

Table of Contents

Abbreviation/Acronyms.....	ix
EXECUTIVE SUMMARY	xvi
Chapter 1 INTRODUCTION	1
CATCHMENT CHARACTERISTICS	3
1.1 Location and Boundaries	3
1.1.1 Plateau State	3
1.1.2 Geographical Coordinates and Boundaries	3
1.1.3 Benue State.....	4
1.1.4 Nasarawa State	4
1.1.5 Taraba State	5
1.2 Topography and Drainage	6
1.2.1 Plateau State	6
1.2.2 Benue State.....	7
1.2.3 Taraba State.....	8
1.2.4 Nasarawa State	9
1.3 River Systems and Drainage.....	11
1.3.1 Plateau State	11
1.3.2 Benue State.....	12
1.3.3 Taraba State.....	12
1.3.4 Nasarawa State	14
1.4 Geology.....	24
1.4.1 Plateau State	24
1.4.2 Benue State.....	25
1.4.3 Taraba State.....	25
1.5 Soil Types	29
1.5.1 Plateau State	29
1.5.2 Benue state	30
1.5.3 Taraba State.....	31
1.5.4 Nasarawa State	33
1.6 Land Use and Land Cover	35
1.6.1 Plateau State	35
1.6.2 Benue State.....	36
1.6.3 Taraba State.....	38
1.6.4 Nasarawa State	39
Chapter 2 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) ANALYSIS OF THE SHEMANKAR-KATSINA-ALA STRATEGIC CATCHMENTS	42
2.1 NDVI From Landsat Imagery	44
2.2 Landsat 8.....	44
2.2.1 Operational Land Imager (OLI)	45
2.2.2 Thermal Infrared Sensor (TIRS)	46
2.3 Landsat 9.....	46
Chapter 3 : CLIMATE AND HYDROLOGY	49
3.1 Plateau State.....	49
3.1.1 Climate	49
3.1.2 Hydrology.....	50

3.2 Benue State	53
3.2.1 Climate	53
3.2.2 Hydrology.....	54
3.3 Taraba State	57
3.3.1 Climate	57
3.3.2 Hydrology.....	58
3.4 Nasarawa State.....	61
3.4.1 Climate	61
3.4.2 Hydrology.....	62
3.5 Historical and Future Climatic Trends.....	67
3.5.1 Temperature Trends for the Shemankar-Katsina-Ala	68
3.5.2 Projected Mean Annual Temperature for Shemankar-Katsina-Ala	70
3.5.3 Projected Annual Rainfall for Shemankar-Katsina-Ala	71
3.4 Summary	73
Chapter 4 WATER RESOURCES	74
4.1 Hydrograph/Water Budget of the Catchment	74
4.2 The Strategic Catchments	77
4.2.1 Shemankar-Katsina-Ala Strategic Catchments	77
4.3 Surface Water Quality	81
4.3.1 Physical Parameters.....	82
4.3.2 Chemical Parameters.....	87
4.3.3 Biological Parameters	92
4.4 Hydrogeological Disposition of the Catchment.....	96
4.5 Water Resources Assessment Concept in the Catchment.....	97
4.5.1 Stream Flow and Discharge	97
4.5.2 Surface Water Resource Potential	101
4.5.3 Ground water potential	104
4.5.4 Groundwater Recharge.....	104
4.5.5 Water Uses and Demands For Shemankar-Katsina-Ala Catchments.....	107
4.5.6 Population.....	108
4.5.7 Calculated Model for Water Demand in the Shemankar-Katsina-Ala Catchment	124
4.5.8 Livestock	127
4.5.9 Inland Fishery	132
4.5.10 Fresh water aquaculture Water Demand Projections	133
4.5.11 Aquaculture Water Requirement.....	133
4.5.12 Irrigation Water Demand Projection	135
4.5.13 Irrigation Water (Net Irrigation Requirement).....	136
4.6 Existing Cropping Pattern	140
4.6.1 Currently practiced cropping pattern in public irrigation schemes	140
Chapter 5 Water quality data for surface and groundwater	141
5.1 Surface Water Quality	141
Chapter 6 CLIMATE CHANGE	144
6.1 Climate Change Scenarios.....	144
6.2 Nigeria’s First National Communication on Climate Change.....	144
6.3 Nigeria’s Second National Communication on Climate Change	145
6.4 Nigeria’s Third National Communication on Climate Change	145
6.5 The Paris Agreement	146

Chapter 7 FLOOD VULNERABILITY AND RISK.....	147
7.1 Flood Vulnerability.....	158
Chapter 8 THE CONCEPTUAL FRAMEWORK OF THE STAKEHOLDER ENGAGEMENT UNDER CONSIDERATION.....	163
8.1 Natural Resources	165
8.1.1 Forestry resources.....	165
8.1.2. Water Resources	167
8.1.3 Soils	171
8.1.4 Mineral Resources	172
8.1.5 Biodiversity Resources.....	174
8.1.6 Tourism Resources	177
8.1.7 Ecosystem Services in the Catchment.....	177
8.1.8 Water-Dependent Ecosystems and Habitats.....	179
8.2 Threats and Challenges	183
8.2.1 Agricultural Challenges.....	183
8.2.2 Proposed Solutions	183
8.2.3 Challenges of water resource management	184
8.2.4 Water levels and storage.....	185
8.2.5 Challenges in Water Storage:	186
8.2.6 Flood and Drought Patterns.....	187
8.2.7 Challenges to Biodiversity and Ecosystem Services.....	192
8.2.8 Security Challenges:	193
8.2.9 Economic Challenges:	194
8.2.10 Social Challenges:	194
8.2.11 Political Challenges:.....	194
8.2.12 Other Challenges:	195
8.3 Socio-Economic Data	198
8.3.1 Population Demographics and Growth in the Catchment	198
8.3.2 Economic Activities and Development Plans in the Catchment.....	201
8.3.3 Social Values and Norms	205
8.3.4 Poverty Index	209
8.4 Policies.....	213
8.4.1 Relevant laws and Policies	213
8.4.2 Institutional Arrangements and Governance.....	217
Chapter 9 Infrastructure and Assets	222
9.1 Water Supply and Treatment Infrastructure in the Catchment	222
9.2 Wastewater Management Infrastructure	225
9.3 Transportation and Communication Networks.....	228
Chapter 10 SHARED VISION	234
REFERENCES	241
GLOSSARY	250

LIST OF FIGURES

Figure 1.1: Map of the 20 strategic Catchment areas showing the Shemankar-Katsina-Ala Catchment Area (Source: MSL, 2024)	2
Figure 1.2: Shemankar-Katsina’ala Catchment showing the LGA's (Source: MSL, 2024)	6
Figure 1.3: Digital Elevation Model of Shemankar-Katsina-Ala Catchment (Source: MSL, 2024)...	10
Figure 1.4: Drainage Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)	15
Figure 1.5: The Catchment Map showing the recorded gauging stations (Source: MSL, 2024)	17
Figure 1.6: Map of Meteorological stations (Source: MSL, 2024)	18
Figure 1.7 Population projection Graph of the Catchment (Source:MSL, 2024)	21
Figure 1.8: Geological map of the catchment area (Source: MSL, 2024)	28
Figure 1.9: Soil map of the catchment area (Source: MSL, 2024)	34
Figure 1.10: Land Use/Land Cover Map of the Catchment (Source: MSL, 2024)	40
Figure 1.11: Map showing the vegetation cover in the catchment area (Source: MSL, 2024)	41
Figure 2.1: NDVI Map of the Catchment (Source: MSL, 2024)	48
Figure 3.1: Rainfall Histogram for Shemankar - Katsina Strategic Catchment	65
Figure 3.2: Evapotranspiration Histogram for Shemankar-Katsina Strategic Catchment	67
Figure 3.3: Mean monthly temperatures from 1981 to 2022 and 2023 to 2050 for Shemankar-Katsina-Ala	69
Figure 3.4: Projected Mean Annual Temperature Trend (1981-2050) for Shemankar-Katsina-Ala...	71
Figure 3.5: Projected Annual Rainfall Trend (1981-2050) for Shemankar-Katsina-Ala	72
Figure 4.1: Hydrograph of Shemankar Strategic Catchment Based on HEC-HMS modelling for Strategic catchment.	78
Figure 4.2: 40 - Year Summary Hydrograph of Shemankar Strategic Catchment	78
Figure 4.3: Hydrograph of Shemankar Strategic Catchment for Specific Year	79
Figure 4.4: Water Budget for Shemankar Strategic Catchment	79

Figure 4.5: Monthly Actual Evapotranspiration Distribution for the Shemankar Catchment..... 80

Figure 4.6: Hydrogeological provinces of the catchment (Source: MSL, 2024).....96

Figure 4.7: Graphical Representation of the Projected Population Shemankar-Katsina-Ala Catchment
..... 113

Figure 4.8: Graphical representation of Municipal Water demand 2006 - 2050 for Shemankar-
Katsina-Ala catchment..... 118

Figure 4.9: Graphical Representation of the Water Capacity of the Catchment 123

Figure 7.1: The flow chat of the methodology 147

Figure 7.2: Digital Elevation Model of Shemankar-Katsina_Ala catchment (Source: MSL, 2024). 148

Figure 7.3: Slope map of Shemankar-Katsina Ala catchment (Source: MSL, 2024)..... 149

Figure 7.4: Rainfall map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024) 151

Figure 7.5: Distance to River Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024).... 153

Figure 7.6: LULC Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024) 155

Figure 7.7: Flood Vulnerability Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024) 157

Figure 7.8: Flood Risk Map of the Catchment (Source: MSL, 2024) 159

Figure 7.9: Flood Event Map of the Catchment (Source: MSL, 2024) 160

Figure 7.10: Graphical Representation of the LULC Analysis (Source: MSL, 2024) 161

Figure 8.1: Forest Reserves in Shemankar-Katsina-Ala Catchment (Source: MSL, 2024) 166

Figure 8.2: Map showing the mineral resources in the catchment area (Source: MSL, 2024) 174

Figure 8.3: Threats and Challenges map of Shemankar-Katsina-ala catchment (Source: MSL, 2024)
..... 197

Figure 8.4: Crops grown in the Catchment (Source: MSL, 2024).....205

Figure 8.5: Poverty Levels Map of the Catchment (Source: MSL, 2024).....212

Figure 8.6: Policy map of Shemankar-Katsina-Ala catchment (Source: MSL, 2024)213

LIST OF TABLES

Table 1.1: Morphometric Analysis of Shemankar-Katsina-Ala Catchment.....	16
Table 1.2: Population projection for Shemankar-Katsina-Ala Catchment	19
Table 1.3: Summary of Shemankar-Katsina-Ala Catchment	22
Table 3.1: Rainfall Data for Shemankar - Katsina Strategic Catchment	64
Table 3.2: Evapotranspiration Data for Shemankar-Katsina Strategic Catchment.....	66
Table 3.3: Mean monthly temperature for Shemankar-Katsina-Ala for 1981-2022 and 2023-2050 ..	68
Table 4.1: Summary of Discharge, Rainfall and Evapotranspiration Data for Shemankar Strategic catchment	80
Table 4.2: Resource Potential for HA4 (Source: JICA project Team)	102
Table 4.3: Runoff Yield for SHAs in HA-4.....	103
Table 4.4: Amount of Groundwater by Newly Drilled Boreholes and Borehole Rehabilitation.	104
Table 4.5: Groundwater Recharge and Groundwater Demand (2030)	105
Table 4.6: Groundwater Recharge and Demand by effect of climate (2030)	106
Table 4.7: Average annual rate of population growth (UN, 2012).....	108
Table 4.8: Population of local government areas covered by the catchment.....	109
Table 4.9: Municipal Water demand 2006 - 2050 for Shemankar-Katsina-Ala catchment.....	114
Table 4.10: Water Capacity of the Catchment.....	119
Table 4.11: Water Requirements (Litre /Animal/Day)	128
Table 4.12: Case of water requirement per head of livestock	128
Table 4.13: Number of livestock heads/ fowls in 2009 / 2010	128
Table 4.14: Corresponding livestock water requirement n 2009 / 2010	129
Table 4.15: Estimated growth rate of livestock heads during the period 2010 ~ 2030.....	129
Table 4.16: Number of livestock heads/ fowls projected in 2030	129
Table 4.17: Corresponding livestock water requirement projected in 2030	130



Table 4.18: Number of livestock heads/ fowls projected in 2050	130
Table 4.19: Corresponding livestock water requirement projected in 2050	130
Table 4.20: Breakdown of water requirement into hydrological area (HA).....	131
Table 4.21: Fish Farm Pond	132
Table 4.22: Projected Water Demand for Inland Aquaculture.....	133
Table 4.23: Projected Human Population, Fish Demand and Supply in Nigeria (2000-2015)	134
Table 4.24: Crop patterns were recommended in the Agriculture Thematic Report (SMEC, 2017)	135
Table 4.25: Estimated Shemankar Catchment Livelihood Water Required in Cubic Meter (M ³) for 2022 to 2050	138
Table 4.26: Water Demand Projections for HA 4 2030 (Source: JICA, 2014)	139
Table 4.27: Cropping Seasons	140
Table 4.28: HAs-2/3/4 Existing Cropping Pattern	140
Table 5.1: Preliminary Conclusion of Water Quality Status of Some Rivers in the Northern States of Nigeria.....	142
Table 5.2: Water Balance Analysis of the Catchment	143
Table 6.1: Class name Parameters for LULC analysis (Source: MSL, 2024)	161

Abbreviation/Acronyms

Abbreviation/ Acronym	Description
°C	Degree Celsius
°F	- Fahrenheit
Abbreviation/ Acronym	Description
ACReSAL	Agro Climate Resilience in Semi- Arid Landscapes.
ADP	Agriculture Development Program
AFOLU	Agriculture, Forestry, and Other Land Use
AfDB	African Development Bank
AMSL	Above Mean Sea Level
ATA	Agricultural Transformation Agenda
AWF	African Water Facility
BCM	Billion Cubic Metre
BENSEPA	Benue State Environmental Protection Agency
CLTS	Community-Led Total Sanitation
CCAFS	Climate Change, Agriculture and Food Security

CHIRPS	Climate Hazards Group InfraRed Precipitation with Station.
CJTF	Civilian Joint Task Force
CMCs	Catchment Management Committees.
CN	Curve Number
DEM	Digital Elevation Model
EA	Executing Agency
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization of United Nations
FDC	Flow Duration Curve
FEPA	Federal Environment Protection Agency
FGD	Focus Group Discussion
FMARFS	Federal Ministry of Agriculture and Food Security
FMEEnv	Federal Ministry of Environment
FMWR	Federal Ministry of Water Resources
GBV	Gender-based violence
GHG	Greenhouse gas

GCM	Global Climate Model
GEFC	Global Environmental Flow Calculator
GIS	Geographic Information System
GPS	Global Positioning System
GRDB	Global Runoff Data Base
GRDC	Global Runoff Data Centre
Ha	Hectares
ICRC	International Committee of the Red Cross.
IDPs	Internal Displace Person's
IP	Irrigation Project
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
IWRMD	Integrated Water Resources Management and Development
IWRMP	Integrated Water Resources Management and Planning
JICA	Japan International Cooperation Agency
LCBC	Lake Chad Basin Commission
LGP	Length of Growing Period
LUA	Land Use Act
LULC	Land Use Land Cover

M	Metres
M&E	Monitoring & Evaluation
masl	Metres above sea level
MCM	Million Cubic Metre
MDG	Millennium Development Goal
MSF	And Médecins Sans Frontières
MSL	Mecon Services Limited
NCWR	National Council on Water Resources
NDVI	Normalized Difference Vegetation Index
NEAZDP	North East Arid Zone Development Programme
NESREA	The Nigerian Environmental Standards and Regulations Enforcement Agency.
NESREA	The Nigerian Environmental Standards and Regulations Enforcement Agency
NSEPA	Nasarawa State Environmental Protection Agency
NFDP	National Fadama Development Program
NGO	Non-Governmental Organization
NGSA	Nigerian Geological Survey Agency
NIHSA	Nigeria Hydrological Services Agency

NIMET	Nigerian Meteorological Agency
NIMET	Nigerian Meteorological Agency
NIP	National Implementation Plan
NIWRMC	Nigeria Integrated Water Resources Management Commission
NNJC	Nigeria-Niger Joint Commission
NRCS	Natural Resources Conservation Service
NRW	Non-Revenue Water
NSE	Nash-Sutcliffe Efficiency
NWRMP	National Water Resource Master Plan
OSGOF	Office of Surveyor General
PET	Potential Evapotranspiration
PIM	Participatory Irrigation Management
PMT	Project Management Team
PPT	Precipitation
PSC	Project Steering Committee
PWD	Projected Water Demand
TSEPA	Taraba State Environmental Protection Agency
TSWSA	The Taraba State Water Supply Agency
RBDA	River Basin Development Authority

RRR	Ministry of Reconstruction, Rehabilitation, and Resettlement
RUWASA	Rural Water Supply and Sanitation Agency
SAP	Strategic Action Plan
SAPDWR	Strategic Action Plan for the Development of Water Resources
SCS	Soil Conservation Service
SESA	Strategic Environmental and Social Assessment
SGS	Streamflow Gauging Station
SHA	Sub Hydrologic Area
SMA	State Ministry of Agriculture
SME	Small Medium Enterprise
SMM	Soil Moisture Method (<i>Hydrology rainfall-runoff model within WEAP</i>)
SMWR	State Ministry of Water Resources
SSEA	Strategic Social and Environmental Assessment
SUBEB	Small Medium Enterprise
SWA	State Water Agencies
TAP	Technical Advisory Panel
TOR	Terms of Reference
TRIMING	Transforming Irrigation Management in Nigeria

UBE	Universal Basic Education
UNESCO	United Nations Educational Scientific & Cultural Organization
UNICEF	United Nations Children’s Fund
UNFCCC	United Nations Framework Convention on Climate Change
UTM	Universal Traverse Mercator
VAPP	Violence against Persons Prohibition
WASH	Water, Sanitation, and Hygiene
WB	World Bank
WEAP	Water Evaluation and Planning
WHO	World Health Organisation
WMO	World Meteorological Organization
WRA	Water Resources Act
WRM	Water Resources Management
WSS	Water Supply and Sanitation
WSSSRP	Water Supply and Sanitation Sector Reform Programme

EXECUTIVE SUMMARY

The Shemankar-Katsina-Ala catchment in Nigeria is a significant portion of the Katsina-Ala River system, covering approximately 5,190,454 hectares. The river network plays a crucial role in central Nigeria's hydrology and supports diverse ecosystems and socioeconomic activities, such as agriculture, fishing, and commerce. The catchment spans parts of Plateau, Benue, Taraba, and Nasarawa states, each with unique geographical and cultural connections.

The region faces environmental and socioeconomic issues, including deforestation, erosion, and flooding risks, particularly during the rainy season. Unregulated agricultural water use heightens water scarcity during dry seasons, impacting productivity and livelihoods. The fertile floodplains support staple crops such as maize, yam, cassava, and rice, while fishing is essential for local sustenance. However, rural poverty, lack of infrastructure, and environmental degradation limit development.

The Shemankar-Katsina-Ala catchment is influenced by the broader hydrological dynamics of the Jos Plateau and surrounding states, with a focus on water resources that support agriculture, biodiversity, and settlement stability. Rivers from the Jos Plateau, including tributaries feeding the Kaduna and Benue rivers, play critical roles in local agriculture, water supply, and erosion patterns. Wetlands and floodplains within the catchment offer valuable flood control and water retention for dry-season farming, though periodic flooding presents challenges, especially during peak rains.

Seasonal rivers and wetlands serve as important water reserves, supporting livestock and irrigation when rainfall is scarce. However, the catchment faces issues like soil erosion on steeper slopes, degradation of wetlands, and water scarcity during dry months. These dynamics make the Shemakar catchment critical for sustaining local agriculture and settlements, though ongoing management challenges impact water availability and land use.

Hydrological challenges across the Shemankar-Katsina-Ala catchment include seasonal flooding, dry-season water scarcity, and environmental degradation. Each state's unique topographical and drainage characteristics necessitate tailored approaches to manage these challenges and sustainably harness the region's water resources.

The geology of the Shemankar-Katsina-Ala catchment spans a geologically diverse area influenced by the Jos Plateau and the Benue Trough, impacting soil fertility, mineral resources, and water retention.

The Shemankar-Katsina-Ala catchment is characterized by its diverse geology and landscape, which supports various agricultural practices and land uses. Its soil types include Ferruginous Tropical Soils, Lateritic Soils, Alluvial Soils, Hydromorphic Soils, and Volcanic Soils. These soil types shape the catchment's agricultural patterns, requiring tailored management practices to maintain soil health and optimize crop yields across diverse ecological zones.

