abadam, Biu and Mubi with Sen's slope value (2.3618717, 4.102222, 3.695524, 2.9016787). The increasing trend is statistically significant in Abadam and not significant in Gombe, Biu and Mubi. From the result above, in Gombe state (that is Akko, Billiri and Gombe) rainfall trend is decreasing in Akko and Billiri while in Gombe, it is increasing. In Borno state (Abadam, Biu and Maiduguri) rainfall was found to be decreasing in Maiduguri and increasing in Abadam and Biu. In Adamawa state

(Numan, Mubi and Yola) rainfall trend is decreasing in Numan and Yola while in Mubi it is increasing. (Appendix B Figure 4).

Table 4.1: Modified Mann-Kendall trend for Rainfall

Station	Kendall's tau	Z	p-value	α
Akko	-0.0378	-0.3371	0.7883**	0.05
Gombe	0.0682	0.61802	0.6266**	0.05
Billiri	-0.0378	-0.33712	0.7883**	0.05
Abadam	0.3317	3.0472	0.0023*	0.05
Biu	0.1317	1.2023	0.2865**	0.05
Maiduguri	-0.1817	-1.6643	0.05289**	0.05
Mubi	0.1390	1.2699	0.2041**	0.05
Numan	-0.3476	-5.4139	0.0000*	0.05
Yola	-0.2512	-2.3047	0.0212*	0.05

*Significant at p-value < 0.05
Source: Ishaku *et al*., 2024

Table 4.2: Sen's innovative trend analysis for Rainfall

Station	Sen's analysis	S	Nature of trend
Akko	-0.9666	12486.4	Decreasing
Gombe	2.3618	12782.1	Increasing
Billiri	-0.9665	12486.4	Decreasing
Abadam	4.1022	7909.3	Increasing
Biu	3.6955	10079.1	Increasing
Maiduguri	-2.5424	5844.8	Decreasing
Mubi	2.9017	7818.7	Increasing
Numan	-10.2809	2751.9	Decreasing
Yola	-5.2733	7912.0	Decreasing

Source: Ishaku *et al*., 2024

(c). Maximum Temperature Trend in some selected stations in Northeast, Nigeria

Tables 4.3 and 4.4 show the Modified Mann-Kendall's test results and Sen's innovative trend analysis for the maximum temperature in all stations. The result shows a statistically significant increasing trend in all stations. (Appendix B Figure 5).

Table 4.3: Modified Mann-Kendall Trend for Maximum Temperature

Station	Kendall's tau	Z	p-value	A
Akko	0.4085	3.5513	0.0004*	0.05
Gombe	0.3951	3.6292	0.0003*	0.05
Billiri	0.4085	3.5513	0.0004*	0.05
Abadam	0.2560	3.3095	0.0009*	0.05
Biu	0.2597	2.1563	0.0311*	0.05
Maiduguri	0.3195	3.7981	0.0002*	0.05
Mubi	0.2560	2.1192	0.0341*	0.05
Numan	0.3524	2.5476	0.0108*	0.05
Yola	0.3573	2.6659	0.0077*	0.05

*Significant at p-value < 0.05
Source: Ishaku *et al*., 2024

Table 4.4: Sen's innovative trend analysis for Maximum Temperature

Station	Sen's analysis	S	Nature of trend
Akko	0.05209	8845.4	Increasing
Gombe	0.00028	7920.7	Increasing
Billiri	0.05209	8845.4	Increasing
Abadam	0.02488	3988.1	Increasing
Biu	0.02882	9666.1	Increasing
Maiduguri	0.03544	4722.2	Increasing
Mubi	0.02914	9725.8	Increasing
Numan	0.07292	12779.0	Increasing
Yola	0.06500	11996.5	Increasing

Source: Ishaku *et al*., 2024

(d). Minimum Temperature Trend in some selected stations in Northeast, Nigeria

The results of the Modified Mann-Kendall test and Sen's innovative trend analysis for the minimum temperature in all stations are presented in Tables 4.5 and 4.6. The result shows a statistically insignificant increasing trend in 3 stations and a statistically insignificant decreasing trend in 6 stations (Appendix B Figure 6).

Table 4.5: Modified Mann-Kendall Trend for Minimum Temperature

Station	Kendall's tau	Z	p-value	α
Akko	-0.0609	-0.5504	0.5821**	0.05
Gombe	0.1659	-1.5163	0.1294**	0.05
Billiri	-0.0609	-0.5504	0.5821**	0.05
Abadam	0.1256	1.6996	0.0892**	0.05
Biu	-0.1134	-1.6556	0.0978**	0.05
Maiduguri	-0.0646	-0.5842	0.5591**	0.05
Mubi	-0.0927	-0.8425	0.3995**	0.05
Numan	0.0427	0.3819	0.7025**	0.05
Yola	0.0353	0.3146	0.7531**	0.05

*Significant at p-value < 0.05
Source: Ishaku *et al*., 2024

Table 4.6: Sen's innovative trend analysis for Minimum temperature

Station	Sen's analysis	S	Nature of trend
Akko	-0.0109	7926.7	Decreasing
Gombe	-0.0295	7926.7	Decreasing
Billiri	-0.0109	7926.7	Decreasing
Abadam	0.0158	3601.6	Increasing
Biu	-0.0180	3088.0	Decreasing
Maiduguri	-0.0125	7923.7	Decreasing
Mubi	-0.0168	7924.7	Decreasing
Numan	0.00708	7923.7	Increasing
Yola	0.00441	7923.7	Increasing

Source: Ishaku *et al*., 2024

4.1.1.2 Inverse Distance Weighting Interpolation of Rainfall and Maximum/Minimum Temperature for the Entire Study Location.

(a). Result of Mean Annual Rainfall

Table 4.1 shows the result of the mean annual rainfall between 1981 to 1990, 1991 to 2000, 2001 to 2010 and 2010 to 2021(see also Figure 4.7) and the sens slope estimation value for the years 1981 to 2021in each of the states in the study location (see Figure 4.2). The Sens slope value for Adamawa state (0.853) signifies a moderate increase in rainfall over the years because its value is positive, while Borno state has a Sens slope value of (-2.401), which signifies a low decrease in rainfall and finally Gombe state with Sens slope value of 1.896 signifies a moderate increase in rainfall. The mean total of the sens slope estimation for the three states (-0.442) shows that generally in the three states, there is a low decrease in rainfall (Ishaku *et al*., 2024).

Table 4.7: Mean Annual Rainfall

State	1981 to 1990	1991 to 2000	2001 to 2010	2010 to 2021	Slope 1981 to 2021	Remark
Adamawa	1140.29	1091.7	926.62	1019.33	0.853	Moderate Increase
Borno	628.65	652.72	548.75	697.22	-2.401	Low Decrease
Gombe	954.78	988.63	753.91	1033.83	1.896	Moderate Increase
Mean Total	871.56	871.59	721.5	874.63	-0.442	Low Decrease

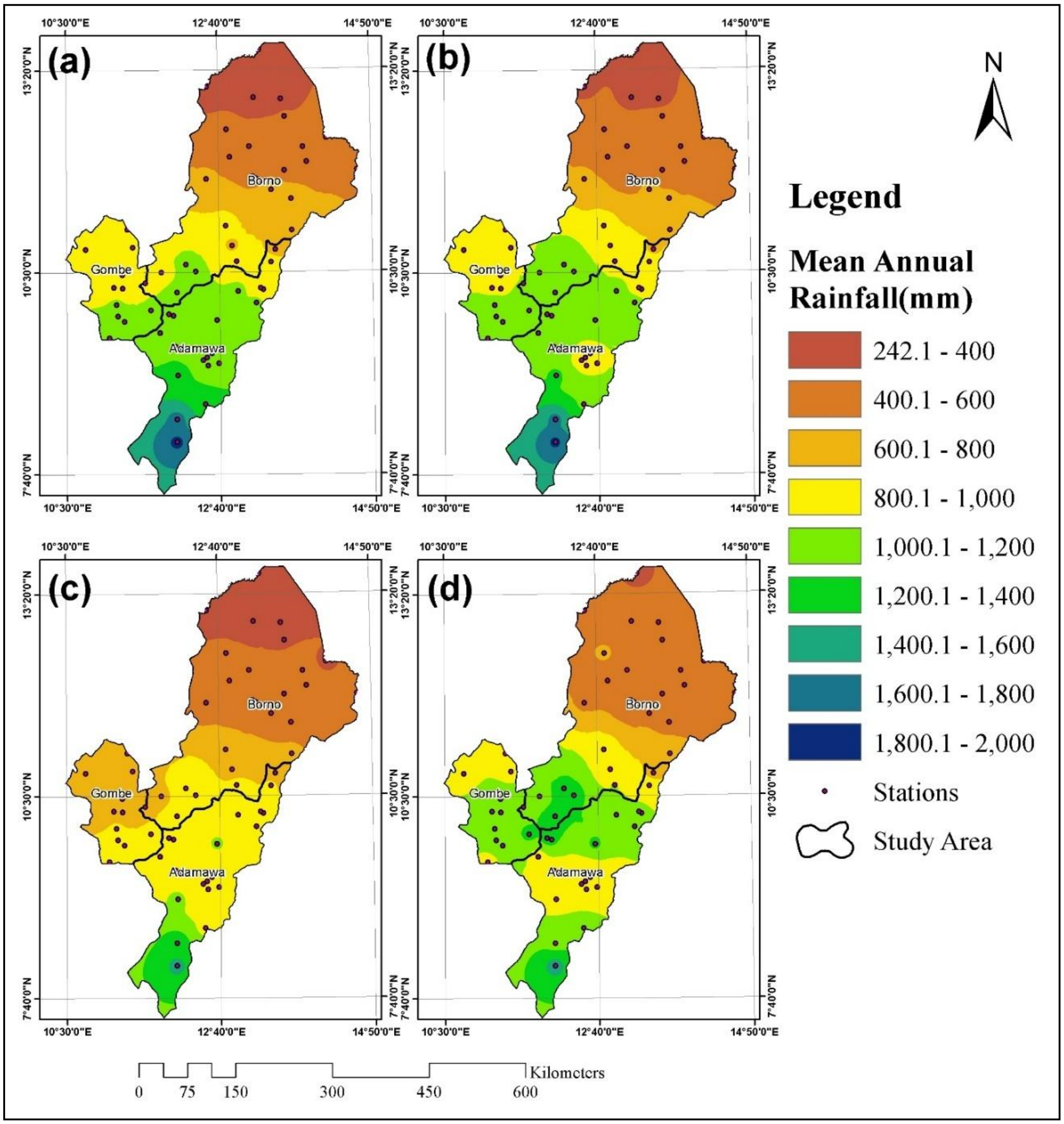

Figure 4.1: Mean Annual Rainfall (1981 – 1990, 1991 – 2000, 2001 – 2010 and 2011 – 2021)

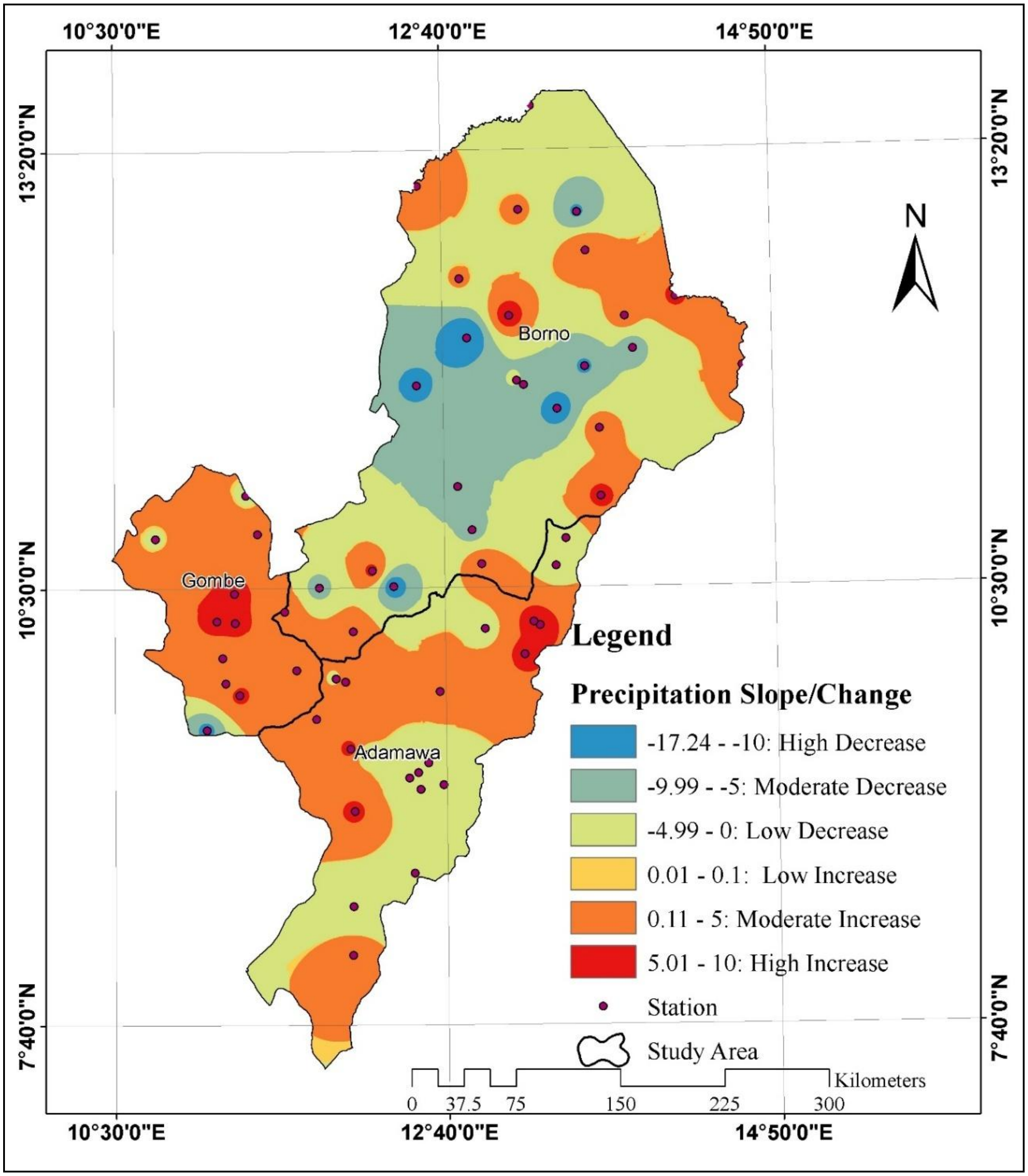

Figure. 4.2: Rainfall Change over the years (1981 to 2021)

(b). Result of Mean Annual Maximum Temperature

Table 4.8 shows the result of the mean annual maximum temperature between 1981 to 1990, 1991 to 2000, 2001 to 2010, 2010 to 2021(see also Figure 4.3) and the sens slope estimation value for the years 1981 to 2021in each of the states in the study location (see Figure 4.4). The Sens slope value for Adamawa state (0.060) signifies a moderate increase in maximum temperature over the years because its value is positive, while Borno state has a Sens slope value of (0.035), which signifies that maximum temperature has a low decrease and finally Gombe state with a Sens slope value of 0.046 signifies a low increase in maximum temperature. The mean total of the sens slope estimation for the three states (0.046) shows that generally, in the three states, there is a low increase in maximum temperature (Ishaku *et al*., 2024).

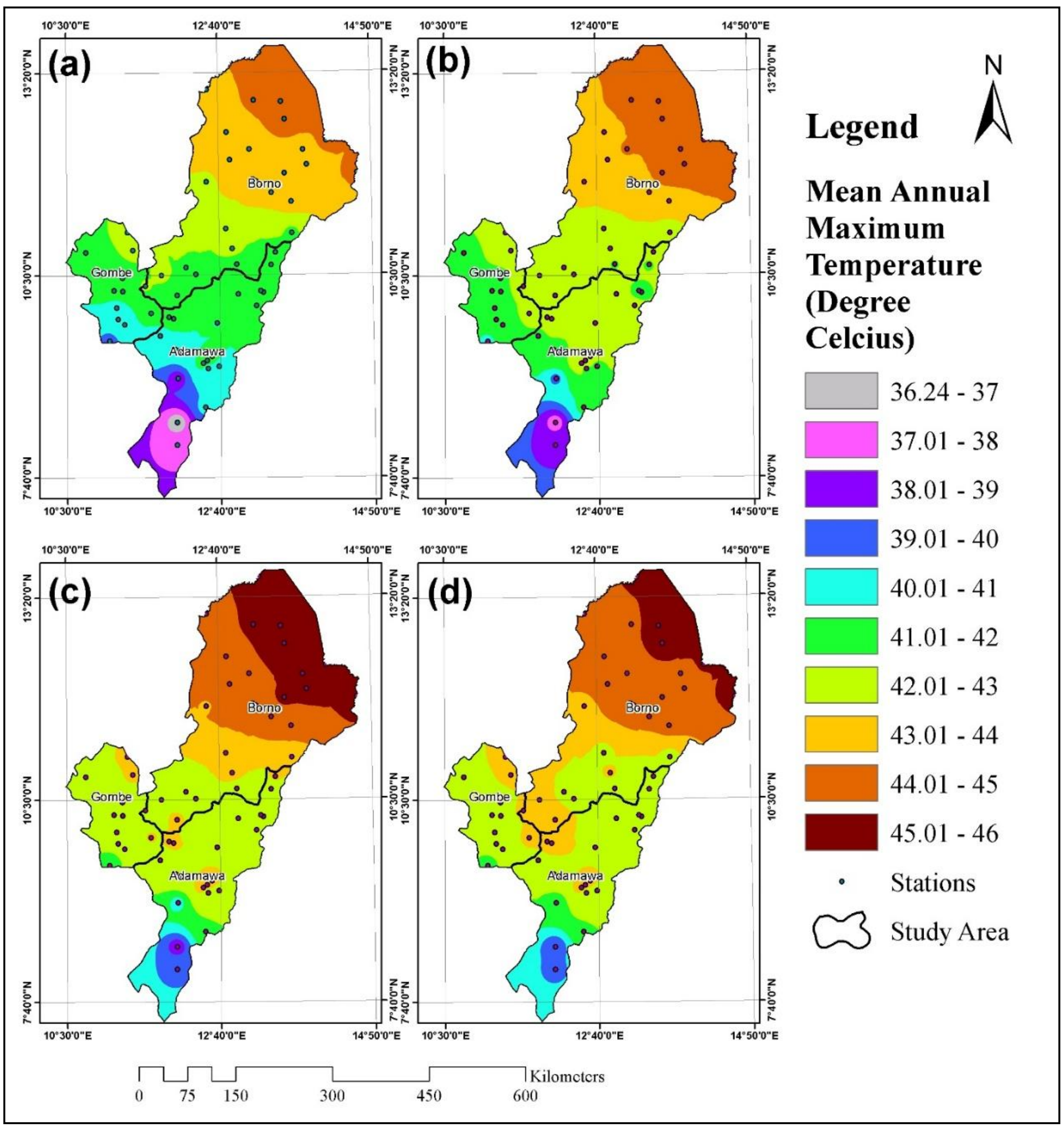

Figure. 4.3 Mean Annual Tmax (1981 – 1990, 1991 – 2000, 2001 – 2010 and 2011 – 2021)

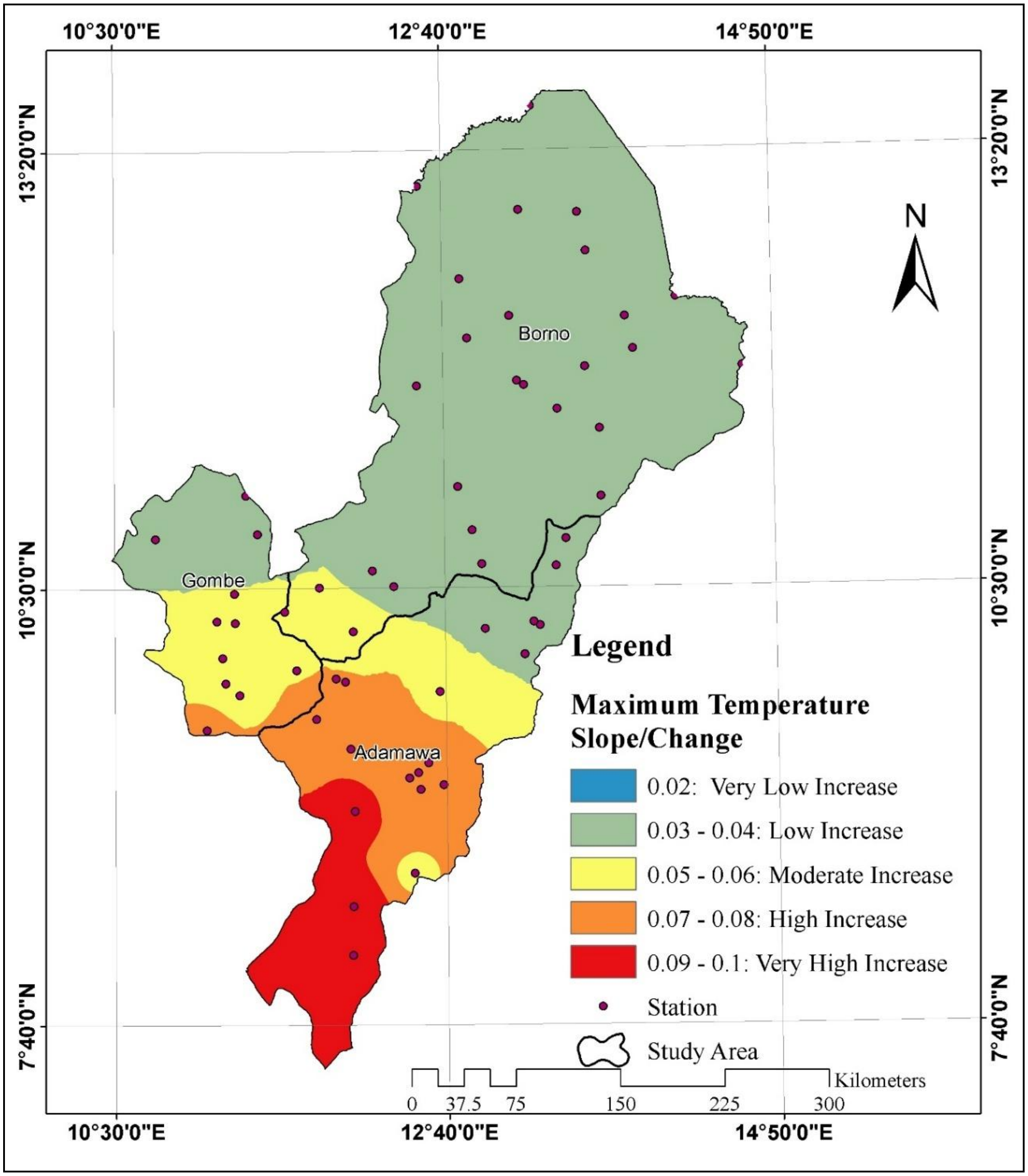

Figure 4.4: Maximum Temperature Changes over the years (1981 to 2021)

Table 4.8: Mean Annual Maximum Temperature

State	1981 to 1990	1991 to 2000	2001 to 2010	2011 to 2021	Slope 1981 to 2021	Remark
Adamawa	40.53	41.56	42.22	42.27	0.060	Moderate Increase
Borno	43.18	43.56	44.27	44.11	0.035	Low Increase
Gombe	41.22	41.75	42.4	42.54	0.046	Low Increase
Mean Total	41.87	42.51	43.19	43.16	0.046	Low Increase

(c). Result of the Mean Annual Minimum Temperature

Table 4.9 shows the result of the mean annual minimum temperature between 1981 to 1990, 1991 to 2000, 2001 to 2010, 2010 to 2021(see also Figure 4.5) and the sens slope estimation value for the years 1981 to 2021in each of the state in the study location (see Figure 4.6). The Sens slope value for Adamawa state (0.005) signifies a low increase in minimum temperature over the years because its value is positive while Borno state has a Sens slope value of (-0.010) which signifies that minimum temperature has a very low decrease and finally Gombe state with Sens slope value of -0.008 signifies a low decrease in minimum temperature. The mean total of the sens slope estimation for the three states (-0.005) shows that generally there is a low minimum temperature decrease in the three states (Ishaku *et al*., 2024).

Table 4.9: Mean Annual Minimum Temperature

States	1981 to 1990	1991 to 2000	2001 to 2010	2011 to 2021	Change1981 to 2021	Remark
Adamawa	12.21	12.33	12.41	12.13	0.005	Low Increase
Borno	11.48	11.01	10.94	10.87	-0.010	Very low decrease
Gombe	11.64	11.34	11.75	11.09	-0.008	Low Decrease
Mean Total	11.77	11.54	11.62	11.36	-0.005	Low Decrease

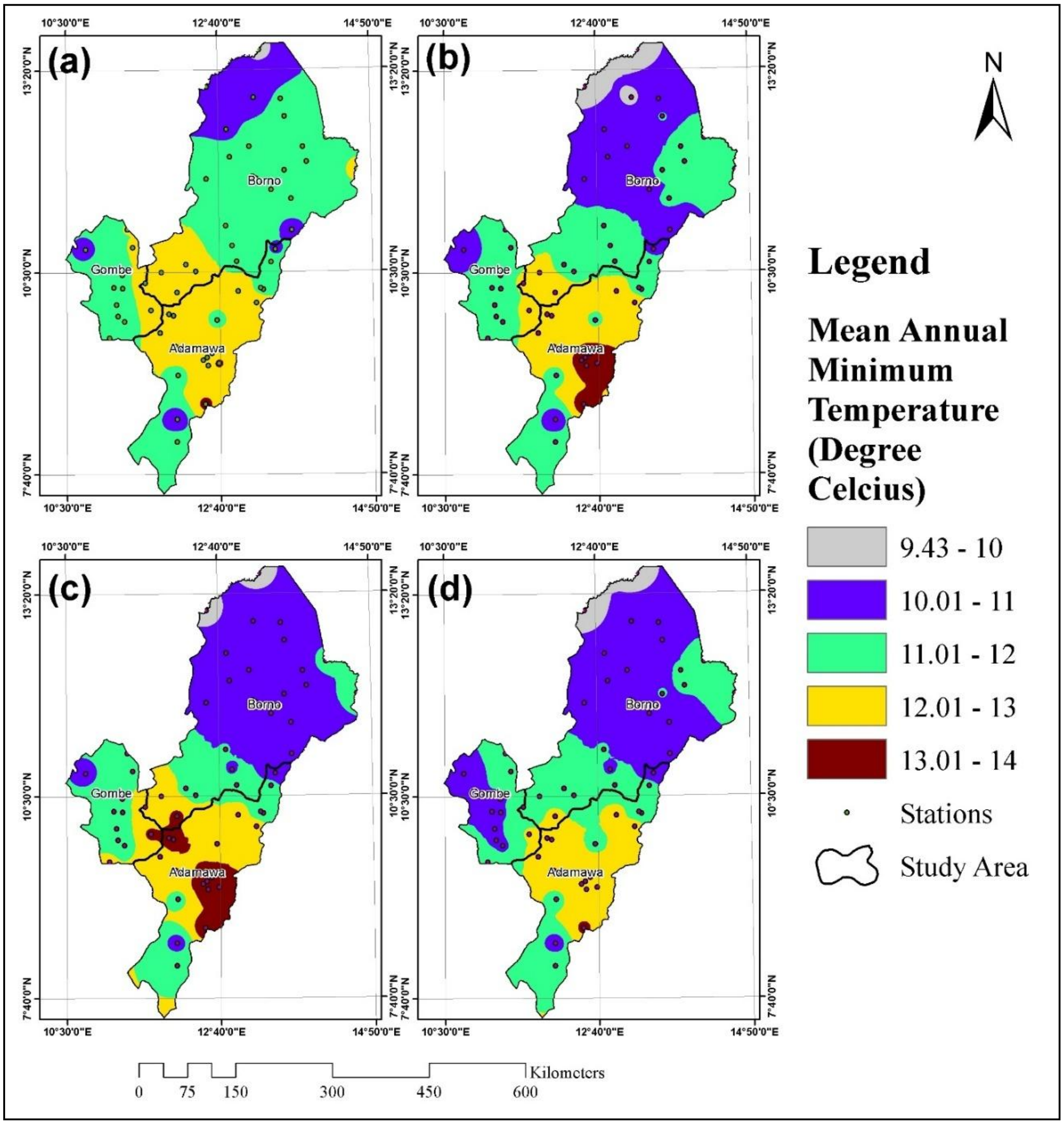

Figure. 4.5: Mean Annual Tmin (1981 – 1990, 1991 – 2000, 2001 – 2010 and 2011 – 2021)

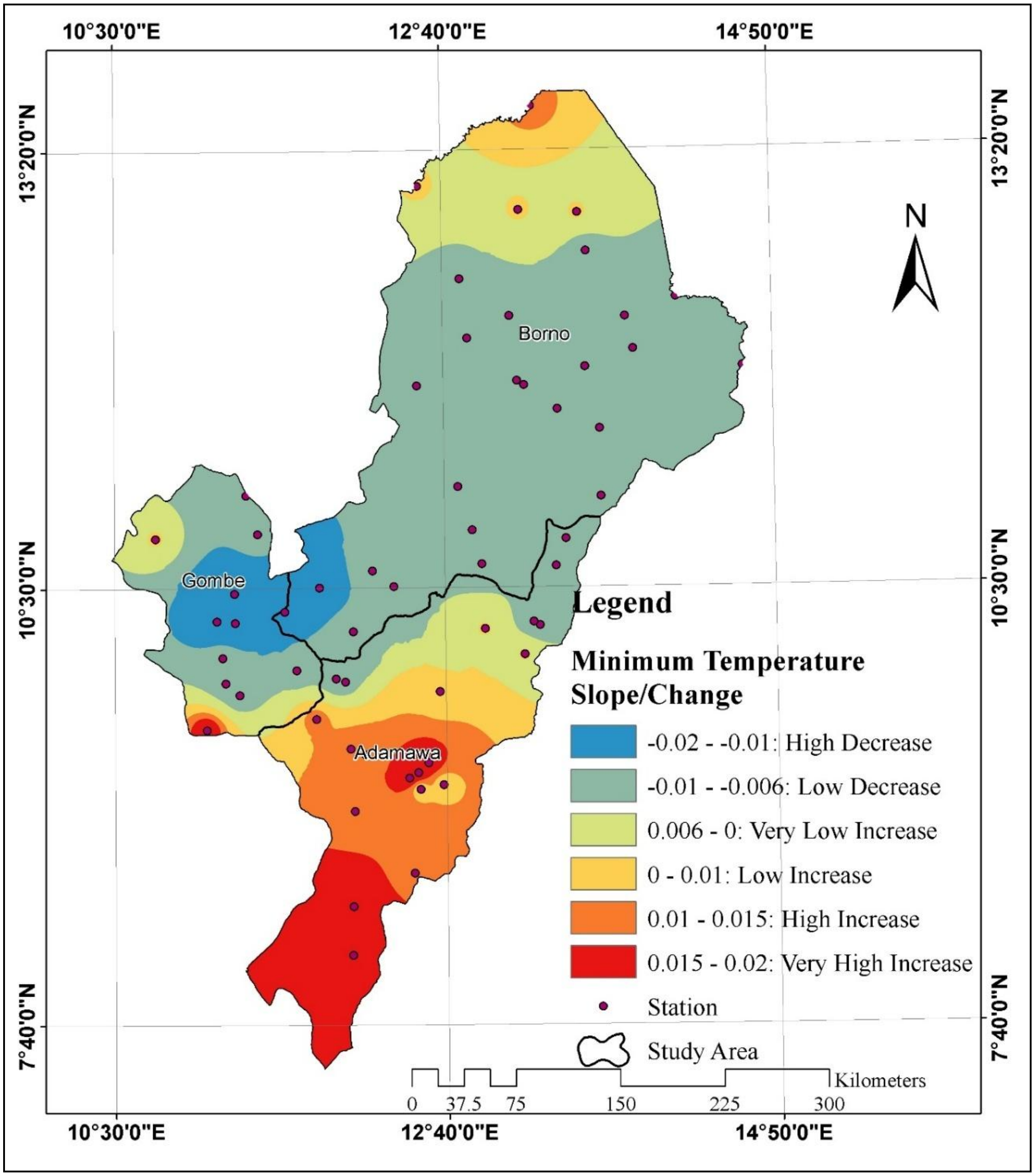

Figure. 4.6: Minimum Temperature Change over the years (1981 to 2021)

(d). Result of Average Monthly Rainfall in Dry and Wet Seasons (mm)

Tables 4.10 and 4.11 show the average monthly rainfall in the dry and wet seasons between 1981 and 2021 at a minimal amount of 1.44 mm (dry) and 100.95 mm (wet) for the entire study location (Figures 4.7 and 4.8).

Table 4.10: Average Monthly Rainfall in Dry Season (mm)

Row Labels	Average Monthly Rainfall in Dry Season (mm)
Adamawa	2.41
Borno	0.44
Gombe	2.06
Mean Total	1.44

Table 4.11: Average Monthly Rainfall in Wet Season (mm)

Row Labels	Average Monthly Precipitation in Wet Season (mm)
Adamawa	131.96
Borno	72.27
Gombe	112.15
Mean Total	100.95

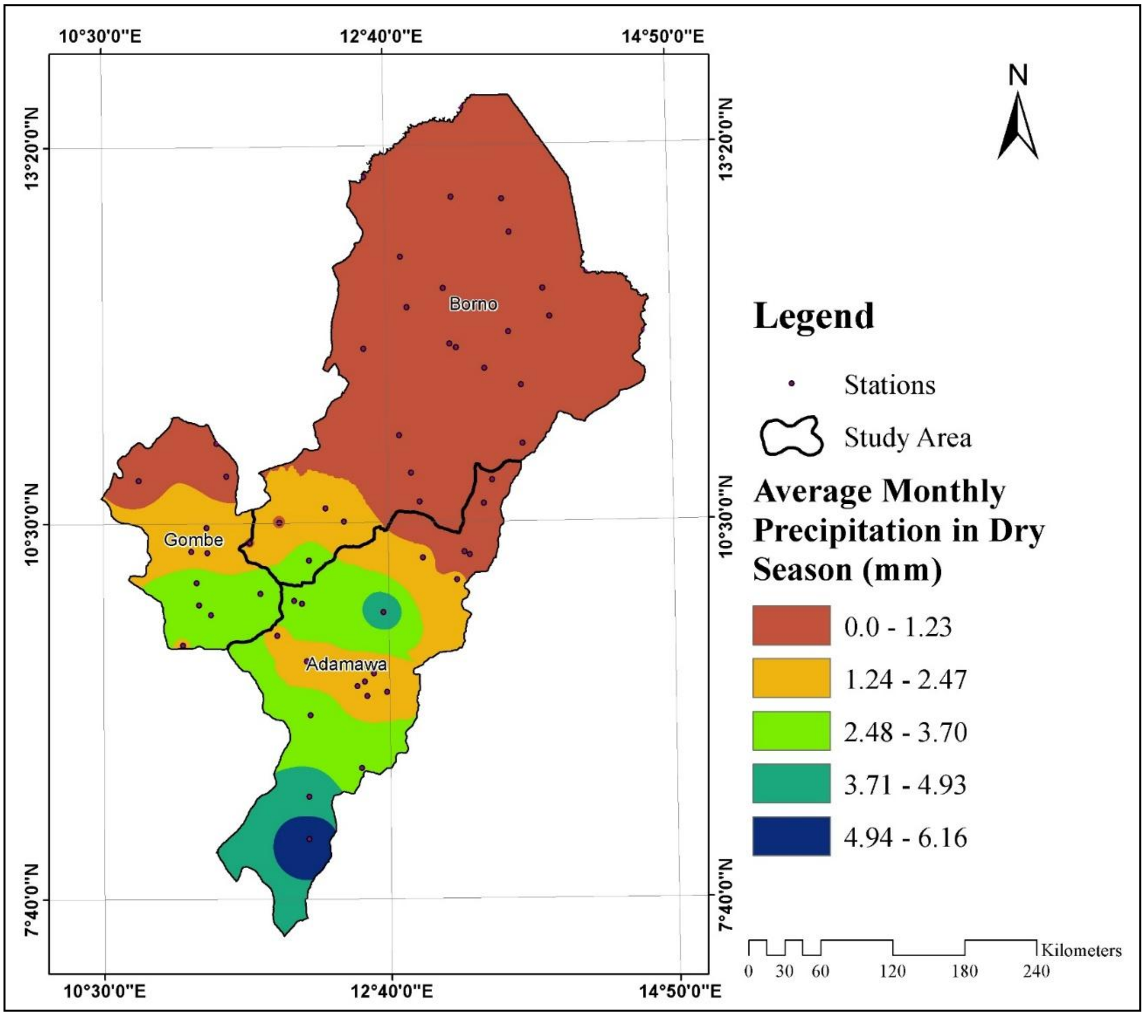

Figure 4.7: Average Monthly Rainfall in Dry Season (mm)

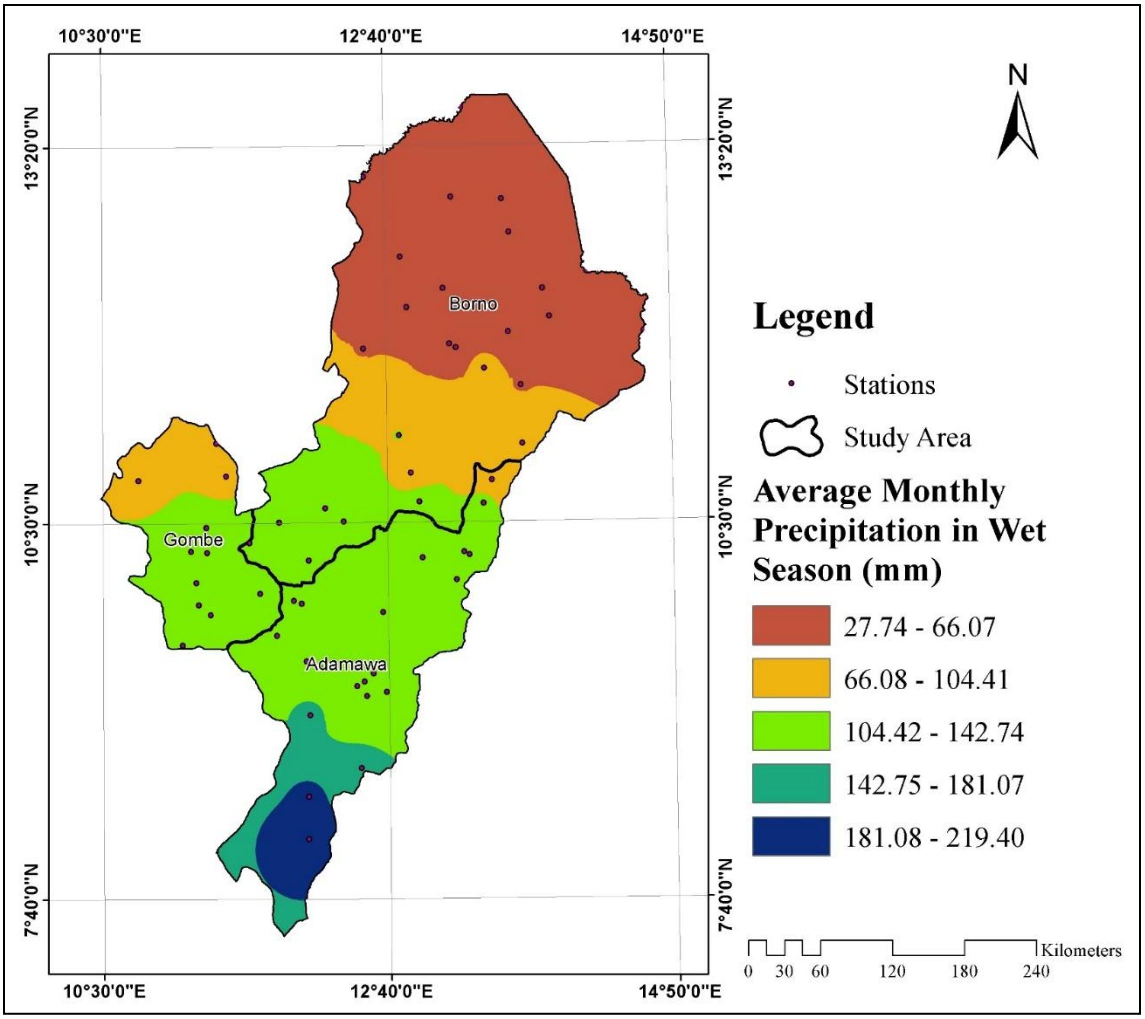

Figure 4.8: Average Monthly Rainfall in Wet Season (mm)

(e). Result of Average Monthly Maximum Temperature in Dry and Wet Seasons (°C)

Tables 4.12 and 4.13 show the average monthly maximum temperature in the dry and wet seasons between 1981 and 2021 at 38.09°C (dry) and 37.17°C (wet) for the entire study location (Figures 4.9 and 4.10).

Table 4.12: Average Monthly Maximum Temperature in Dry Season (°C)

Row Labels	Average Monthly Maximum Temperature in Dry Season (°C)
Adamawa	37.61
Borno	38.66
Gombe	37.62
Mean Total	38.09

Table 4.13: Average Monthly Maximum Temperature in Wet Seasons (°C)

Row Labels	Average Monthly Maximum Temperature in Wet Season (°C)
Adamawa	35.14
Borno	39.29
Gombe	35.84
Mean Total	37.17

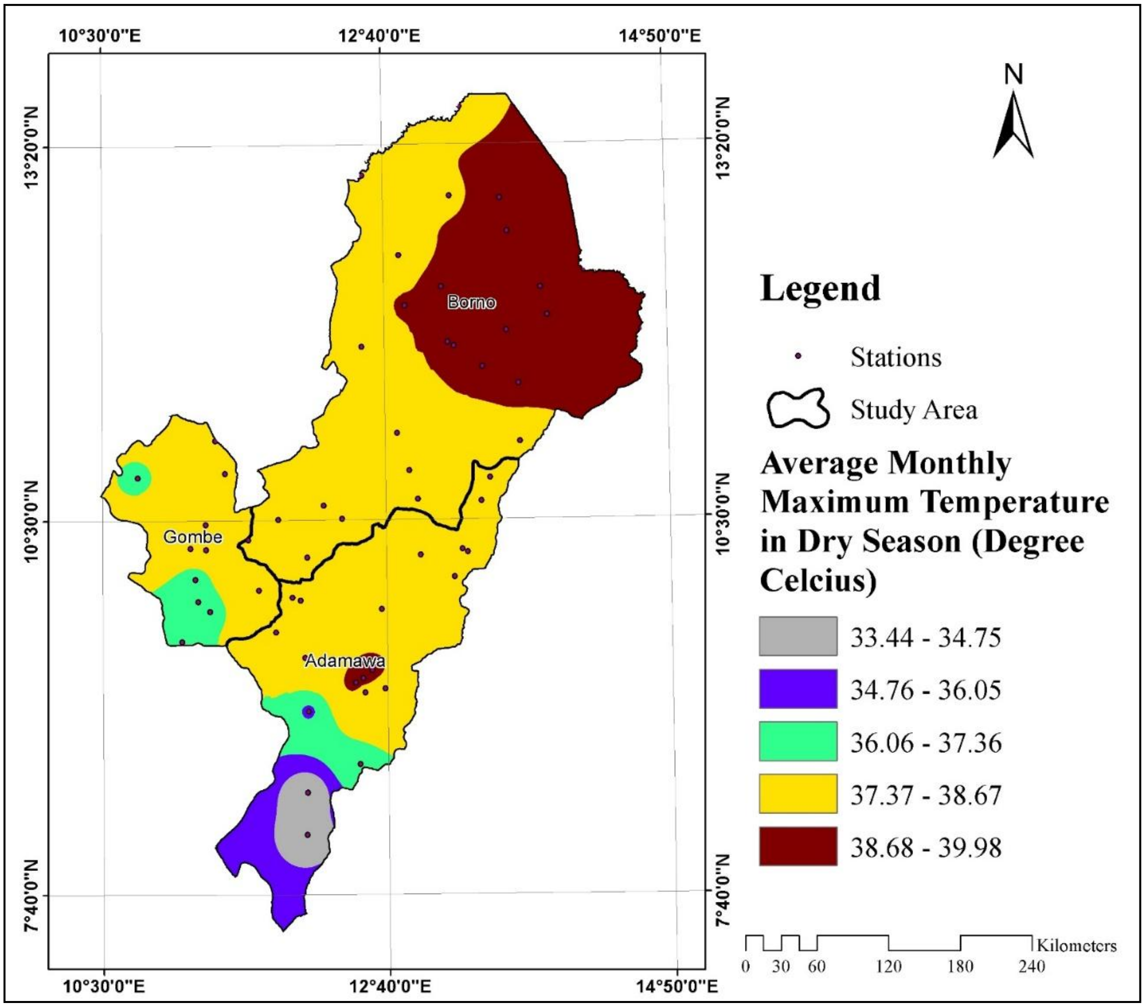

Figure 4.9: Average Monthly Maximum Temperature in Dry Season (^oC)

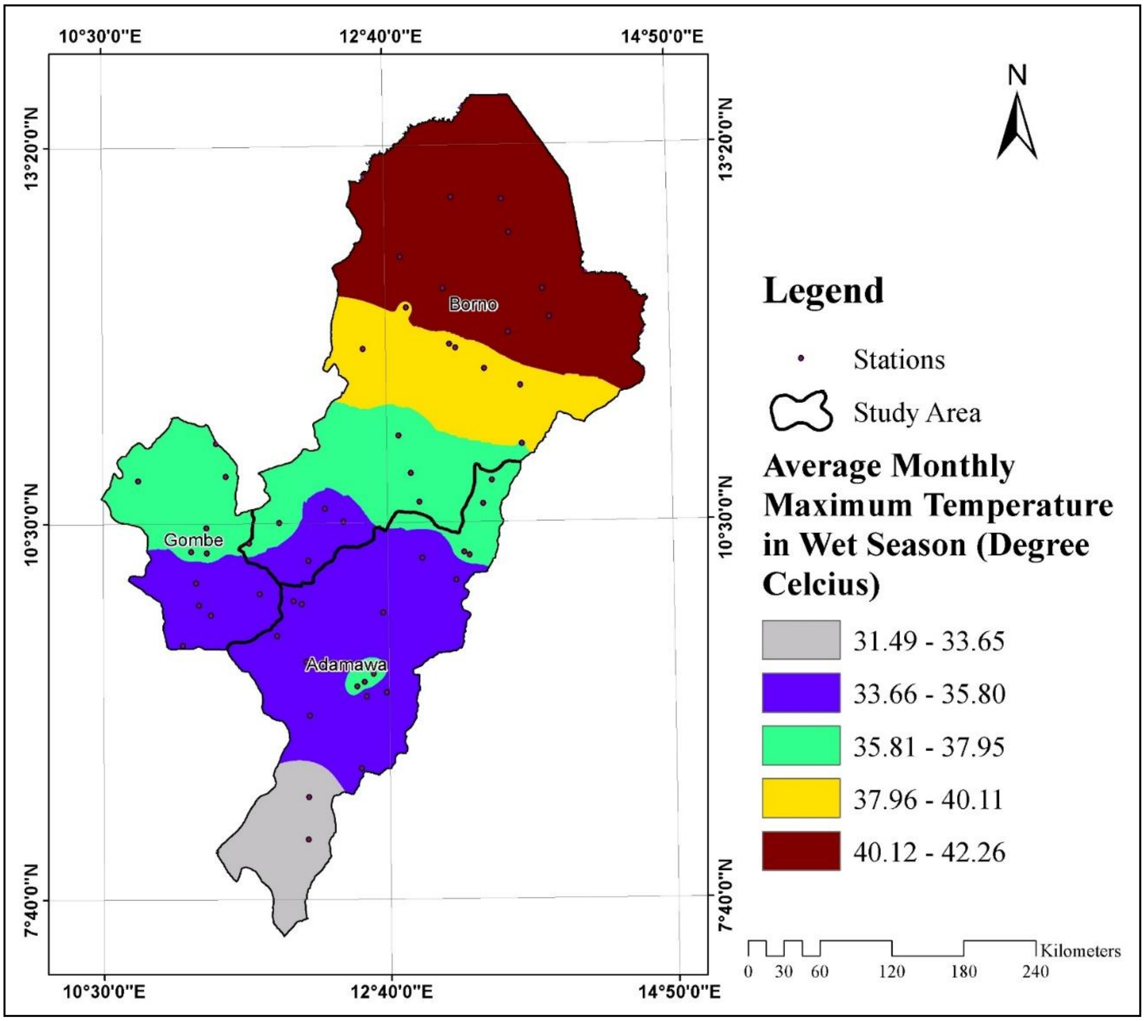

Figure 4.10: Average Monthly Maximum Temperature in Wet Season (^{o}C)

(f). Result of Average Monthly Minimum Temperature in Dry and Wet Seasons (^{o}C)

Tables 4.14 and 4.15 show the average monthly maximum temperature in the dry and wet seasons between 1981 and 2021 at 14.67^{o}C (dry) and 20.94^{o}C (wet) for the entire study location (Figures 4.11 and 4.12).

Table 4.14: Average Monthly Minimum Temperature in Dry Season (^{o}C)

Row Labels	Average Monthly Minimum Temperature in Dry Season (^{o}C)
Adamawa	15.36
Borno	14.26
Gombe	14.42
Mean Total	14.68

Table 4.15: Average Monthly Minimum Temperature in Wet Season (^{o}C)

Row Labels	Average Monthly Minimum Temperature in Wet Season (^{o}C)
Adamawa	20.64
Borno	21.34
Gombe	20.55
Mean Total	20.94

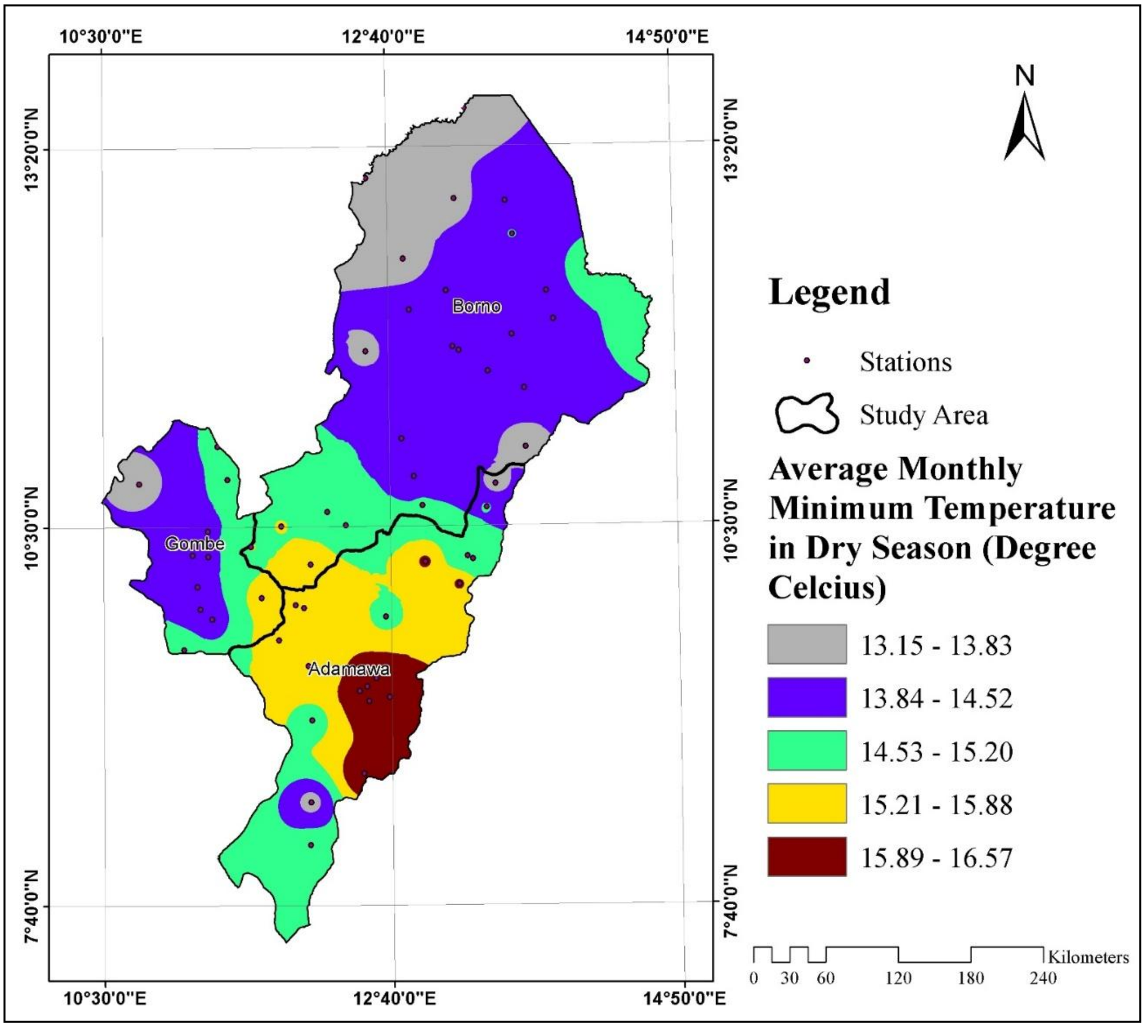

Figure 4.11: Average Monthly Minimum Temperature in Dry Season (^oC)

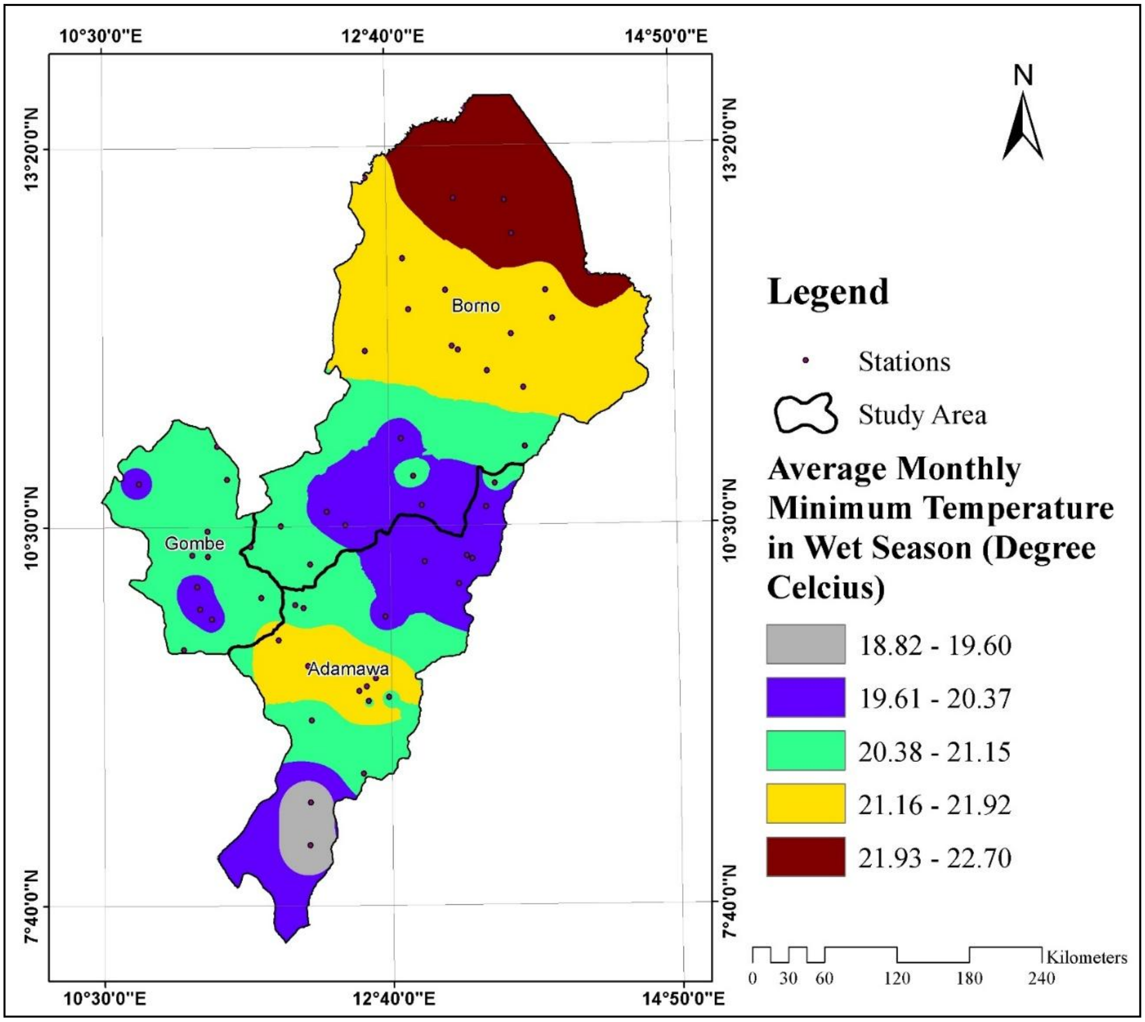

Figure 4.12: Average Monthly Minimum Temperature in Wet Season (^oC)

4.1.2 Factors that influence migration

This section presents the descriptive statistics (mean total) of the field survey carried out using individual questionnaire analysis via purposive random sampling targeted at migrants within the study area.