The catchment is characterized by a range of land use and land cover types, reflecting its varied topography, climate, and socio-economic activities. Agriculture is the dominant land use, with extensive areas dedicated to crop cultivation, especially cereals, root crops, and legumes. Floodplains along major rivers are key for rice and vegetable farming, while upland areas with cooler climates support crops like potatoes, cabbage, and tea. Livestock farming also plays a significant role, particularly cattle, sheep, and goats, which thrive in expansive grasslands and savanna regions.

Mining activities have left a marked impact on the landscape, with historical tin mining leaving a legacy of degraded lands and disrupting the natural environment. Urbanization has transformed agricultural land and natural vegetation into residential and commercial areas, promoting agricultural expansion and new settlements. However, urban growth also exerts pressure on natural resources, particularly forests.

Forests and woodlands provide essential ecosystem services, but deforestation is a major challenge. Protected areas, including wildlife parks and forest reserves, support biodiversity conservation and eco-tourism. Conservation efforts, such as afforestation and reforestation programs, aim to counteract deforestation and stabilize soils. Wetlands along the catchment's rivers contribute to economic activities like fishing and rice farming, but face pressures from sand dredging and land reclamation, disrupting their ecological functions.

The Shemankar-Katsina-Ala catchment presents a complex landscape shaped by agricultural dependency, mineral resource extraction, urban growth, and ongoing conservation efforts, underscoring the need for sustainable land-use practices to support local livelihoods and environmental health.

The Shemankar Katsina Ala catchment, has a tropical savanna climate with distinct wet and dry seasons. The catchment experiences average annual temperatures ranging from 18°C to 25°C, with

cooler nights during Harmattan and warmer days in the hot season. Rainfall is crucial for agriculture but can lead to flooding. Humidity is high during the wet season but significantly lower in the dry season.

Hydrology includes major rivers and dams, stream flow, flood and drought, groundwater resources, and access challenges. Groundwater is essential for rural areas, but access challenges include boreholes and wells, and northern regions with crystalline rocks face significant water scarcity. Flooding and water management are crucial, as the Benue River floods during the rainy season, benefiting agriculture but also causing damage and disruption. Irrigation schemes enhance dry-season agricultural output, while small-scale hydropower projects aim to provide renewable energy and support local economies.

Climatic trends and water quality parameters highlight the critical need for effective water resource management within the catchment to ensure ecological health and the safety of water supplies for agricultural and domestic use. The Climate Hazards Group InfraRed Precipitation with Station (CHIRPS) dataset offers high-resolution precipitation estimates from 1981 to the present, making it ideal for hydrological studies in data-scarce regions. The SCS Rainfall-Runoff Model estimates runoff based on rainfall and catchment characteristics using the Curve Number (CN) method, which varies from 30 to 100, reflecting land cover and soil permeability.

The hydrograph and water budget are essential tools for understanding the flow rate of a river over time, as well as the water budget. The strategic catchments analysis includes Farin Ruwa Catchment, Katsina Ala Catchment, and Shemankar Catchment. Farin Ruwa and Shemankar have a seasonal pattern with minimal rainfall, peak flow in August, six months of water surplus, and six months of deficit. The overall water budget for these catchments is 20,337.43 mm, indicating positive opportunities for agricultural activities.

The surface water quality within the catchment area of Plateau, Benue, Taraba, and Nasarawa States is critical for ecological health, public safety, agricultural productivity, and industrial processes. The catchment experiences varying water quality influenced by climatic, geological, and anthropogenic factors. Physical parameters include temperature, pH, turbidity, nutrients, heavy metals, and dissolved oxygen levels. High temperatures during the dry season can lead to reduced dissolved oxygen levels, which are vital for aquatic life.

Heavy metals, such as lead and cadmium, are present in the catchment, especially in areas adjacent to mining activities and industrial sites. Regular monitoring is necessary to assess the risk of

contamination and its implications for public health and aquatic ecosystems. Dissolved oxygen levels in the catchment generally range from 4.0 to 8.0 mg/L, but in heavily polluted areas, they can drop significantly, posing a threat to fish and other aquatic organisms that depend on oxygen-rich water.

Effective water resources assessment is essential for managing water availability, agricultural productivity, and environmental health, particularly in regions with semi-arid climates and unpredictable rainfall. Key aspects of this assessment include stream flow and discharge, topography, water quantity implications, and sustainability challenges. Over-reliance on groundwater during dry periods poses risks of depletion, and land use changes, such as deforestation, further exacerbate these challenges.

The Shemankar catchment receives an average annual precipitation of 1,150 mm, with 24% contributing to runoff. The total internal runoff generation is estimated at 244 billion cubic meters per year, leading to a surface water resource potential of around 330 BCM annually. When considering inflows from neighboring countries, the total water resources potential increases to approximately 374 BCM, with around 89 BCM derived from these external sources. The groundwater resources potential for the catchment is estimated at 142 BCM per year, based on groundwater recharge estimates.

The average annual runoff yield for the Shemankar catchment is 178,483 km², with an average annual precipitation of 610 mm/year, total runoff volume of 7.2 BCM/year, and groundwater recharge of 24 mm/year. Groundwater recharge has been impacted by climate change, leading to varying levels of reduction across different areas. Effective management of surface and groundwater resources in the Shemankar catchment is critical, especially considering the impacts of climate change on water availability and the reliance on both internal and external water sources.

The projected water requirements for the Shemankar-Katsina-Ala catchment from 2022 to 2050 highlight the increasing challenges posed by population growth, environmental changes, and socio-economic dynamics. The report details the water needs for human domestic use and livestock across the catchment, emphasizing the need for sustainable water resource management to support agricultural activities and ensure community resilience.

A GIS-based weighted overlay analysis was employed to assess flood vulnerability within the Shemankar-Katsina Ala catchment, which involved several key steps: data collection, standardization, weight assignment, and weighted overlay analysis.

The flood vulnerability map in the Shemankar-Katsina-Ala catchment has identified five distinct risk zones: Highly Not Vulnerable, Moderate, Vulnerable, and Highly Vulnerable. These zones are characterized by low elevation, distance from rivers, and favorable LULC. The GIS-based flood vulnerability assessment provides valuable insights into the spatial distribution of flood risk within the catchment, which can be crucial for developing effective flood mitigation and management strategies.

Stakeholder engagement concepts include natural resources, threats and challenges, socio-economics, and policies. The study entailed the engagement of institutional stakeholders to develop a strategic catchment management plan at a macro level. The catchment is endowed with diverse natural resources, including forest reserves, water resources, soil resources, agricultural resources, mineral resources, biodiversity, and threats such as deforestation, soil erosion, water scarcity, climate change, and conflict and insecurity.

The catchment is a biodiversity hotspot, with unique ecosystems, endangered species, and diverse wildlife. Ecosystem services provide essential services such as provisioning services, regulating services, cultural services, and supporting services. Challenges and threats include deforestation, habitat loss due to urbanization and infrastructure development, pollution from agriculture, industry, and domestic sources, climate change, and overexploitation of natural resources.

Protecting and managing the biodiversity and ecosystem services requires sustainable land use practices, protected area management, community-based conservation, policy and legislation, and education and awareness. Addressing these challenges and implementing effective conservation strategies will help the Shemankar-Katsina-Ala catchment support the livelihoods of its people and maintain its ecological integrity for future generations.

Water resource management challenges in the Shemankar Catchment include heavy rainfall, rapid runoff, inadequate drainage systems, and droughts. Flooding causes heavy rainfall, rapid runoff, and inadequate drainage systems, while droughts cause prolonged periods of below-average rainfall, increased evapotranspiration, reduced water availability, crop failure, food insecurity, soil degradation, and desertification. Other challenges include sedimentation, competition for limited water resources among agriculture, industry, and urban settlements, and seasonal variability.

The Shemankar Catchment faces numerous water resource challenges, including water quality degradation, weak water governance, infrastructure limitations, habitat disruption and degradation, water scarcity, security challenges, and economic and social issues. These challenges require a multi-faceted approach that includes improved water management practices, infrastructure development, robust governance frameworks, and conflict resolution strategies.

The catchment area is characterized by rapid population growth, diverse ethnic groups, rural dominance, and a rich cultural heritage. Agriculture is the primary economic activity, with crops like maize, yam, cassava, and rice being major staples. Mining is also a significant economic activity, with the region rich in mineral resources. Tourism has potential due to its diverse landscapes, cultural heritage, and wildlife.

Cultural diversity and religious diversity are also significant aspects of the region. Education and healthcare access persist, particularly in rural areas. Environmental laws and policies protect the environment, land use and planning laws guide land development and resource management, and water resource management laws govern the use, conservation, and protection of water resources. Mining regulations govern mining activities.

Challenges and opportunities include population growth, environmental degradation, poverty, and climate change. Sustainable management of water, land, and mineral resources is crucial, and climate change impacts agriculture, water resources, and ecosystems pose risks. Effective governance, sustainable development practices, and community engagement are necessary to address these challenges and capitalize on the region's potential.

The classification of local governments in the Shemankar - Katsina Ala Catchment reveals four main categories of poverty, namely **Moderate Poverty (31% - 50%)** which encompasses the following LGA's – Makurdi, Akwanga, Keana, Lafia, Vandeikya and Shendam, **High Poverty (51% - 70%)** which encompasses the following LGA's – Gboko, Gwer East, Gwer West, Kwande, Tarka, Awe, Doma, Obi, Barkin Ladi, Bokkos, Kanke, Langtang North & South, Mangu, Mikang, Pankshi, Qua'an Pan, Wase, Donga, Kurmi, Takum, Ussa, and Wukari., and **Very High Poverty (71% and above)** encompassing this LGA's- Buruku, Guma, Katsina-Ala, Logo, Ukum and Ibi. No local governments were categorized in the very low or low poverty ranges, highlighting the severity of the poverty situation in this catchment.

A shared vision for the Shemankar-Katsina-Ala catchment aims to establish a harmonious mechanism for resource utilization and drive sustainable development. Objectives include improved water quality, sustainable land use, biodiversity conservation, community empowerment, climate change resilience, and gender equality. Stakeholder engagement involves government agencies, local communities, private organizations, NGOs, and academic institutions, while implementing water management strategies, sustainable land use, environmental protection, community benefits, economic development, climate change resilience, and monitoring and evaluation. By working together and implementing these strategies, the Shemankar-Katsina-Ala catchment can achieve sustainable development and ensure a healthy environment for future generations.

CHAPTER 1 INTRODUCTION

Shemankar Katsina-Ala is a geographical area associated with the catchment of the Katsina-Ala River, covering about 5,194,000 Hectars, which is a significant waterway in Nigeria. It is a transboundary catchment that is influenced by the Katsina-Ala River, a major tributary of the Benue River, contributing to its flow and playing an essential role in the hydrology of central Nigeria. The Katsina-Ala River originates in the Bamenda Highlands of Cameroon and flows through Nigeria, primarily the states of Benue and Taraba. The river passes through notable areas including Katsina-Ala town in Benue State. The entire Katsina-Ala River basin is part of the larger Benue River basin, which covers an expansive area across several states including Plateau State, Benue State, Taraba State and Nasarawa State. The Shemankar River partly flows through this region, contributing to the wider hydrological network. The catchment is subject to environmental issues such as deforestation, erosion, and potential flooding, especially during the rainy season. Sustainable water management is essential for preserving the ecosystems and agricultural productivity dependent on the Katsina-Ala River. Water management in the Shemankar Katsina-Ala catchment is crucial due to varying rainfall patterns, soil erosion, deforestation, and the potential for both seasonal flooding and drought. Unregulated water usage, especially for agriculture, poses long-term challenges to water availability.

The communities around the Shemankar Katsina-Ala catchment area rely heavily on the river for agriculture, fishing, commerce and transportation. It provides water for irrigation, fishing, and other forms of agriculture in the region. During the dry season, water scarcity can become an issue, affecting livelihoods. However, there are potentials for improvement in terms of modern irrigation techniques to maximize water use efficiency. The rivers support fishing, a key livelihood for many residents. The fertile floodplains around the Katsina-Ala River support agriculture, including crops like maize, yam, cassava, and rice. Socioeconomic challenges include rural poverty, lack of infrastructure, and environmental degradation.

The absence of advanced water management systems impacts productivity, particularly during periods of drought or flooding. The catchment area consists of savannah grasslands, riverine forests, and gallery forests along the riverbanks. The region's ecology is shaped by a tropical climate with a rainy season (May to October) and a dry season (November to April). Wildlife is diverse, with species ranging from aquatic animals such as fish and amphibians to land species like antelopes, monkeys, and various birds.

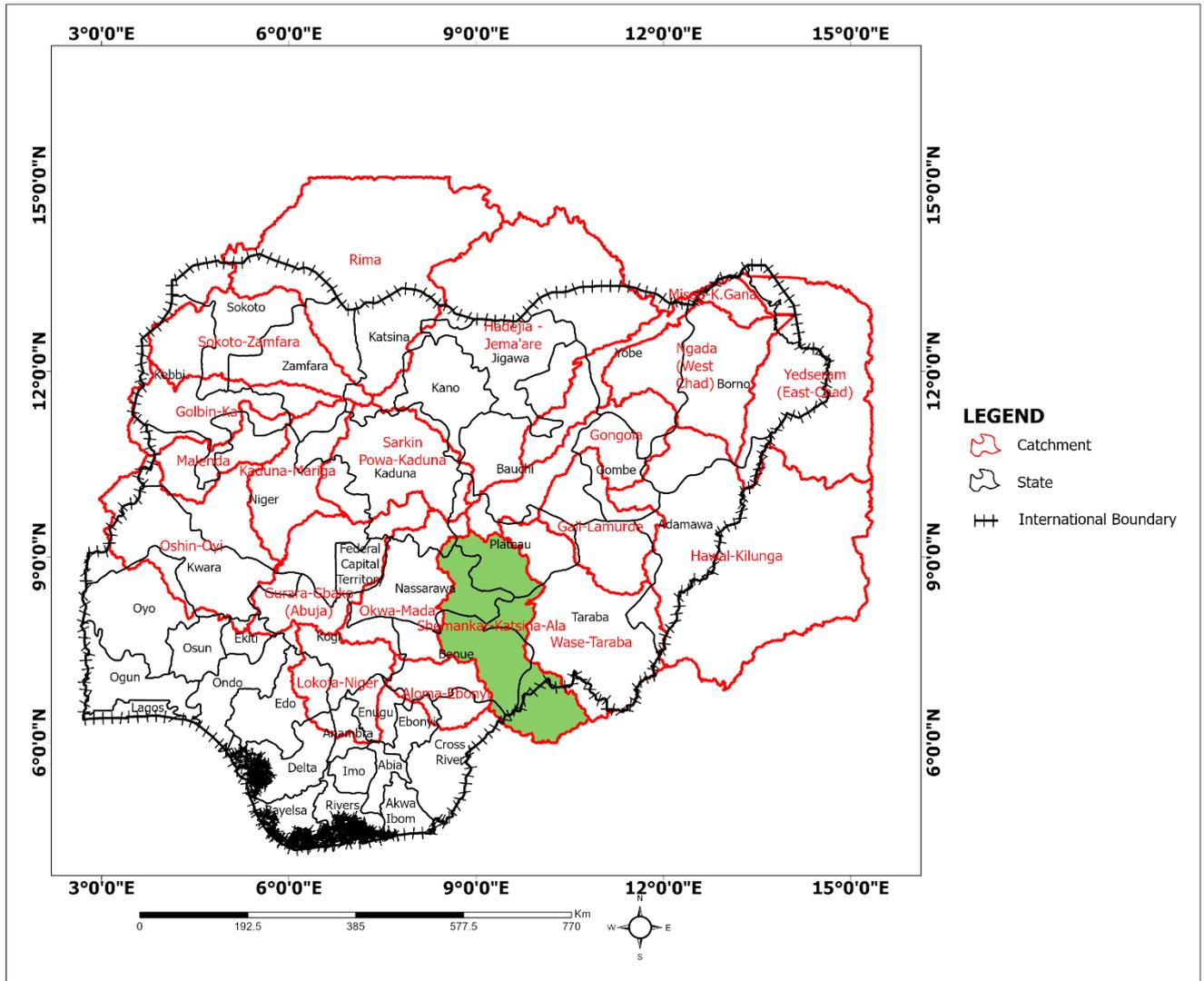


Figure 1.1: Map of the 20 strategic Catchment areas showing the Shemankar-Katsina-Ala Catchment Area (Source: MSL, 2024)

CATCHMENT CHARACTERISTICS

1.1 Location and Boundaries

1.1.1 Plateau State

Plateau State, located in the North-Central region of Nigeria, holds a central position within the country, often described as the "Home of Peace and Tourism" due to its temperate climate and scenic landscapes. The state is named after the Jos Plateau, a prominent geological feature that defines much of its landscape and has historically influenced its cultural and economic development.

1.1.2 Geographical Coordinates and Boundaries

Plateau State lies between latitudes 8°24'N and 10°30'N and longitudes 8°32'E and 10°38'E, placing it near the geographical center of Nigeria. This location provides the state with strategic importance, both in terms of accessibility and its role as a cultural crossroads within Nigeria.

- **Northern Boundary:** The state is bordered to the north by Kaduna State. This boundary is significant for its historical and cultural connections, as well as for trade routes that link Plateau State with northern Nigeria.
- **Eastern Boundary:** Plateau State shares its eastern boundary with Bauchi and Taraba States. The boundary with Bauchi is particularly important due to the economic ties and shared historical heritage, especially with respect to the tin mining industry, which has played a significant role in the development of both states (*Oyeniya & Hassan, 2018*).
- **Southern Boundary:** To the south, the state is bordered by Nasarawa and Benue States. This southern boundary is crucial for agricultural exchange and cultural interactions within the Middle Belt region, a zone known for its diverse agricultural production (*Adeoye, 2013*).
- **Western Boundary:** The western boundary of Plateau State with Nasarawa State connects it directly to the Federal Capital Territory (FCT), Abuja. This proximity has led to increased urbanization and economic integration, particularly in the areas of commerce and infrastructure development (*Eze & Abubakar, 2015*).

1.1.3 Benue State

Benue State is located in the north-central region of Nigeria and shares boundaries with several other states, making it a strategically important state both geographically and economically. It lies between latitudes 6°30'N and 8°10'N and longitudes 7°30'E and 10°00'E, placing it firmly in Nigeria's Middle Belt region. The state covers a land area of approximately 34,059 square kilometers and ranks as one of the larger states in Nigeria in terms of geographical size (*Adejo, 2020*).

To the north, Benue State shares boundaries with Nasarawa State, while to the northeast, it is bordered by Taraba State. To the southeast, the state is bounded by Cross River State, and to the south, it is flanked by Ebonyi and Enugu states. On its western side, Benue State borders Kogi State. Additionally, Benue State shares an international boundary with the Republic of Cameroon to the east. The River Benue, from which the state derives its name, flows through the state from the northeast to the west, providing a natural boundary and an essential resource for agricultural activities and transportation (*Abah, 2019*).

Benue State is strategically located as a connecting point between the northern and southern parts of Nigeria, making it a vital link for trade and movement of goods between these regions. This geographic positioning also facilitates the state's involvement in the agricultural supply chain, where it is often referred to as the "food basket of the nation" due to its extensive production of crops like yam, maize, and rice (*Omada, 2021*).

1.1.4 Nasarawa State

Nasarawa State is situated in the central region of Nigeria, forming part of the North Central geopolitical zone. It was created on October 1, 1996, from the old Plateau State, with the intention of enhancing governance and fostering development in the region. The state's capital, Lafia, governs an area of approximately 27,117 square kilometers. Known as the "Home of Solid Minerals," Nasarawa State is rich in natural resources, particularly minerals like barite, limestone, and gemstones (*Afolayan & Popoola, 2019*).

The state is bordered by several other states, which significantly influence its socio-political and economic landscape. To the north, it shares a boundary with Kaduna State, while to the west, it borders the Federal Capital Territory (FCT) of Abuja, positioning it strategically close to Nigeria's political hub. To the south, Nasarawa borders Benue State, and to the east, it shares boundaries with both Plateau and Taraba States. This positioning provides Nasarawa with a unique role as a connector between northern and southern Nigeria (*Iloeje, 2017*).

The proximity of Nasarawa to the FCT gives it considerable advantages in terms of socio-economic development. Opportunities for trade, investment, and employment stem from its location adjacent to Abuja. The boundary with Benue State also promotes agricultural and cultural exchanges between the two regions. As a centrally located state, Nasarawa acts as a vital bridge, facilitating communication and interaction between Nigeria's northern and southern regions. Its positioning within the tropical savannah climate zone is key to its agricultural potential (*Ajayi, 2020*).