(a). Demographic characteristics of the respondents

Table 4.16 shows the demographic characteristics of the respondents in the study area. 5.83 percent are within the childhood age below 15 years, while 89.29 percent are within the youthful age, then 4.88 percent are within the age of 56 and above. Also, the study had 64.06 percent male respondents and 35.94 percent female respondents.

The response of marital status recorded 41.06 percent single, 53.15 percent married, 2.73 percent divorced and 3.06 percent are widowed. In response to educational qualification, 22.80 percent had no formal education then 11.39 percent had primary education, 28.82 percent had secondary education then 28.26 percent had tertiary education, while 8.73 percent had other educational qualifications.

Twenty-eight percent of respondents' monthly income is less than 26,000 Naira, 32.0 percent have income between 26,001 - 52,000 Naira, 19.98 percent have income between 52,001 to 156,000 Naira. Then, 3.46 percent have an income of 156,001 and above, while respondents without earnings are 16.56 percent. For the household size, 27.03 percent of the respondents are single, while 17.4 percent, 65.12 percent have a household size of between 2 to 10 persons, then 5.60 percent have a household size between 11- 20, 2.25 percent have a household size between 21 and above persons. The response shows that more than 70 percent of the respondents have a household size of 2 people and above.

Table 4.16: Demographic Characteristics of Respondents

Variable	percentage
Age	
Below 15 years	5.83
15 - 25 years	22.50
26 - 35 years	33.46
36 - 45 years	24.13
46 - 55 years	9.20
56 and above	4.88
Sex	
Male	64.06
Female	35.94
Marital Status	
Single	41.06
Married	53.15
Divorced	2.73
Widowed	3.06
Education Level	
No Formal education	22.80
Primary	11.39
JSS	6.06
SSS	22.76
Tertiary	28.26
Others	8.73
Monthly Income	
Less than 26,000 Naira	28.00
26,001 - 52,000 Naira	32.00
52,001 - 104,000 Naira	16.02
104,001 - 156,000 Naira	3.96
156,001 - 260.000 Naira	1.56
Above 260,000 Naira	1.90
No earnings	16.56
Household Size	
Single	27.03
2 - 5	33.96
6 - 10	31.16
11 - 20	5.60
21 - 30	1.83
31 – above	0.42

(b). Migrant’s Origin

Figure 4.13 illustrates the original states from which migrants in the study area originated. The migrants seem to have a similar pattern of movement. Most of the migrants move within the state, followed by those that come from neighboring northeastern states, then those that come from other Nigerian states and then a few from other countries outside Nigeria.

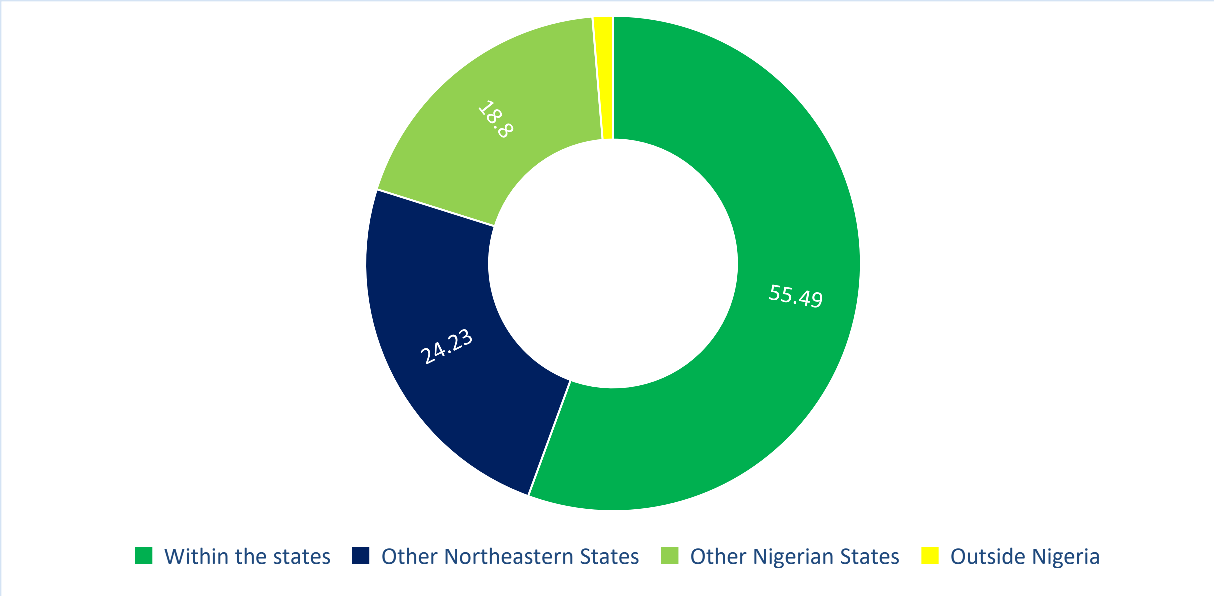

Figure 4.13: Migrants' Origin

(c) Reasons for Migration

Figure 4.14 shows the various reasons why people migrate from their various origins. 35.00 percent migrated to their new location in search of job opportunities, 4.46 percent due to environmental or climate-related issues, 20.73 percent for educational purposes, 2.33 percent due to the availability of land in the current location, while 32.86 percent migrated due to insecurity. The remaining 0.61 percent migrated for other reasons.

(d). Comparison of livelihoods between the previous and current location

When asked to compare their livelihood between their previous and current location, 38.20 percent reported that it was very good, 44.83 percent reported good, 5.46 percent reported the same as previous, 10.90 percent reported poor, and 0.61 percent reported very poor. (Figure 4.15).

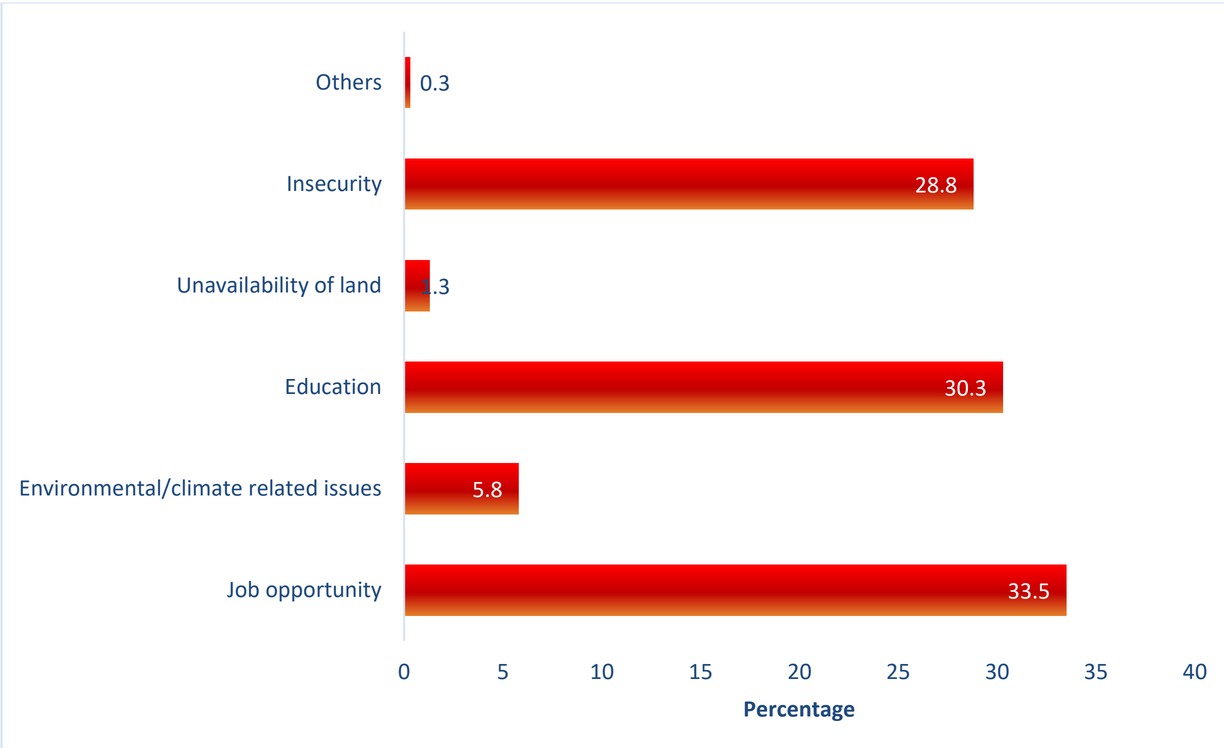

Figure 4.14: Reasons for Migration

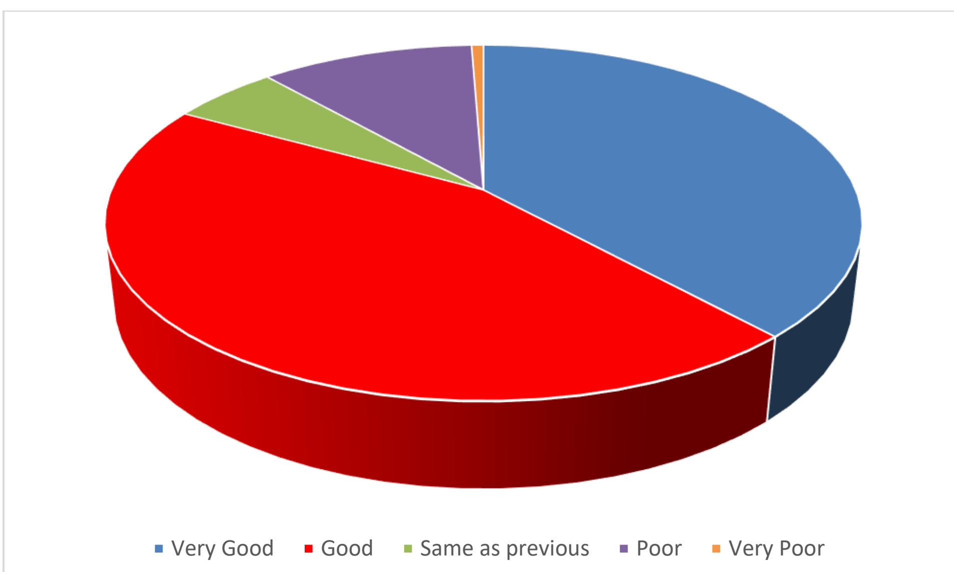

Figure 4.15: Comparison of livelihoods between previous and current location

(e). Barriers to main livelihood at the present location

In response to the question of the barriers to main livelihood at the present location for the migrants, 19.36 percent attribute it to a declining market, 7.03 percent attribute it to deteriorating environmental and climate-related issues, 18.16 percent attribute it to inadequate capital, 28.36 percent attribute it to the rising cost of transport while others with other opinion are 27.09 percent (Figure 4.16).

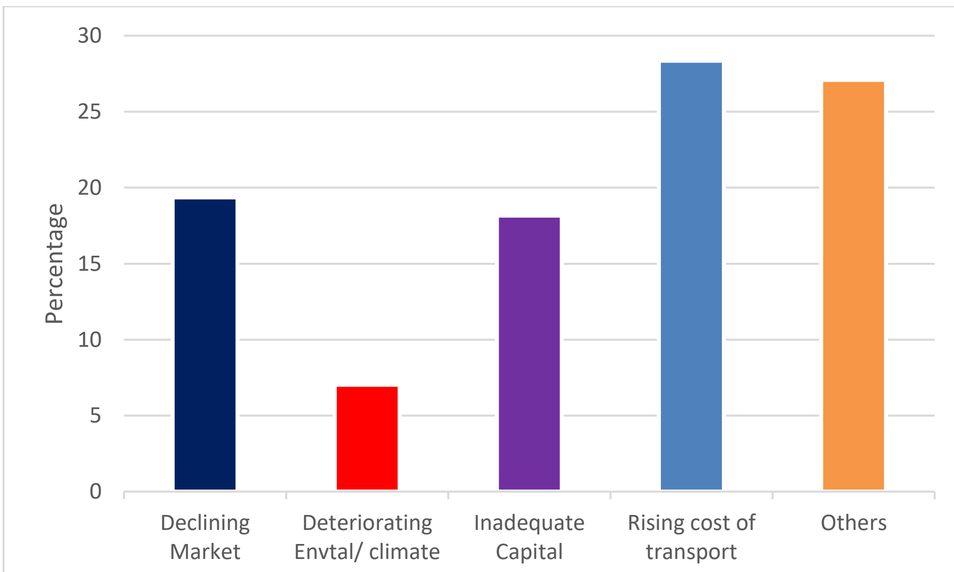

Figure 4.16: Barriers to main livelihood at present location

(f). Extent of migration benefits

Figure 4.17 shows the extent to which migrants agree or disagree that migration was beneficial to them. 26.90 percent of respondents strongly agree that migration was beneficial to them, 48.73 percent agree, 12.08 percent are neutral, 11.05 percent disagree, and 1.23 percent strongly disagree.

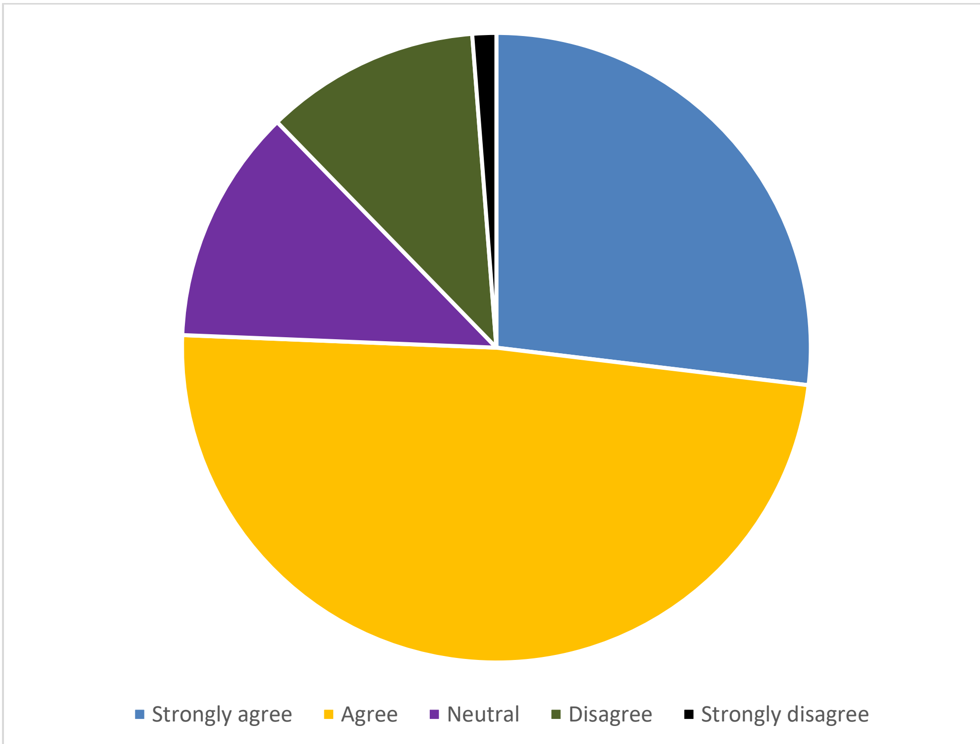

Figure 4.17: Extent of migration benefits

(g). Migration Companions

According to the results from Figure 4.18, 38.80 percent migrated alone, 10.56 percent migrated with their spouse, 29.26 percent migrated with their spouse and children, 3.33 percent migrated with their children only, 2.28 percent migrated with their friends, 13.01 percent migrated with their parent and siblings while others 2.76 percent. Others include colleagues, bosses or other relatives.

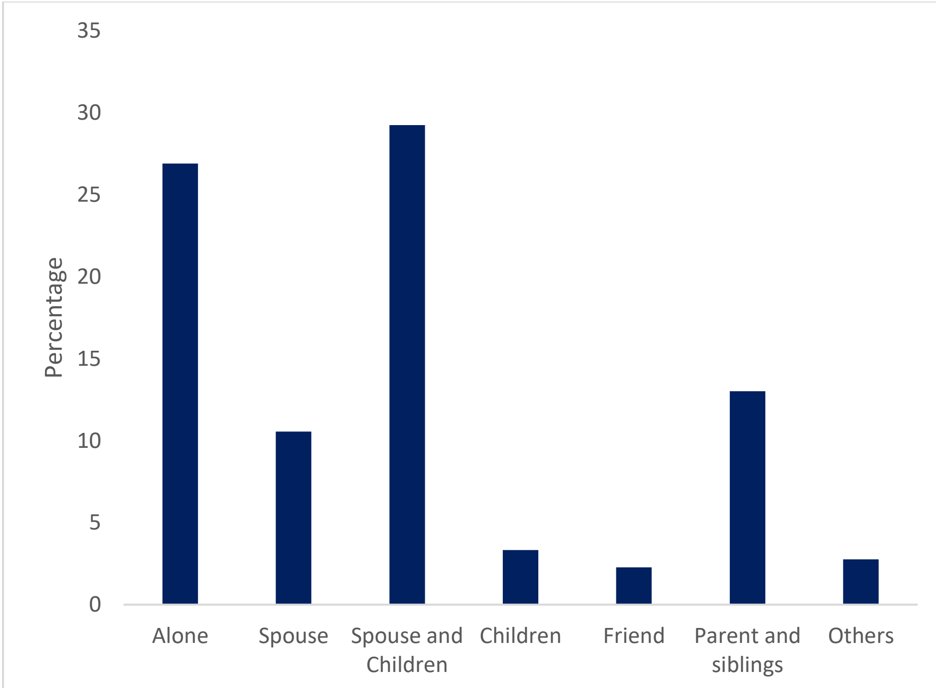

Figure 4.18: Migration Companions

(h). Challenges of leaving ones' origin

The survey conducted in Adamawa, Borno, and Gombe states revealed challenges of leaving ones' origin. 49.60 percent of respondents cited finance as the main challenge, followed by 26.80 percent who mentioned leaving their family, 3.60 percent leaving their jobs, 10.10 percent facing difficulty in finding a place to settle, and 9.90 percent cited other reasons to include fear of the unknown and fear of isolation (Figures 4.19).

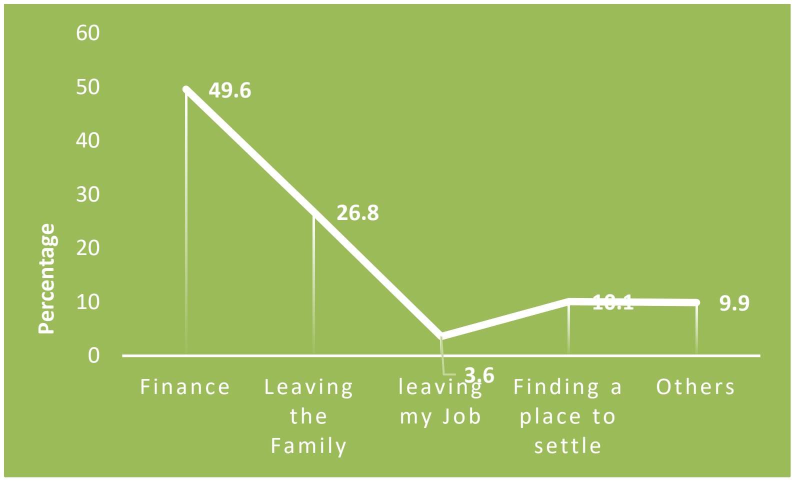

Figure 4.19: Challenges of leaving ones' origin

(i). Challenges at present location

Migrants either forced or willful migrants encounter challenges in their new location. 49.56 percent of respondents face financial problems, 3.63 percent face Language barriers, 26.76 percent face accommodation issues, 10.05 percent have health challenges and people with other reasons are 9.87 percent.

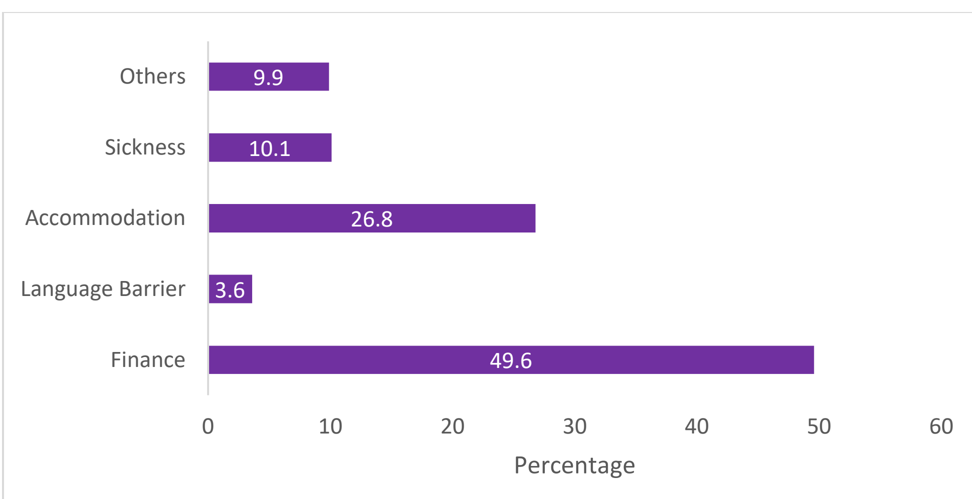

Figure 4.20: Challenges at present location

(j). General Attitude to Migration

When questioned about which age group and gender migrate more in all the study locations, respondents indicated that over 80 percent of migrants fall within the youthful age bracket of 15 to 55 years, with males being the predominant gender that migrates more.

In response to how migration can be controlled, 12.30 percent of the respondents suggested that migration can be controlled by the provision of social amenities, 8.66 percent said set policies and implement, 40.35 percent said security, 24.20 percent said youth empowerment, 6.86 percent said loans and incentives and 7.63 percent said other reasons.

Table 4.17: Attitude to Migration

Variable	percentage
What age group migrates the more?	
Below 15 years	3.93
15 - 25 years	25.36
26 - 35 years	49.26
36 - 45 years	19.63
46 - 55 years	1.42
56 and above	0.46
What gender migrates more?	
Male	78.66
Female	21.34
How can migration be controlled?	
Provision of social amenities	12.30
Set policies and implement	8.66
Security	40.35
Youth Empowerment	24.20
Loans and incentives	6.86
Others	7.63

(k). Positive effect of migration on the destination

The positive effect of migration on the destination as seen from the response 32.54 percent said new ideas and innovations, 31.61 percent said increased labor force, 9.43 percent said competition of businesses, 13.20 percent said cultural diversity and 13.44 percent said others (Figure 4.21).

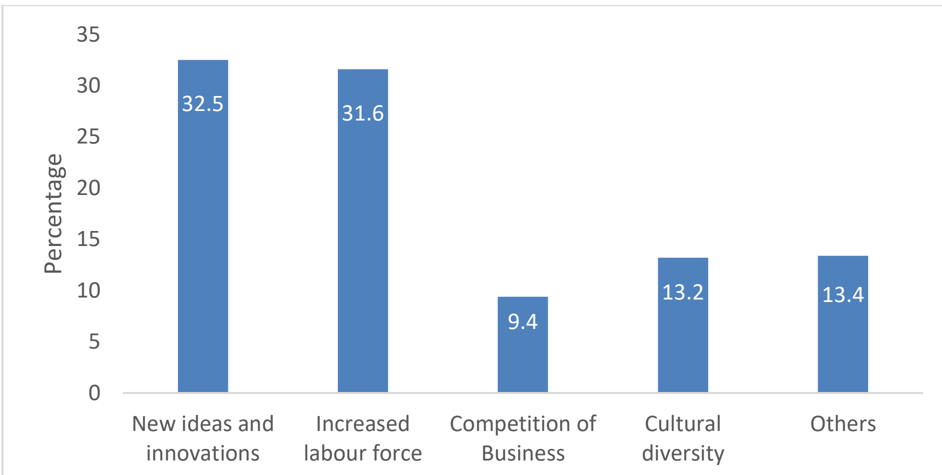

Figure 4.21: Positive effect of migration on the destination

(l). Negative effect of migration on the destination

Responding to the negative effect of migration on destination, 27.36 percent of respondents attributed it to Unemployment, 23.73 percent overcrowding, 20.76 percent pressure on existing social amenities, 14.46 percent pressure on land, 5.99 percent exploitation of migrants and 7.70 percent others (Figure 4.22).

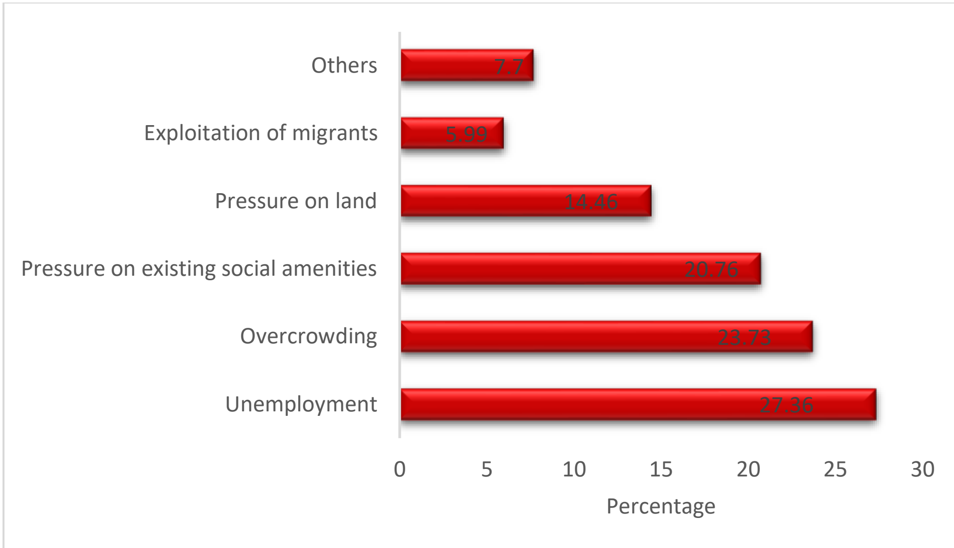

Figure 4.22: Negative effect of migration on the destination

(m). Positive effect of migration on the origin

In response to the positive effects of migration on the origin, the following percentages of respondents mentioned various benefits: 16.00 percent said reduced crime rate, 20.80 percent said less pressure on existing social amenities, 20.63 percent said reduced pollution, 16.80 percent said money remittance to family and friends, 10.26 percent said reduced pressure on land, and 15.59 percent cited other reasons (Figure 4.23).