1.1.5 Taraba State

Taraba State is located in the northeastern region of Nigeria. It was created from the former Gongola State in 1991 and shares boundaries with several Nigerian states as well as international borders. Geographically, Taraba State lies between latitudes 6°25'N and 9°30'N and longitudes 9°30'E and 11°45'E, covering an estimated land area of about 54,473 square kilometers, making it one of Nigeria's largest states by landmass.

Taraba is bordered to the north by Bauchi and Gombe States, while its north-eastern boundary is with Adamawa State. To the east, it shares an international boundary with the Republic of Cameroon, a feature that plays a significant role in both trade and the socio-cultural ties between the people of Taraba and their Cameroonian neighbors. To the south, Taraba State is bounded by Benue State, while its western borders are shared with Plateau and Nasarawa States. The strategic location of Taraba State in relation to its neighbors gives it access to a diversity of cultural, economic, and environmental influences.

The state's capital, Jalingo, is centrally located, serving as a key hub for governance and economic activities in the region. Jalingo is also connected by major highways to other parts of Nigeria, particularly through routes leading to Adamawa and Benue States. Additionally, the state's position along the Nigeria-Cameroon border facilitates international trade, especially in agricultural products and livestock.

The boundaries of Taraba State define a region characterized by a variety of landscapes, from river valleys to mountainous highlands, each contributing to its rich ecological diversity and agricultural productivity [*Udo, 2020*]. The state's borders also play a role in shaping its ethnic composition, as it is home to a wide variety of ethnic groups, including the Tiv, Jukun, Fulani, and Mumuye, among others, many of whom share cultural ties with communities across state and international boundaries.

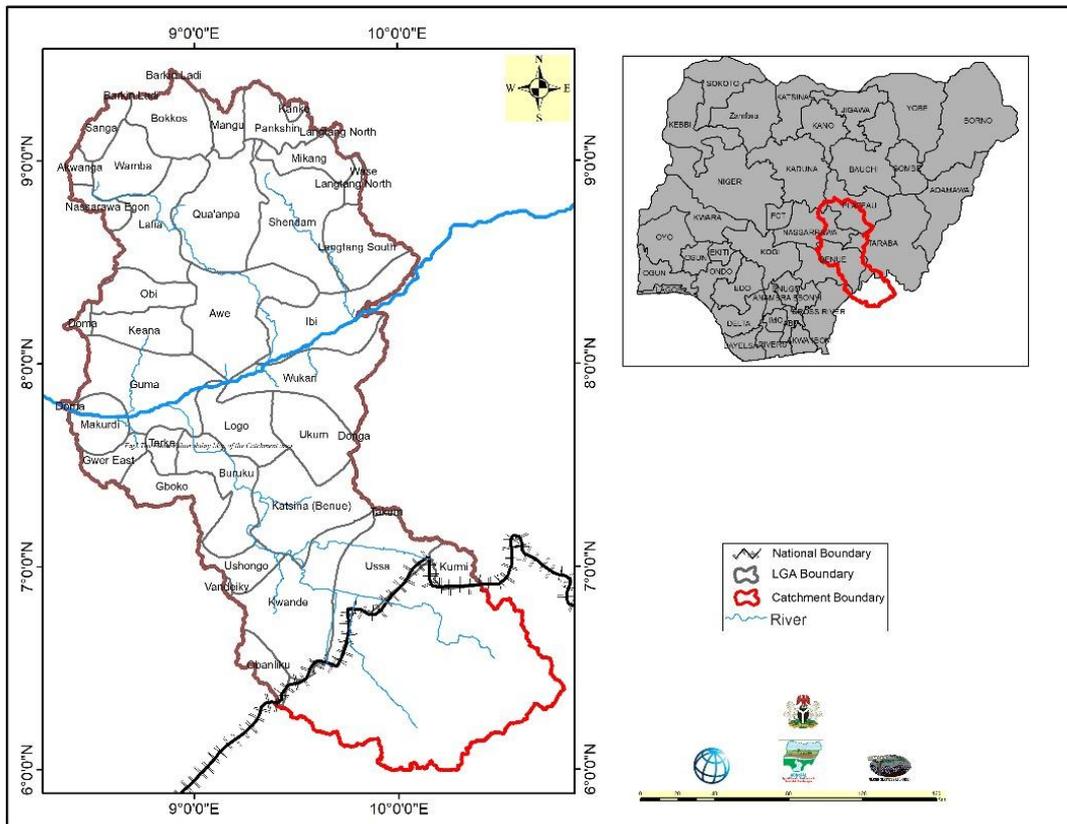


Figure 1.2: Shemankar-Katsina'ala Catchment showing the LGA's (Source: MSL, 2024)

1.2 Topography and Drainage

1.2.1 Plateau State

The topography and drainage systems of Plateau State are heavily influenced by its location on the Jos Plateau, a highland area that is one of the most prominent features in Nigeria's physical geography. The state's varied landscape, characterized by high plains, rugged hills, and deep valleys, has shaped its climate, agricultural potential, and settlement patterns.

The Jos Plateau, which occupies much of the central part of the state, is an elevated region with an average height of about 1,200 meters (3,937 feet) above sea level. The highest point on the Plateau is the Shere Hills, which rise to 1,829 meters (6,001 feet), making it one of the highest points in Nigeria (Oyeniyi & Hassan, 2018). This elevation contributes to the state's cool climate, which is markedly

different from the surrounding lowlands and is favorable for both human habitation and the cultivation of crops such as potatoes, vegetables, and fruits.

1.2.1.1 Rock Formations and Geomorphology

The Plateau is distinguished by its extensive rock formations, primarily composed of granites and other igneous rocks that form inselbergs, ridges, and other unique geological features. These formations not only define the physical landscape but also have significant implications for the region's mineral wealth, particularly in the form of tin and columbite deposits that have been extensively mined since the early 20th century (*Adeoye, 2013*).

1.2.1.2 Valleys and Escarpments

The topography of Plateau State is also characterized by a series of valleys and escarpments that dissect the Plateau, creating a rugged terrain. These valleys have been formed over millennia by the action of rivers and streams, which have cut through the softer rock layers, leading to the creation of narrow, steep-sided valleys and gorges (*Okeke & Onwuemesi, 2016*). The escarpments and valleys are important not only for their scenic beauty but also for their role in the state's drainage system.

1.2.2 Benue State

Benue State's topography is primarily characterized by rolling plains and low-lying valleys, with elevations ranging from 100 meters to 300 meters above sea level. The terrain is generally undulating, interspersed with occasional highlands, especially in the southeastern and northern parts of the state. The most notable highland in the state is the Shebshi Hills, which form part of the boundary between Benue and Taraba states. These hills rise to an elevation of approximately 1,200 meters, creating a distinct contrast to the otherwise gently sloping landscape (*Adakole, 2020*).

The state is also marked by a series of river valleys, most prominently that of the River Benue. The river flows through the state's central region, cutting through the plains and creating fertile alluvial deposits along its course. These river valleys are significant for both agriculture and settlement patterns in the state, as the rich soils support extensive farming activities. The relatively flat nature of the state's topography also makes it suitable for mechanized farming and facilitates the development of infrastructure like roads and railways (*Odu, 2020*).

In the northern part of Benue, the topography transitions to a more dissected landscape, with streams and smaller rivers creating narrow valleys. This area, while less suitable for large-scale agriculture, supports a variety of crops, particularly those adapted to hilly terrains, such as millet and sorghum. In

the southern part of the state, near the border with Cross River and Ebonyi states, the terrain becomes slightly more rugged, with rolling hills and forests that mark the transition to the more tropical regions of southern Nigeria (Abah, 2019).

1.2.3 Taraba State

The topography of Taraba State is one of its most distinctive geographical features, contributing significantly to its diverse climate, vegetation, and land use patterns. The state is characterized by an array of highlands, plateaus, valleys, and plains that vary in elevation from as low as 200 meters in the riverine plains to over 2,400 meters in the mountainous regions.

1.2.3.1 Mambilla Plateau

One of the most prominent topographical features of Taraba State is the Mambilla Plateau, located in the southeastern part of the state. The plateau stands as the highest point in Nigeria, with elevations ranging from 1,600 to over 2,400 meters above sea level. The Mambilla Plateau is a major landmark not only in Taraba but also in Nigeria as a whole, often referred to as Nigeria's "highland paradise" due to its temperate climate and picturesque landscapes [Olofin, 2018].

The Mambilla Plateau is crucial to both the agricultural and hydrological systems of the state. Its high elevation creates cooler temperatures and more rainfall, making it suitable for temperate crops such as tea, coffee, and potatoes. The plateau also serves as a watershed for major rivers in the state, contributing to the Taraba River and other tributaries that feed into the Benue River [Olofin, 2018].

1.2.3.2 Valleys and Plains

In contrast to the highlands of the Mambilla Plateau, much of the northern and central parts of Taraba State consist of rolling plains and valleys. These areas, which include the valleys of the Benue and Taraba Rivers, have elevations ranging from 200 to 500 meters above sea level. These plains are primarily used for agriculture, particularly for the cultivation of staple crops such as maize, millet, and rice.

The northern parts of the state are generally flatter, transitioning into the drier Sudan Savanna zone. This region is less elevated and experiences different climatic conditions compared to the southern highlands. It is characterized by expansive grasslands and savanna woodlands, suitable for livestock grazing and dry-season farming.

1.2.3.3 Mountain Ranges and Hills

Apart from the Mambilla Plateau, Taraba State is also home to other significant mountain ranges and hills, such as the Shebshi and Adamawa Mountains in the northern and eastern parts of the state. These ranges form part of the broader highland systems that extend into neighbouring Adamawa State and the Republic of Cameroon. These mountainous regions provide natural habitats for wildlife and support various forms of traditional farming, including terracing in areas where slopes are steep.

1.2.4 Nasarawa State

The topography of Nasarawa State is diverse, characterized by a combination of plains, hills, and valleys. This complexity is largely due to its location within the Benue Valley and its proximity to the Jos Plateau. The state's central region consists of gently undulating plains, while the northern and eastern parts of the state feature more rugged and elevated terrain. Some of the highland areas, particularly near the Plateau State boundary, rise as high as 1,200 meters above sea level (*Afolayan & Popoola, 2019*).

In the central region, the Lafia Plains dominate the landscape. These plains are critical for agriculture due to their relatively flat terrain, fertile soils, and moderate rainfall, making them ideal for crops like maize, yams, and millet. The higher elevations in the northern part of the state are part of the extension of the Jos Plateau, contributing to the state's diverse landforms and creating micro-climatic conditions that are cooler than the surrounding plains (*Udo, 2016*).

The state also contains several hills and ridges, particularly in the southern and eastern regions. For example, the Akwanga Hills in the north-central part of the state offer panoramic views of the surrounding landscape. In the Karu area, which lies near the boundary with the FCT, the terrain is hilly, gradually sloping downwards as one moves southward. This topographical variation has a profound effect on local climates, agriculture, and settlement patterns. The elevated areas tend to have cooler climates, while the flatlands are more conducive to large-scale farming (*Iloeje, 2017*).

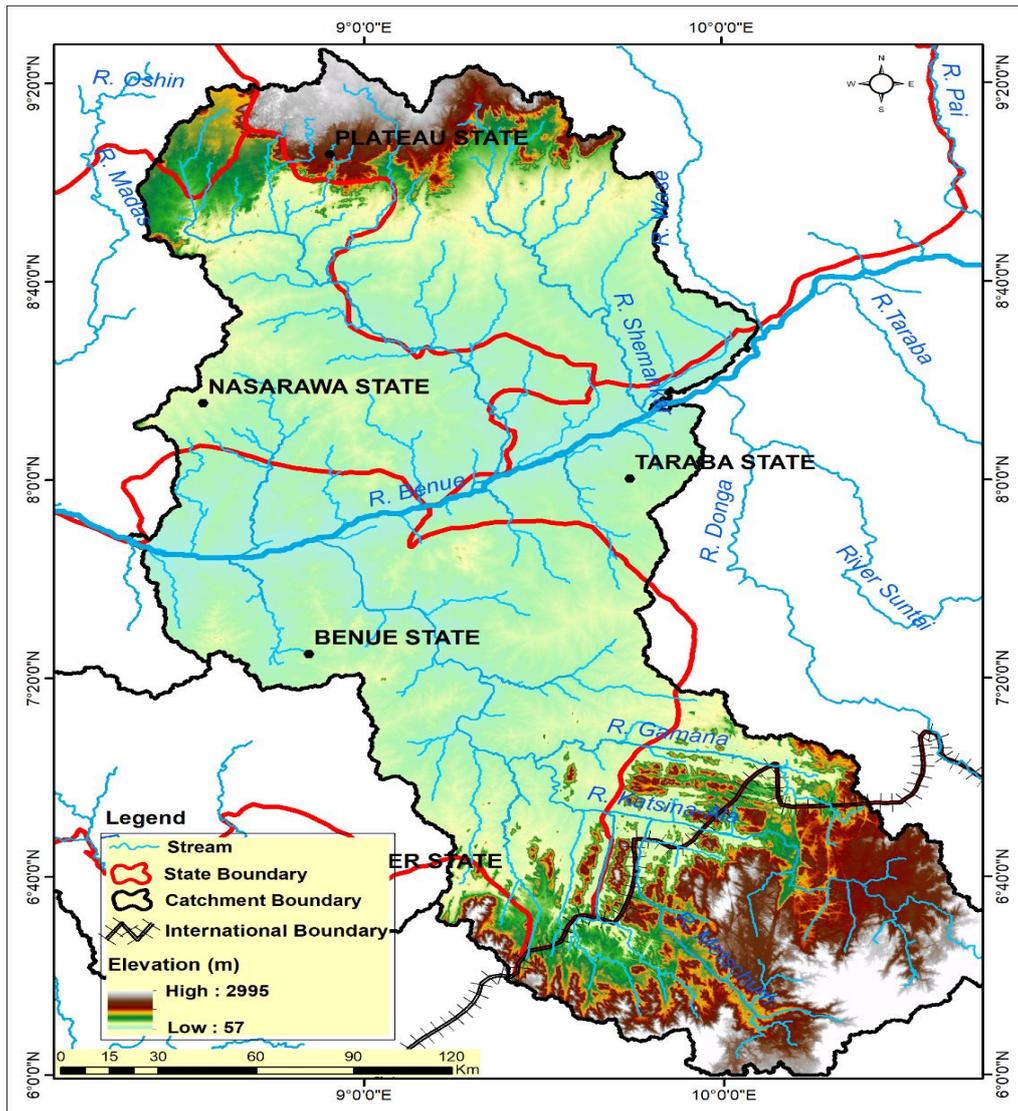


Figure 1.3: Digital Elevation Model of Shemankar-Katsina-Ala Catchment (Source: MSL, 2024)

1.3 River Systems and Drainage

1.3.1 Plateau State

1.3.1.1 Drainage

Plateau State is drained by a network of rivers and streams that originate from the highlands of the Jos Plateau. The most significant of these rivers include the Kaduna, Gongola, and Benue Rivers, all of which are part of larger river systems that drain into the Niger and Benue River basins (*Eze & Abubakar, 2015*).

Kaduna River: Originating from the Jos Plateau, the Kaduna River is a major tributary of the Niger River, flowing westward through Kaduna State. It plays a crucial role in the hydrology of the region, providing water for agriculture, industry, and domestic use (*Adeoye, 2013*).

Gongola River: The Gongola River, which also originates in the eastern part of the Plateau, flows north-eastward through Bauchi State before joining the Benue River. It is particularly important for irrigation and other agricultural activities in the region (*Oyeniya & Hassan, 2018*).

Benue River: While the Benue River itself does not originate within Plateau State, several of its tributaries, such as the Donga and Taraba Rivers, have their headwaters in the southeastern part of the state. These rivers contribute to the drainage of the Benue River basin, one of the largest and most significant river systems in Nigeria (*Okeke & Onwuemesi, 2016*).

1.3.1.2 Lakes and Wetlands

In addition to rivers, Plateau State also features several natural lakes and wetlands, which are important for local biodiversity and agriculture. These water bodies are often found in the valleys and low-lying areas, serving as crucial habitats for various species of flora and fauna, and providing water for irrigation and domestic use (*Eze & Abubakar, 2015*).

1.3.1.3 Erosion and Soil Degradation

The topography of Plateau State makes it particularly susceptible to erosion, especially in areas with steep slopes and fragile soils. Soil degradation, resulting from both natural and anthropogenic factors, is a significant environmental challenge in the state. This has implications for agriculture, as erosion reduces soil fertility, and for the stability of settlements built on or near eroded lands (*Okeke & Onwuemesi, 2016*).

1.3.2 Benue State

The drainage system of Benue State is dominated by the River Benue and its numerous tributaries, which play a crucial role in the state's hydrology, agriculture, and transportation. The River Benue, Nigeria's second-largest river, originates in the Adamawa Plateau of Cameroon and flows westward through Benue State, where it converges with the River Niger at Lokoja. The Benue River basin is extensive, covering not only Benue State but also parts of neighboring states like Taraba and Nasarawa (*Omada, 2021*).

Within the state, the River Benue receives several tributaries that contribute to its flow, including the Katsina-Ala River, which drains the northern part of the state, and the Okpokwu River, which drains the southern part. These rivers, along with smaller streams and seasonal watercourses, create a well-developed drainage network that supports agricultural activities by providing water for irrigation. The presence of these rivers also means that the state is prone to seasonal flooding, particularly during the rainy season from May to October, when river levels rise significantly (*Adejo, 2020*).

Flooding is a significant environmental issue in Benue State, especially in areas close to the River Benue, such as Makurdi, the state capital. The annual floods are caused by the overflow of rivers during heavy rainfall, exacerbated by poor drainage systems in urban areas. This flooding not only affects agricultural production but also leads to the displacement of people and damage to infrastructure (*Adakole, 2020*).

Additionally, the floodplains of the River Benue are fertile, making them ideal for rice farming and other forms of irrigated agriculture. The state government has invested in several irrigation projects to harness the water resources of the River Benue for year-round farming. These irrigation systems are crucial for boosting agricultural productivity, particularly in the dry season when rainfall is scarce. However, the management of water resources in the state faces challenges such as siltation of river channels and inadequate maintenance of irrigation infrastructure (*Odu, 2020*).

1.3.3 Taraba State

1.3.3.1 Drainage

Taraba State has a complex and extensive drainage system shaped by its diverse topography and climate. The state's rivers and streams play a critical role in supporting agriculture, providing water for domestic use, and contributing to regional hydrological systems such as the Niger-Benue River Basin.

1.3.3.2 Major Rivers

The state's most prominent river is the Benue River, which forms part of the southern boundary of the state. The Benue River is one of the major tributaries of the River Niger and serves as a key watercourse for both Taraba and Nigeria as a whole. The river facilitates transportation, irrigation, and fishing activities and is integral to the livelihoods of many communities along its banks [Ajayi, 2019]. In Taraba State, the Benue River receives inflows from several smaller rivers, including the Donga and Taraba Rivers.

The Taraba River is another major waterway within the state, running through the northern and central regions before joining the Benue River. The Taraba River and its tributaries, such as the Gashaka and Kam, are crucial for irrigation agriculture and provide water for both livestock and wildlife. These rivers originate from the highlands of the Mambilla Plateau and flow downwards, contributing to the region's fertile alluvial plains [Udo, 2020].

1.3.3.3 Seasonal Streams and Wetlands

In addition to its major rivers, Taraba State is dotted with numerous seasonal streams and wetlands that fluctuate in size and flow depending on the rainy and dry seasons. These water bodies are essential for sustaining agriculture and livestock farming during the rainy season, particularly in the low-lying floodplains.

The floodplains along the Benue and Taraba Rivers are also home to several wetlands, which act as natural reservoirs and flood mitigation systems. During the rainy season, these wetlands absorb excess water, preventing floods in nearby communities. However, during the dry season, these wetlands provide a crucial water source for pastoralists and farmers engaged in dry-season farming activities [Ajayi, 2019].

1.3.3.4 Hydrological Challenges

Despite its rich drainage system, Taraba State faces several hydrological challenges, particularly with regard to water management and flood control. The state's rivers, particularly the Benue and Taraba Rivers, are prone to seasonal flooding during the peak of the rainy season, often resulting in damage to farmlands, infrastructure, and settlements. The 2012 flood disaster, which affected several states in Nigeria, had significant impacts on Taraba, displacing thousands of residents and causing widespread agricultural losses [Olofin, 2018].

Water scarcity during the dry season also poses challenges for agriculture and livestock management in the northern parts of the state. The reliance on seasonal rivers and rain-fed agriculture limits

productivity during the dry months, often forcing communities to adapt through water conservation techniques and dry-season farming.

1.3.4 Nasarawa State

1.3.4.1 Drainage

The drainage system in Nasarawa State is largely defined by the Benue River, which forms the state's southern boundary. As one of Nigeria's major rivers, the Benue River plays a crucial role in the state's hydrology, providing water for irrigation, fishing, and domestic use. The river also serves as a natural boundary between Nasarawa and Benue States (*Ajayi, 2020*).

In addition to the Benue River, Nasarawa is drained by numerous smaller rivers and streams. Notable among them are the Mada and Gurara Rivers, which flow through the western and northwestern parts of the state, respectively. These rivers support agriculture, especially in areas that rely on irrigation during the dry season. The rivers are also vital sources of domestic water supply for rural communities. However, many smaller streams in the state are seasonal, flowing only during the rainy season and drying up during the dry months (*Afolayan & Popoola, 2019*).

The state's drainage system also includes several wetlands, especially along the Benue River and its tributaries. These wetlands are critical for the local ecology, supporting a variety of plant and animal species. They also help control floods by absorbing excess water during periods of heavy rainfall. Despite their ecological importance, these wetlands face degradation due to activities like farming and sand dredging, which have led to habitat loss in some areas (*Udo, 2016*).

Nasarawa's topography plays an important role in shaping its drainage patterns. In the more elevated regions in the north and east, rivers tend to flow rapidly through narrow valleys, whereas in the central and southern plains, the rivers meander slowly, forming wide floodplains. This variation influences water availability and management, especially concerning flood control and irrigation (*Ajayi, 2020*).

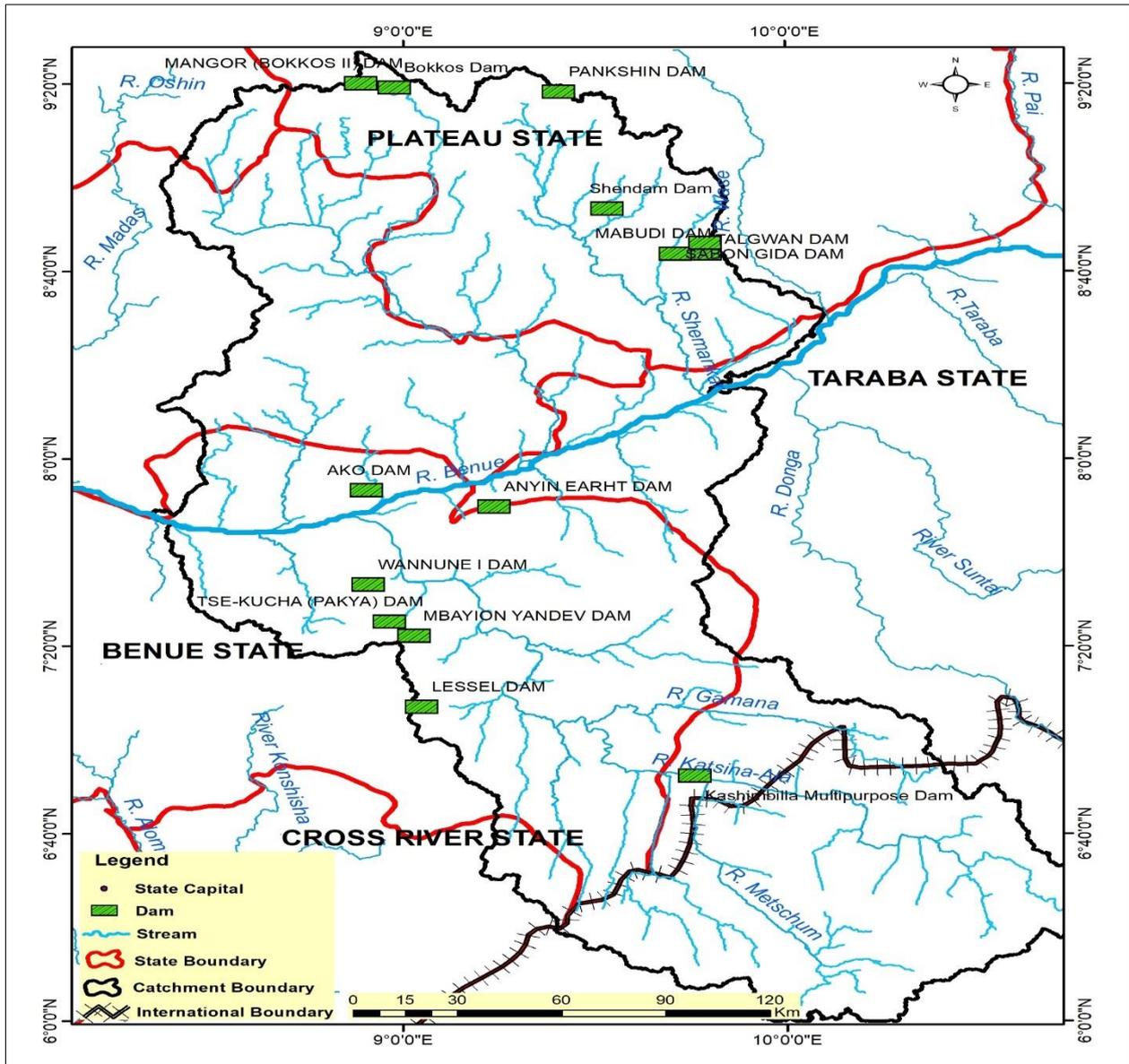


Figure 1.4: Drainage Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)

STATES OF INFLUENCE

1. Plateau State
2. Taraba State
3. Benue State
4. Nasarawa State

Table 1.1: Morphometric Analysis of Shemankar-Katsina-Ala Catchment

Morphometric Parameters		
Area(sq.km)	A	51,904.54096
Perimeter(km)	P	1,843.521792
Drainage Density(km/sq.km)	$D = Lu/A$	0.0881
Stream Frequency	$F_s = Nu/A$	0.005914
Texture Ratio	$T = N1/P$	0.0835
Basin Length(km)	L_b	406.35
Elongation Ratio	$R_e = 2\sqrt{(A/\pi/L_b)}$	12.7528
Circulatory Ratio	$R_c = (4 \pi A) / P^2$	0.1919
Form Factor Ratio	$R_f = A/L_b^2$	0.3143

Stream Order (u)	Number of Streams (Nu)	Total Length of Streams in km (Lu)	Log (Nu)	Log (Lu)
1	154	2,382.973282	2.1875	3.3771
2	74	1,064.58641	1.8692	3.0271
3	47	767.204335	1.6720	2.8849
4	26	301.480789	1.4149	2.4791
5	6	59.522972	0.7781	1.7745
Bifurcation Ratio (R_b)				Mean Bifurcation Ratio
1 st order/2 nd order	2 nd order/3 rd order	3 rd order/4 th order	4 th order/5 th order	
2.081	1.5744	1.8076	4.333	2.449

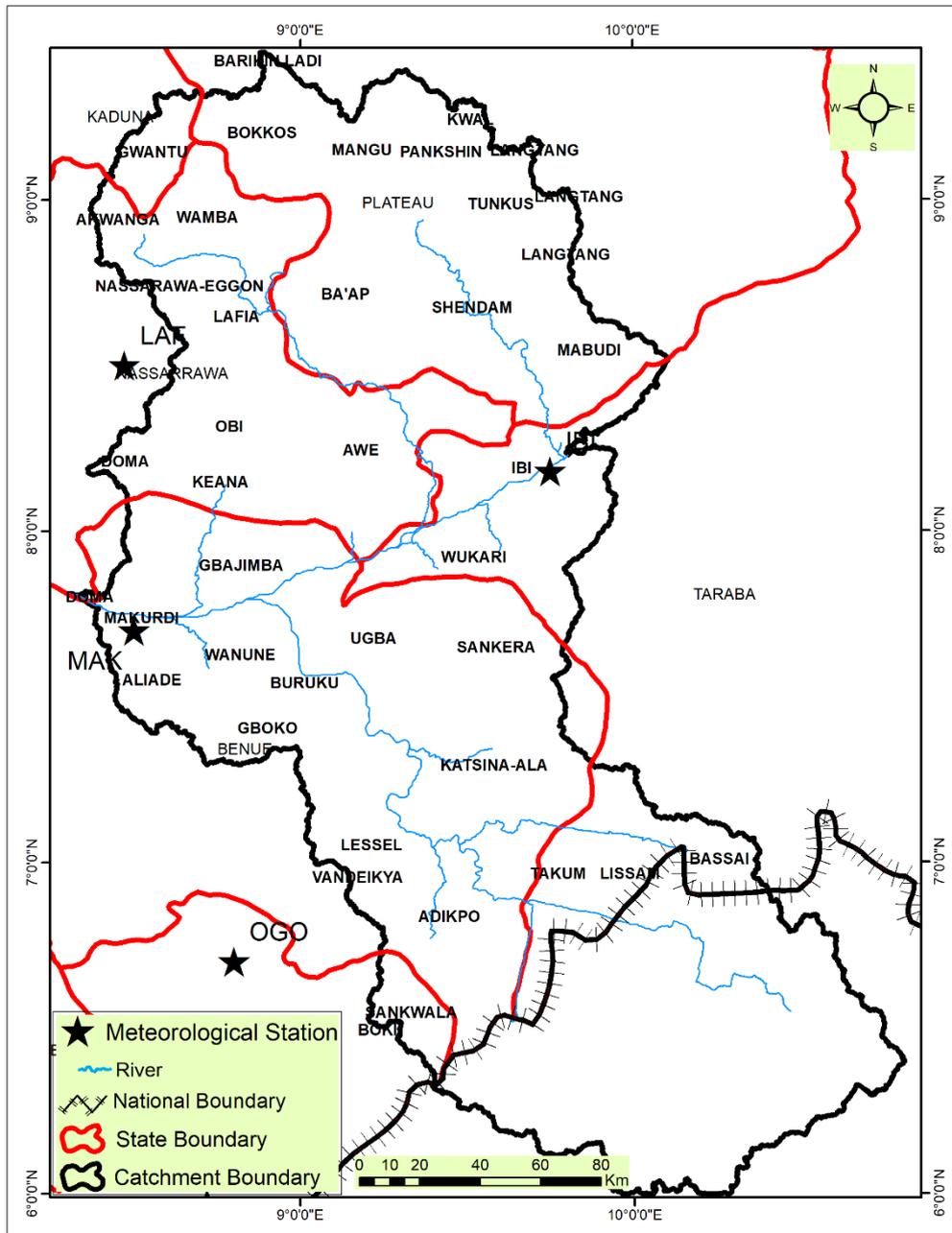


Figure 1.6: Map of Meteorological stations (Source: MSL, 2024)

World Meteorological Organization (WMO) recommends 970 out of which 291 are recorded, however data is only received from 45(NIMET)



Table 1.2: Population projection for Shemankar-Katsina-Ala Catchment

State	LGA	2006	2022	2025	2030	2035	2040	2045	2050
Benue	Buruku	206,215	297,700	319653	359897	405208	456224	513662	578333
Benue	Gboko	361,325	521,700	560171	630697	710101	799503	900160	1013490
Benue	Guma	194,164	280,300	300970	338862	381525	429559	483640	544530
Benue	Gwer East	168,660	243,500	261456	294373	331435	373163	420144	473040
Benue	GwerWest	122,313	176,600	189623	213496	240375	270639	304712	343075
Benue	Katsina (Benue)	225,471	325,500	349503	393505	443048	498827	561630	632339
Benue	Kwande	248,642	359,000	385473	434004	488645	550166	619432	697418
Benue	Logo	169,570	244,800	262852	295945	333204	375155	422387	475565
Benue	Makurdi	300,377	433,700	465682	524311	590322	664643	748322	842535
Benue	Tarka	79,280	114,500	122943	138422	155849	175471	197562	222436
Benue	Ukum	216,983	313,300	336403	378756	426442	480131	540579	608638
Benue	Ushongo	191,935	277,100	297534	334993	377169	424655	478118	538314
Benue	Vandeiky	234,567	338,700	363676	409463	461015	519056	584405	657982
Cross River	Obanliku	109,633	167,000	179315	201891	227309	255927	288148	324426
Kaduna	Sanga	151,485	223,800	240303	270558	304621	342973	386153	434769
Nassarawa	Akwanga	111,902	172,800	185543	208902	235203	264815	298155	335693
Nassarawa	Awe	113,083	174,600	187475	211078	237653	267574	301261	339190
Nassarawa	Doma	138,991	214,600	230425	259435	292098	328874	370279	416897
Nassarawa	Keana	81,801	126,300	135614	152687	171911	193554	217923	245359
Nassarawa	Lafia	329,922	509,300	546857	615706	693223	780500	878765	989401
Nassarawa	Nassarawa Egon	148,405	229,100	245994	276965	311835	351095	395298	445065
Nassarawa	Obi	148,977	230,000	246961	278053	313060	352474	396850	446814
Nassarawa	Wamba	72,687	112,200	120474	135641	152719	171946	193594	217967
Plateau	Barkin Ladi	179,805	264,500	284005	319761	360019	405345	456378	513836
Plateau	Bokkos	179,550	264,100	283575	319277	359474	404732	455688	513059
Plateau	Kanke	124,268	182,800	196280	220992	248814	280140	315410	355120
Plateau	Langtang North	142,316	209,400	224842	253149	285021	320905	361306	406795
Plateau	Langtang South	105,173	154,700	166108	187021	210567	237077	266925	300531



Plateau	Mangu	300,520	442,100	474701	534466	601755	677516	762816	858854
Plateau	Mikang	96,388	141,800	152257	171426	193008	217308	244667	275470
Plateau	Pankshin	190,114	279,700	300326	338137	380708	428639	482605	543364
Plateau	Qua'anpa	197,276	290,200	311600	350830	395000	444730	500722	563763
Plateau	Shendam	205,119	301,800	324055	364854	410789	462507	520737	586297
Plateau	Wase	159,861	235,200	252544	284339	320138	360443	405823	456916
Taraba	Donga	133,105	209,400	224842	253149	285021	320905	361306	406795
Taraba	Ibi	84,302	132,600	142378	160304	180486	203209	228793	257598
Taraba	Kurmi	91,282	143,600	154189	173602	195458	220066	247773	278967
Taraba	Takum	134,576	211,700	227311	255930	288151	324429	365275	411263
Taraba	Ussa	90,889	143,000	153545	172876	194642	219147	246737	277802
Taraba	Wukari	238,283	374,800	402438	453105	510151	574379	646694	728112
TOTAL		6,779,215	10,067,500	10,809,896	12,170,861	13,703,171	15,428,399	17,370,833	19,557,819

2006	2022	2025	2030	2035	2040	2045	2050
6.8	10.1	10.8	12.2	13.7	15.4	17.4	19.6

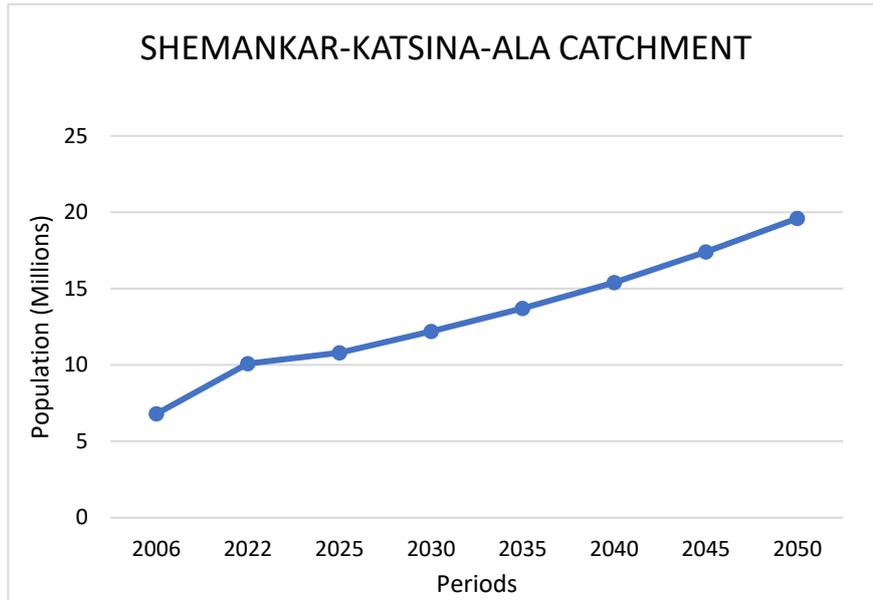


Figure 1.7 Population projection Graph of the Catchment (Source:MSL, 2024)



Table 1.3: Summary of Shemankar-Katsina-Ala Catchment

NAME	STATES	POPULATION	GEOGRAPHY	GEOLOGY	HYDROGEOLOGY	VEGETATION	SOCIAL ECONOMICS
Shemankar -Katsina- Ala Catchments	Plateau State, Benue, Taraba	Over 10 million	The Shemenkar-Katsina-Ala catchment is located in northern Nigeria, spanning parts of Taraba, Plateau and Benue States. The landscape varies from savannah woodlands to grasslands and hills. The	Geologically, the area consists of sedimentary rock with alluvial deposits along river valleys and floodplains., Igneous rocks and Volcanic intrusions are, influencing soil fertility and agriculture in localized areas	The Rivers are major watercourses in the catchment, providing seasonal flows that support agriculture and local communities. Groundwater resources are important for irrigation and domestic use, particularly during dry periods.	Vegetation in the Taraba-Wase catchment includes savannah woodlands, grasslands, and shrubs adapted to semi-arid conditions. Riparian vegetation along riverbanks includes trees such as acacias and doum	Agriculture is the backbone of the economy in the Shemankar catchment, with crops like maize, rice, yams, and cassava grown in the rainy season. Livestock rearing (cattle, sheep, and goats) is widespread, supporting pastoralist communities. Trade in agricultural



			<p>terrain is generally flat with occasional hills and valleys</p>			<p>palms, providing habitat for wildlife and shade for farming communities</p>	<p>products and handicrafts contributes to local economies, with markets playing a central role in economic exchange</p>
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1.4 Geology

1.4.1 Plateau State

Plateau State, located in the North-Central region of Nigeria, is geologically significant due to its complex and varied formations. The geology of the state has played a pivotal role in shaping its landscape, soil types, and economic activities, particularly in terms of agriculture and mining.

The geological structure of Plateau State is primarily defined by the Precambrian Basement Complex rocks, which are among the oldest rocks on the African continent, dating back over 600 million years. These rocks are composed mainly of granites, gneisses, migmatites, and schists [Adeoye, 2013]. The state's geology is further characterized by large granite intrusions that are particularly prominent on the Jos Plateau. These granites form the core of the Plateau and have weathered into the rolling hills and inselbergs that dot the landscape.

- i. **Granite Intrusions:** The granitic rocks in Plateau State are significant not only for their contribution to the region's topography but also for their economic value. The granitic intrusions are associated with extensive deposits of tin and columbite, which have been mined in the region for over a century. The tin mining industry, which peaked in the 20th century, has left a lasting impact on the state's economy and landscape [Oyeniyi & Hassan, 2018].
- ii. **Volcanic Activity:** The geological history of Plateau State also includes evidence of past volcanic activity. Volcanic rocks such as basalts and rhyolites are scattered across the region, particularly in the form of extinct volcanic cones and craters. These volcanic formations are remnants of ancient volcanic processes that contributed to the diversity of the state's geological landscape. The volcanic rocks have also influenced soil formation in certain areas, creating fertile lands suitable for agriculture [Olofin, 1985].
- iii. **Sedimentary Deposits:** In addition to the igneous and metamorphic rocks, parts of Plateau State are covered by younger sedimentary deposits, particularly in the river valleys and low-lying areas. These sediments are derived from the weathering of the surrounding highlands and have been deposited over time by rivers and streams. These deposits are often rich in minerals and contribute to the fertility of the soils in these areas [Oguntoyinbo, 1983].

1.4.2 Benue State

Benue State lies within the Benue Trough, a major geological formation that extends from the Niger Delta in the south to the north-eastern parts of Nigeria. The Benue Trough is a rift basin that formed during the early Cretaceous period, around 130 million years ago, when the African and South American tectonic plates began to separate. The trough is a significant feature in Nigeria's geology because it hosts large deposits of minerals, including lead, zinc, limestone, and coal (*Obaje, 2009*).

The geological formations in Benue State are diverse and consist primarily of sedimentary rocks. These include sandstones, shales, and limestones, which were deposited during the Cretaceous period. In particular, the Asu River Group and the Eze-Aku Group represent the main geological formations in the state. The Asu River Group is predominantly composed of sandstone and shale, while the Eze-Aku Group is largely made up of limestone, siltstone, and sandstone (*Olapade, 2018*).