(n). Negative effect of migration on origin

In response to the negative effects of migration on the origin, the following percentages of respondents listed the negative impact: 25.66 percent cited loss of labor/manpower, 28.86 percent mentioned low competition of businesses, 25.23 percent indicated reduced birthrate, 14.19 percent pointed to land use/land and others 6.19 percent (Figure 4.24).

Figure 4.23: Positive effect of migration on origin

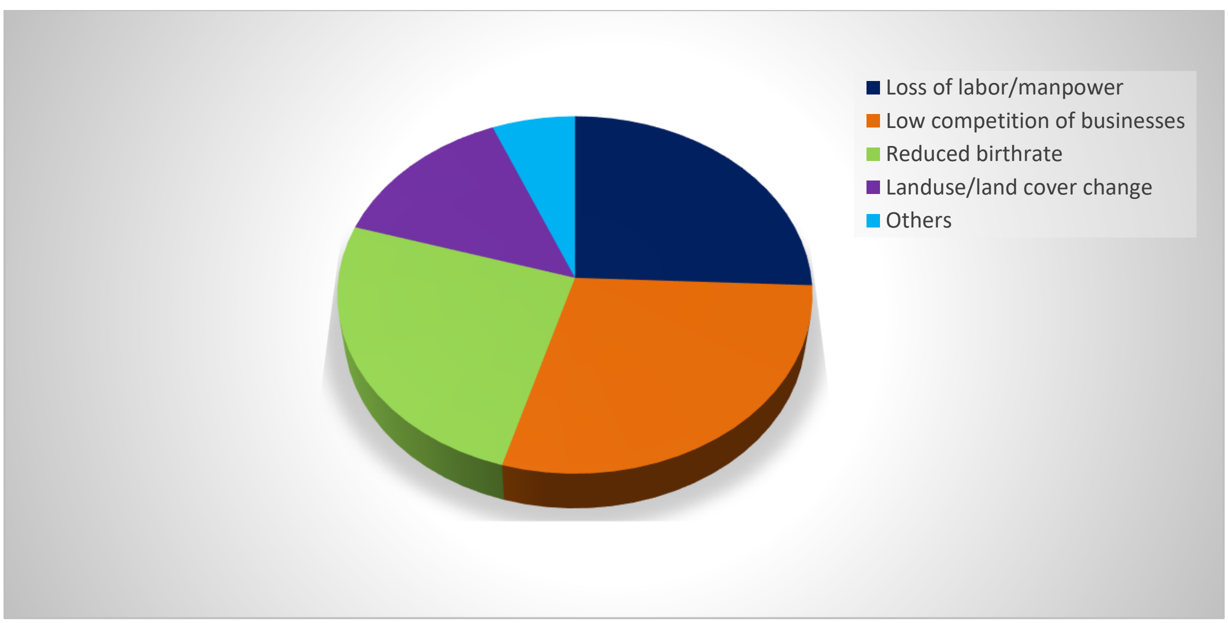

Figure 4.24: Negative effect of migration on origin

(o). Negative effects of migration on Land use/ Land cover at the destination

The impact of migration on land use/land cover at the destination, as reported by respondents in shows that 21.49 percent of respondents mentioned pressure on buildings, 24.31 percent mentioned indiscriminate land development, 27.58 percent mentioned pollution of land resources, 19.06 percent pollution of water resources, and 7.56 percent cited other reasons. (see Plate I).

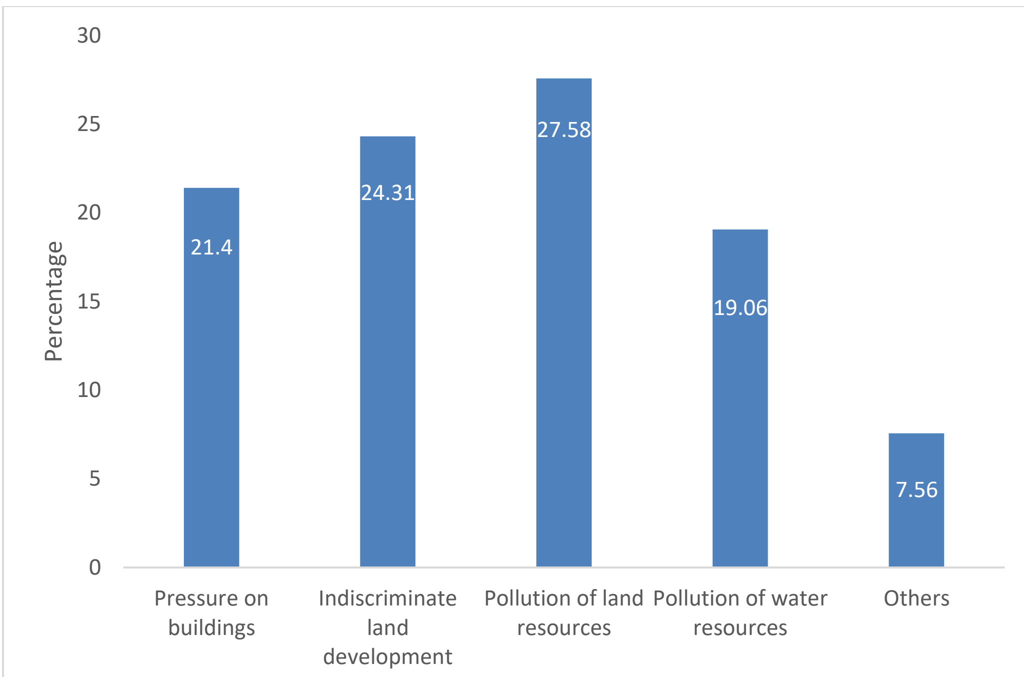

Figure 4.25: Effects of migration on Land use/ Land cover at the destination

Plate I: Indiscriminately developed IDPs camp in Jere Local Government Area, Borno

Source: Field work, 2023

(p). Effects of migration on land use and land cover at the origin

The impact of migration on land use and land cover at the origin (Figure 4.26), as reported by respondents is as follows: 8.16 percent of respondents mentioned less pollution of water resources, 19.36 percent cited abandonment of buildings, 19.83 percent noted abandonment of land, and 12.73 percent indicated loss of existing infrastructure, while 39.92 percent had other reasons. (see Plate II).

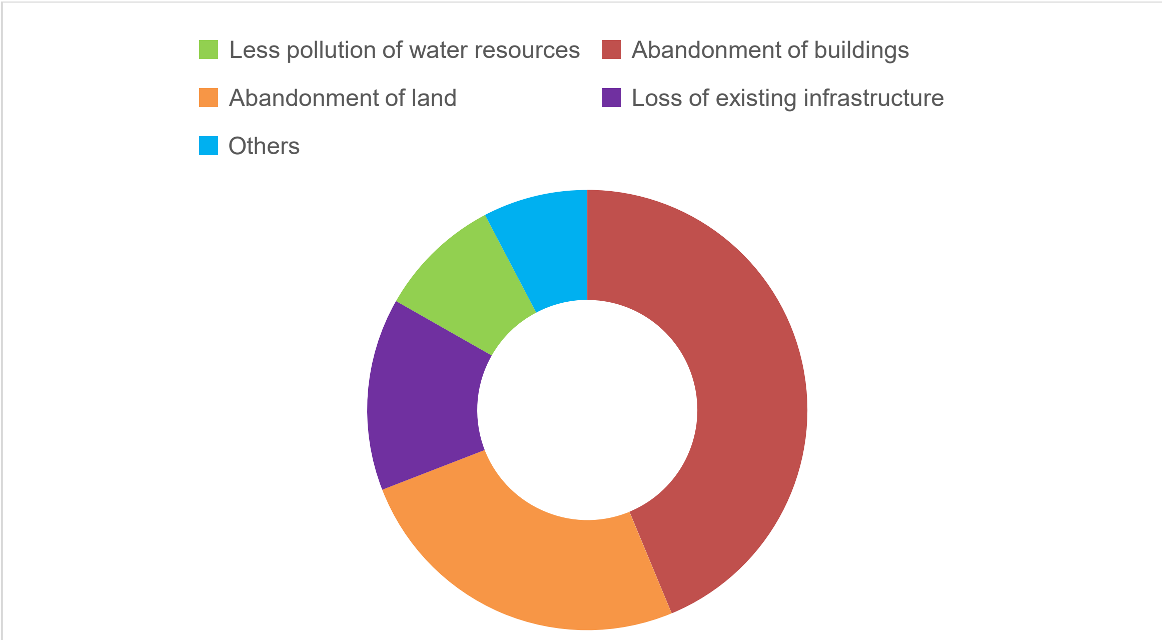

Figure 4.26: Effects of migration on land use and Landcover at the origin

Plate II: A dilapidating building in Chibok Local Government Area, Borno State

Source: Online images by ABC News

(Q). Migration hotspots

Figure 4.27 shows a few migration hotspots where data was collected (sampled locations) include IDP camps (Malkohi camp Yola, Education must continue initiative camp Yola, EYN camp Maiduguri, Jere camp Maiduguri, GG camp Biu) and communities like (Gwange, Galtimari, wulari, Sabon gari, Sabon layi, Fori, Bagadaza, BCGA, Kentengereng, Anguwan foloti, Sabon pagi, Kantin daji, Tudun wada, Jimeta e.t.c) were found to be the host communities of migrants.

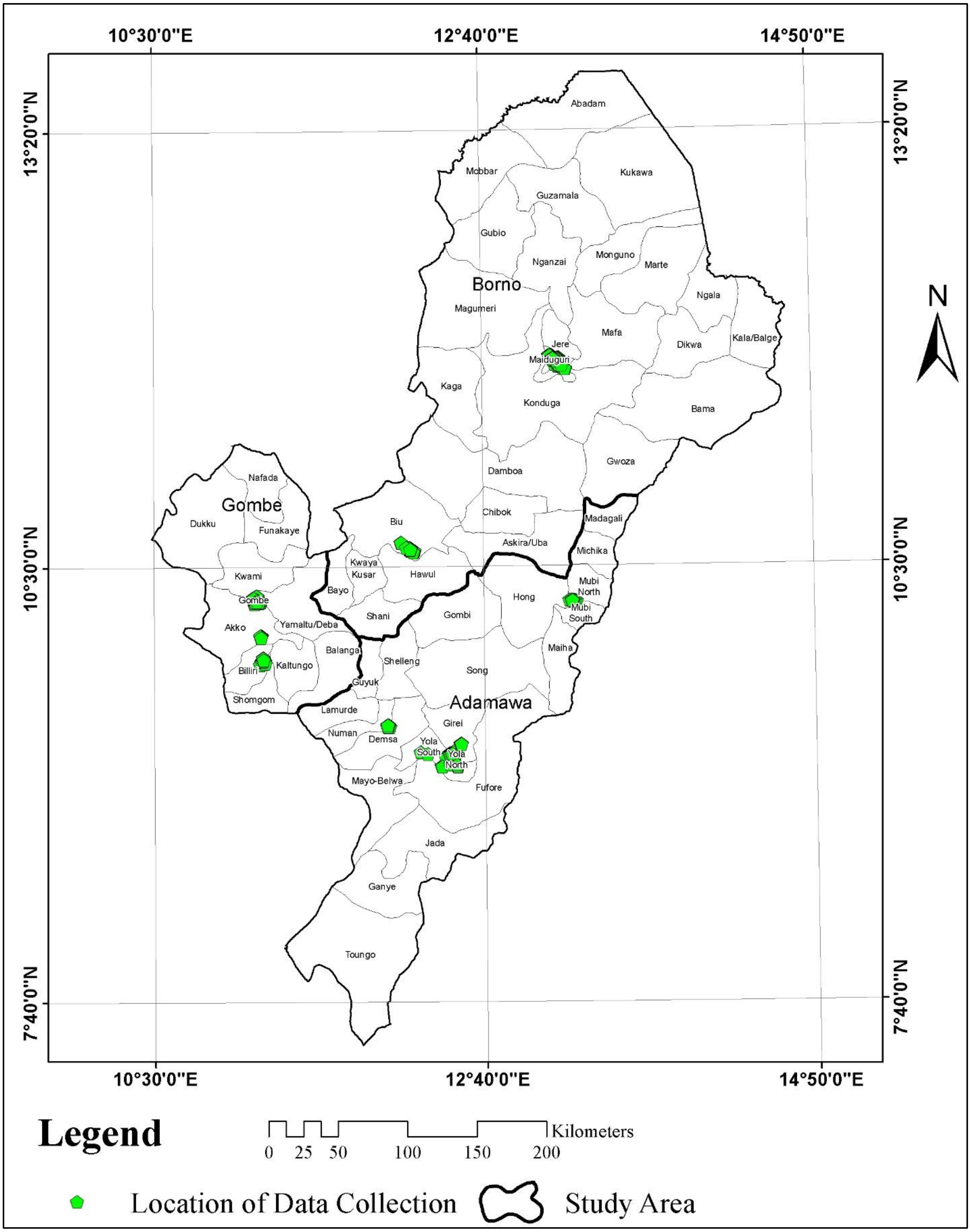

Figure 4.27: Migration hotspots where data was collected

4.1.3 Land use and land cover dynamics between 1991 and 2021 in the study area

4.1.3.1 Land use and land cover of 1991 across the study area

The Land Use and Land Cover (LULC) distribution across (Figure 4.28) Adamawa, Borno, and Gombe states in 1991 reveals distinct patterns in how land was utilized across the region. The analysis in Table 4.18 shows that Bare/Sparse Vegetation was most prominent in Borno, covering 6.17 percent of its area, while it was nearly negligible in Adamawa (0.01 percent) and minimal in Gombe (0.04 percent). Overall, this category occupied 3.50 percent of the entire study area, indicating limited regions with sparse or no vegetation. Built-up areas, although covering a small percentage overall, showed notable distribution differences across the states. Gombe, despite being the smallest in area, had a built-up area covering 0.32 percent, while Borno had 0.31 percent, and Adamawa had the highest percentage at 0.49 percent. This indicates early urbanization trends, particularly in Adamawa, which had the most significant portion of built-up land.

Table 4.18: LULC of 1991 Across Study States

LULC Class	Adamawa		Borno		Gombe		Mean Total	
	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent
Bare/Sparse Vegetation	5.01	0.01	4453.08	6.17	7.21	0.04	4465.30	3.50
Built up	183.74	0.49	223.72	0.31	55.38	0.32	462.84	0.36
Cultivated Land	2357.92	6.23	14808.11	20.52	8035.52	46.11	25201.55	19.78
Forest	12358.67	32.68	6716.07	9.31	1120.58	6.43	20195.32	15.85
Grassland/Shrubs	22364.47	59.13	40093.89	55.57	7762.12	44.54	70220.48	55.12
Water Bodies	551.86	1.46	5861.73	8.12	445.85	2.56	6859.44	5.38
Grand Total	**37821.67**	**100.00**	**72156.60**	**100.00**	**17426.65**	**100.00**	**127404.92**	**100.00**

Cultivated Land was another significant land cover class, particularly in Gombe, where it accounted for 46.11 percent of the state's area. In Borno, it covered 20.52 percent, and in Adamawa, it was less extensive, covering 6.23 percent. The total cultivated land across the three states amounted to 19.78 percent, reflecting considerable agricultural activity, especially in Gombe. Forest cover was most extensive in Adamawa, occupying 32.68 percent of the state's area, while it was less prevalent in Borno (9.31 percent) and Gombe (6.43 percent). Overall, forests made up 15.85 percent of the entire study area.

Grassland/Shrubs was the dominant land cover type across the three states, particularly in Borno, where it covered 55.57 percent of the state's area, and in Adamawa, where it made up 59.13 percent. Gombe also had a significant proportion of grassland and shrubs, accounting for 44.54 percent of its area. Across the entire study area, grassland and shrubs occupied 55.12 percent, indicating their predominance in the region's landscape. Water Bodies were more concentrated in Borno (8.12 percent) and relatively less in Adamawa (1.46 percent) and Gombe (2.56 percent). The overall area covered by water bodies was 5.38 percent, reflecting their spatial distribution across the states.

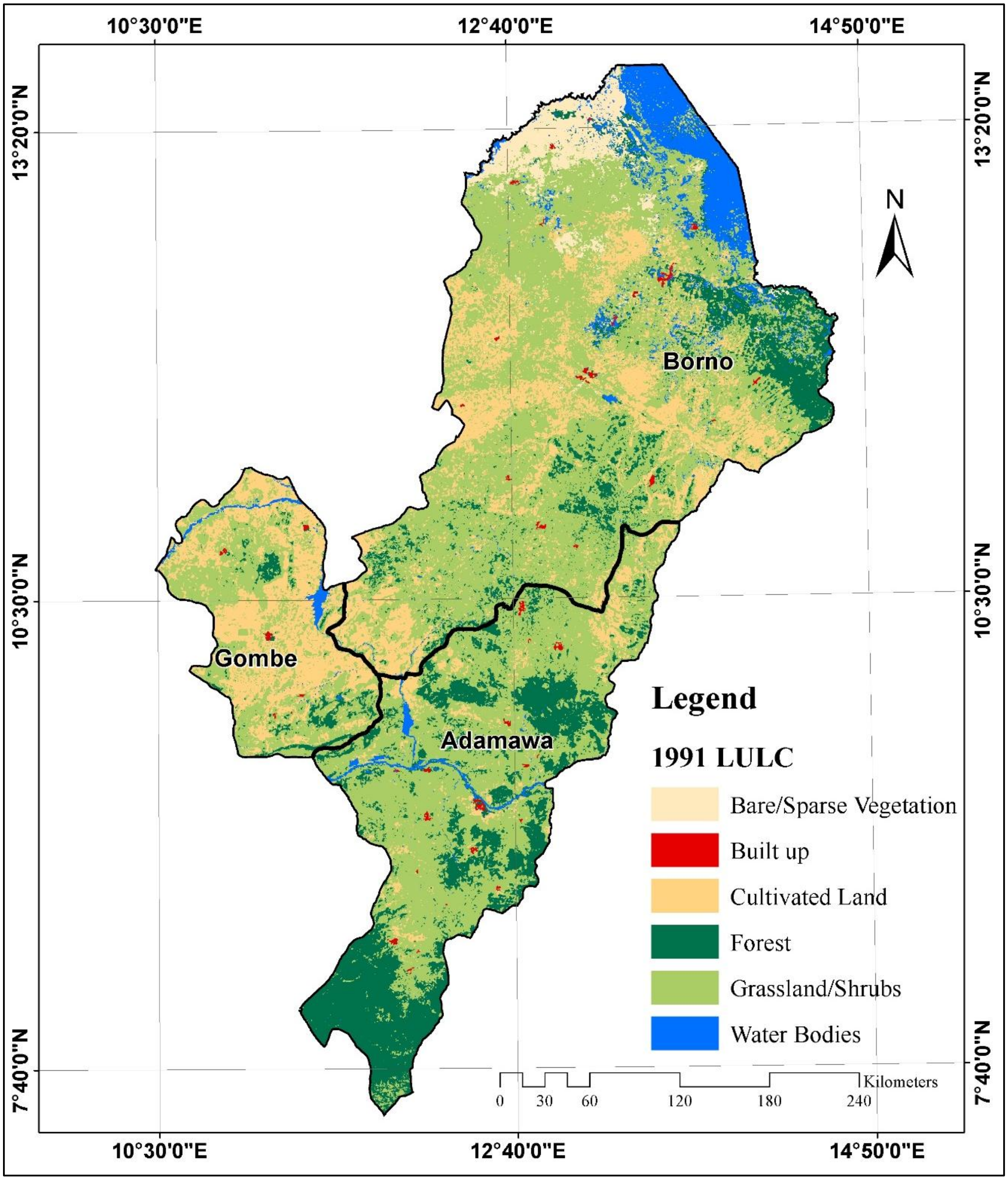

Figure 4.28: 1991 Land use and Land cover map of the Study Area

4.1.3.2 Land use and land cover of study area in 2001

The Land Use and Land Cover (LULC) distribution in 2001 (Figure 4.29) across Adamawa, Borno, and Gombe states shows significant shifts compared to 1991, reflecting changes in land utilization over the decade (Table 4.19). Bare/Sparse Vegetation saw a dramatic reduction across all three states, with its presence shrinking to just 0.13 percent of the total study area, down from 3.50 percent in 1991. This decline is consistent across the states, with Borno showing the highest area at 0.14 percent. The reduction suggests intensified land use, likely due to expanding agriculture and urbanization.

Built-up areas experienced substantial growth, expanding from 0.36 percent in 1991 to 0.74 percent in 2001. Gombe had the most significant increase, with built-up land covering 1.05 percent of its area, indicating a notable rise in urban development within the state. Adamawa and Borno also saw increases to 0.78 percent and 0.65 percent, respectively, reflecting broader trends of urban expansion and infrastructure development across the region. The significant increase in built-up areas highlights ongoing urbanization and the pressure on land resources.

Table 4.19: LULC of 2001 Across Study States

LULC	Adamawa		Borno		Gombe		Mean Total	
	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent
Bare/Sparse Vegetation	37.57	0.10	103.03	0.14	29.47	0.17	170.07	0.13
Built up	293.17	0.78	467.40	0.65	182.41	1.05	942.98	0.74
Cultivated Land	23696.71	62.65	36511.07	50.60	11755.14	67.45	71962.92	56.48
Forest	12424.04	32.85	9544.11	13.23	1144.34	6.57	23112.49	18.14
Grassland/Shrubs	907.42	2.40	21177.33	29.35	3889.87	22.32	25974.63	20.39
Water Bodies	462.76	1.22	4353.65	6.03	425.42	2.44	5241.82	4.11
Grand Total	**37821.67**	**100.00**	**72156.60**	**100.00**	**17426.65**	**100.00**	**127404.92**	**100.00**

Cultivated Land became the dominant land cover class by 2001, occupying 56.48 percent of the total study area, a substantial increase from 19.78 percent in 1991. This increase was most pronounced in Gombe, where cultivated land covered 67.45 percent of the state, indicating intensified agricultural activities. Borno and Adamawa also saw large areas dedicated to cultivation, covering 50.60 percent and 62.65 percent of their respective areas. In contrast, Forest

Cover decreased overall, particularly in Gombe and Borno, dropping to 6.57 percent and 13.23 percent, respectively. Adamawa, however, maintained a relatively high forest cover at 32.85 percent, though it still saw a reduction from 1991 levels.

Grassland/Shrubs also saw a notable decrease, particularly in Gombe, where it dropped to 22.32 percent of the state's area. Borno and Adamawa followed with 29.35 percent and 2.40 percent, respectively. This reduction is likely due to the conversion of grasslands into agricultural land. Water Bodies remained relatively stable, covering 4.11 percent of the total area, with the largest concentration in Borno (6.03 percent).

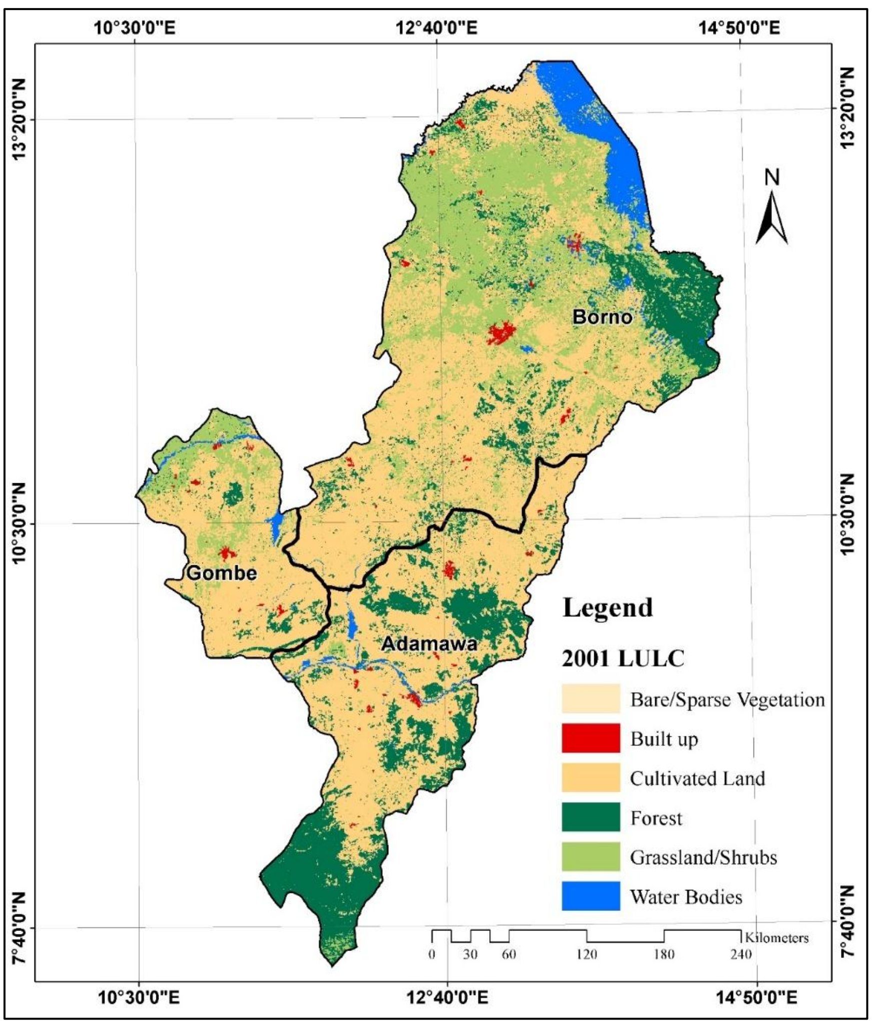

Figure 4.29: 2001 Land use and Land cover of the Study Area

4.1.3.3 Land use and land cover of study area in 2011

The Land Use and Land Cover (LULC) analysis for 2011 across (Figure 4.30) Adamawa, Borno, and Gombe states reveals continued shifts in the landscape, reflecting ongoing changes in land use practices and environmental conditions. Bare/Sparse Vegetation showed a slight increase compared to 2001, covering 0.54 percent of the total study area. This increase was primarily driven by a rise in Adamawa, where it covered 1.75 percent of the state. The resurgence of bare or sparsely vegetated areas may indicate localized land degradation or shifts in land management practices (Table 4.20).

Table 4.20: LULC of 2011 Across Study States

LULC	Adamawa		Borno		Gombe		Mean Total	
	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent
Bare/Sparse Vegetation	662.32	1.75	3.18	0.00	19.28	0.11	684.78	0.54
Built up	498.36	1.32	703.15	0.97	209.08	1.20	1410.59	1.11
Cultivated Land	18698.16	49.44	21878.06	30.32	11838.76	67.93	52414.98	41.14
Forest	7114.26	18.81	707.63	0.98	643.44	3.69	8465.32	6.64
Grassland/Shrubs	10147.86	26.83	44849.10	62.16	4513.63	25.90	59510.58	46.71
Water Bodies	700.72	1.85	4015.48	5.56	202.45	1.16	4918.66	3.86
Grand Total	**37821.67**	**100.00**	**72156.60**	**100.00**	**17426.65**	**100.00**	**127404.92**	**100.00**

Built-up areas continued to expand, growing from 0.74 percent in 2001 to 1.11 percent in 2011. This trend is evident across all three states, with Gombe maintaining a notable increase, where built-up areas covered 1.20 percent of the state's land. Adamawa and Borno followed with built-up areas covering 1.32 percent and 0.97 percent, respectively. The ongoing expansion of urban and infrastructural development is reflected in these figures, underscoring the region's growing population and urbanization pressures.