Additionally, the state is known for its mineral resources, especially limestone, which is abundant in areas such as Gboko and Yandev. Limestone is a crucial resource for the cement industry, and its extraction has contributed significantly to the local economy. Benue State also has deposits of gypsum, which is used in the construction industry, as well as traces of coal, lead, and zinc, particularly in the areas around Makurdi and Otukpo (*Okonkwo, 2020*).

The state's geology is also important for its water resources, as the porous nature of the sedimentary rocks allows for the formation of aquifers, which provide groundwater for agricultural and domestic use. However, due to the presence of shale in some areas, the groundwater can be of variable quality, with some regions experiencing issues with water salinity or hardness (*Obaje, 2009*).

1.4.3 Taraba State

Taraba State is located in the north-eastern part of Nigeria, which is geologically significant because it lies in a transition zone between the Basement Complex and sedimentary basins. The geology of Taraba State is diverse, with rocks ranging from Precambrian crystalline formations to younger sedimentary deposits, which have implications for the state's natural resources and land use.

- i. Basement Complex:** The Basement Complex underlies much of the state, especially in the northern and central parts. This complex consists of ancient Precambrian rocks, including gneisses, schists, and granites. These rocks are part of the broader Nigerian Basement Complex that extends across much of the country, forming the foundation upon which younger sedimentary rocks are deposited. The Basement Complex is associated with various mineral resources, including gemstones, tin, and columbite, which have been mined in parts of the state. In particular, the Adamawa Highlands, located to the northeast, are dominated by crystalline rocks that form part of this complex [Obaje, 2009]. The presence of the Basement Complex also influences the state's topography, as these ancient rocks are more resistant to erosion, forming hilly and rugged terrains in some areas. The Mambilla Plateau, for example, is characterized by granite and gneissic formations, contributing to its high elevation and distinctive landscape [Usman, 2011].
- ii. Sedimentary Basins:** In the southern and western parts of the state, the geology transitions into sedimentary formations associated with the Benue Trough, which is part of the larger West African rift system. The Benue Trough is a major structural feature in Nigeria, and it is filled with Cretaceous and Tertiary sedimentary rocks, including sandstones, shales, and limestones. These formations are important for both agriculture and mineral exploration. The sedimentary rocks in the Benue Trough are associated with potential hydrocarbon deposits, though commercial quantities of oil have not yet been discovered in Taraba State. The trough also hosts limestone deposits, which are used in cement production, and the sandstone formations are valuable for construction materials. Furthermore, the region is known for its coal deposits, especially in the southern part of the state near the Benue River [Obaje, 2009].
- iii. Volcanic Features:** In some areas of the state, particularly around the Mambilla Plateau, volcanic rocks can be found. These are primarily basaltic in nature and are remnants of volcanic activity that occurred during the Tertiary period. The volcanic rocks, along with the fertile soils they produce, make this region one of the most agriculturally productive in the state [Usman, 2011]. The volcanic activity also contributed to the region's unique landscape, with the plateau's rolling hills and craters offering distinct geomorphological features.

The geology of Nasarawa State is complex and reflects its location within the Middle Benue Trough, a prominent geological structure in Nigeria. The Benue Trough, an elongated basin, stretches from the Gulf of Guinea in the south to the north-eastern part of Nigeria. Nasarawa lies in the central part of this structure, and its geological features have played a significant role in the state's economic development, particularly in the extraction of mineral resources. The diversity of geological formations in Nasarawa State has not only shaped its physical landscape but also influenced its economic activities. The state's mineral wealth, derived from both its crystalline and sedimentary rocks, has positioned it as a key player in Nigeria's mining sector. The state is particularly known for its deposits of gemstones, tin, and tantalite, which are mined both by artisanal and large-scale operators (*Udo, 2016*). Nasarawa State is underlain by a variety of rock types, which are broadly categorized into two geological formations: the Basement Complex and the Sedimentary Basin.

- i. The Basement Complex consists primarily of Precambrian rocks such as granite, gneiss, and schist, which are common in the northern and eastern parts of the state. These older, crystalline rocks form part of the Nigerian Basement Complex, which is one of the oldest geological formations in the country (*Iloeje, 2017*). These rocks provide the foundation for the hilly terrain in areas such as Akwanga and Keffi, where highland features are prominent.
- ii. The southern and central regions of Nasarawa are dominated by sedimentary rocks, which were deposited during the Cretaceous period. These sedimentary rocks are part of the Middle Benue Trough and consist of sandstone, shale, limestone, and siltstone (*Ajayi, 2020*). The presence of these sedimentary formations is significant for two main reasons. First, they contain rich deposits of solid minerals, including barite, limestone, and lead-zinc, making Nasarawa one of Nigeria's major mining hubs. Second, the sedimentary rocks have contributed to the relatively flat topography in the southern part of the state, which is suitable for agriculture.
- iii. In addition to the Basement Complex and sedimentary rocks, Nasarawa State also contains younger volcanic rocks. These rocks, mostly basalt, are found in scattered locations, particularly in the north-eastern part of the state near the Jos Plateau. These volcanic deposits are associated with past volcanic activities that shaped the landscape of the region, contributing to the fertility of the soils in certain areas (*Afolayan & Popoola, 2019*).

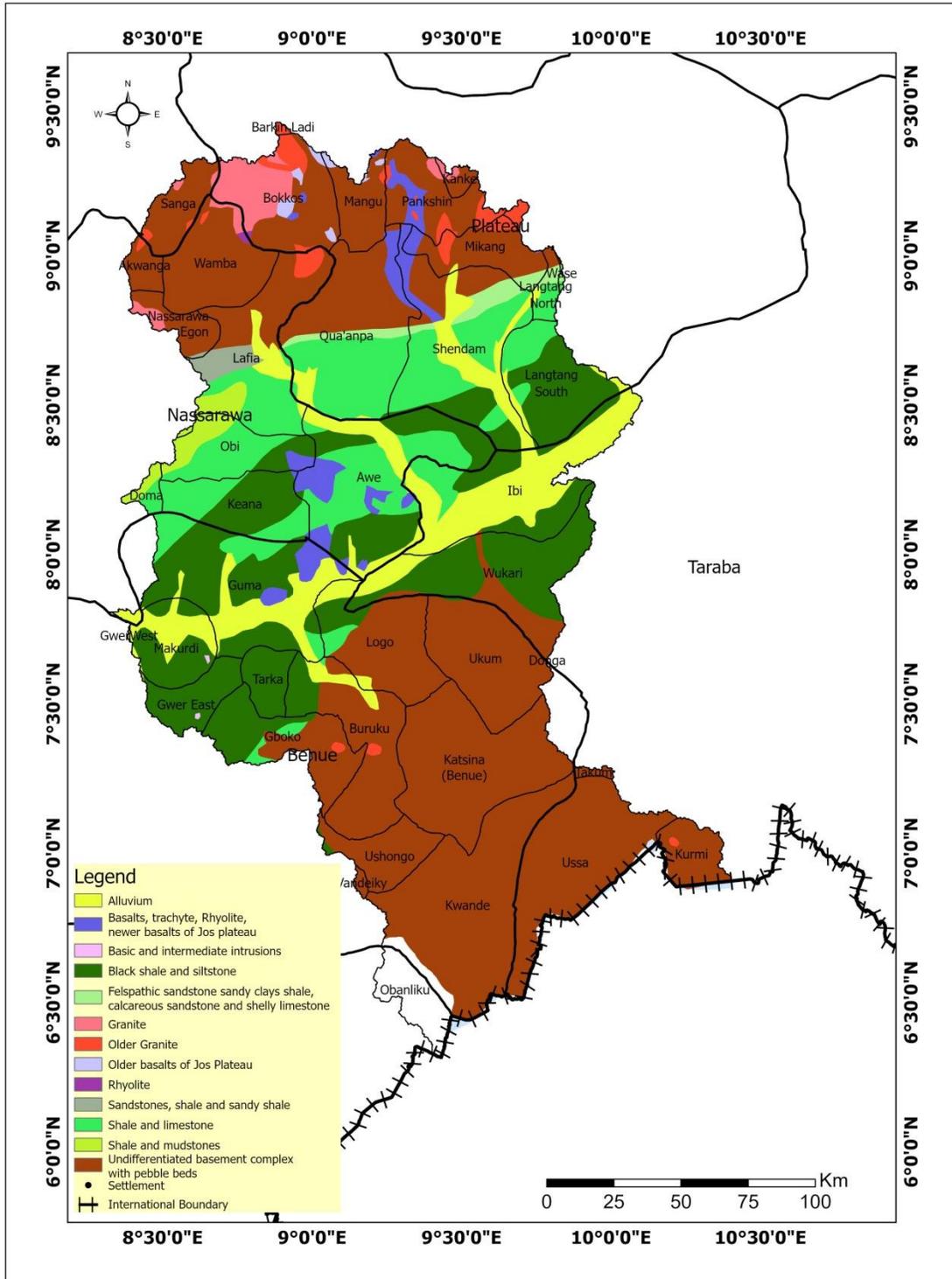


Figure 1.8: Geological map of the catchment area (Source: MSL, 2024)

1.5 Soil Types

1.5.1 Plateau State

The FAO soil classification system uses a two-level structure: a primary soil group name and an adjective to specify a soil unit within that group on the FAO Soil Map of the World. This system is intended to support comparisons across national systems. Soil Taxonomy, not replace them. It classifies soils into major groups: four based on parent material, four on topographic factors, and 22 on climate, organisms, and time. The FAO system relies on detailed field and lab data and specific technical criteria to define soil groups.

The diverse geology of Plateau State gives rise to various soil types, each with distinct characteristics and suitability for different land uses. The state's soils can be broadly categorized into ferruginous tropical soils, hydromorphic soils, and volcanic soils.

- i. **Ferruginous Tropical Soils:** These soils are the most widespread in Plateau State, particularly on the uplands and plateau regions. Ferruginous soils are typically reddish or yellowish, a result of the high iron oxide content, and are formed from the weathering of the Basement Complex rocks. These soils are generally well-drained but can be acidic and low in organic matter. The fertility of these soils is often limited by their acidity, which can be managed through the application of lime and organic matter to improve agricultural productivity [Oguntoyinbo, 1983].
- ii. **Lateritic Soils:** A subtype of ferruginous soils, lateritic soils are common in areas with high rainfall and intense weathering. These soils are characterized by a hardpan layer of iron and aluminum oxides in the subsoil, which can impede root growth and water infiltration. Despite these challenges, lateritic soils can be productive with proper management, especially for crops like cassava, maize, and millet [Oguntoyinbo, 1983].
- iii. **Hydromorphic Soils:** Found in the lower-lying areas, particularly along river valleys and floodplains, hydromorphic soils are associated with poor drainage and high-water tables. These soils are typically dark-colored, rich in organic matter, and more fertile than the upland ferruginous soils. They are well-suited for wetland rice cultivation and other water-

loving crops, but they require careful management to avoid waterlogging and salinization [Adeoye, 2013].

- iv. **Volcanic Soils:** Volcanic soils, also known as andosols, are found in areas influenced by past volcanic activity, particularly around extinct volcanic cones. These soils are typically rich in minerals such as phosphorus and potassium, making them highly fertile and suitable for intensive agriculture. They are less widespread than ferruginous and hydromorphic soils but are important for the cultivation of crops like vegetables, fruits, and Irish potatoes [Olofin, 1985].

1.5.2 Benue state

The soil types in Benue State are closely linked to its geological formations and are predominantly of sedimentary origin. The state's soils can be broadly classified into three main types: alluvial soils, lateritic soils, and hydromorphic soils. These soil types vary in their composition, fertility, and suitability for agriculture.

- i. **Alluvial Soils:** Alluvial soils are found primarily along the floodplains of the River Benue and its tributaries. These soils are formed by the deposition of silt, clay, and organic matter during seasonal floods. Alluvial soils are typically rich in nutrients, making them highly suitable for agriculture, particularly for crops such as rice, maize, and vegetables. The fertility of these soils has made the river valleys of Benue State some of the most agriculturally productive areas in Nigeria (Adamu & Shuaibu, 2019). However, the annual flooding that replenishes these soils also poses challenges for infrastructure development and settlement in the floodplains.
- ii. **Lateritic Soils:** Lateritic soils are the most widespread in Benue State, covering much of the upland areas and plateaus. These soils are characterized by their reddish color, which results from the accumulation of iron and aluminum oxides through leaching. While lateritic soils are generally less fertile than alluvial soils, they are still suitable for growing crops like yams, cassava, and groundnuts, particularly when supplemented with organic or inorganic fertilizers (Eze & Echekwube, 2018). Lateritic soils in Benue State are often prone to erosion, especially in areas with steep slopes and inadequate vegetation cover. This erosion is exacerbated by heavy rainfall during the wet season, which can strip the soil of its nutrients and reduce agricultural productivity. The state government has initiated

several soil conservations programs to mitigate this issue, including the promotion of terracing and agroforestry (Obaje, 2009).

- iii. **Hydromorphic Soils:** Hydromorphic soils are found in low-lying areas and are associated with wetlands, swamps, and floodplains. These soils are often waterlogged, especially during the rainy season, making them unsuitable for many types of crops. However, they are ideal for rice cultivation, which thrives in waterlogged conditions. In Benue State, hydromorphic soils are primarily located in the south-eastern parts of the state, near the confluence of the River Benue and its tributaries (Adamu & Shuaibu, 2019). Hydromorphic soils are also important for maintaining the ecological balance of wetlands and supporting biodiversity. They provide habitats for various species of fish, birds, and amphibians, contributing to the state's rich natural heritage (Okonkwo, 2020).

1.5.3 Taraba State

The diversity of Taraba State's geology gives rise to a variety of soil types, each with its own characteristics and implications for agriculture and land use. The state's soils can be broadly categorized based on their geological origins and the processes of weathering and erosion that shape them.

- i. **Ferruginous Tropical Soils:** Much of Taraba State, particularly in the central and northern regions, is covered by ferruginous tropical soils. These soils develop from the weathering of Basement Complex rocks, especially granites and gneisses. Ferruginous soils are generally well-drained and reddish-brown in color due to the high iron content. While they can be fertile for certain crops, these soils are often prone to erosion, particularly on sloping lands [Ogunwole, 2008]. In the highland areas, these soils are often leached, reducing their nutrient content, but they can still support crops like maize, millet, and sorghum with proper management.
- ii. **Alluvial Soils:** The floodplains of the Benue River and its tributaries are dominated by alluvial soils, which are formed from riverine deposits. These soils are typically fertile and have a high-water retention capacity, making them ideal for floodplain agriculture. Farmers in these areas often grow rice, vegetables, and sugarcane, taking advantage of the rich, well-drained soils. The alluvial soils in Taraba State are subject to seasonal flooding, which

replenishes their nutrient content but also requires effective flood control and water management strategies [Obaje, 2009].

- iii. **Volcanic Soils:** On the Mambilla Plateau, volcanic soils derived from basaltic rocks are prevalent. These soils are typically dark, rich in organic matter, and highly fertile, supporting intensive agriculture. The cool climate and fertile volcanic soils of the plateau make it ideal for the cultivation of crops such as tea, coffee, and Irish potatoes. These soils are also less prone to erosion compared to the ferruginous soils of the lowland areas, making them sustainable for long-term agricultural use [Usman, 2011].

1.5.4 Nasarawa State

The soil types in Nasarawa State are largely influenced by its geology, topography, and climate. The state's soils can be classified into several groups, each with distinct characteristics that determine their suitability for different land uses. In the northern and eastern parts of Nasarawa, which are underlain by the Basement Complex rocks, the dominant soils are lithosols and ferruginous tropical soils.

- i. Lithosols are shallow, stony soils that form on steep slopes and hilly terrain. These soils are typically thin and poorly developed due to the rapid erosion of surface materials. As a result, they are not highly suitable for intensive agriculture, but they support grazing and limited crop cultivation, particularly in areas with improved soil management practices (*Ajayi, 2020*).
- ii. Ferruginous tropical soils, on the other hand, are more widespread and are found in areas with moderate rainfall. These soils are characterized by a reddish-brown color, due to the presence of iron oxides, and are generally more fertile than lithosols. They have a loamy to sandy texture and are well-drained, making them suitable for a variety of crops, including yams, maize, and millet. However, their fertility can be affected by continuous cultivation without adequate replenishment of nutrients, which is a common issue in Nasarawa due to the reliance on traditional farming methods (*Iloeje, 2017*).
- iii. In the southern and central parts of the state, where sedimentary rocks dominate, the soils are predominantly alluvial and hydromorphic. Alluvial soils are found along river valleys, particularly in areas adjacent to the Benue River. These soils are rich in organic matter and nutrients due to the deposition of silt and clay during seasonal flooding. As a result, alluvial soils are highly fertile and are ideal for the cultivation of crops such as rice, vegetables, and sugarcane. These areas also support irrigation farming, which is essential for dry-season agriculture (*Afolayan & Popoola, 2019*).
- iv. Hydromorphic soils are found in areas with poor drainage, such as wetlands and low-lying floodplains. These soils tend to be waterlogged for extended periods, making them suitable for rice farming but less ideal for other crops. Hydromorphic soils are often heavy, clayey, and slow-draining, which can pose challenges for agricultural productivity during the rainy season. However, with proper management, these soils can be improved for a wider range of agricultural uses (*Udo, 2016*).

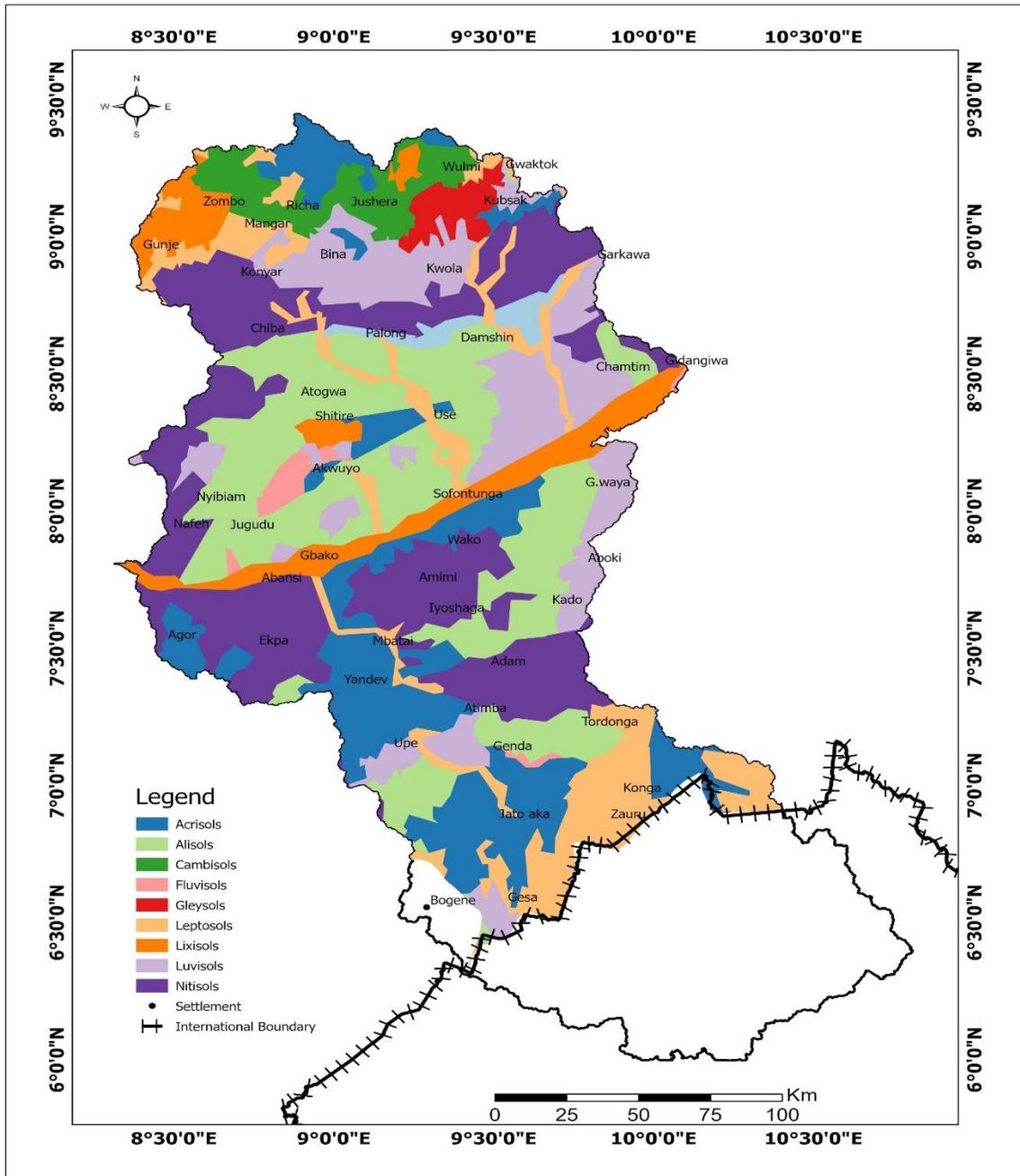


Figure 1.9: Soil map of the catchment area (Source: MSL, 2024)

1.6 Land Use and Land Cover

1.6.1 Plateau State

The land use and land cover in Plateau State are shaped by its diverse topography, climate, and soil types. Human activities such as agriculture, mining, and urbanization have significantly transformed the natural landscape, leading to a variety of land use patterns across the state.

- i. Agricultural Land Use:** Agriculture is the dominant land use in Plateau State, with a significant portion of the land dedicated to crop farming. The state's cooler climate, due to its elevation, makes it suitable for the cultivation of a variety of crops, including cereals (maize, sorghum, millet), tubers (potatoes, yams), and legumes (beans, groundnuts) [Adeoye, 2013]. The highland areas, particularly around Jos, are renowned for the cultivation of vegetables such as tomatoes, cabbage, and carrots, which are marketed both locally and to other parts of Nigeria.
- ii. Irrigated Agriculture:** In the river valleys and floodplains, where hydromorphic soils are prevalent, irrigated agriculture is practiced. This includes the cultivation of rice and vegetables during the dry season. The availability of rivers and streams supports small-scale irrigation schemes, which are vital for food security in the state [Olofin, 1985].
- iii. Livestock Farming:** Plateau State is also an important area for livestock farming, particularly cattle, sheep, and goats. The state's vast grasslands and open savannas provide ample grazing grounds. Livestock farming is particularly prominent among the pastoral Fulani communities, who practice transhumance, moving their herds seasonally in search of pasture and water [Udo, 1994].
- iv. Mining Activities:** Mining has been a major land use in Plateau State, particularly in the Jos Plateau region. The state was historically one of the world's leading producers of tin and columbite, and extensive mining activities have left a significant impact on the landscape. Mining has led to the creation of numerous mine pits, spoil heaps, and tailings, which have altered the natural land cover and drainage patterns [Oyeniya & Hassan, 2018]. The environmental impact of mining in Plateau State is evident in the form of degraded lands, deforestation, and water pollution. Many of the abandoned mine sites are now being reclaimed for other uses, including agriculture and forestry, though the process of land restoration remains challenging due to the extent of the degradation [Ezekiel, 2017].

- v. **Urbanization and Infrastructure Development:** Urban growth is another significant factor influencing land use in Plateau State, particularly around Jos, the state capital. Jos has grown into a major urban center due to its administrative, commercial, and educational functions. The expansion of Jos has led to the conversion of agricultural land and natural vegetation into residential, commercial, and industrial areas [Adeoye, 2013]. The development of infrastructure, including roads, schools, hospitals, and markets, has also influenced land use patterns in Plateau State. Improved road networks have facilitated access to remote areas, leading to the expansion of agricultural activities and the establishment of new settlements [Udo, 1994].
- vi. **Forestry and Conservation:** Forestry and conservation efforts in Plateau State are aimed at preserving the remaining natural vegetation and protecting the environment from further degradation. The state's natural vegetation varies from savanna grasslands in the lowlands to montane forests in the highland areas.
- vii. **Afforestation and Reforestation:** In response to deforestation and land degradation, afforestation and reforestation programs have been initiated. These efforts aim to restore degraded lands, protect watersheds, and provide resources such as fuelwood and timber. Community-based Forest management practices are being encouraged to ensure the sustainability of these efforts [Ezekiel, 2017].
- viii. **Protected Areas:** Plateau State is home to several protected areas, including the Pandam Wildlife Park and the Jos Wildlife Park. These areas are set aside for the conservation of wildlife and natural habitats, contributing to the preservation of the state's biodiversity. However, challenges such as encroachment and illegal activities, including poaching and logging, pose significant threats to the effective management of these protected areas [Ezekiel, 2017].

1.6.2 Benue State

Benue State's land use and land cover are shaped by its agricultural economy, population distribution, and natural resources. The state is predominantly rural, with agriculture serving as the main land use activity. However, land cover varies significantly across the state, reflecting the diversity of its ecosystems, from savannah grasslands to wetlands and forests.

- i. Agricultural Land Use:** Agriculture is the dominant land use in Benue State, occupying approximately 75% of the state's total land area. The state is often referred to as the “food basket of the nation” due to its vast agricultural output. Major crops grown in the state include yams, cassava, rice, maize, and groundnuts, with yam production being particularly prominent. The fertile floodplains along the River Benue are ideal for the cultivation of rice, while the upland areas are used for growing root crops and cereals (*Ayuba, 2020*).
- ii.** In addition to crop farming, Benue State also has a significant livestock farming industry, particularly in its northern regions. Cattle, sheep, and goats are commonly raised, contributing to both the local economy and food security. However, the expansion of agricultural land has led to the clearing of natural vegetation, raising concerns about deforestation and biodiversity loss (*Eze & Echekwube, 2018*).
- iii. Forests and Woodlands:** Forests and woodlands cover about 10% of Benue State’s land area, though this has been steadily declining due to agricultural expansion, logging, and population growth. The remaining forests are primarily located in the south-eastern parts of the state, near the border with Cross River State. These forests are rich in biodiversity, hosting a variety of plant and animal species, some of which are endemic to the region (*Omada, 2019*). The state government has established several forest reserves, such as the Okwangwo Forest Reserve, to protect these ecosystems and promote sustainable forestry practices. However, enforcement of conservation laws remains a challenge, and illegal logging continues to threaten the state's forest resources (*Ayuba, 2020*).
- iv. Urbanization:** Urban areas occupy a relatively small portion of Benue State’s land cover, with Makurdi, the state capital, being the largest urban center. Other notable towns include Gboko, Otukpo, and Katsina-Ala. The state’s urban areas are characterized by a mix of residential, commercial, and industrial land uses, though the level of urbanization is still relatively low compared to other parts of Nigeria (*Obaje, 2009*).
- v.** Infrastructure development in Benue State is concentrated in urban centers and along major transportation corridors. However, rural areas often lack basic infrastructure, such as roads, electricity, and healthcare facilities. The state government has launched several development initiatives aimed at improving rural infrastructure and reducing the urban-rural divide (*Okonkwo, 2020*).

1.6.3 Taraba State

Taraba State's diverse topography and soil types influence its land use and land cover patterns. The state is predominantly rural, with agriculture being the primary land use. However, there are significant variations in land cover across the different ecological zones of the state.

- i. Agricultural Land Use:** Agriculture is the dominant land use in Taraba State, employing the majority of the population and accounting for most of the state's economic activities. The state's diverse climate and soil types allow for the cultivation of a wide range of crops, including cereals, legumes, root crops, and cash crops. In the northern part of the state, which lies in the Sudan Savanna zone, farmers predominantly grow crops such as millet, sorghum, and maize, while the southern and central regions, with more fertile soils, are suitable for crops like yam, cassava, rice, and groundnuts [Fasona, 2016].
- ii.** The Mambilla Plateau, with its temperate climate and fertile volcanic soils, supports the cultivation of cash crops such as tea, coffee, and fruits. Livestock farming, including cattle rearing, is also an important agricultural activity, particularly in the northern and central parts of the state, where pastoralism is widely practiced. The presence of expansive grasslands makes the state conducive to both farming and livestock activities, contributing to food security and economic development [Ogunwole, 2008].
- iii. Forests and Woodlands:** Taraba State is also home to extensive forested areas, particularly in the southern and eastern parts, where tropical rainforests and savanna woodlands are found. These forests provide important ecosystem services, including biodiversity conservation, carbon sequestration, and the provision of timber and non-timber forest products. Protected areas such as the Gashaka-Gumti National Park, located in the eastern part of the state, play a vital role in conserving biodiversity and promoting eco-tourism. The Park is one of the largest in Nigeria and harbors a wide variety of wildlife, including primates, elephants, and rare bird species [Fasona, 2016].
- iv.** Deforestation, however, remains a significant environmental challenge in the state, driven by the expansion of agricultural land, logging, and the demand for firewood. The loss of forest cover has implications for biodiversity, climate regulation, and water catchment management, making sustainable land-use practices critical for the state's environmental health [Obaje, 2009].

- v. **Urbanization:** Urban land use in Taraba State is concentrated in the state capital, Jalingo, and other major towns such as Wukari and Takum. These urban areas have seen growth in recent years, driven by population increases and economic development. However, the rate of urbanization remains relatively low compared to other parts of Nigeria, and most of the population still resides in rural areas [Usman, 2011].
- vi. **Infrastructure Development:** The state's land cover is also influenced by infrastructure development, including the construction of roads, bridges, and public buildings. The presence of important natural resources, such as limestone and coal, has led to the development of extractive industries, which also contribute to changes in land cover.

1.6.4 Nasarawa State

The land cover of Nasarawa State is a reflection of its diverse ecological zones and land use practices. The state's land cover consists of a mixture of forests, grasslands, wetlands, and agricultural lands. In the northern and central parts of the state, the land cover is dominated by Guinea savannah vegetation, characterized by scattered trees, shrubs, and grasses. This savannah ecosystem supports both agriculture and grazing activities and is adapted to the region's seasonal rainfall patterns (Udo, 2016).

In the southern part of Nasarawa, the land cover transitions to more forested areas, particularly along river valleys and wetlands. These forested areas are home to a variety of plant and animal species and play a crucial role in maintaining biodiversity. However, deforestation has become a major issue in these areas, driven by agricultural expansion, logging, and mining activities. The loss of forest cover has led to concerns about soil erosion, reduced water quality, and the disruption of local ecosystems (Ajayi, 2020).

Wetlands, particularly along the Benue River and its tributaries, form an important component of the state's land cover. These wetlands support fishing, rice farming, and flood control, making them valuable for both economic and environmental reasons. However, like the forests, the wetlands are under threat from human activities such as sand dredging and land reclamation for agriculture and development (Afolayan & Popoola, 2019).

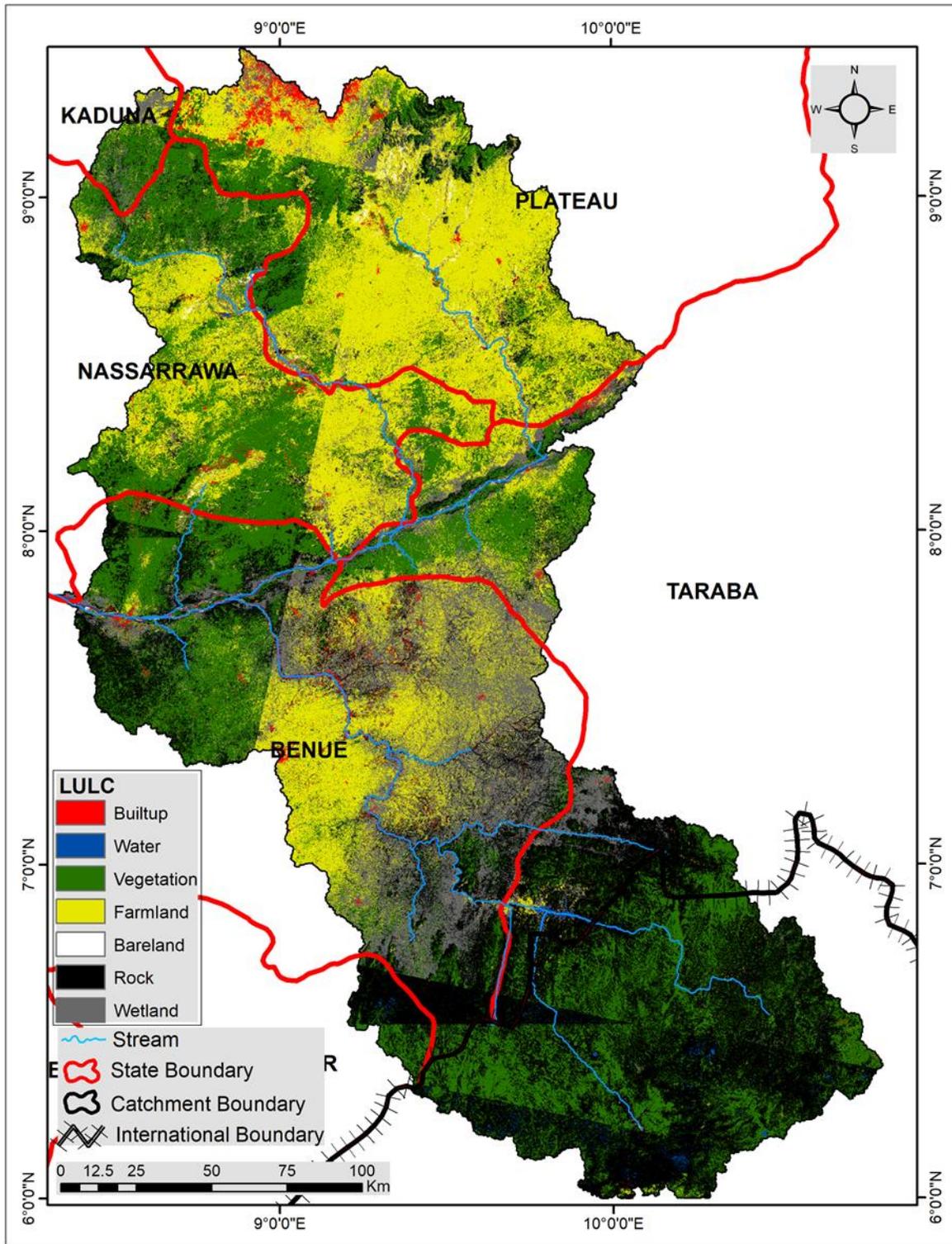


Figure 1.10: Land Use/Land Cover Map of the Catchment (Source: MSL, 2024)

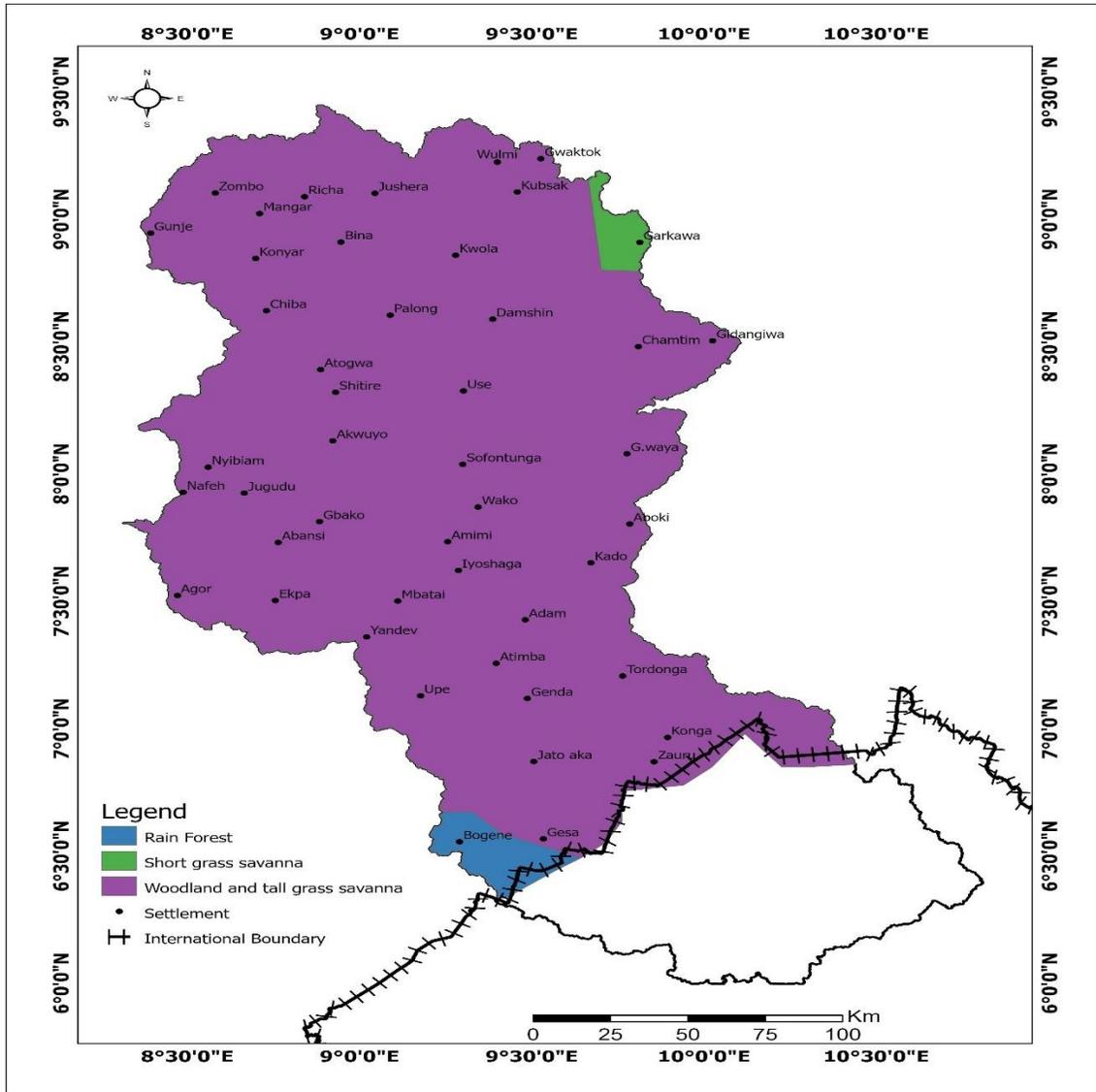


Figure 1.11: Map showing the vegetation cover in the catchment area (Source: MSL, 2024)

CHAPTER 2 NORMALIZED DIFFERENCE VEGETATION INDEX (NDVI) ANALYSIS OF THE SHEMANKAR-KATSINA-ALA STRATEGIC CATCHMENTS

NDVI or Normalized Difference Vegetation Index is a remote sensing method that uses the reflectance of light in the visible and near-infrared (NIR) wavelengths to determine the amount and health of vegetation in an area. NDVI is widely used in agriculture, forestry, and ecology to monitor the growth and health of vegetation and to identify areas of stress or damage. NDVI values can also be used to map and classify vegetation types, and to detect changes in vegetation cover over time. Simply put, the Normalized Difference Vegetation Index is an indicator of a plant's health entirely based on how the cell structures reflect the different light waves in visible and near-infrared bands. In other words, it aids in detecting and quantifying the presence of live green vegetation based on how objects interact with light. To understand the plant's health condition, one needs to compare the absorption and reflection values of red and NIR (near-infrared) light.

NDVI (Normalized Difference Vegetation Index) is a remote sensing method that was first developed in the 1970s. The concept of using the reflectance of light in the visible and near-infrared (NIR) wavelengths to determine the amount and health of vegetation was first proposed by a scientist named Rouse, in 1973. He used two filters, one to detect the red light and one to detect the near-infrared light. He calculated NDVI by subtracting the reflectance of the NIR band from the reflectance of the red band and then dividing that value by the sum of the reflectance of the NIR and red bands. In the 1980s, NDVI was further developed and applied to satellite imagery, enabling large-scale monitoring of vegetation cover. The first NDVI images from satellites were generated in the early 1980s and were used to map and classify vegetation types and monitor vegetation cover changes. In the 1990s, NDVI was used to monitor vegetation health and productivity in agriculture and was also applied to the monitoring of forest and rangeland ecosystems. With the advent of high-resolution satellite imagery and unmanned aerial vehicles (UAVs), NDVI has become increasingly accessible and widely used in a variety of applications such as precision agriculture, land use and land cover mapping, and monitoring of ecosystem health. Today NDVI is widely used in many applications such as monitoring of crops, vegetation health, precision agriculture, land use and land cover mapping, and monitoring of ecosystem health.

Plants have a unique reflectance characteristic; they reflect more near-infrared (NIR) light and absorb more visible light. When plants are healthy, they have a high chlorophyll content, which allows them to absorb more light in the red region of the spectrum and reflect more light in the NIR region. So NDVI uses this characteristic of plants to differentiate healthy vegetation from non-vegetation or unhealthy vegetation.

NDVI is calculated by subtracting the reflectance of the NIR band from the reflectance of the red band and then dividing that value by the sum of the reflectance of the NIR and red bands. NDVI values range from -1 to 1, with -1 indicating no vegetation, 0 indicating bare soil or water, and values closer to 1 indicating greater amounts and healthier vegetation.

In mathematical terms, comparing the red and near-infrared light signals can help differentiate between healthy and sick plants or distinguish non-plants from plants.