Cultivated Land remained a significant land cover class, though it decreased slightly from 56.48 percent in 2001 to 41.14 percent in 2011. Despite this reduction, Gombe continued to have the highest proportion of cultivated land, covering 67.93 percent of its area, while Adamawa and Borno had 49.44 percent and 30.32 percent, respectively. The decrease in cultivated land might be attributed to the conversion of some agricultural lands into built-up areas or other land cover classes. Meanwhile, Forest Cover saw a substantial decline, particularly in Borno, where it dropped to a mere 0.98 percent of the state's area. Overall, forests covered only 6.64 percent of the study area, down from 18.14 percent in 2001, indicating significant deforestation and land conversion.

Grassland/Shrubs became the dominant land cover type by 2011, covering 46.71 percent of the total area, with Borno having the largest proportion at 62.16 percent. This suggests a shift from forests to grasslands, possibly due to deforestation or changes in land management practices. Water Bodies slightly decreased, covering 3.86 percent of the total area, with the largest concentration still in Borno (5.56 percent).

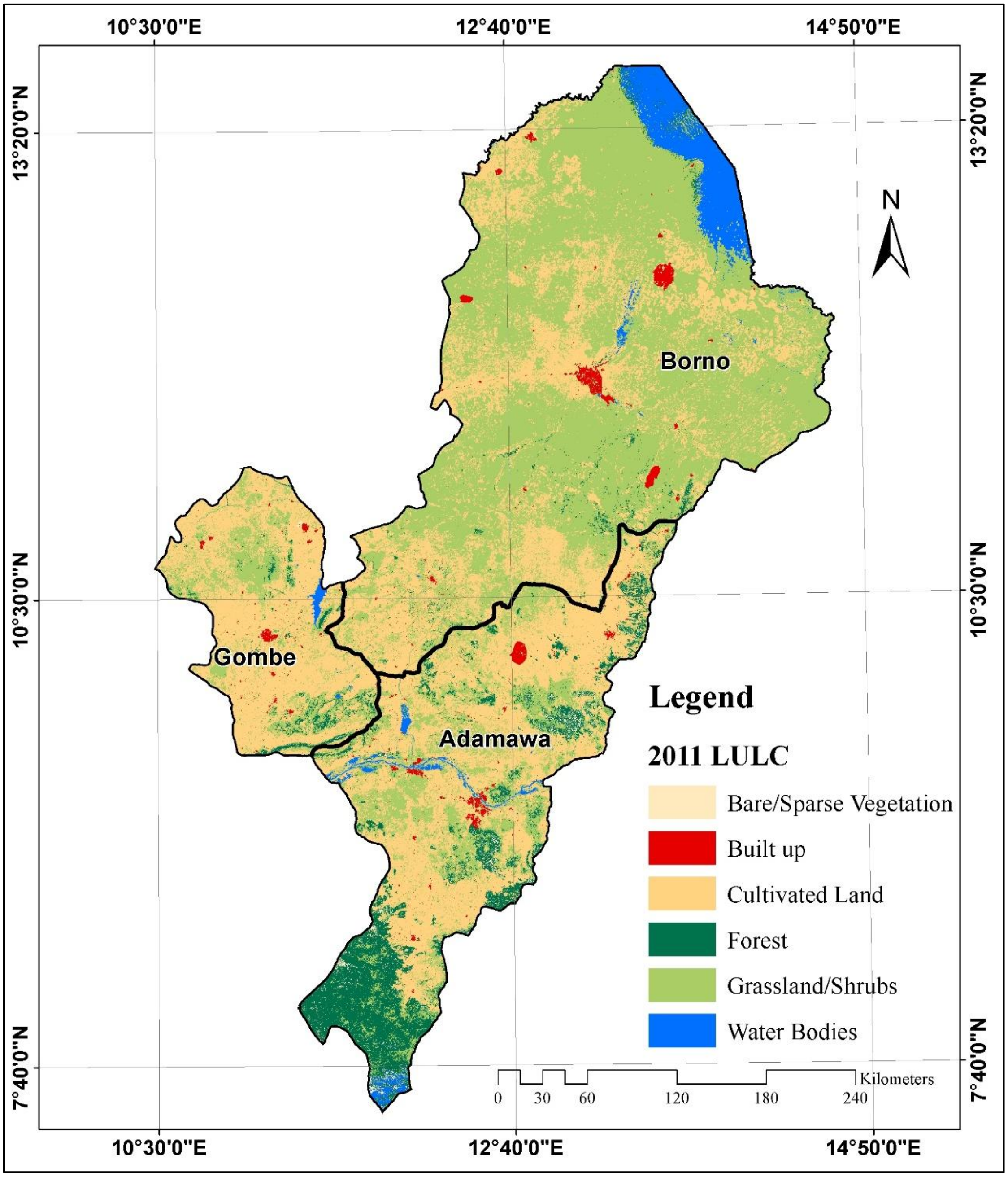

Figure 4.30: 2011 Land use and Land cover of the Study Area

4.1.3.4 Land use and land cover of study area in 2021

The Land Use and Land Cover (LULC) analysis for 2021 across (Figure 4.31) Adamawa, Borno, and Gombe states (Table 4.21) shows ongoing transformation in the landscape, driven by factors such as urbanization, agriculture, and environmental change. Bare/Sparse Vegetation continued its downward trend, covering just 0.48 percent of the total study area, with the largest concentration in Gombe (1.11 percent). This reduction indicates that previously bare areas have likely been converted for other land uses, such as agriculture or built-up areas.

Table 4.21: LULC of 2021 Across Study States

LULC	Adamawa		Borno		Gombe		Mean Total	
	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent
Bare/Sparse Vegetation	176.34	0.47	243.68	0.34	193.66	1.11	613.67	0.48
Built up	720.61	1.91	623.74	0.86	381.33	2.19	1725.67	1.35
Cultivated Land	17423.64	46.07	10919.61	15.13	10829.10	62.14	39172.34	30.75
Forest	5360.55	14.17	686.41	0.95	215.26	1.24	6262.21	4.92
Grassland/Shrubs	13836.38	36.58	55581.31	77.03	5577.57	32.01	74995.27	58.86
Water Bodies	304.16	0.80	4101.85	5.68	229.73	1.32	4635.74	3.64
Grand Total	**37821.67**	**100.00**	**72156.60**	**100.00**	**17426.65**	**100.00**	**127404.92**	**100.00**

Built-up areas further expanded significantly, covering 1.35 percent of the total area, up from 1.11 percent in 2011. Gombe experienced the highest growth in built-up land, where it covered 2.19 percent of the state’s area, reflecting an ongoing trend of urban expansion. Adamawa and Borno also saw increases, with built-up areas covering 1.91 percent and 0.86 percent, respectively. The continuous growth in built-up land emphasizes the region's accelerating urbanization and infrastructural development, with significant implications for land use planning and management.

Cultivated Land saw a further decrease in its overall coverage, now occupying 30.75 percent of the total study area, down from 41.14 percent in 2011. Gombe, however, maintained a high proportion of cultivated land at 62.14 percent, while Adamawa and Borno had 46.07 percent and 15.13 percent, respectively. The decrease in cultivated land across the study area may be due to the increasing conversion of agricultural land into urban areas or the expansion of other land cover types such as grasslands.

Forest Cover continued to decline, covering only 4.92 percent of the total area in 2021. Borno saw a particularly sharp reduction, with forests covering just 0.95 percent of its area. Adamawa, with 14.17 percent, had the most substantial forest cover, though still diminished from previous years. The ongoing loss of forests indicates deforestation pressures, possibly driven by agricultural expansion and other land use changes.

Grassland/Shrubs emerged as the dominant land cover, occupying 58.86 percent of the study area, a notable increase from 46.71 percent in 2011. This expansion was especially pronounced in Borno, where grasslands and shrubs covered 77.03 percent of the state, suggesting significant land conversion from forests or other land uses. Water Bodies remained relatively stable, covering 3.64 percent of the total area, with Borno having the largest proportion at 5.68 percent.

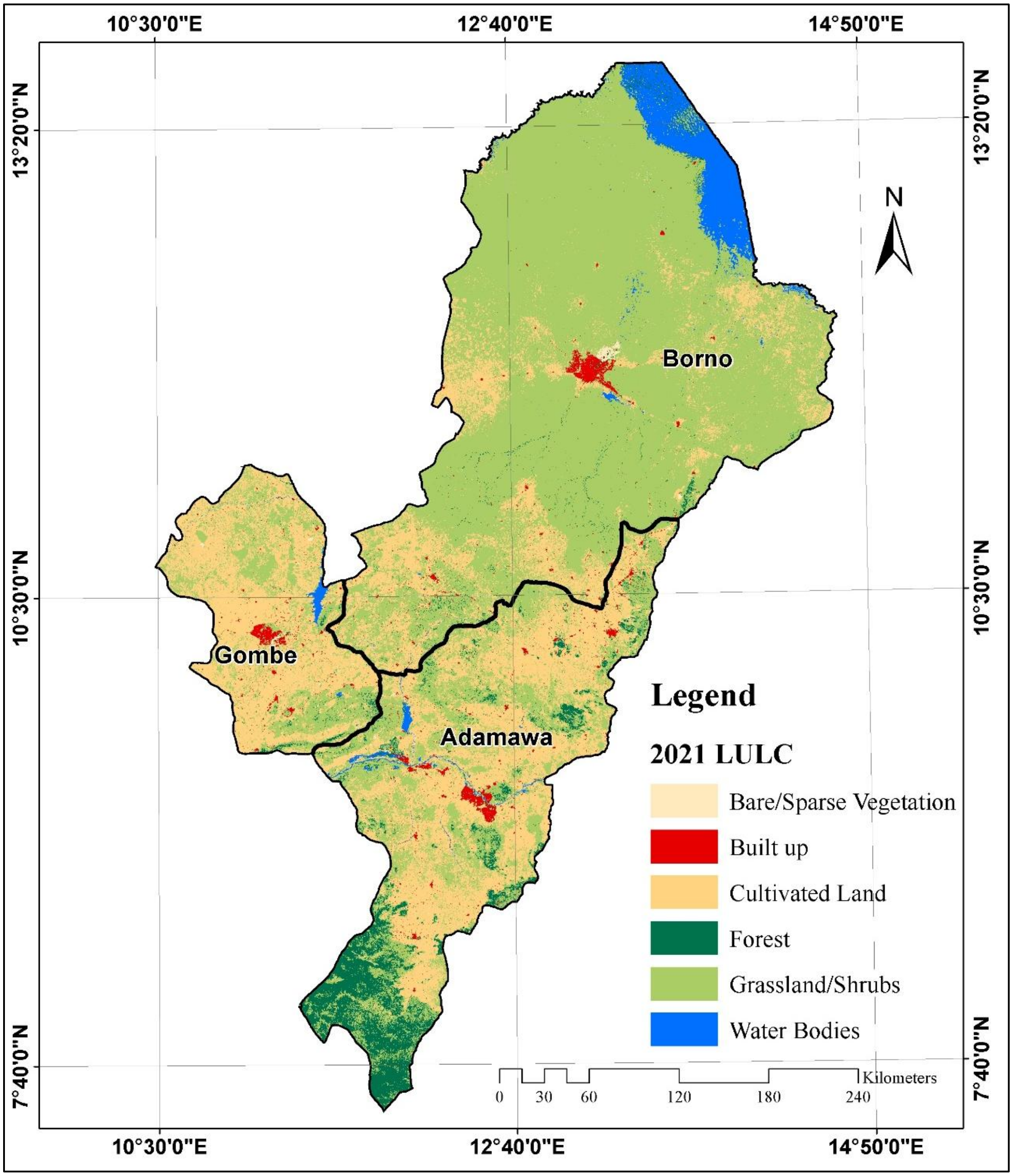

Figure 4.31: 2021 Land use and Landcover of the Study Area

4.1.3.5 Accuracy assessment

The User's and Producer's Accuracy tables provide a detailed assessment of how accurately each LULC category was classified in each year. High User’s Accuracy values indicate that the classification for that category was accurate in identifying true positives, while high Producer’s Accuracy values show that the classification correctly identified the category among all instances of that land cover type.

Table 4.22 displays the accuracy assessment for 1991 shows a strong overall classification performance, with an overall accuracy of 88.17 percent and a Kappa Coefficient of 0.84. The User’s Accuracy values are high for most categories, notably for Cultivated Land and Water Bodies at 92 percent and 93 percent, respectively, indicating that these categories were reliably identified as true positives. Producer’s Accuracy is also high, particularly for Cultivated Land at 94 percent, suggesting that the classification accurately represented the extent of this land cover type. The slightly lower accuracy for Bare/Sparse Vegetation and Forest, with User’s Accuracy of 85 percent and 86 percent, respectively, reflects some challenges in correctly classifying these categories.

Table 4.22: 1991 LULC Accuracy Assessment

LULC Category	User's Accuracy (percent)	Producer's Accuracy (percent)
Bare/Sparse Vegetation	85	82
Built up	88	90
Cultivated Land	92	94
Forest	86	84
Grassland/Shrubs	89	87
Water Bodies	93	91
Overall Accuracy: 88.17 percent		
Kappa Coefficient: 0.84		

From Table 4.23, in 2001, the overall accuracy slightly decreased to 87.50 percent, with a Kappa Coefficient of 0.82. The User's Accuracy for Built up and Water Bodies remains high at 89 percent and 90 percent, respectively, showing good precision in identifying these categories. However, there is a noticeable drop in accuracy for Bare/Sparse Vegetation, with User's Accuracy at 80 percent, which indicates some difficulty in distinguishing this land cover type. The Producer's Accuracy shows improvement for most categories, with Cultivated Land and Water Bodies reaching 92 percent, demonstrating that the classification effectively identified these categories in the field.

Table 4.23: 2001 LULC Accuracy Assessment

LULC Category	User's Accuracy (percent)	Producer's Accuracy (percent)
Bare/Sparse Vegetation	80	83
Built up	89	87
Cultivated Land	91	92
Forest	85	86
Grassland/Shrubs	88	89
Water Bodies	90	92
Overall Accuracy: 87.50 percent		
Kappa Coefficient: 0.82		

For 2011 (Table 4.24), the overall accuracy is 88.00 percent, with a Kappa Coefficient of 0.83, indicating a reliable classification with consistent performance across categories. The User's Accuracy for Cultivated Land is particularly high at 93 percent, and Producer's Accuracy also shows strong performance, especially for Grassland/Shrubs at 92 percent. Despite this, there is a slight decrease in accuracy for Forest and Water Bodies, with User's Accuracy at 83 percent and 87 percent, respectively, reflecting some challenges in accurately classifying these land cover types.

Table 4.24: 2011 LULC Accuracy Assessment

LULC Category	User's Accuracy (percent)	Producer's Accuracy (percent)
Bare/Sparse Vegetation	84	86
Built up	91	88
Cultivated Land	93	95
Forest	83	85
Grassland/Shrubs	90	92
Water Bodies	87	89
Overall Accuracy: 88.00 percent		
Kappa Coefficient: 0.83		

The accuracy assessment for 2021 (Table 4.25) demonstrates the highest overall accuracy of 90.33 percent and a Kappa Coefficient of 0.86. This indicates a high level of agreement and classification performance. The User's Accuracy for Cultivated Land and Built up is particularly notable, at 95 percent and 93 percent, respectively, indicating excellent precision. Producer's Accuracy is also strong, with Cultivated Land at 94 percent and Water Bodies at 90 percent. The classification of Bare/Sparse Vegetation and Forest remains accurate but shows a slight decrease in comparison to other categories, reflecting some difficulties in maintaining high accuracy for these land covers. Overall, the high accuracy values in 2021 reflect significant improvements and effective classification methodologies.

Table 4.25: 2021 LULC Accuracy Assessment

LULC Category	User's Accuracy (percent)	Producer's Accuracy (percent)
Bare/Sparse Vegetation	87	85
Built up	93	91
Cultivated Land	95	94
Forest	86	87
Grassland/Shrubs	89	88
Water Bodies	92	90
Overall Accuracy: 90.33 percent		
Kappa Coefficient: 0.86		

4.1.4 Land use and land cover projection of study area for year 2040

The Land Use and Land Cover (LULC) projection for 2040 shown in Figure 4.32, across Adamawa, Borno, and Gombe states (Table 4.26) offers a glimpse into the future landscape, assuming current trends continue. Bare/Sparse Vegetation is expected to further diminish, covering only 0.15 percent of the total study area, down from 0.48 percent in 2021. This suggests that nearly all previously barren areas will have been converted to other land uses, indicating ongoing land development and a potential decline in naturally vegetated, undeveloped areas.

Table 4.26: 2040 Projected Land use and Land cover

	Adamawa		**Borno**		**Gombe**		**Mean Total**	
	Area(km^2)	**percent**	**Area(km^2)**	**percent**	**Area(km^2)**	**percent**	**Area(km^2)**	**percent**
Bare/Sparse Vegetation	22.39	0.06	90.04	0.12	79.81	0.46	192.24	0.15
Built up	1271.22	3.36	1462.62	2.03	651.43	3.74	3385.27	2.66
Cultivated Land	16760.50	44.31	37472.17	51.93	10909.60	62.60	65142.27	51.13
Forest	17767.81	46.98	12584.09	17.44	2057.45	11.81	32409.36	25.44
Grassland/Shrubs	1629.57	4.31	16453.13	22.80	3497.18	20.07	21579.88	16.94
Water Bodies	370.19	0.98	4094.54	5.67	231.17	1.33	4695.90	3.69
Grand Total	**37821.67**	100.00	**72156.60**	100.00	**17426.66**	100.00	127404.93	100.00

Built-up areas are projected to expand significantly, covering 2.66 percent of the total area by 2040, a substantial increase from 1.35 percent in 2021. This growth will be particularly prominent in Adamawa and Gombe, where built-up areas are expected to cover 3.36 percent and 3.74 percent of their respective states. Borno will also see an increase to 2.03 percent. This expansion highlights the anticipated continuation of urbanization and infrastructure development, driven by population growth and economic activities in the region.

Cultivated Land is expected to remain the dominant land cover type, occupying 51.13 percent of the total study area, a slight increase from 2021. Gombe will continue to have the highest proportion of cultivated land, covering 62.60 percent of the state, while Adamawa and Borno will see 44.31 percent and 51.93 percent of their areas, respectively, dedicated to agriculture. This projection indicates that agriculture will continue to be a significant land use in the region, driven by the need to support food production and livelihoods.

Forest Cover is projected to recover significantly, increasing to 25.44 percent of the total area by 2040. This marks a substantial rise from 4.92 percent in 2021, suggesting a potential focus on reforestation or conservation efforts. The most significant forest cover will be in Adamawa, where forests are expected to cover 46.98 percent of the state, while Borno and Gombe will see more modest increases to 17.44 percent and 11.81 percent, respectively. The anticipated recovery of forests underscores the importance of sustainable land management practices and environmental conservation.

Grassland/Shrubs are projected to decrease, covering 16.94 percent of the study area, down from 58.86 percent in 2021. The largest reduction will be seen in Borno, where grasslands will occupy 22.80 percent of the state, and in Adamawa and Gombe, where they will cover 4.31 percent and 20.07 percent, respectively. The reduction in grasslands is likely linked to the expansion of forests and cultivated lands, reflecting changes in land use priorities.

Water Bodies are expected to remain relatively stable, covering 3.69 percent of the total area, with Borno continuing to have the largest proportion at 5.67 percent. The slight increase in water bodies may be related to better water management practices or natural changes in the landscape.

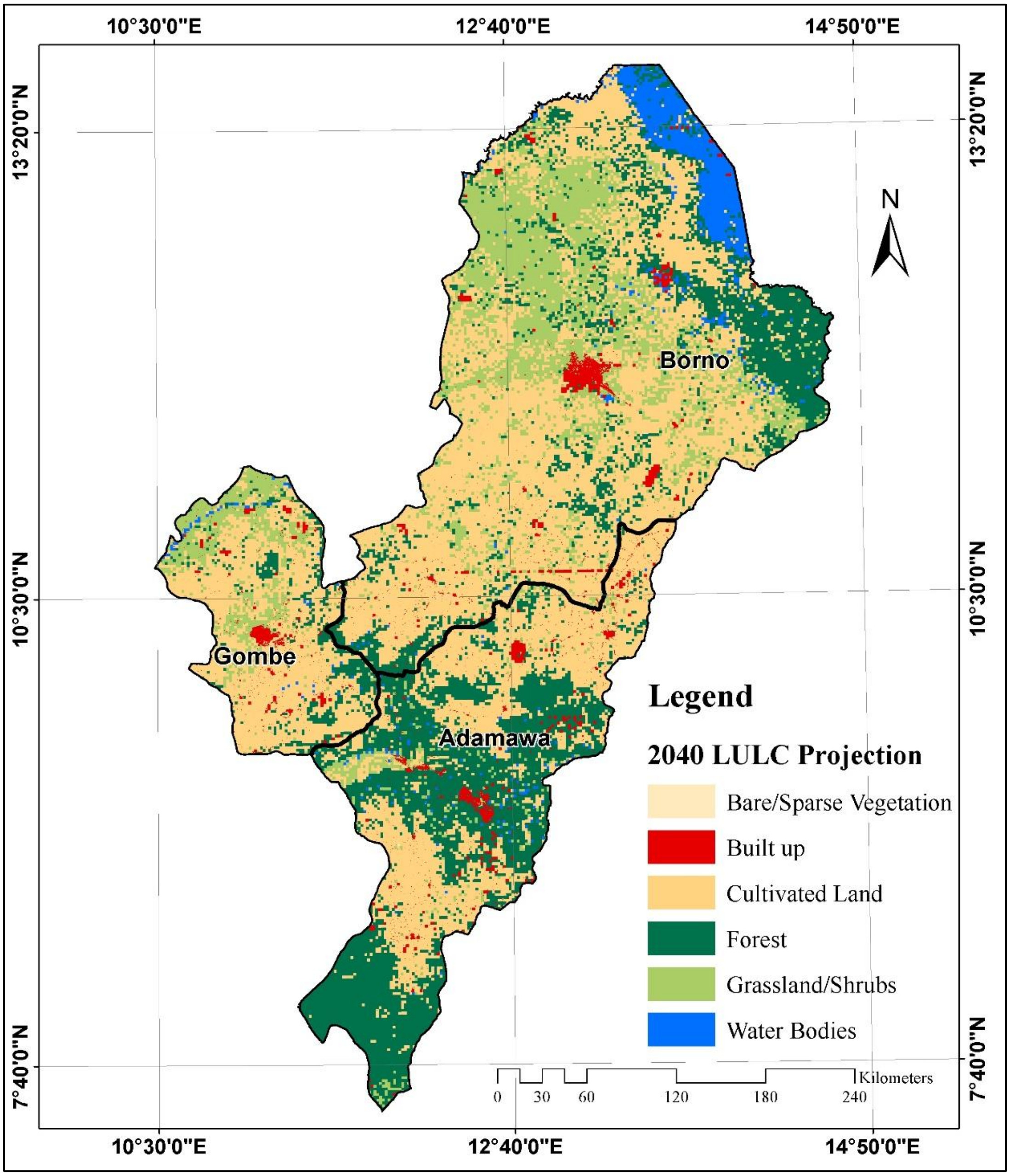

Figure 4.32: 2040 Projected Land use and Land cover of the Study Area.

In summary, the Land Use and Land Cover (LULC) trend analysis from 1991 to 2021 across Adamawa, Borno, and Gombe states highlights significant changes in the region's landscape. Bare/sparse vegetation has notably decreased from 3.50 percent in 1991 to 0.48 percent in 2021, with a further decline projected to 0.15 percent by 2040. This trend suggests a reduction in areas with minimal vegetation, likely due to increasing land use and environmental changes. Conversely, built-up areas have steadily expanded, growing from 0.36 percent in 1991 to 1.35 percent in 2021, with projections indicating a rise to 2.66 percent by 2040. This increase reflects ongoing urbanization and infrastructure development (Table 4.27).

Table 4.27: LULC of the Study for all Periods

class	1991		2001		2011		2021		2040	
	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent	Area(km^2)	percent
Bare/Sparse Vegetation	4465.30	3.50	170.07	0.13	684.78	0.54	613.67	0.48	192.24	0.15
Built up	462.84	0.36	942.98	0.74	1410.59	1.11	1725.67	1.35	3385.27	2.66
Cultivated Land	25201.55	19.78	71962.92	56.48	52414.98	41.14	39172.34	30.75	65142.27	51.13
Forest	20192.31	15.85	23112.49	18.14	8465.32	6.64	6262.21	4.92	32409.36	25.44
Grassland/Shrubs	70220.48	55.12	25974.63	20.39	59510.58	46.71	74995.27	58.86	21579.87	16.94
Water Bodies	6862.44	5.39	5241.82	4.11	4918.66	3.86	4635.74	3.64	4695.91	3.69
Total	**127404.92**	**100.00**	**127404.92**	**100.00**	**127404.92**	**100.00**	**127404.92**	**100.00**	**127404.92**	**100.00**

Cultivated land has experienced fluctuations, initially covering 19.78 percent in 1991, peaking at 56.48 percent in 2001, and then decreasing to 30.75 percent by 2021. Despite this fluctuation, cultivated land is expected to increase to 51.13 percent by 2040, suggesting a future rise in agricultural activities. In contrast, forest cover has sharply decreased from 15.85 percent in 1991 to 4.92 percent in 2021, but a significant increase to 25.44 percent is projected for 2040, potentially indicating a future recovery in forest areas or reforestation efforts.

Grassland and shrub areas have also declined from 55.12 percent in 1991 to 58.86 percent in 2021, with a further decrease expected to 16.94 percent by 2040. This trend might be due to land conversion for agriculture or urban development. Water bodies have remained relatively stable, with a slight decrease from 5.39 percent in 1991 to 3.64 percent in 2021 and a marginal increase projected for 2040 corroborating the studies carried out by Abubakar *et al.* (2022). These trends reflect various pressures on land use and cover, with significant implications for environmental management and planning in the region.

4.1.5 Impact of migration and climate change on land use and land cover

Correlation coefficients provide insights into the relationship, strength and direction between the independent variables (Migration and Climate variables) and the dependent variables (LULC classes). Prior to Spearman's rank correlation analysis, a Shapira-Wilk Normality test was carried out.

4.1.5.1 Result of the Shapira-Wilk normality test

The result of the Shapira-Wilk Normality Test in Table 4.27 shows that not all the data have a p-value greater than 0.05, it is concluded that the data is not normally distributed (Galadanci and Mukhtar, 2017). And therefore, fit for spearman's rank correlation analysis.

Table 4.28: Shapira-Wilk Normality Test Result

Variable	Shapiro-Wilk statistic	p-value	Status
Net Migration	0.7793	0.0700	Normal
Mean Rainfall	0.7948	0.0933	Normal
Mean Tmax	0.8260	0.1577	Normal
Mean Tmin	0.9165	0.5174	Normal
Bare/Sparse land	0.7313	0.0254	Not normal
Built-Up	0.9920	0.8965	Normal
Cultivated Land	0.9920	0.9674	Normal
Forest	0,8683	0.2912	Normal
Grassland	0.8585	0.2548	Normal
Water	0.8424	0.2026	Normal

4.1.5.2 Impact of migration on land use and land cover

Figure 4.33 clearly shows the strength and direction of relationships between Net Migration and Land use and Land cover classes. The Spearman correlation analysis reveals how net migration correlates with various land use types. Grassland (G) shows a strong negative correlation (-0.8) with net migration. This means that as net migration increases, grassland areas tend to decrease, or vice versa, indicating a substantial inverse relationship between these two variables.