The formula below was used for the evaluation of NDVI:

$$\text{NDVI} = (\text{NIR}-\text{Red})/(\text{NIR}+\text{Red})$$

Where NIR is reflectance in the near-infrared band and RED is reflectance in the visible red band. The NDVI algorithm takes advantage of the fact that green vegetation reflects less visible light and more NIR, while sparse or less green vegetation reflects a greater portion of the visible and less near-IR. NDVI combines these reflectance characteristics in a ratio so it is an index related to photosynthetic capacity. The range of values obtained is between -1 and +1. Only positive values correspond to vegetated zones; the higher the index, the greater the chlorophyll content of the target. A higher or more positive value indicates greater plant vigor and general health.

NDVI has been used to monitor desertification (Tucker et al. 1991), land-use change (US Environmental Protection Agency 1997) and the effects of global warming in high latitudes (Myneni et al. 1997). Comparisons can only be made across the three decades for which satellite sensor data are available

The Landsat archive is one of the most effective remote sensing tools for earth system science research because it provides long-term continuous observations, global coverage, and moderate temporal and spatial resolutions, and thus it is used widely for monitoring vegetation dynamics (Nagendra et al., 2013).

2.1 NDVI From Landsat Imagery

Satellite remote sensing (SRS) allows for the calculation of NDVI globally at a range of temporal intervals and spatial resolutions dependent on sensor characteristics and the satellite orbit, with a common inverse relationship between temporal and spatial resolutions. The Landsat Mission, with its first sensor launched in 1972, is the only uninterrupted long-term (>30 years) high-resolution remote sensing dataset that can provide a continuous historic NDVI record globally. The Landsat record at 30-m resolution is ideally suited for local or regional scale time-series applications, particularly with the release of higher-level surface reflectance products from Landsat sensors 5 ETM, 7 ETM+, 8 OLI and 9 OLI2.

Landsat 8 and 9 acquired in February 2023 were used to derive the NDVI for the nineteen Northern States and the FCT for the ACRoSAL project.

2.2 Landsat 8

Landsat 8 (formerly the Landsat Data Continuity Mission, or LDCM) was launched on an Atlas-V rocket from Vandenberg Air Force Base, California on February 11, 2013. The satellite carries the Operational Land Imager (OLI) and the Thermal Infrared Sensor (TIRS) instruments.

The OLI measures in the visible, near infrared, and shortwave infrared portions (VNIR, NIR, and SWIR) of the spectrum. The TIRS measures land surface temperature in two thermal bands with a new technology that applies quantum physics to detect heat. Landsat 8 images have 15-meter panchromatic and 30-meter multi-spectral spatial resolutions along a 185 km (115 mi) swath.

Landsat 8 carries two sensors. The Operational Land Imager sensor is built by Ball Aerospace & Technologies Corporation. The Thermal Infrared Sensor is built by NASA Goddard Space Flight Center.

2.2.1 Operational Land Imager (OLI)

- Nine spectral bands, including a pan band:
 - Band 1 Coastal Aerosol (0.43 - 0.45 μm) 30 m
 - Band 2 Blue (0.450 - 0.51 μm) 30 m
 - Band 3 Green (0.53 - 0.59 μm) 30 m
 - Band 4 Red (0.64 - 0.67 μm) 30 m
 - Band 5 Near-Infrared (0.85 - 0.88 μm) 30 m
 - Band 6 SWIR 1 (1.57 - 1.65 μm) 30 m
 - Band 7 SWIR 2 (2.11 - 2.29 μm) 30 m
 - Band 8 Panchromatic (PAN) (0.50 - 0.68 μm) 15 m
 - Band 9 Cirrus (1.36 - 1.38 μm) 30 m

OLI captures data with improved radiometric precision over a 12-bit dynamic range, which improves overall signal to noise ratio. This translates into 4096 potential grey levels, compared with only 256 grey levels in Landsat 1-7 8-bit instruments. Improved signal to noise performance enables improved characterization of land cover state and condition.

The 12-bit data are scaled to 16-bit integers and delivered in the Level-1 data products. Products are scaled to 55,000 grey levels, and can be rescaled to the Top of Atmosphere (TOA) reflectance and/or radiance using radiometric rescaling coefficients provided in the product metadata file (MTL file).

2.2.2 Thermal Infrared Sensor (TIRS)

- Two spectral bands:
 - Band 10 TIRS 1 (10.6 - 11.19 μm) 100 m
 - Band 11 TIRS 2 (11.5 - 12.51 μm) 100 m

2.3 Landsat 9

The instruments onboard Landsat 9 are improved replicas of those currently collecting data onboard [Landsat 8](#), which are already providing data that is radiometrically and geometrically superior than instruments on previous generation Landsat satellites.

The satellite carries two science instruments, the Operational Land Imager 2 (OLI-2) and the Thermal Infrared Sensor 2 (TIRS-2). The OLI-2 captures observations of the Earth's surface in visible, near-infrared, and shortwave-infrared bands, and TIRS-2 measures thermal infrared radiation, or heat, emitted from the Earth's surface. Both OLI and TIRS have a 5-year mission design life, although the spacecraft has 10+ years of consumables.

Landsat 9 improvements include higher radiometric resolution for OLI-2 (14-bit quantization increased from 12-bits for Landsat 8) allowing sensors to detect more subtle differences, especially over darker areas such as water or dense forests. With the higher radiometric resolution, Landsat 9 can differentiate 16,384 shades of a given wavelength. In comparison, Landsat 8 provides 12-bit data and 4,096 shades, and Landsat 7 detects only 256 shades with its 8-bit resolution. In addition to the OLI-2 improvement, TIRS-2 has significantly reduced stray light compared to the Landsat 8 Thermal Infrared Sensor (TIRS) which enables improved atmospheric correction and more accurate surface temperature measurements.

The OLI-2 design is a copy of Landsat 8's OLI, and provides imagery consistent with previous Landsat spectral, spatial, radiometric and geometric qualities. OLI-2 will provide data for nine spectral bands with a maximum ground sampling distance (GSD), both in-track and cross track, of 30-meters (m) (98 feet) for all bands except the panchromatic band, which has a 15-meter (49 feet) GSD. OLI-2 provides both internal calibration sources to ensure radiometric accuracy and stability, as well as the ability to perform solar and lunar calibrations. OLI-2 is designed by Ball Aerospace in Boulder, Colorado.

Nine spectral bands:

- Band 1 Visible Coastal Aerosol (0.43 - 0.45 μm) 30-m
- Band 2 Visible Blue (0.450 - 0.51 μm) 30-m
- Band 3 Visible Green (0.53 - 0.59 μm) 30-m
- Band 4 Red (0.64 - 0.67 μm) 30-m
- Band 5 Near-Infrared (0.85 - 0.88 μm) 30-m
- Band 6 SWIR 1 (1.57 - 1.65 μm) 30-m
- Band 7 SWIR 2 (2.11 - 2.29 μm) 30-m
- Band 8 Panchromatic (PAN) (0.50 - 0.68 μm) 15-m
- Band 9 Cirrus (1.36 - 1.38 μm) 30-m

In Landsat 8-9, $\text{NDVI} = (\text{Band } 5 - \text{Band } 4) / (\text{Band } 5 + \text{Band } 4)$.

Figure 2.1 shows the NDVI map of the Shemankar Katsina-Ala

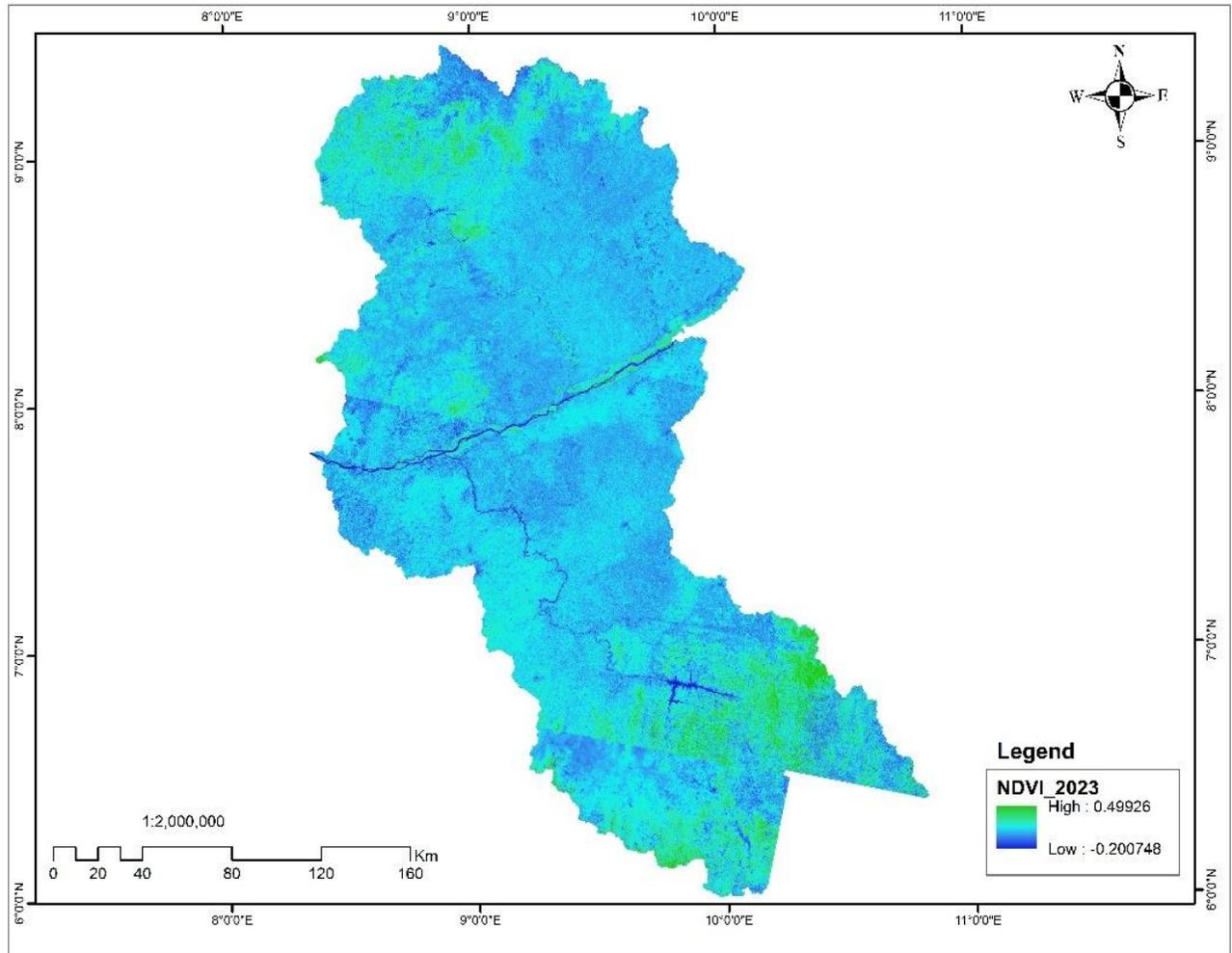


Figure 2.1: NDVI Map of the Catchment (Source: MSL, 2024)

CHAPTER 3 : CLIMATE AND HYDROLOGY

3.1 Plateau State

3.1.1 Climate

Plateau State's climate is characterized by two main seasons: the wet season and the dry season, which are typical of the tropical savanna climate. However, due to its elevation, Plateau State enjoys a cooler climate compared to other regions in Nigeria, with temperatures and rainfall patterns that are distinct from those of the surrounding lowlands.

- i. **Temperature:** The average annual temperature in Plateau State ranges between 18°C and 25°C, with variations depending on the season and altitude. The Jos Plateau, the highest point in the state, experiences cooler temperatures, particularly during the Harmattan season (December to February), when temperatures can drop to as low as 11°C at night [Mallo, 2019]. The temperature during the hot season (March to May) can rise to around 30°C, but this is still relatively mild compared to other parts of Nigeria. The state's cooler climate makes it a favorable environment for temperate crops and a popular destination for tourists seeking relief from the heat.
- ii. **Rainfall:** Rainfall in Plateau State is highly seasonal, with the majority of precipitation occurring during the wet season, which lasts from April to October. The state receives an average annual rainfall of between 1,100 mm and 1,600 mm, with the highest amounts recorded on the Jos Plateau and other elevated areas [Obot et al., 2016]. The distribution of rainfall across the state is influenced by its topography, with higher elevations receiving more rainfall than the surrounding lowlands. The wet season is characterized by frequent thunderstorms and heavy rains, which are essential for agriculture but can also lead to soil erosion and flooding in some areas.
- iii. **Humidity:** Humidity levels in Plateau State are generally high during the wet season, ranging from 70% to 90%, contributing to the lush vegetation and agricultural productivity of the region. During the dry season, humidity levels drop significantly, especially during the Harmattan, when the air becomes dry and dusty due to the north-east trade winds [Egwudah & David, 2020]. The Harmattan season is also marked by reduced visibility and cooler temperatures, which can affect transportation and outdoor activities.

3.1.1.1 Seasonal Variations and Climatic Influences

The climate of Plateau State is influenced by several factors, including its elevation, latitude, and prevailing wind patterns. The state's elevated terrain acts as a barrier to the moist south-westerly winds from the Atlantic Ocean, causing them to rise and cool, leading to the formation of clouds and precipitation.

- i. **Wet Season:** The wet season in Plateau State is driven by the movement of the Intertropical Convergence Zone (ITCZ), which brings moist air from the Atlantic Ocean. This season is marked by heavy rainfall, which is vital for replenishing water bodies, supporting agriculture, and sustaining the state's ecosystems. The wet season also contributes to the lush vegetation and cooler temperatures that Plateau State is known for [Mallo, 2019].
- ii. **Dry Season:** The dry season is characterized by the dominance of the Harmattan, a dry and dusty wind that blows from the Sahara Desert. During this period, the state experiences lower humidity, reduced rainfall, and cooler temperatures, particularly at night. The Harmattan season can also lead to increased respiratory problems due to the dry and dusty conditions [Egwudah & David, 2020].
- iii. **Climate Change Impacts:** Like many other regions, Plateau State is experiencing the effects of climate change, which are manifesting in altered rainfall patterns, increased frequency of extreme weather events, and changes in temperature regimes. These changes pose significant challenges to agriculture, water resources, and overall livelihoods in the state [Eze & Ijeoma, 2018].

3.1.2 Hydrology

3.1.2.1 Major Rivers and Water Bodies

Plateau State is blessed with numerous rivers, streams, and other water bodies, which are integral to the state's hydrology and support a variety of uses, including agriculture, domestic water supply, and hydroelectric power generation.

- i. **Rivers:** The state is traversed by several major rivers, including the Kaduna River, the Gongola River, and the Hadejia-Jama'are River. These rivers originate from the Jos Plateau and flow through various parts of the state, providing water for irrigation, fishing, and other economic activities [Olanrewaju et al., 2017]. The rivers are fed by numerous smaller

streams and tributaries, which are replenished during the wet season. The Kaduna River, in particular, is a significant watercourse that flows southwestward through the state and is a major tributary of the Niger River.

- ii. **Dams and Reservoirs:** Plateau State has several dams and reservoirs that play a crucial role in water storage and regulation. The Lamingo Dam, located near Jos, is one of the major reservoirs in the state, providing water for domestic and agricultural use. Other notable dams include the Kura Falls Dam and the Pankshin Dam, which also support irrigation and water supply [Ayuba & Shehu, 2016]. These dams are critical for managing water resources in the state, particularly during the dry season when river flows decrease.
- iii. **Wetlands and Lakes:** The state is also home to several wetlands and small lakes, which provide important habitats for wildlife and support biodiversity. The Pandam Wildlife Park, located in the southern part of the state, includes a large wetland area that is important for birdlife and other species. These wetlands are also crucial for groundwater recharge and flood mitigation [Obot et al., 2016].

3.1.2.2 Stream Flow and Discharge

The hydrology of Plateau State is characterized by seasonal variations in stream flow and discharge, which are closely linked to the state's rainfall patterns. During the wet season, rivers and streams experience high flows due to the influx of rainwater, while the dry season is marked by reduced flows and in some cases, the drying up of smaller streams.

- i. **Wet Season Flows:** The wet season, from April to October, is the period of peak flow for most rivers and streams in Plateau State. The heavy rainfall during this season leads to increased river discharge, which can result in flooding, particularly in low-lying areas [Olanrewaju et al., 2017]. The high flows are essential for replenishing reservoirs and maintaining the ecological health of wetlands and riparian zones. However, the intensity of rainfall during this period can also lead to soil erosion and sedimentation in rivers, which affects water quality and aquatic habitats.
- ii. **Dry Season Flows:** During the dry season, river flows decrease significantly as rainfall diminishes and temperatures rise. Many smaller streams and tributaries may dry up completely, while larger rivers such as the Kaduna River experience reduced discharge. The decreased flow during this period can lead to water shortages, affecting agriculture,

domestic water supply, and hydropower generation [Ayuba & Shehu, 2016]. The state relies on its dams and reservoirs to store water during the wet season for use during the dry season, but these water bodies are often under pressure due to increasing demand and climate variability.

3.1.2.3 Flood and Drought Patterns

Plateau State is susceptible to both flooding and drought, which are influenced by its climate and hydrological conditions. These events have significant implications for the state's agriculture, water resources, and infrastructure.

- i. **Flooding:** Flooding is a common occurrence during the wet season in Plateau State, particularly in areas along rivers and streams. Heavy rainfall can lead to the overflow of rivers, causing floods that damage crops, homes, and infrastructure. Flooding also contributes to soil erosion and the deposition of sediments in water bodies, which can reduce the capacity of reservoirs and affect water quality [Olanrewaju *et al.*, 2017]. The state has implemented various flood control measures, including the construction of levees and the development of early warning systems, but challenges remain in managing the impacts of floods, especially in rural areas.
- ii. **Drought:** Droughts occur during the dry season when rainfall is scarce, and temperatures are high, leading to reduced water availability. Droughts in Plateau State can have severe impacts on agriculture, as crops fail and livestock suffer from lack of water and pasture. The state's reliance on rain-fed agriculture makes it particularly vulnerable to drought, which can lead to food insecurity and economic losses [Eze & Ijeoma, 2018]. To mitigate the effects of drought, the state has been promoting the adoption of water conservation practices, the use of drought-resistant crops, and the development of irrigation systems.

3.1.2.4 Groundwater Resources

Groundwater is an important source of water in Plateau State, particularly in rural areas where access to surface water may be limited. The state's geology, characterized by crystalline basement rocks, influences the availability and quality of groundwater.

- i. **Aquifers and Groundwater Recharge:** The main aquifers in Plateau State are found in the weathered and fractured zones of the crystalline basement rocks. Groundwater recharge

occurs primarily during the wet season, when rainfall infiltrates the soil and percolates down to the water table [Obot *et al.*, 2016]. However, the rate of recharge is limited by the state's geology and topography, and groundwater resources are often under pressure due to over-extraction and pollution.

- ii. **Groundwater Quality:** The quality of groundwater in Plateau State is generally good, but it can be affected by factors such as mining activities, agricultural runoff, and the improper disposal of waste. In some areas, groundwater has been found to contain elevated levels of heavy metals, such as lead and arsenic, which pose health risks to the local population [Ayuba & Shehu, 2016]. The state government, through the Plateau State Water Board and other agencies, monitors groundwater quality and implements measures to protect and manage this vital resource.

3.2 Benue State

3.2.1 Climate

Benue State experiences a tropical climate characterized by distinct wet and dry seasons, typical of the Guinea Savanna region in Nigeria. The climate plays a critical role in shaping the state's agricultural productivity, biodiversity, and overall socioeconomic conditions. Benue State falls within latitudes 6°30'N and 8°10'N and longitudes 7°30'E and 10°00'E, placing it in the tropical zone where both tropical maritime (wet) and tropical continental (dry) air masses influence the weather patterns.

- i. **Rainfall:** Rainfall is one of the most significant climatic factors in Benue State, as it influences agricultural practices, water resources, and overall livelihood. The rainy season typically begins in April and lasts until October, with peak rainfall occurring between July and September. The average annual rainfall ranges from 1,200 mm to 1,800 mm, depending on the location within the state (Obaje, 2009). Areas closer to the southeastern part of the state, such as Oju and Otukpo, receive higher rainfall, while the northern parts, like Makurdi and Gboko, receive slightly less. Rainfall in Benue State is often influenced by the movement of the Inter-Tropical Convergence Zone (ITCZ), which oscillates between the equator and the Tropic of Cancer. During the rainy season, the ITCZ draws moisture-laden winds from the Atlantic Ocean, causing widespread rains across the state. The wet season is vital for agriculture, particularly for the cultivation of crops like yams, maize,

rice, and soybeans (*Abah & Omada, 2019*). However, excessive rainfall often leads to flooding, especially in low-lying areas along the River Benue, disrupting farming activities and displacing communities.