Also Cultivated Land (CL) has a moderate positive correlation (0.6) with net migration, suggesting that as more people migrate into an area, cultivated land areas are likely to increase, possibly due to expanded agricultural activities to meet population needs. Similarly, Forest (F) shows a weak positive correlation (0.4), which implies a slight tendency for forest areas to grow as net migration increases, though the relationship is not very strong.

Built-up Areas (BU) have a weak negative correlation (-0.2), indicating a minor tendency for developed areas to decrease as net migration increases. Water (W) has a weak positive correlation (0.2), suggesting a small tendency for water bodies to expand with increased net migration, though the relationship is minimal. Bare Surface (BS) shows no correlation (0), indicating no clear relationship between net migration and bare surface areas.

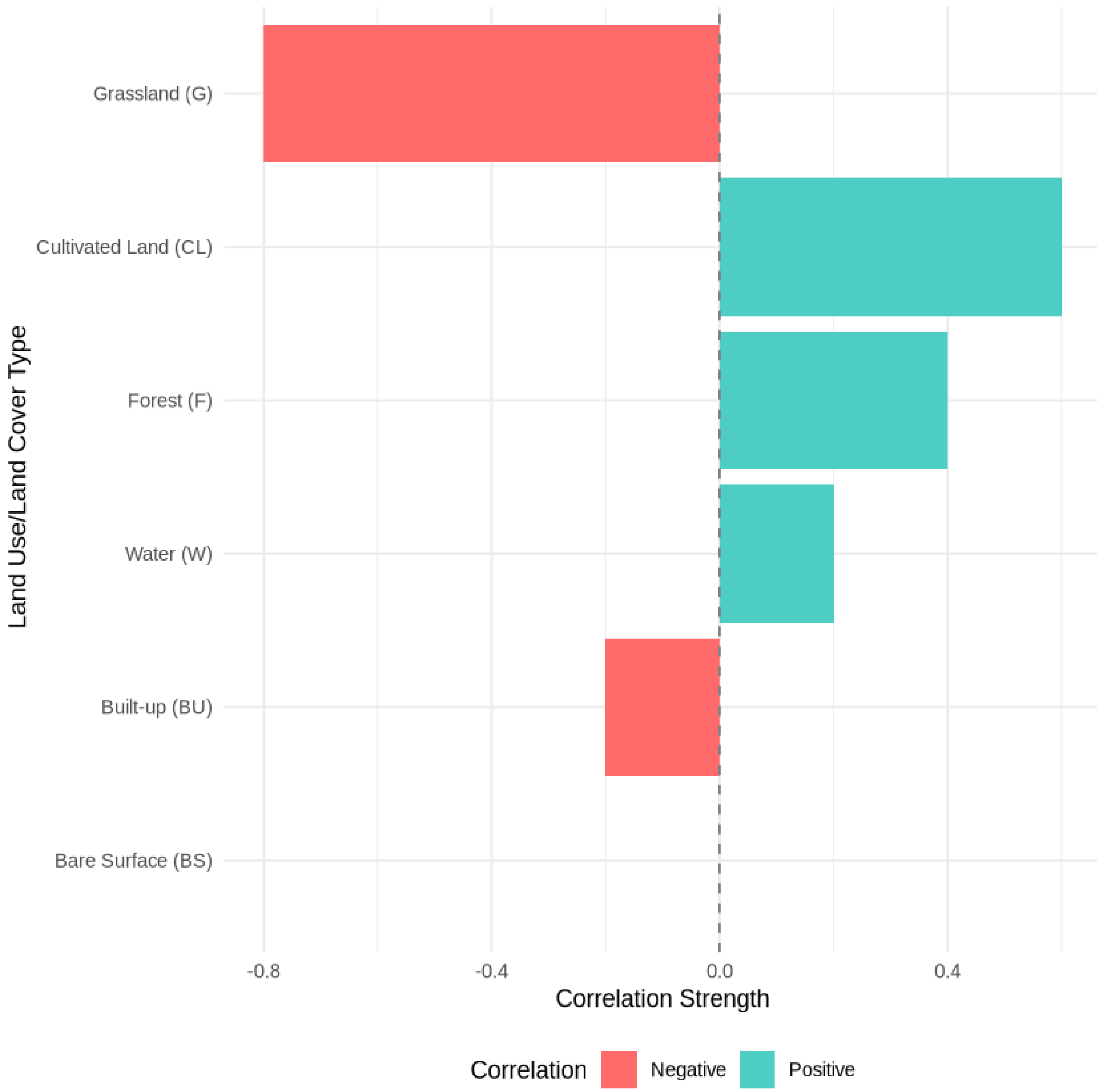

Figure 4.33: Correlation between Net migration and LULC classes

4.1.5.3 Impact of rainfall on land use and land cover

Figure 4.34 shows the result of the correlation test for the total mean annual rainfall with LULC at the study area. Helping us understand how different land use types might influence or be influenced by rainfall patterns. Bare/sparse land (BS) has strongest negative correlation (-0.6) with rainfall suggests that areas dominated by barren soil generally receive less rainfall. This may imply that barren landscapes lack features that could help retain or attract moisture.

Built-up (BU) Shows a moderate positive correlation (0.4), built-up areas tend to receive more rainfall. This could be due to urban features that alter microclimates, potentially enhancing rainfall. Grassland (G) also with a moderate positive correlation (0.4), signifies that grassland areas may support or attract rainfall, perhaps through evapotranspiration processes that contribute to local humidity. Forest (F) with slight negative correlation indicates a weak inverse relationship with rainfall, suggesting forests in this region might not play a strong role in local rainfall patterns or could be affected differently compared to other land types (- 0.2).

Similarly, Water bodies(W) with a slight negative correlation signify that areas with more water bodies tend to receive slightly less rainfall, which could point to a minor influence of water bodies on local rainfall, potentially due to cooling effects that stabilize the atmosphere (-0.4). Cultivated land (CL) lacks of correlation (0) indicate that cropland extent does not significantly interact with rainfall patterns, suggesting that rainfall in these areas is unaffected by or does not notably affect cropland distribution because agricultural areas are mainly set up to grow crops, not to impact rainfall, so they tend to have little effect on local rain patterns.

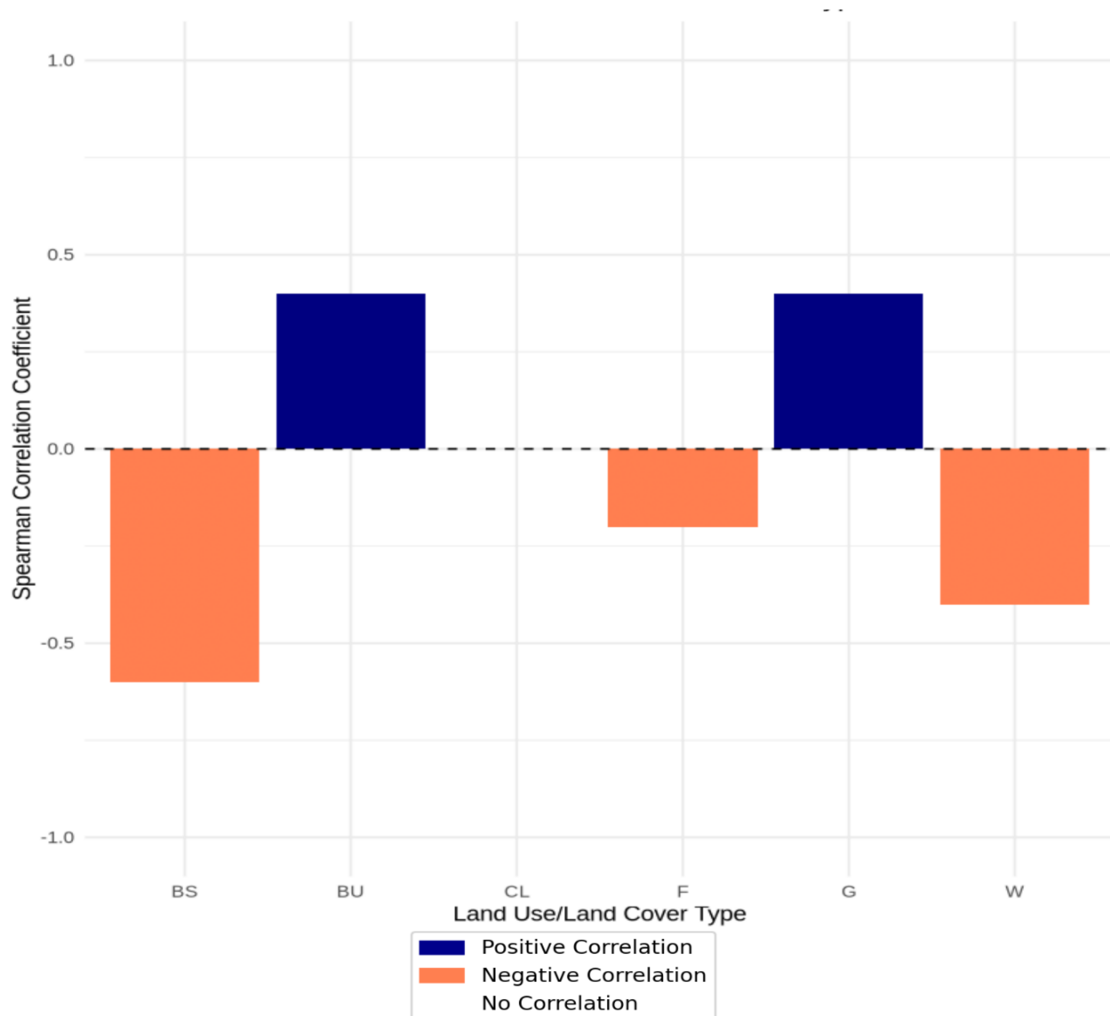

Figure 4.34: Correlation between Mean Annual Rainfall and LULC classes

4.1.5.4 Impact of mean annual maximum temperature on land use and land cover

The result of the correlation test for mean annual maximum temperature at the study area, signifies that, Built-Up Areas has a strong positive correlation with mean annual maximum temperature, indicating that as built-up areas increase, the mean maximum temperature tends to rise. Grassland has a moderate positive correlation, suggesting that grasslands are associated with higher temperatures, but not as strongly as built-up areas. Cultivated land displays a weak positive correlation, meaning croplands have a slight tendency to be associated with higher temperatures.

Bare/ Sparse land shows a moderate negative correlation, indicating that areas with more bare soil tend to have lower mean maximum temperatures. Forest exhibits a strong negative correlation, suggesting that higher temperatures are associated with a decrease in forest areas while Water Bodies have a very strong negative correlation, meaning that higher temperatures are associated with a decrease in water bodies (Figure 4.35).

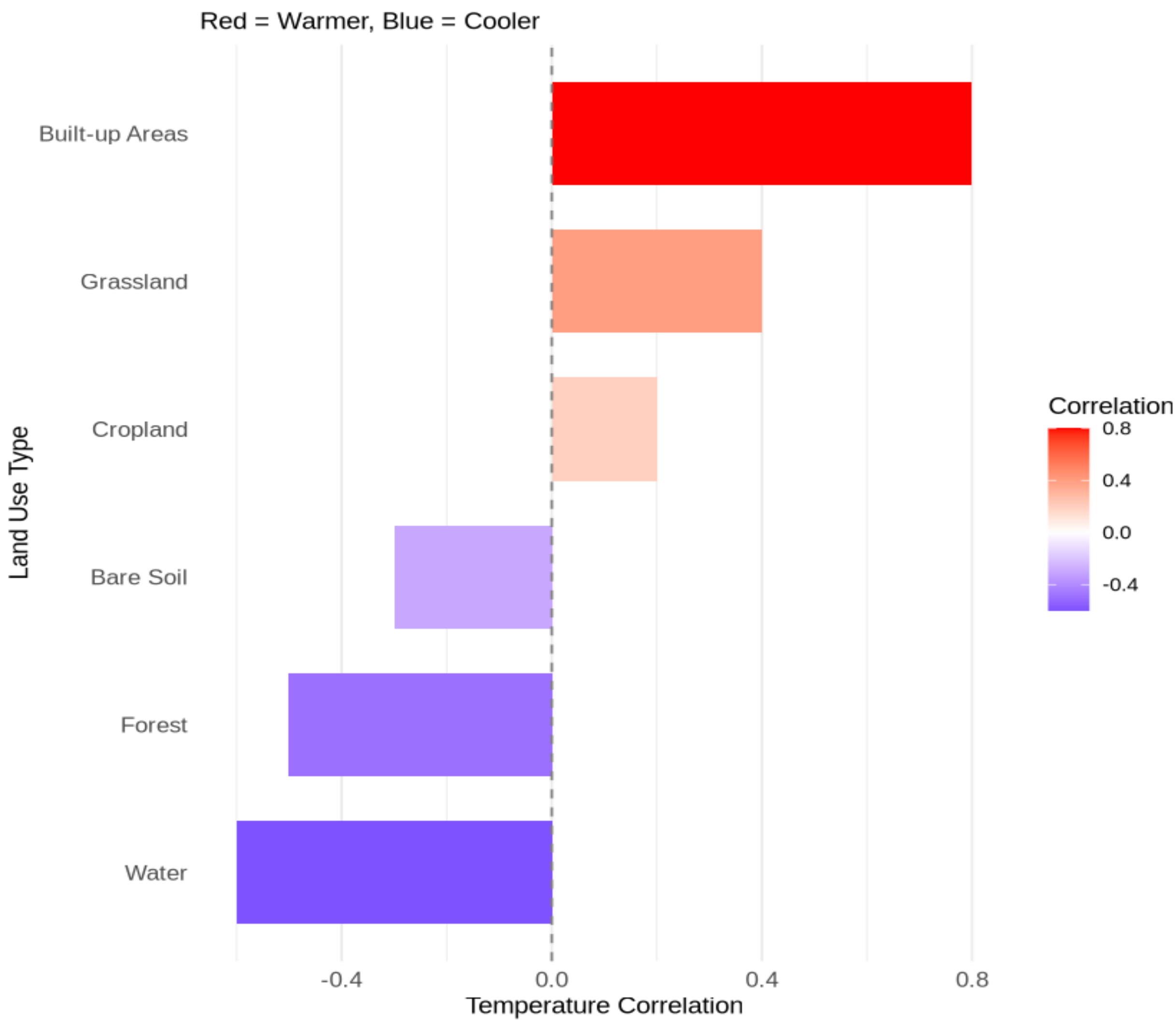

Figure 4.35: Correlation between Mean Annual Maximum Temperature and LULC classes

4.1.5.5 Impact of mean annual minimum temperature on land use and land cover

Figure 4.36 shows the result of the correlation test for mean annual minimum temperature. The Spearman's rank correlation results reveal a positive correlation between mean annual minimum temperature and Built-up and Grassland areas, suggesting that urbanized areas and grasslands are most strongly linked to higher minimum temperatures.

This could be due to the urban heat island effect, where buildings and other impervious surfaces retain heat, especially at night. Bare surface showed no correlation. In contrast, cultivated land, forest and water bodies show a negative correlation with minimum temperatures, indicating that these natural areas are associated with cooler temperatures. This cooling effect is due to vegetation and moisture retention, which help moderate temperature fluctuations.

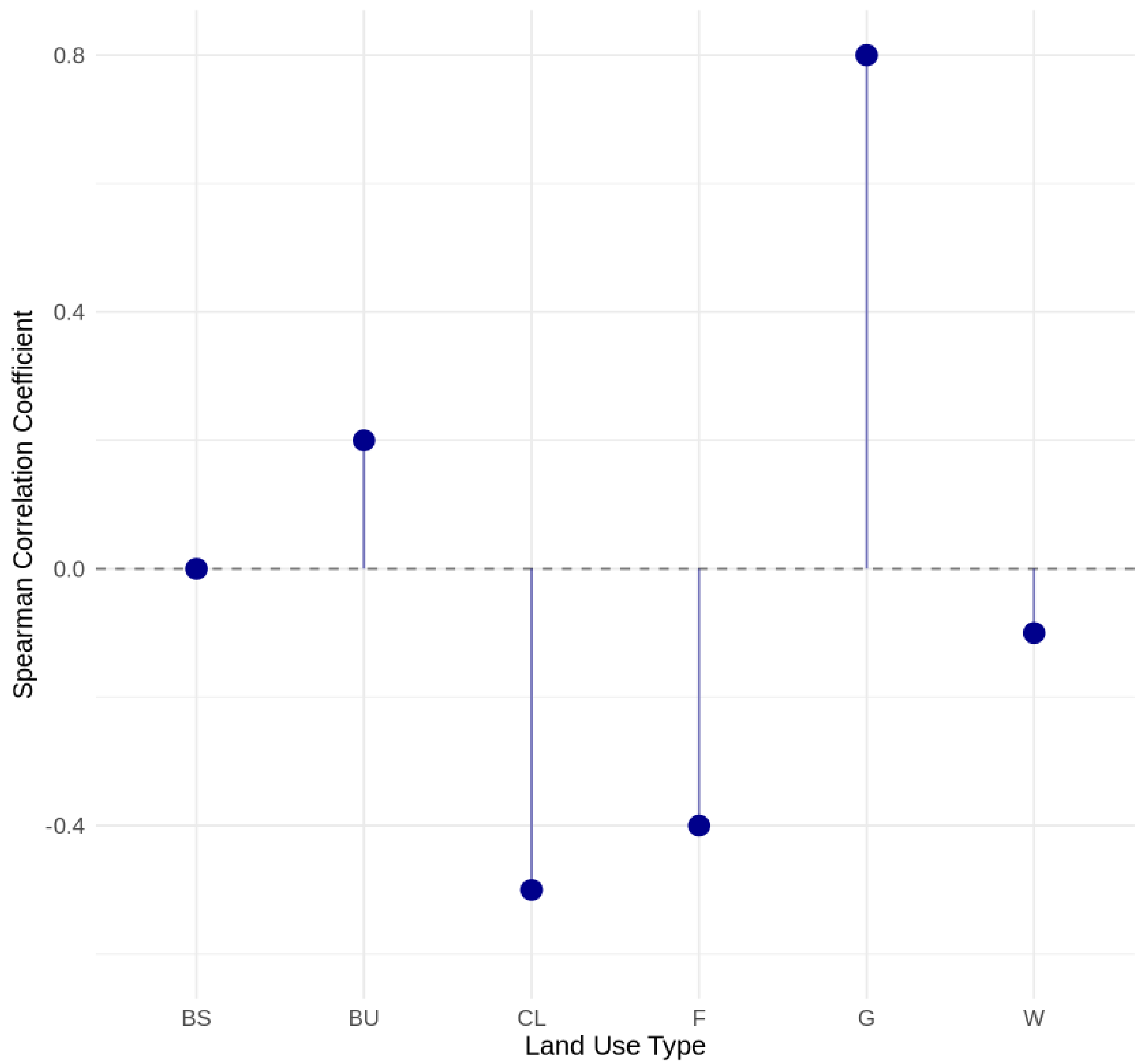

Figure 4.36: Correlation between Mean Annual Minimum Temperature and LULC classes

4.2 Discussion of Results

4.2.1 Trend in rainfall and temperature between 1981 and 2021

4.2.1.1 Autocorrelation test

Serial Auto-correlation was observed in the result thus making the dataset viable for Modified Mann–Kendall trend analysis. Modified Mann-Kendall (MMK) is recommended to correct the effects of autocorrelation in a given time series (Alashan, 2020). The time gap is called Lag. The value of the time gap is given by k. A lag 1 autocorrelation (i.e., k=1) is the correlation between values that are one time period apart (Appendix B Figures 1, 2 and 3).

4.2.1.2. Rainfall, maximum temperature and minimum temperature

On a general note, between 1981 to 2021 the rainfall trend seems to be on low decrease in the study location, based on the calculation of the mean annual rainfall, the Sen's slope value is -0.0442 (see Table 4.7). The result seems to agree with the findings of Bello *et al*. (2020); Abe *et al*. (2022) and Ikusemoran *et al*. (2023) which discovered rainfall was decreasing in the southern and northern parts of the state but increasing in the central region of Gombe state. See also the result of the Modified Mann-Kendall trend and Sen's slope result in Tables 4.1 and 4.2. Similarly, in Adamawa state, Ankindawa *et al*. (2023) discovered that most of the state is experiencing a decreasing rainfall trend. While Adedeji *et al*. (2018) and Bose *et al*. (2015) discovered that in Northeast Nigeria, especially Borno and Adamawa there was an increasing trend in rainfall between 1970 -2015.

The mean total of the annual maximum temperature has a Sen's slope value of 0.046. this signifies that the maximum temperature in the study area is on a low increase (see Table 4.8). This is in tandem with Alhaji *et al*. (2018); Bello *et al.* (2020) and Ikusemoran *et al*. (2023), which discovered a statistically significant increasing maximum temperature in Gombe state. Adebayo *et al*. (2012); Adedeji *et al*. (2018) and Ankindawa *et al*. (2023) also discovered a statistically significant increasing maximum temperature in Adamawa state. Similarly, John *et al*. (2018), discovered that the maximum temperature is increasing in Borno State. See also the result of the Modified Mann-Kendall trend and Sen's slope result in Tables 4.3 and 4.4.

Ikusemoran *et al*. (2023) revealed that the mean minimum temperature was found to be increasing in all the sampled parts of the state, also Alhaji *et al*. (2018) in a study observed that between 1987 – 2016, the mean minimum temperature increased in Gombe and it is not statistically significant, In Adamawa State minimum temperature also showed a similar pattern of increase (Ezra *et al*., 2021) in Borno minimum temperature is increasing (John *et al*., 2018). However, this study observed that the mean total of the annual minimum temperature has a Sen's slope value of -0.005 which signifies that the minimum temperature in the study area is on a low decrease (see Table 4.9). See also the result of the Modified Mann-Kendall trend and Sen's slope result in Tables 4.5 and 4.6.

Decreasing rainfall patterns and rising temperatures in the study location have significant consequences. It implies that Northeast, Nigeria is susceptible to consequences of global warming, leading to instances like drought, which affects crop yields, and resulting in food shortages. It disrupts ecosystems leading to habitat loss, migration and extinction. It also influences the spread of diseases (Taddese 2017; Abdullahi *et al*., 2019; Kanayochukwu and Dogo, 2019). These have resulted in increased conflict, communal clashes and terrorism in the study location, further aggravating the decreasing rainfall and rising temperature patterns. That is because people in the study location depend on agriculture, an economic activity that is rainfall-sensitive (Abubakar *et al*., 2025).

In conclusion, the results of Modified Mann-Kendall and Sen's innovative trend analysis for annual time series on individual stations show that the number of statistically significant negative trends is greater than the statistically significant positive trends in rainfall. Similarly, the number of statistically significant positive trends is greater than the statistically significant negative trends in temperature thus, indicating the decreasing trend in rainfall and increasing trend in maximum and minimum temperature. In the same vein, Sen's slope estimator result of the trend analysis from the IDW interpolation shows that rainfall is on a low decrease, maximum temperature is on a low increase and minimum temperature is on a low decrease in the study location.

4.2.1.3. Seasonal variation

The results indicate distinct climatic patterns in Northeast Nigeria, with more rainfall occurring during the wet season, higher maximum temperatures observed during the dry season, and lower minimum temperatures during the same dry period. Previous studies corroborate these findings, identifying four distinct seasons in the region, each with unique climatic characteristics. The hot dry season, spanning from November to April, is marked by high temperatures and low humidity. The wet or rainy season, extending from May to October is characterized by increased rainfall and cooler temperatures. During the Harmattan season, occurring between December and February, the region experiences dry, cold winds originating from the Sahara Desert. Lastly, the pre-rainy season in March and April serves as a transitional phase, featuring rising temperatures and increasing humidity (Hassan *et al*., 2017; Ndakara and Eyefia, 2021).

Temperature variations in the region are particularly pronounced, with the hot dry season (November to March) sharply contrasting with the warm rainy season (April to October). These patterns are influenced by the region's location within the West African Sahel, a zone characterized by its semi-arid climate. Such seasonal variations have significant implications for various sectors, including agricultural planning, water resource management, public health, and climate change adaptation. For instance, understanding these patterns can aid in optimizing planting schedules, managing water resources more effectively, and preparing for climate-related health challenges. These insights are instrumental for enhancing resilience and promoting sustainable development in Northeast Nigeria (Dammo *et al*., 2015; Salami *et al*., 2021).

4.2.1.4 Summary of rainfall, maximum and minimum temperature trends across the study area (1981–2021)

Over the past four decades, rainfall trends have exhibited notable variations across the study area, with distinct trends observed in different Local Government Areas (LGAs). A significant increase in rainfall has been recorded in Gombe, Kwami, Yamaltu Deba, and parts of Kaltungo LGAs (Gombe State); Ngazai and Bama LGAs (Borno State); and Mubi North, Mubi South, Mayo Belwa, and Demsa LGAs (Adamawa State).

Moderate increases in rainfall were observed in parts of Akko, Balanga, Billiri, Dukku, Funakaye, and Nafada LGAs (Gombe State); Askira-Uba, Gwoza, Bama, Ngala, Marte, Mongono, Guzamala, Gubio, and Mobbar LGAs (Borno State); and Demsa, Lamurde, Guyuk, Shelleng, Numan, Song, and Hong LGAs (Adamawa State).

Conversely, a slight decline in rainfall was detected in parts of Nafada and Dukku LGAs (Gombe State), as well as in Yola North, Yola South, and parts of Demsa, Girei, Fufore, Jada, Toungo, and Ganye LGAs (Adamawa State). A pronounced decline in rainfall was observed in parts of Shongom LGA (Gombe State) and in Hawul, Kwaya Kusar, Kaga, Magumeri, and Mafa LGAs (Borno State).

This spatial variability in rainfall trends underscores the need for localized climate adaptation strategies to mitigate potential impacts on agriculture, water resources, and livelihoods within the region.

Maximum temperature trends have displayed great variations across the study area, with significant spatial differences observed across the Local Government Areas (LGAs). A very high increase in maximum temperature has been recorded in Toungo, Ganye, Mayo-Belwa, and parts of Jada LGAs (Adamawa State). Similarly, a high increase has been observed in Yola North, Yola South, Girei, Fufore, Demsa, Numan, Lamurde, Guyuk, and parts of Jada (Adamawa State), as well as in sections of Shongom and Balanga LGAs (Gombe State).

A moderate increase in maximum temperature was detected in Song, Shelleng, and parts of Maiha and Fufore LGAs (Adamawa State); Shani, Bayo, and parts of Kwaya-Kusar and Hawul LGAs (Borno State); and in Gombe, Yamaltu Deba, Akko, Kwami, Billiri, Kaltungo, and parts of Balanga and Shongom LGAs (Gombe State).

A low increase in maximum temperature was recorded in Dukku, Nafada, and Funakaye LGAs (Gombe State); Madagali, Michika, Mubi North, Mubi South, Hong, and parts of Gombi, Song, and Maiha LGAs (Adamawa State); and in Biu, Askira Uba, Chibok, Damboa, Konduga, Kaga, Magumeri, Maiduguri, Jere, Ngazai, Gubio, Gwoza, Bama, Dikwa, Mongono, Kala Balge, Marte, and the entire northern region of Borno State.

Minimum temperature trends have exhibited significant spatial variability across the study area, with notable increases and decreases observed in the Local Government Areas (LGAs). A very high increase in minimum temperature has been recorded in Toungo, Ganye, Yola North, Yola South, and Girei LGAs (Adamawa State), as well as in parts of Shongom LGA (Gombe State). A high increase was observed in Fufore, Song, Lamurde, and Numan LGAs (Adamawa State), along with sections of Shongom LGA (Gombe State).

Conversely, a low decrease in minimum temperature was detected in parts of Balanga, Kaltungo, Billiri, Akko, Funakaye, and Nafada LGAs (Gombe State), as well as in Shani, Hawul, Kwaya Kusar, Askira Uba, Biu, Chibok, Damboa, Gwoza, Bama, Konduga, Maiduguri, Jere, Magumeri, Ngazai, Gubio, Monguno, Marte, Ngala, and Kala Balge LGAs (Borno State).A very high decrease in minimum temperature was recorded in Gombe, Yamaltu Deba, and Kwami LGAs (Gombe State), as well as in Bayo, Biu and Kwaya Kusar LGAs (Borno State).

These variations in minimum temperature trends underscore the complex nature of climate change impacts across North-Eastern Nigeria, necessitating further research and adaptive strategies to mitigate potential environmental and socio-economic consequences.

4.2.2 Factors that influence migration.

The findings reveal that most respondents are within the youthful age group. This demographic is characterized by physical strength and agility, enabling them to migrate for various reasons. These results align with the findings of Milasi (2020), which emphasize the dynamic mobility and resilience of young populations. Additionally, over 60 percent of the respondents possess some educational qualification, signifying a relatively educated demographic. However, most respondents are low-income earners, often those displaced by insurgency and compelled to engage in menial jobs to meet basic needs.

The origin of migrants reflects a pattern observed in similar studies, such as Strikwerda (1999) and Regmi *et al*. (2020), which demonstrate that migrants tend to move to nearby areas with high population densities. These areas often have shared language, ethnic backgrounds, and better access to amenities. For instance, micro-data from France, Germany, the UK, and the USA indicate that robust education and health systems are significant pull factors for migrants (Geis *et al*., 2013).

Migration in the study area is predominantly driven by conflict, crisis, insurgency, terrorism, and environmental or climate-related issues. Many respondents have been forced to relocate to Internally Displaced Persons (IDPs) camps or integrate into host communities. These migrants face profound challenges, including widowhood, orphanhood, homelessness, and hunger. Despite these adversities, interventions from organizations such as the National Emergency Management Agency (NEMA), State Emergency Management Agency (SEMA), World Bank, United State Agency for International Development (USAID), United Nations, Norwegian Refugee Council (NRC), The International Organization for Migration (IOM), Red cross, religious bodies, Non-Governmental Organizations (NGO) and others, have provided critical relief in the form of food, clothing, medical care and temporary shelters.

A significant portion of respondents reported that migration has been beneficial, as they have secured better job opportunities compared to their previous locations. However, others expressed dissatisfaction, citing losses such as familial connections, properties, and livelihoods due to crises, environmental issues, or job transfers. These findings are consistent with the push and pull theory of migration (Lee, 1966; Mlambo and Mpanza, 2019).

Respondents identified several barriers to sustaining livelihoods at their current locations, including lack of capital, depression, sickness, hunger, economic hardship, climate change, conflict, political instability, and lack of motivation. Nonetheless, some individuals have adapted by engaging in petty businesses such as firewood sales, snack vending, petty trading, hair plaiting, and farming within IDP camps. These findings corroborate Iwuoha's (2020) study on the economic activities of displaced populations.

Most migrants perceive migration as beneficial, citing improved access to better jobs, education, security, and enabling environments for livelihoods. For instance, a study by Liman *et al*., (2023) identified seasonal migration (known locally as *ci rani*) as a common adaptive strategy among agrarian communities, where individuals temporarily migrate to urban areas for business during the dry season and return to their villages for farming activities when the rainy season begins. Conversely, those who disagree are individuals who have suffered significant losses, including jobs, family members, communities, and properties, without achieving equivalent compensation or stability in their new locations.

The study shows that many respondents migrated alone, either forcibly due to crises or voluntarily in pursuit of better opportunities. However, a substantial number also migrated with family members. These findings resonate with Kanics *et al*. (2010), which highlighted patterns of child migration and asylum-seeking behavior in Europe.

Migration in the study area is predominantly driven by Job opportunities, Education and insecurity (conflict, crisis, insurgency and terrorism). Many respondents have been forced to relocate to Internally Displaced Persons (IDPs) camps or integrate into host communities. A study by Ruppel and Funteh, (2019), identified migration drivers in Northeast Nigeria, including climate change and the shrinking of Lake Chad, which has severely impacted over 15 million Nigerians and 10 million others in neighboring countries. The loss of livelihoods tied to the lake has escalated conflicts over scarce resources, leading to blood clashes and insurgencies. The Boko Haram crisis especially in Adamawa and Borno states, which began in 2009, exemplifies the security challenges faced by the region.

Respondents highlighted various challenges in the current location of migrants, including unemployment, culture shock, loneliness, stereotyping, and discrimination. These challenges mirror findings from Idemudia (2021), which explored the mental health and post-traumatic stress disorder experienced by homeless migrants.

The study identifies young males as the predominant demographic in migration trends. Their youthful vigor, curiosity, and determination to improve living conditions for themselves and their families drive this trend. This aligns with Mlambo and Mpanza (2019) and Milasi (2020). Additionally, Nwosu *et al*. (2022) emphasize the need for government interventions to reduce poverty and provide education to discourage illegal migration.

Regarding the effects of migration on Land use/ Land cover at the destination, the study found that 27.58 percent of respondents reported land pollution at their destinations. This finding aligns with Asiedu's (2018) research on the causes and effects of uncontrolled development.

Migration effects on land use and Landcover at the origin have led to abandonment of buildings, reduced pollution of water resources, abandonment of land, and loss of existing infrastructure. These findings support Park *et al.* (2021), which examined the relationship between migration and land cover change in rural U.S. communities.

The study highlights the complex interaction of factors driving migration in Northeast Nigeria and its diverse impacts on individuals and communities. While migration has provided some respondents with better opportunities for livelihoods, education, and security, it has also led to significant challenges, including economic hardship, social disconnection, and environmental degradation. The findings underscore the importance of targeted interventions to address the root causes of migration, improve conditions in both origin and destination locations, and support displaced populations. Policymakers must focus on enhancing educational opportunities, creating sustainable livelihoods, and fostering resilience in affected communities to mitigate the adverse effects of migration while maximizing its potential benefits.

4.2.3 Land use and land cover dynamics between 1991 and 2021

The 1991 Land Use and Land Cover Map (Figure 4.28) visually represent these patterns, highlighting the dominance of grasslands, the significant forest cover in Adamawa, and the early signs of urbanization seen in the distribution of built-up areas across the study region. The variation in built-up land underscores the different stages of development and urban expansion occurring in these states at the time (Maina *et al.*, 2017; Sambo and Ikusemoran, 2022).

The 2001 Land Use and Land Cover (LULC) map (Figure 4.29) highlights significant changes in the study area, with a marked expansion of cultivated land and urban areas, alongside a decline in forest and grassland/shrubs cover. These trends reflect the region's evolving land use patterns, driven primarily by increased agricultural demand and urban growth, which continue to reshape the landscape.

Notable changes across Local Government Areas (LGAs) between 1991 and 2001 include transitions in parts of Abadam and Mobar (Borno State), where previously bare ground became forested and cultivated land. Several tributaries of Lake Chad disappeared in Monguno, Ngala, Marte, and Mafa (Borno State), transforming into grassland/shrubs, while grasslands/shrubs in areas such as Biu, Hawul, Chibok, Askira-Uba, Damboa, Konduga, Gwoza, and Kaga (Borno State) were converted into cultivated lands. In Gombe State, grasslands/shrubs around Kaltungo, Shongom, and Balanga became cultivated lands, and settlements expanded significantly around Nafada, Dukku, and Funakaye. In Adamawa State, grasslands/shrubs in Ganye, Jada, Mayo-Belwa, Numan, Demsa, Lamurde, Hong, Song, and Gombi transitioned into cultivated lands by 2001, while built-up areas notably increased around Gombi and Song, consistent with the findings of Dishan *et al.*, (2022) and Mbaya *et al*. (2019). These observations illustrate the dynamic interplay between natural resource availability, human activities, and climatic factors, driving substantial changes in land use and land cover over the decade. Understanding these trends is essential for sustainable land management and regional planning.

The 2011 Land Use and Land Cover (LULC) map (Figure 4.30) provides a comprehensive depiction of land use trends, highlighting the continued expansion of built-up areas, a reduction in cultivated and forested lands, and the predominance of grasslands/shrubs across the study area. Between 2001 and 2011, significant changes were observed in various Local Government Areas (LGAs). In Borno State, areas such as Konduga, Kaga, Gwoza, Damboa, and Chibok that were previously cultivated lands in 2001 transitioned into grasslands/shrubs by 2011. In Gombe State, grasslands/shrubs in Nafada, Dukku, and Funakaye were converted into cultivated lands, while the forested areas around Funakaye and Kwami experienced substantial reductions, becoming grasslands. Similarly, in Adamawa State, previously cultivated lands in Demsa, Numan, Mayo-Belwa, Jada, and Fufore transformed into grasslands/shrubs.

Additionally, forested areas in Shelleng, Song, and Fufore were converted into cultivated lands. These changes underscore the dynamic evolution of land use in the region, influenced by urbanization, shifting agricultural practices, and environmental pressures. As noted by Adetunji (2023), these trends emphasize the need for sustainable land management strategies to mitigate the impacts of ongoing land cover changes.

The 2021 Land Use and Land Cover (LULC) map (Figure 4.31) provides a detailed representation of land use trends in the study area, highlighting the significant expansion of grasslands/shrubs, the persistent growth of built-up areas, and the continued decline of forests and cultivated lands. Between 2011 and 2021, notable changes were observed across various Local Government Areas (LGAs). In Gombe State, forested areas around Funakaye and Kwami transitioned into grasslands/shrubs, while built-up areas in Funakaye and Dukku decreased significantly, converting into grasslands/shrubs and cultivated lands. Conversely, built-up areas expanded significantly around state capitals, including Gombe, Yola, and Maiduguri, whereas built-up zones in neighboring LGAs declined and, in some cases, disappeared entirely.

In Borno State, forested spots around Damboa, Gwoza, and Askira-Uba disappeared, giving way to grasslands/shrubs, while rivers in Ngazai, Mafa, and Jere shrank and transformed into grasslands. Additionally, parts of Jere LGA that were once cultivated lands became bare surfaces. In Adamawa State, built-up areas around Gombi and Song were converted into grasslands/shrubs and cultivated lands. These observed changes align with the findings of Aliyu *et al.* (2023), which emphasize the complex interplay of environmental and socio-economic factors driving land cover transitions. These shifts underscore the urgency of adopting sustainable land management strategies that balance development needs with conservation priorities, ensuring long-term environmental resilience and socio-economic stability in the region.

4.2.3.1. Overview of the overall accuracy and Kappa coefficient

The overall accuracy exceeding 85 percent (1991–2021) reflects a strong correspondence between the classified data and the reference or ground truth information. This high level of accuracy, achieved across classifications such as water bodies, grassland/shrubs, and urban built-up areas, underscores the robustness and appropriateness of the classification methodology and data sources used in the LULC analysis. Such accuracy is regarded as exceptional for LULC mapping, signifying that the classification outputs are dependable for critical decision-making. These maps are particularly valuable for applications such as monitoring land use and land cover changes, environmental and urban planning, and assessing climate change impacts.

The results further highlight a substantial agreement between the classified map and the reference data, with minimal errors, attesting to the reliability of the supervised classification process. The quality of input data, including satellite imagery and training samples, and the rigor of the validation approach—incorporating random sampling and confusion matrix analysis—also contribute significantly to the study's credibility. Moreover, the kappa coefficients of 0.84, 0.82, 0.83 and 0.86 indicate an almost perfect agreement, reinforcing confidence among stakeholders in the accuracy and applicability of the maps for informed decision-making regarding land use and land cover in the study area.

4.2.4 Land use and land cover projection

The 2040 Projected Land Use and Land Cover (LULC) map (Figure 4.32) provides a forward-looking visualization of anticipated changes, offering critical insights into the region's dynamic landscape and the potential impacts of urbanization, agricultural expansion, and environmental conservation efforts. Key projections indicate a significant increase in built-up areas across all states in the region. In Borno State, areas such as Monguno, Marte, Ngala, Kala-Balge, and Guzamala, currently characterized by grasslands and cultivated lands, are projected to transition into forested areas. Similarly, regions like Konduga, Kaga, Gwoza, and Damboa, which were primarily grasslands in 2021, are expected to become cultivated lands by 2040.

In Gombe State, cultivated lands and water bodies in Kaltungo and Balanga are projected to convert into forests, while parts of Nafada, Dukku, and Funakaye, currently cultivated lands, are anticipated to transition into forested and grassland areas. In Adamawa State, substantial changes are expected in areas such as Fufore, Mayo-Belwa, Yola North, Yola South, Demsa, Numan, Lamurde, and Guyuk. These regions, which were characterized by a mix of cultivated lands, water bodies, and grasslands in 2021, are projected to become forested by 2040.

The projection of increased forested lands by 2040 reflects the potential impact of deliberate afforestation efforts, reforestation programs, and natural vegetation recovery due to reduced human pressure in some areas. As urbanization and agriculture become more concentrated, marginal lands may be abandoned, allowing forests to regenerate. Policy-driven initiatives, such as tree-planting campaigns and sustainable land management programs, along with climate change mitigation strategies emphasizing afforestation, are expected to play a crucial role. Increased environmental awareness and community-driven conservation efforts further support this projection, highlighting a shift toward balancing development with ecological restoration in the region.

These projections emphasize the urgent need for effective planning and sustainable land management practices to address the competing demands of development and environmental preservation. The findings corroborate previous studies, including those by Mbaya *et al*. (2019), Koko *et al*. (2020) and Aliyu *et al*. (2023), further underscoring the importance of proactive measures to ensure ecological balance and long-term resilience in the region.

4.2.5 The Impact of Migration and Climate on Land use and Land cover

4.2.5.1. The impact of migration on LULC

Grassland (G) and Built-up (BU) show negative correlation with net migration. This means that as net migration increases, grassland and BU areas tend to decrease, or vice versa. Cultivated land (CL), Forest(F) and Water bodies(W) have positive correlation with net migration, as net migration increases, cultivated land, F and W are likely to increase. BS shows no correlation (0), indicating no clear relationship between net migration and bare surface areas (Figure 4.33).

Research supports results observed, especially in Sub-Saharan Africa, where migration pressures often drive changes in land use. Studies found that in-migration generally leads to more intense land changes, like converting grasslands into farms or residential areas to meet food and housing needs (Nebie and West, 2019; Chiaka and Zhen, 2021). Forest areas sometimes increase slightly with migration, thanks to conservation efforts in places like East Africa, although agricultural expansion remains a threat (Assede *et al*., 2023).

4.2.5.2. The impact of mean annual rainfall on LULC

Bare/sparse land (BS), Forest (F) and Water bodies (W) have negative correlation with rainfall suggesting that areas dominated by BS, F and W generally receive less rainfall. BU (Built-Up) and Grassland (G) exhibit positive relation, suggesting that increased rainfall is associated with more built-up and grassland areas. CL (Cultivated Land) lacks of correlation (0) suggesting that rainfall in these areas is unaffected by or does not notably affect cultivated land distribution.

Studies show that bare land loses moisture faster than areas with vegetation because it lacks plants that help hold water. This dryness makes it less likely to attract rainfall, especially in drier regions (Yaswanth *et al*., 2022). In contrast, urban areas can create conditions that increase rainfall due to the way buildings and surfaces affect local temperatures. Grasslands, by releasing moisture through plants (a process called evapotranspiration), can add humidity to the air, sometimes helping to trigger rain (Zhou *et al*., 2024).

4.2.5.3. The impact of mean maximum temperature on LULC

BU, G and CL show a positive correlation with Mean Annual Maximum temperature, indicating that as temperature increases, BU, G and CL areas tend to increase. W, F and BS exhibit negative correlation, suggesting that higher temperatures are associated with a decrease in W, F and BS areas (Figure 4.35).

It is very clear how urbanization and increasing temperature affects specific land covers, aligning with observed global trends in land use/ land cover transformation (Ibrahim *et al.,* 2016). Studies suggest that as cities grow, the type of land cover—like paved surfaces and vegetation—affects temperature changes in Nigerian cities. For example, paved surfaces trap heat at night, while vegetation cools areas during the day (Buyantuyev and Wu, 2010; Ossola *et al.,* 2021). Between 1991 and 2020, the average land surface temperature rose by 0.82 °C, highlighting the need for balanced land use. Managing urban growth carefully can help protect natural areas and reduce the warming effects of urbanization and climate change (Singh *et al*., 2024).

4.2.5.4. The impact of mean minimum temperature on LULC

A positive correlation between mean annual minimum temperature and Built-up and Grassland areas, suggesting that urbanized areas and grasslands are most strongly linked to higher minimum temperatures. Bare surface showed no correlation. Forest and Water bodies show a negative correlation with minimum temperatures, indicating that these natural areas are associated with cooler temperatures. This cooling effect is due to vegetation and moisture retention, which help moderate temperature fluctuations.

For instance, Myint *et al*. (2013) found that business and industrial areas contribute significantly more to the urban heat island effect than natural land covers, which generally provide cooling benefits. Similarly, Li *et al*. (2011) observed that residential areas with low-rise buildings and sparse vegetation were warmer than areas with high-rise buildings and more greenery. A study by Han *et al*. (2024) further supports this, showing that vegetated land types like forests and croplands are often cooler compared to urban areas due to their ability to lower Land Surface Temperatures (LST).

Water bodies also play a role in moderating temperature by stabilizing it, owing to their high specific heat, which prevents rapid temperature changes. Grasslands and bare/sparse land, while generally cooler than built-up areas, exhibit more varied impacts on temperature depending on the season and specific land cover characteristics. For example, bare soils may cool quickly at night but heat up rapidly during the day.

Overall, these findings highlight that urbanization tends to increase local minimum temperatures, while natural land covers such as forests, cultivated lands, and water bodies contribute to cooling effects. These insights are important for urban planning and climate adaptation strategies aimed at mitigating the impacts of rising temperatures in expanding urban areas. The results also emphasize the need to manage land use effectively to balance ecological preservation and urban growth.

It can be deduced from the results above that the impact that could arise from migration and climate change and its resultant effect on land use and land cover includes increasing urbanization, deforestation, increased competition of water resources, loss of biodiversity, increased land fragmentation, land degradation, loss of cultural heritage and spread of diseases among others.

4.3 Major Findings

Results of the study revealed that rainfall is decreasing (z = - 0.442), maximum temperature is increasing (z = 0.046) while minimum temperature is on a marginal decline (z = - 0.005). Higher precipitation was observed during the Wet season (100.95mm), Maximum temperatures peaked during the Dry season (38.09 ^{o}C) while Minimum temperatures were higher during the Wet season (20.94 ^{o}C). Transformation in the land use and land cover was observed, especially in the increasing trend in built-up (720.61km^2 in 1991 to 1725.67km^2 in 2021) and projected to increase to (3385.27) km^2 in 2040, these confirms the corresponding decrease in other land uses between 1991 and 2021. Accuracy assessment result exceeds 80 percent.

Result from the questionnaire administered showed 55.5 percent of migrants tend to converge more into the state capital from neighboring surrounding rural communities and migration in the study area is predominantly driven by job opportunities (33.5 percent), education (30.3 percent) and insecurity (28.8 percent). Complex interactions were observed between climatic variables (rainfall and temperature), net migration, and LULC classes. Variations suggest how climatic factors and migration influence land use and land cover changes.

CHAPTER FIVE

5.0 CONCLUSION AND RECOMMENDATIONS

5.1 Conclusion

The study highlights the devastating consequences of migration and climate change on land use and land cover transformation in North-Eastern Nigeria emphasizing the need for urgent policy interventions to mitigate and ensure long-term sustainability of the region. The study revealed that rainfall is decreasing, maximum temperature is increasing while minimum temperature is declining. Also, the result shows that job opportunity, education and security are the three main factors that influence migration and migrants tend to move from the surrounding rural area to the state capital. This corroborates the result of the LULC changes which showed an expansion of built-up over the years in the state capital across the study locations. Finally, varying impacts were identified in the relationship between rainfall, temperature, net migration and LULC classes.

It is evident that migration and climate change have resultant effects on LULC. Some of the impacts identified and inferred include increasing urbanization, deforestation, increased competition for water resources, loss of biodiversity, increased land fragmentation, land degradation, loss of cultural heritage and spread of diseases which boomerang as Urban heat islands, loss of green spaces, increased crime rates, water cycle disruption, soil erosion, ecosystem collapse, reduced crop yields, impacting food security, loss of forestry industries, increased poverty, increased healthcare costs and reduced economic growth. Migration, climate change and their impacts on LULC are disastrous. Therefore, immediate action is needed.

5.2 Recommendations

From the findings of the research, the following is recommended

5.2.1 Recommendations for policy improvement

Findings from the current study pose a need for a pragmatic approach in addressing the impact of migration and climate change on land use and land cover (LULC) transformation in North-Eastern Nigeria which requires a multifaceted policy framework. This study has shown the need to take necessary actions to address the trend in rainfall and temperature, migration and the changes in LULC classes by encouraging policy actors such as governments at all levels (For example, Ministries of Agriculture and Rural Development, Ministries of Environment, Ministries of Culture and Tourism, Ministries of Works and Housing and Ministries of Humanitarian Affairs and Disaster Management), the media, non-governmental organizations and other stakeholders in various aspects to be empowered for decision making. This is because the research involves action plans to improve people's ecological sustainability and socio-economic conditions.

Therefore, for policy improvement (having in mind SDG 11, 13 and existing policies like The Nigeria Climate Change Policy Response and Strategy (NCCPRS), the Great Green Wall Policy for Sahara and Sahel Initiative National Strategic Action Plan (GGWSAP), the National Adaptation Strategy and Plan of Action on Climate Change for Nigeria (NASPA-CCN), and the National Policy on Environment), it is crucial to adopt inclusive, people-centered policies that prioritize support for farmers and communities. This includes promoting climate-smart agriculture, implementing zoning laws to safeguard fragile ecosystems, and investing in reforestation initiatives to restore degraded lands. Such policies should focus on creating sustainable livelihood opportunities through skill development, small-scale enterprises, and microfinance initiatives to alleviate economic pressures driving migration.

Strengthening conflict resolution mechanisms is essential for mitigating disputes over land and resources, while the establishment of early warning systems, climate-resilient irrigation, and water harvesting facilities can protect livelihoods against climate-induced shocks. Additionally, the development of institutional frameworks for monitoring and managing land use changes using GIS technology will enable more effective planning and decision-making. Integrating Internally Displaced Persons (IDPs) into host communities by ensuring access to land, housing, and essential services is vital for fostering social stability.

Furthermore, raising public awareness about sustainable practices and incorporating climate education into school curricula will help build long-term community resilience. Regional cooperation is necessary to address transboundary challenges such as desertification and migration, while leveraging global climate finance mechanisms, such as the Green Climate Fund, can provide critical resources for implementing impactful projects. Finally, supporting research on migration patterns, climate impacts, and land use transformations will ensure that policies are informed by evidence, enhancing their effectiveness and sustainability.

5.2.2 Recommendations for performance improvement

The northeast region of Nigeria faces significant challenges from the combined effects of migration and climate change, which demand a thoughtful and strategic response. To address these issues, the Ministry of Environment has a vital role to play in developing climate-resilient land use plans and policies while ensuring that environmental regulations are effectively enforced. Such measures will promote sustainable management of the region's natural resources. Similarly, the Ministry of Agriculture and Tourism can drive change by encouraging sustainable land practices, such as agroforestry and conservation agriculture, while promoting ecosystem-based adaptation and integrated resource management to build resilience against climate impacts. At the same time, the Ministry of Works and Housing should prioritize improving housing and social amenities in areas hosting large numbers of migrants. This will help alleviate environmental pressure and enhance the well-being of both migrants and host communities.

A collaborative approach is essential. The government should engage with local communities, NGOs, and relevant agencies to understand their specific needs and challenges. Policymakers must be involved in designing evidence-based strategies that address migration and climate change while fostering international cooperation and knowledge sharing. Building capacity is also critical, which includes creating policy briefs and fact sheets for stakeholders and establishing systems for regular monitoring and evaluation to track the success and effectiveness of implemented policies.

Innovative solutions are needed to address these complex issues. Interdisciplinary approaches can help develop robust modeling frameworks that examine the connections between climate change and migration. Exploring modern tools, such as advanced land-use planning, adopting smart agricultural methods, promoting renewable energy sources, and leveraging artificial intelligence, can significantly enhance decision-making and outcomes.

Collaboration with neighboring countries is equally important to combat desertification, manage migration, and share critical resources effectively. Additionally, the region should seek financial support from global funding mechanisms like the Green Climate Fund and UNFCCC adaptation programs to implement these initiatives. Together, these actions aim to create a more sustainable, resilient, and socio-economically stable northeast Nigeria, addressing the pressing challenges of migration and climate change in a meaningful and practical way.

5.3 Contribution to knowledge

This research reveals clear signs that the climate is changing across the Northeastern region. Over the years, there has been a noticeable decline in total annual rainfall ($z = -0.442$), indicating a trend toward drier conditions. At the same time, maximum temperatures are steadily rising ($z = 0.046$), while minimum temperatures are slightly dropping ($z = -0.005$), making the nights cooler. Rainfall is heaviest during the wet season, averaging about 100.95mm. In contrast, the dry season brings the hottest days, with maximum temperatures reaching around 38.09°C. Interestingly, the nights are warmer during the wet season (20.94°C), likely due to more clouds and moisture in the air, which help trap heat and reduce cooling at night. The top reasons people relocate are for better job opportunities (33.5%), access to education (30.3%), and security (28.8%). A strong trend of people moving from rural areas to nearby state capitals was observed, with 55% of migrants making this shift. Cities are drawing people in with the promise of work, schools, and more secure living, while rural communities continue to struggle with poor infrastructure, insecurity, hunger, and hardship. These migration patterns are backed by how land use has changed over time. Built-up areas in the state capitals have expanded dramatically—from 720.61 km² in 1991 to 1,725.67 km² in 2021. This growth came at the cost of cultivated lands (which shrank from 41.14% to 30.75%), forests (6.64% to 4.92%), bare/sparse areas (0.54% to 0.48%), and water bodies (3.86% to 3.64%). Looking ahead to 2040, projections show more expansion: built-up areas will grow by 2.66%, cultivated land to 51.13%, forests to 25.44%, and water bodies to 3.68%. The accuracy assessment exceeds 80% confidence. The implication is that there is an increased urbanization trend, land degradation, and biodiversity loss, which threaten not only the ecosystems of Northeastern Nigeria but also its cultural heritage and the well-being of its population.

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APPENDICES

APPENDIX A Questionnaire

Questionnaire on the impact of migration and climate change on land use and land cover transformation of North-Eastern, Nigeria

INSTRUCTION: Choose the appropriate answer by clicking on it or filling in the blank space where necessary.

Section A: DEMOGRAPHIC CHARACTERISTICS OF RESPONDENTS

1. Gender: a. Male () b. Female ()
2. Age: a. Below 15 years () b. 15 – 25 () c. 26 – 35 () d. 36 – 45 () e. 46 – 55 () f. 55 and above.
3. Marital status: a. Single (), b. Married (), c. Divorced (), d. Widowed ().
4. Educational level: a. No formal education (), b. Primary (), c. JSS (), d. SSS (), e. Tertiary f. Others
5. Monthly Income: a. Less than 26,000 naira, b. 26,001 – 52,000, c. 52,001 – 104,000, d. 104,001 – 156,000, e.156,001 – 260,000 f. Above 260,000 g. No earnings
6. Household size: a. 2 - 5, b. 6 - 10, c. 11 - 20, d. 21 - 30, e. 31 – above

Section B: REASONS FOR MIGRATION

7. Are you a migrant (between states)? a. Yes (), b. No () If yes
8. From where to where? ………………………. To………………………
9. What was your reason for migration?
   a. Job opportunity (), b. Environmental/climate-related issues (), c. Education (), d. Unavailability of land () e. Insecurity () f. Others ()

Section C: LIVELIHOOD IMPACT

10. Compare the livelihood between the previous and current location
    a. Very good () b. Good () c. Same as previous () d. Poor () e. Very poor ()
11. What are the barriers to your main livelihood at current location?
    a. Declining market b. Deteriorating environmental/climate-related issues c. Inadequate capital d. Rising cost of transport e. Others
12. To what extent do you agree or disagree that migration was beneficial to you?
    a. Strongly agree b. Agree c. Neutral d. Disagree e. Strongly disagree
13. Who did you migrate with? a. Alone (), b. spouse (), c. spouse and children d. children e. friend (), f. Parents and siblings g. Others
14. What was the most difficult part of leaving your origin?
    a. Finance (), b. Leaving the family (), c. Leaving my Job (), d. finding a place to settle (), e. others ()

15. Problem faced in your new location?
    a. Finance (), b. Language barrier (), c. Accommodation (), d. Sickness (), e. Others

Section D: ATTITUDE TO MIGRATION

16. What age group migrates more?
    a. Below 15 years (), b. 15 – 25 (), c. 26 – 35 (), d. 36 – 45 (), e. 46 – 55 (), f. 56 and above.
17. What gender migrates the most? a. Male (), b. Female ()
18. How can migration be controlled?
    a. Provision of social amenities (), b. set policies and implement (), c. Security (), d. Youth empowerment () e. Loans and incentives f. Others

Section E: MIGRATION AT ORIGIN AND DESTINATION

19. What are the positive effects of migration on the Destination? a. New ideas and innovations (), b. Increased labor force (), c. Competition of businesses (), d. Cultural diversity () e. Others
20. What are the negative effects of migration on the destination? a. Unemployment (), b. Overcrowding (), c. Pressure on existing social amenities (), d. Pressure on land () e. Exploitation of migrants f. Others
21. What are the positive effects of migration on the origin? a. Reduced crime rate (), b. Less pressure on existing social amenities (), c. Reduced pollution (), d. Money is remitted to family and friends () e. Reduced pressure on land f. Others
22. What are the negative effects of migration on the origin? a. Loss of labor/man power (), b. Low competition of businesses (), c. Reduced birth rate (), d. Land use / Land cover change () e. Others
23. What are the effects of migration on land use and land cover in destination? a. Pressure on buildings (), b. Indiscriminate land development (), c. Pollution of land resources (), d. Pollution of water resources () e. Others
24. What are the effects of migration on land use and land cover in the origin? a. Less pollution of water resources (), b. Abandonment of buildings (), c. Abandonment of land (), d. Loss of existing infrastructure () e. Others

APPENDIX B Some figures

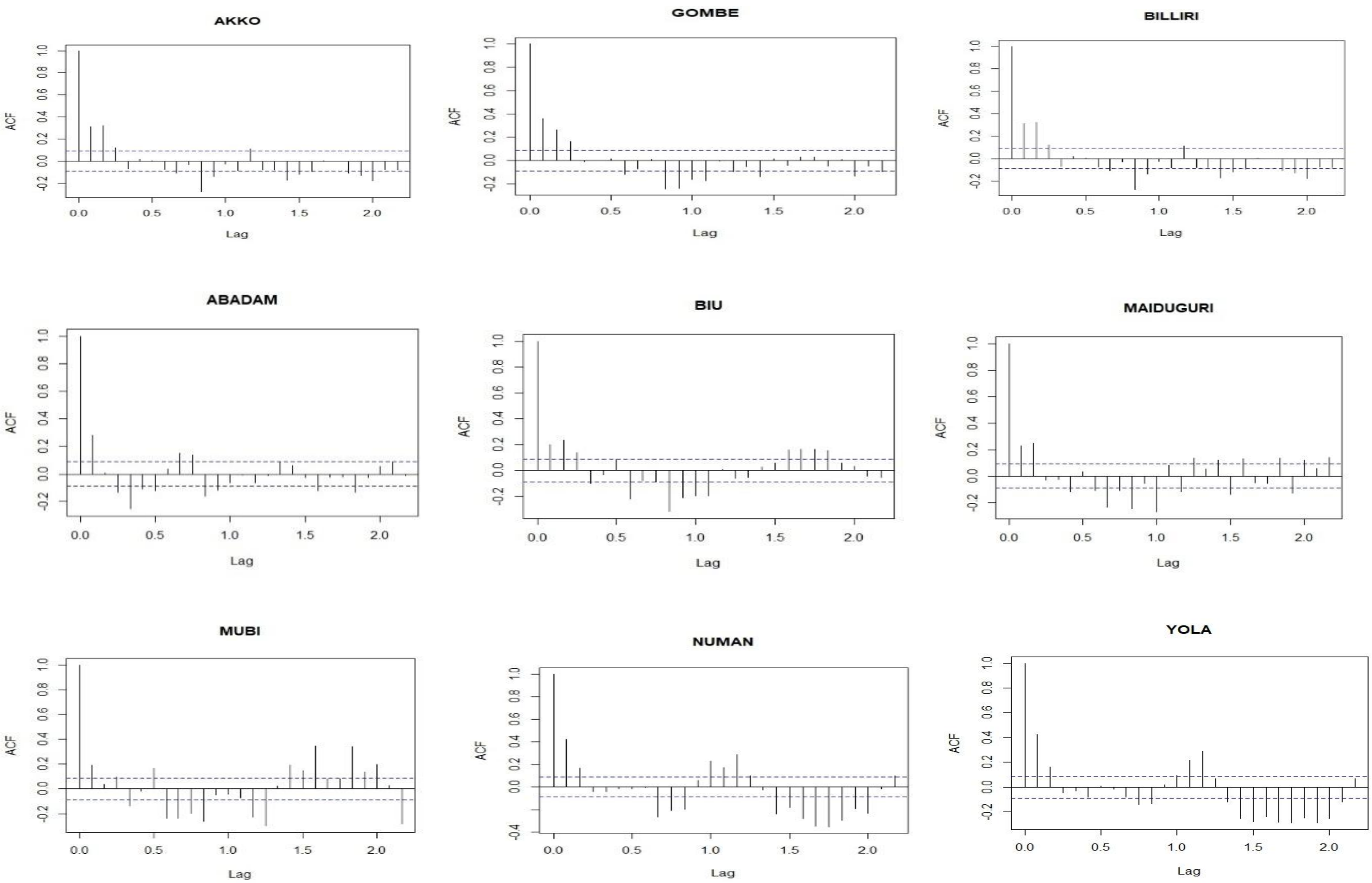

Figure. 1 Test for serial autocorrelation in total annual rainfall

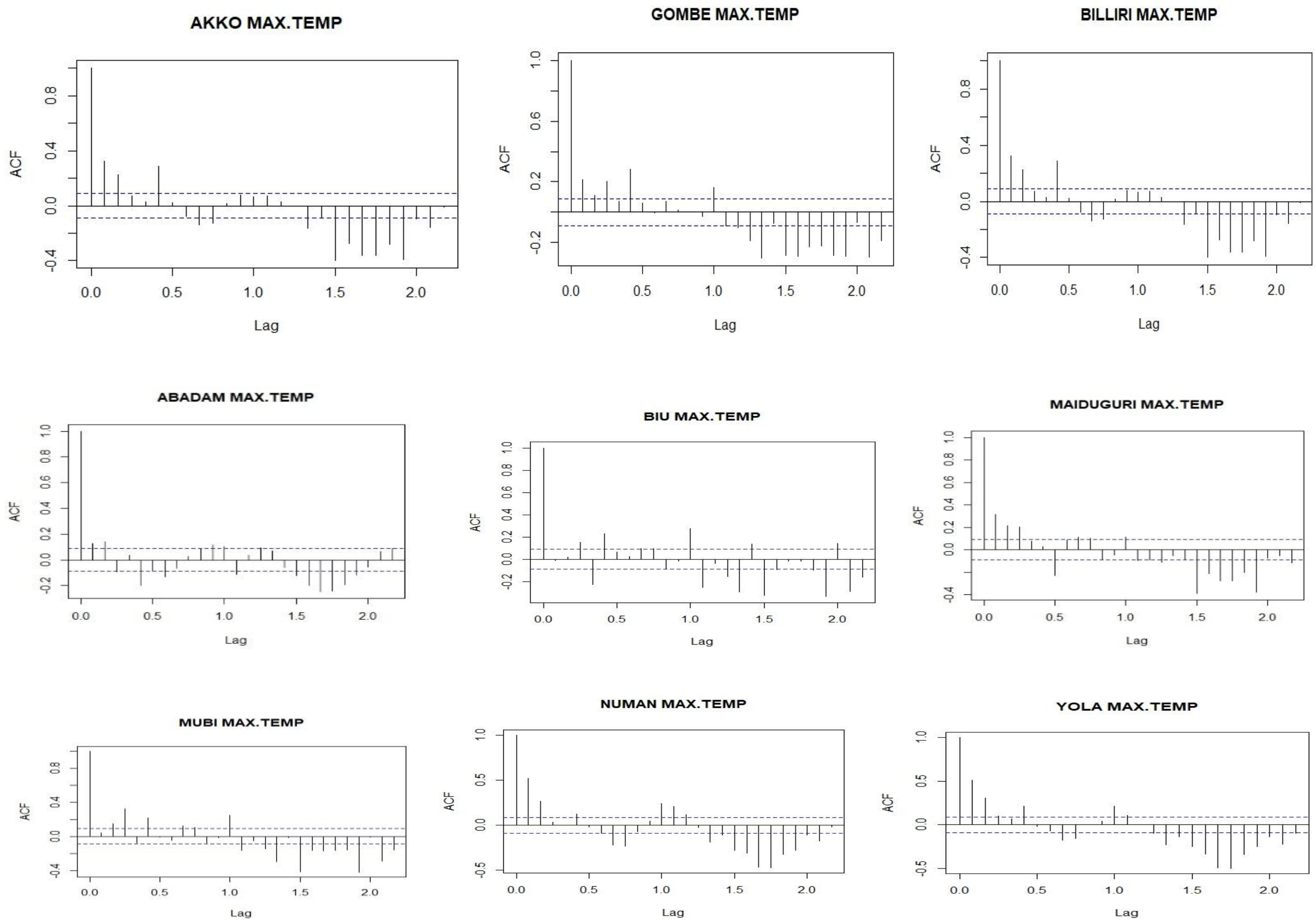

Figure. 2 Test for serial autocorrelation in maximum temperature

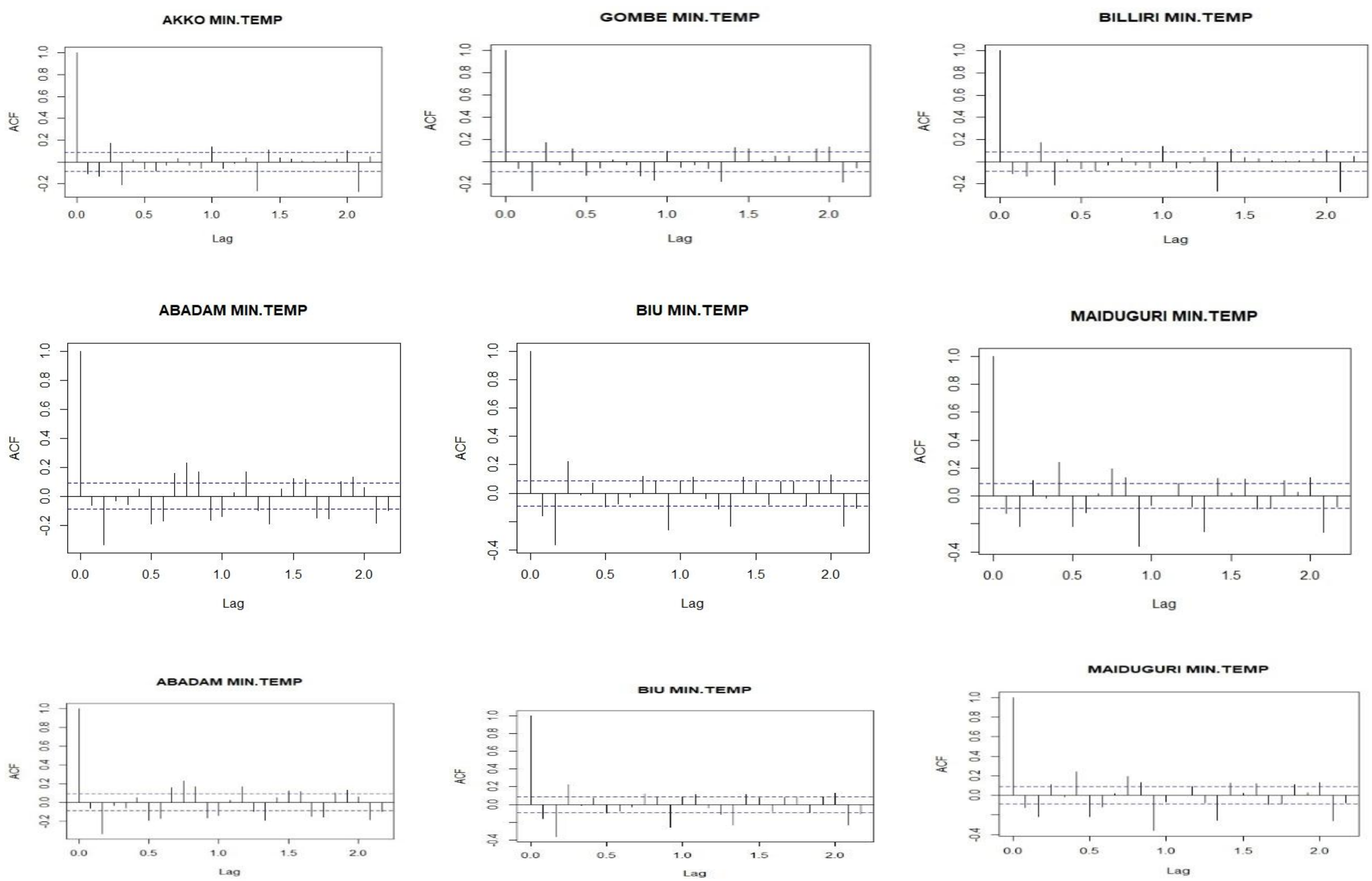

Figure. 3 Test for serial autocorrelation in minimum temperature

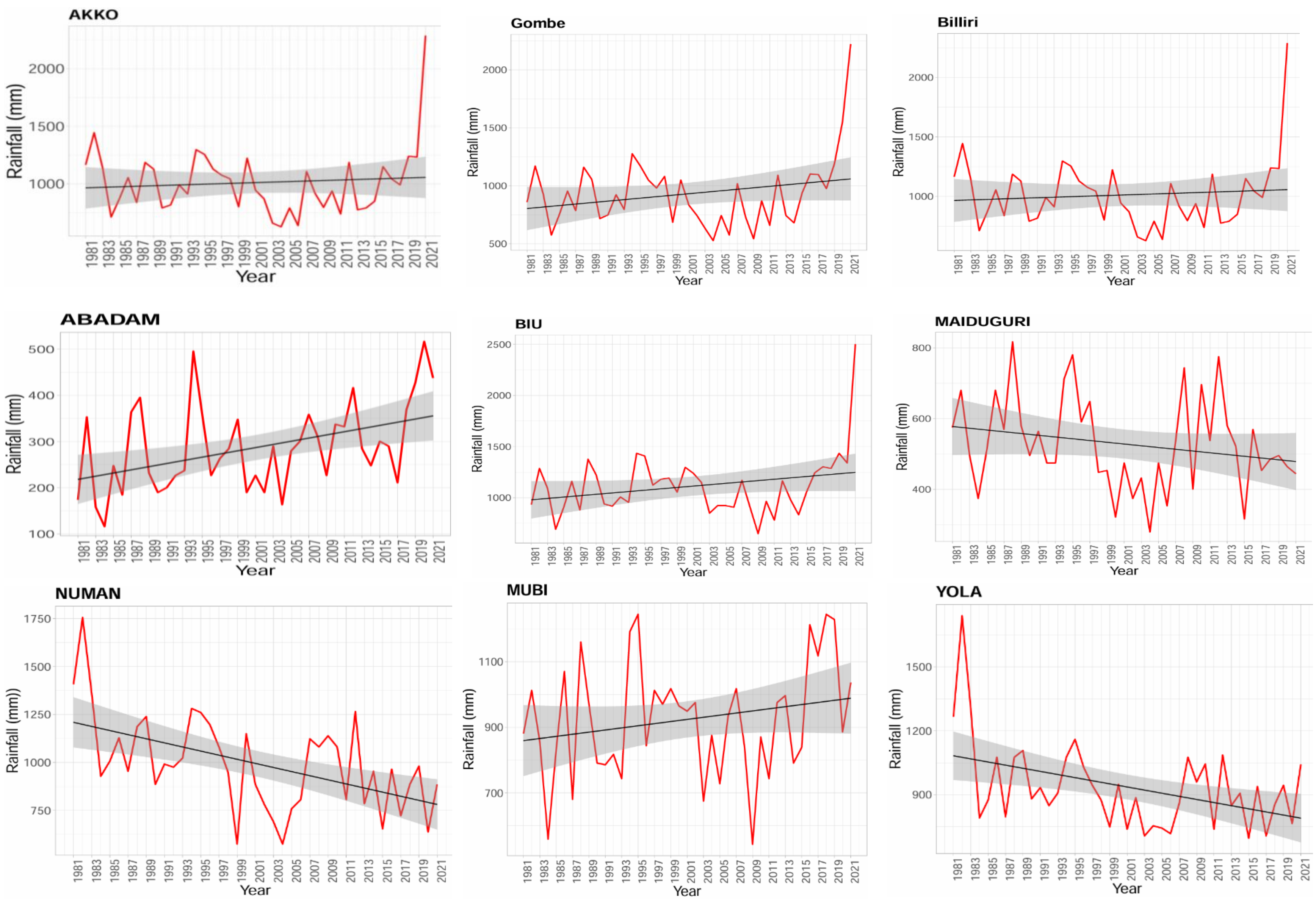

Figure. 4 Rainfall trend between 1991 to 2021 in the study area

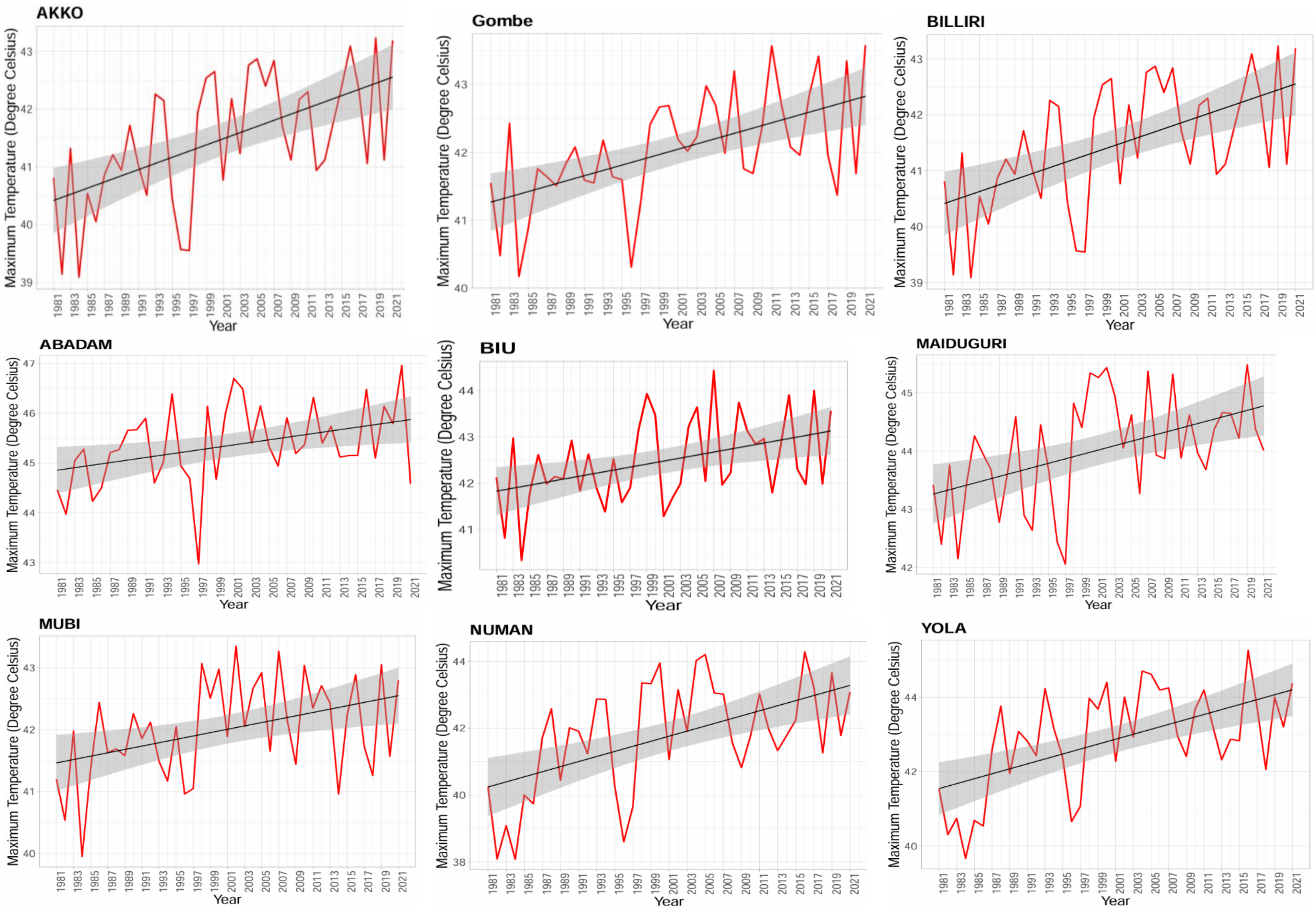

Figure. 5 Maximum Temperature between 1991 to 2021 in the study area

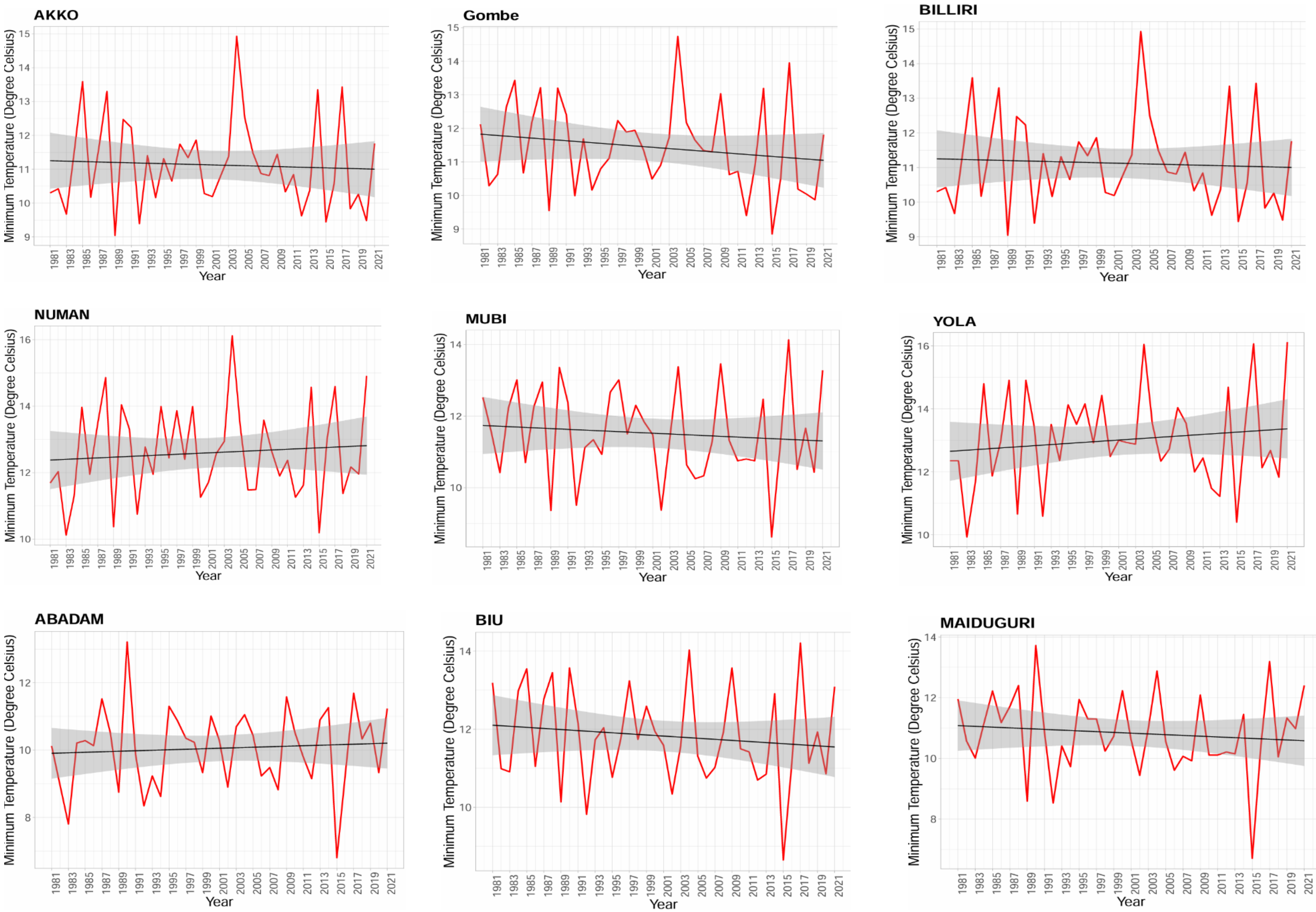

Figure. 6 Minimum Temperature trend between 1991 to 2021 in the study area

APPENDIX C Publication

climate

MDPI

Article

Analysis of the Observed Trends in Rainfall and Temperature Patterns in North-Eastern Nigeria

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Abstract: The present study offers a comprehensive evaluation of the monthly rainfall and temperature patterns across nine stations and fifty-nine points in North-Eastern Nigeria using NASA's Prediction of Worldwide Energy Resources data, spanning four decades (1981–2021). By employing the Mann–Kendall (MK) test and inverse distance weighting (IDW) interpolation, the researchers effectively detected and visualized trends in climate variables. The MK test results indicate contrasting rainfall trends, with notable decreases in Akko, Billiri, Maiduguri, Numan, and Yola, and increases in Gombe, Abadam, Biu, and Mubi. The trends in the maximum temperature were found to be statistically significant across all stations, showing a consistent increase, whereas the minimum temperature trends exhibited a slight but insignificant decrease. The application of the Theil–Sen slope estimator quantified these trends, providing nuanced insights into the magnitudes of changes in climate variables. The IDW results further corroborate the general trend of decreasing rainfall ($z = -0.442$), modest increases in the maximum temperature ($z = 0.046$), and a marginal decline in the minimum temperature ($z = -0.005$). This study makes an important contribution by advocating for the proactive dissemination of climate information. Given the evident climate shifts, particularly the increasing temperatures and fluctuating rainfall patterns, timely access to such information is crucial to enhancing climate resilience in the region. The rigorous statistical methods applied and the detailed spatial analysis strengthen the validity of these findings, making this study a valuable resource for both researchers and policymakers aiming to address climate variability in North-Eastern Nigeria. These research results may also be useful for understanding the climate variabilities in different parts of the world.

Keywords: rainfall; temperature; Mann–Kendall test; inverse distance weighting; Theil–Sen slope

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1. Introduction

The 2023 IPCC (Intergovernmental Panel on Climate Change) report emphasizes the urgent need for global cooperation to implement significantly more ambitious climate action plans to mitigate the impacts of climate change. It is imperative to substantially reduce greenhouse gas emissions into the atmosphere. Climatic factor variabilities, such as rainfall and temperature, have been widely empirically documented due to their profound