- ii. Temperature:** Temperature in Benue State is generally high, typical of tropical regions. The state experiences an average temperature range of 24°C to 35°C throughout the year. During the dry season (November to March), daytime temperatures can soar above 35°C, particularly in February and March, which are the hottest months. In contrast, the wet season brings more moderate temperatures due to increased cloud cover and rainfall, with averages around 27°C to 30°C (*Eze, 2018*). The state also experiences significant diurnal temperature variations, particularly in the dry season when nighttime temperatures can drop to as low as 18°C. This temperature variation is more pronounced in areas with higher elevation, such as parts of the southwestern and northeastern regions of the state (*Olapade, 2018*). High temperatures during the dry season, coupled with low humidity, often lead to drought conditions, which can adversely affect crop yields and water availability.
- iii. Humidity and Wind Patterns:** Humidity in Benue State is generally high during the rainy season, reaching levels of 70-80%, especially in the months of July and August. During the dry season, however, humidity levels drop significantly, often falling below 40%. The Harmattan, a dry and dusty trade wind that blows from the Sahara Desert, typically affects the state from November to February. The Harmattan brings cooler temperatures, low humidity, and dust-laden winds, creating hazy conditions that can affect visibility and respiratory health (*Obaje, 2009*). Wind speeds in Benue State are generally moderate, ranging from 2 to 5 meters per second. The rainy season is associated with more turbulent weather, including thunderstorms and squalls, which can cause localized damage to crops and infrastructure. The dry season, particularly during the Harmattan, brings calmer winds, although the dust storms that accompany the Harmattan can reduce air quality and contribute to the drying out of soils (*Olapade, 2018*).

3.2.2 Hydrology

The hydrology of Benue State is heavily influenced by the presence of the River Benue and its extensive network of tributaries. The state's water resources are critical for agriculture, domestic

use, and industrial activities. However, seasonal variations in rainfall and river flow, coupled with challenges such as flooding and drought, make water management an important issue in the state.

3.2.2.1 River Benue

The River Benue is the dominant hydrological feature in Benue State, and it plays a vital role in the state's economy and ecology. The river is Nigeria's second-largest, stretching from its source in the Adamawa Plateau of Cameroon and flowing westward across Benue State before merging with the River Niger at Lokoja. In Benue State, the river traverses a distance of approximately 500 kilometers, cutting across major towns such as Makurdi, where it serves as a focal point for transportation, fishing, and irrigation (*Adamu, 2019*).

The river experiences seasonal fluctuations in flow, with peak discharge occurring during the rainy season (July to September), when runoff from heavy rains in the upper basin increases water levels. The dry season (November to March) is characterized by lower water levels, which can affect agricultural irrigation and water supply to communities that depend on the river (*Eze, 2018*).

Flooding is a major hydrological concern in Benue State, particularly along the floodplains of the River Benue. Heavy rains, coupled with runoff from upstream areas, often cause the river to overflow its banks, leading to widespread flooding. The city of Makurdi is especially prone to flooding, with recent major floods in 2012 and 2017 displacing thousands of people and causing significant economic damage (*Ayuba, 2020*). Flood mitigation measures, such as the construction of embankments and dredging of river channels, have been proposed, but the implementation of these measures remains a challenge due to financial and logistical constraints.

3.2.2.2 Tributaries and Drainage

In addition to the River Benue, Benue State is drained by several smaller rivers and streams, which contribute to the overall hydrological network. Notable tributaries of the River Benue include the Katsina-Ala River, the Okpokwu River, and the Dura River. These tributaries provide water for both domestic use and agricultural irrigation, particularly in rural areas where access to piped water is limited (*Abah & Omada, 2019*). The drainage pattern in Benue State is largely dendritic, with rivers and streams radiating outwards from the central River Benue. This pattern is shaped by the underlying geology of the state, particularly the sedimentary rocks that allow for the formation of

aquifers and groundwater recharge areas. Groundwater is an important resource in Benue State, especially in areas far from the major rivers. Boreholes and wells are commonly used to access groundwater, particularly during the dry season when surface water sources are depleted (*Olapade, 2018*).

3.2.2.3 Groundwater Resources

Groundwater is an essential component of the hydrological system in Benue State, particularly in rural areas where surface water availability is limited during the dry season. The state's geology, characterized by sedimentary formations, supports the presence of aquifers, which store groundwater that can be tapped for domestic, agricultural, and industrial use. However, the quality of groundwater varies across the state, with some areas experiencing issues such as high salinity and the presence of heavy metals (*Adamu, 2019*). Groundwater levels fluctuate seasonally, with recharge occurring during the rainy season when rainfall infiltrates the soil and replenishes aquifers. During the dry season, groundwater levels drop, leading to water scarcity in some areas. Over-extraction of groundwater, particularly through the use of boreholes, has raised concerns about the long-term sustainability of this resource, especially as the state's population continues to grow (*Ayuba, 2020*).

3.2.2.4 Flood and Drought Patterns

Benue State is highly susceptible to both flooding and drought, with significant impacts on agriculture, water supply, and infrastructure. As mentioned earlier, flooding is a recurring problem, particularly in low-lying areas along the River Benue and its tributaries. Flooding typically occurs during the peak of the rainy season, when heavy rains cause rivers to overflow their banks. The floodplains of the River Benue are particularly vulnerable, with major flood events recorded in 2012, 2017, and 2020 (*Ayuba, 2020*). In contrast, drought is more common during the dry season, particularly in the northern parts of the state. Droughts occur when rainfall is insufficient to meet the water demands of crops, livestock, and human populations. The dry season in Benue State is often exacerbated by the Harmattan, which brings dry, dusty winds and further depletes soil moisture levels. Droughts can have devastating effects on agricultural productivity, leading to food insecurity and economic losses (*Eze, 2018*).

3.3 Taraba State

3.3.1 Climate

Taraba State, located in northeastern Nigeria, experiences a climate that is heavily influenced by its geographical position and diverse topography. The state falls within two major climatic zones: the tropical savanna climate and the montane climate in the highland areas, particularly on the Mambilla Plateau. The climate of the state plays a crucial role in shaping the region's agriculture, water resources, and overall livelihoods.

- i. **Tropical Savanna Climate:** Much of Taraba State, particularly the lowland and central areas, experiences a tropical savanna climate (Aw in the Köppen climate classification). This climate is characterized by distinct wet and dry seasons, influenced by the movement of the Intertropical Convergence Zone (ITCZ) and the trade winds.
- ii. **Rainfall:** The wet season typically lasts from April to October, with the state receiving a significant amount of its annual rainfall during this period. Rainfall varies considerably across the state due to its diverse topography. In the southern parts of the state, particularly around the Benue River basin, annual rainfall can exceed 1,500 mm. In contrast, the northern and central regions receive between 1,000 and 1,300 mm of rainfall annually [Ayoade, 2004]. The onset of the rainy season is usually marked by thunderstorms, and rainfall tends to be heaviest in July and August. The presence of hills and mountains, such as the Mambilla Plateau, creates orographic rainfall, leading to increased precipitation in these highland areas.
- iii. **Temperature:** Temperatures in Taraba State are generally high throughout the year, although they fluctuate depending on the season. During the dry season (November to March), the region experiences high temperatures, with average daytime temperatures ranging from 28°C to 35°C. The harmattan winds, which blow from the Sahara Desert, bring dry, dusty conditions and can cause temperatures to drop at night, particularly in December and January [Olaniran, 1983]. In the wet season, temperatures are moderated by cloud cover and rainfall, with average temperatures ranging from 25°C to 30°C. However, the highland areas, especially the Mambilla Plateau, have a much cooler climate due to their elevation. Temperatures on the plateau can range from 16°C to 25°C, making

it one of the coolest regions in Nigeria. This cool climate supports the cultivation of temperate crops such as tea, coffee, and Irish potatoes [Olowolafe, 2002].

- iv. **Humidity:** Humidity levels in Taraba State vary significantly between the wet and dry seasons. During the rainy season, relative humidity can reach up to 80-90%, particularly in the southern parts of the state, where dense vegetation and high rainfall contribute to elevated moisture levels. In contrast, the harmattan season brings extremely dry conditions, with humidity levels dropping to as low as 20-30%, especially in the northern and central areas [Ayoade, 2004]. These variations in humidity have implications for agriculture, water management, and human comfort in the state.
- v. **Montane Climate on the Mambilla Plateau:** The Mambilla Plateau, located in the southeastern part of the state, experiences a distinct montane climate due to its high elevation (rising over 1,800 meters above sea level). The plateau's climate is classified as temperate, with cool temperatures and a more consistent rainfall pattern compared to the lowland areas.
- vi. **Rainfall and Temperature:** Rainfall on the Mambilla Plateau is relatively high, with annual precipitation exceeding 1,800 mm, and the rainy season can extend from March to November. The cooler temperatures on the plateau, which range from 16°C to 25°C year-round, are ideal for the cultivation of crops that thrive in temperate climates, such as coffee, tea, and fruits [Olowolafe, 2002]. The climate of the plateau also supports livestock farming, particularly cattle rearing, as the cooler temperatures reduce the prevalence of diseases such as trypanosomiasis (sleeping sickness), which is common in warmer lowland areas.

3.3.2 Hydrology

The hydrology of Taraba State is defined by its river systems, floodplains, and water bodies. The state is endowed with significant water resources, including the Benue River, which is one of the major rivers in Nigeria. The availability of water resources plays a critical role in agriculture, human settlements, and biodiversity in the region.

3.3.2.1 Major River Systems

Taraba State is primarily drained by the Benue River and its numerous tributaries. The Benue River, a major tributary of the Niger River, flows through the southern part of the state, forming

its boundary with neighbouring states and providing vital water resources for irrigation, fishing, and domestic use.

- i. Benue River:** The Benue River is the most significant river in the state, flowing from the eastern parts of Nigeria towards the confluence with the Niger River in Lokoja. In Taraba State, the river supports a wide range of economic activities, including fishing, irrigation, and transportation. The river also contributes to the floodplain agriculture practiced by communities along its banks, particularly in the southern part of the state [Iloje, 1981]. The Benue River has a seasonal flow pattern, with water levels rising significantly during the rainy season (April to October) and receding during the dry season. The river's seasonal flooding replenishes soil nutrients in the floodplains, making them fertile for agriculture. However, these floods can also pose risks to communities living in flood-prone areas, especially during years of excessive rainfall.
- ii. Tributaries:** Several important tributaries feed into the Benue River in Taraba State. These include the Donga River, Taraba River, and Katsina-Ala River, all of which contribute to the hydrological complexity of the region. These rivers are essential for both surface water and groundwater recharge, supporting agricultural activities, domestic water supply, and ecosystems along their courses [Adakole, 2000]. The Taraba River, which flows from the central highlands of the state, is particularly important for irrigation in areas such as Jalingo and surrounding communities. The river's flow is seasonal, with peak discharge occurring during the rainy season. However, reduced flow during the dry season can lead to water scarcity, particularly for farmers who depend on river water for irrigation.
- iii. Floodplains and Wetlands:** The extensive floodplains of the Benue River and its tributaries create wetland ecosystems that are rich in biodiversity and provide essential ecosystem services. These floodplains support a variety of plant and animal species, including migratory birds, fish, and amphibians. Wetland areas such as the Donga River basin are important for flood control, groundwater recharge, and carbon sequestration [Adakole, 2000]. The wetlands also play a crucial role in traditional floodplain agriculture, where farmers plant crops such as rice, maize, and vegetables in the nutrient-rich soils left behind by receding floodwaters. However, the expansion of agriculture and human settlements into wetland areas has led to concerns about habitat degradation and loss of biodiversity.

3.3.2.2 Groundwater Resources

In addition to surface water, Taraba State also relies on groundwater resources, particularly in rural areas where boreholes and wells provide drinking water for communities. The state's geology, particularly in areas underlain by the Basement Complex, influences groundwater availability. Crystalline rocks such as granites and gneisses have low porosity and permeability, limiting the storage and flow of groundwater. However, weathered zones and fractures within these rocks can serve as aquifers, providing localized sources of groundwater [Olorunfemi, 2000]. In the sedimentary areas of the state, particularly in the Benue Trough, groundwater is more readily available due to the presence of porous sandstones and alluvial deposits. These aquifers are recharged by rainfall and river systems, and they play a vital role in supporting agriculture and domestic water supply, particularly during the dry season when surface water resources are limited.

3.3.2.3 Flooding and Drought Patterns

Taraba State is prone to both flooding and drought, with significant implications for water management, agriculture, and human livelihoods. Flooding is a regular occurrence along the Benue River and its tributaries, particularly during the rainy season when heavy rainfall and runoff increase river discharge. Flood events can cause displacement of communities, damage to infrastructure, and loss of agricultural land [Ayoade, 2004]. Conversely, droughts are also a recurrent challenge, particularly in the northern and central parts of the state, where rainfall is more erratic. During prolonged dry spells, river flows decrease, groundwater levels drop, and water scarcity becomes a serious issue for both farmers and households. The state's dependence on rain-fed agriculture makes it particularly vulnerable to the impacts of drought, and climate change is expected to exacerbate these challenges by altering rainfall patterns and increasing the frequency of extreme weather events [Olaniran, 1983].

3.4 Nasarawa State

3.4.1 Climate

Nasarawa State, located in the north-central region of Nigeria, experiences a tropical climate, which is influenced by both its geographical location and topography. The climate of the state can be categorized into two distinct seasons: the wet (rainy) season and the dry season. These seasons are largely controlled by the interaction between the tropical continental air mass (dry winds) and the tropical maritime air mass (moist winds), which dominate different times of the year.

- i. Rainy Season:** The rainy season in Nasarawa State typically begins in late April or early May and lasts until October. During this period, the state receives the bulk of its annual rainfall, which averages between 1,100 mm to 1,600 mm annually, depending on the specific location within the state (*Afolayan & Popoola, 2019*). The amount of rainfall decreases from the southern parts of the state, which are closer to the Benue River, to the northern parts, which border the drier savannah regions of Kaduna State. The highest rainfall occurs in the southern areas, especially near Lafia and along the riverine areas, where the topography encourages orographic rainfall. The state experiences its peak rainfall in the months of July and August, when the Intertropical Convergence Zone (ITCZ) is at its northernmost position, drawing in moist air from the Atlantic Ocean. During this time, daily thunderstorms are common, and the state often experiences heavy downpours that contribute to the state's rich agricultural productivity (*Ajayi, 2020*). These rains are essential for the cultivation of crops such as rice, maize, millet, and yams, which rely on the consistent moisture provided by the rainy season. However, excessive rainfall can also lead to flooding in low-lying areas, particularly along the Benue River and other water bodies (*Udo, 2016*).
- ii. Dry Season:** The dry season begins in November and lasts until March, with the peak of dryness occurring between December and February. During this period, the state comes under the influence of the Harmattan winds, which are dry, dusty, and cold winds that blow from the Sahara Desert. The Harmattan winds lead to a significant drop in humidity, and temperatures can drop as low as 15°C at night, especially in the northern and hilly areas (*Afolayan & Popoola, 2019*). During the day, however, temperatures can rise to around 35°C, making the dry season a period of extreme temperature variations. The dry season is

characterized by little to no rainfall, and the vegetation tends to dry out due to the lack of moisture and intense solar radiation. This period is critical for the harvesting of dry season crops such as millet and sorghum, as well as for grazing, which is important for the state's livestock sector. However, the dry season also poses challenges such as dust storms, wildfires, and water scarcity, particularly in rural areas where access to groundwater is limited (Iloeje, 2017).

- iii. **Temperature and Humidity:** The average temperature in Nasarawa State ranges from 25°C to 32°C throughout the year, although temperatures can rise significantly during the hottest months of February and March, reaching up to 40°C in some areas (Udo, 2016). The relatively high temperatures are moderated by the state's topographical features, especially in the hilly areas, where the climate is slightly cooler due to elevation. Humidity levels fluctuate greatly throughout the year, being highest during the rainy season when they can exceed 85%, and lowest during the Harmattan season, when they can drop below 20% (Ajayi, 2020).

The combination of temperature, humidity, and rainfall patterns makes Nasarawa State's climate ideal for a variety of agricultural activities. However, the state also faces challenges related to climate variability, including erratic rainfall patterns and prolonged dry spells, which can affect crop yields and water availability. In recent years, climate change has exacerbated these issues, leading to greater unpredictability in weather patterns, which has significant implications for agriculture and water management in the state (Afolayan & Popoola, 2019).

3.4.2 Hydrology

Nasarawa State's hydrology is heavily influenced by its location within the Benue River Basin. The state's surface and groundwater resources are vital for agricultural, domestic, and industrial uses, particularly given the state's reliance on agriculture and its growing urban population.

3.4.2.1 Major Rivers and Water Bodies

- i. The Benue River is the most significant water body in Nasarawa State, forming part of the state's southern boundary with Benue State. It is one of Nigeria's largest rivers and plays a crucial role in the hydrological and economic landscape of the state. The river supports a range of activities, including fishing, transportation, irrigation, and hydropower generation.

During the rainy season, the Benue River often floods, providing essential water for irrigation but also posing a risk to settlements and farmlands in the floodplain (*Afolayan & Popoola, 2019*).

- ii. In addition to the Benue River, Nasarawa State is drained by several other smaller rivers, many of which are tributaries of the Benue. Notable among these are the Mada, Gurara, and Farin Ruwa Rivers. The Mada River flows through the western part of the state, providing water for irrigation and serving as a critical water source for local communities. The Gurara River, which originates from the highlands near the boundary with the FCT and Plateau State, flows through Nasarawa and eventually drains into the Niger River. The river is an important source of freshwater for domestic use and has the potential for hydroelectric development (*Ajayi, 2020*).
- iii. The Farin Ruwa River is particularly notable for its dramatic waterfalls, which are located in the northern part of the state. The waterfalls are a significant tourist attraction and also hold potential for small-scale hydropower development. The presence of numerous smaller streams and seasonal rivers across the state contributes to the state's overall hydrology, although many of these streams dry up during the long dry season (*Udo, 2016*).

3.4.2.2 Groundwater Resources

Groundwater is another critical component of Nasarawa State's hydrology, especially in rural areas where access to surface water may be limited. The state's geological formations, particularly the sedimentary rocks in the southern and central regions, are favorable for groundwater storage. Aquifers in these regions provide water for domestic use, irrigation, and livestock rearing (*Iloje, 2017*). Boreholes and wells are commonly used to tap into these aquifers, and groundwater serves as a lifeline during the dry season when surface water sources dwindle.

However, the availability of groundwater is uneven across the state. In areas underlain by crystalline Basement Complex rocks, such as in the northern parts of the state, groundwater is less abundant due to the limited porosity and permeability of the rock formations. These areas often face water scarcity during the dry season, and local communities rely on rainwater harvesting and shallow wells to meet their water needs (*Afolayan & Popoola, 2019*).

3.4.2.3 Flooding and Water Management

Flooding is a recurring hydrological challenge in Nasarawa State, particularly along the floodplains of the Benue River and its tributaries. During the peak of the rainy season, the Benue River often overflows its banks, inundating farmlands and settlements. While these floods provide vital water for agriculture, they also cause significant damage to infrastructure and disrupt livelihoods (Ajayi, 2020). The government and local communities have implemented various flood control measures, including the construction of embankments and the promotion of flood-resilient agricultural practices. However, the increasing frequency and intensity of floods, exacerbated by climate change, highlight the need for improved water management and disaster preparedness.

Water management in Nasarawa State is critical for sustaining its agricultural productivity and supporting its growing population. The state has implemented various irrigation schemes, particularly along the Benue River, to enhance agricultural output during the dry season. These schemes provide water for rice cultivation, vegetable farming, and other crops that require consistent water supply. Additionally, there are efforts to develop small-scale hydropower projects, particularly in areas with significant river systems, such as the Farin Ruwa Waterfalls, to provide renewable energy and support local economic development (Udo, 2016).

Table 3.1: Rainfall Data for Shemankar - Katsina Strategic Catchment

Month	Magama-Ankwe	Katsina Ala	Shemankar	Average
Jan	29.71	231.19	17.19	92.70
Feb	90.86	681.04	50.25	274.05
Mar	1154.55	3497.28	872.75	1841.53
Apr	2579.94	5588.43	2158.13	3442.16
May	6338.01	8722.43	5542.84	6867.76
Jun	6481.07	11867.39	6078.34	8142.27
Jul	9656.49	13991.87	7887.40	10511.92
Aug	12258.32	13460.80	10370.76	12029.96
Sep	10050.93	15503.55	9247.46	11600.65
Oct	4971.10	13442.76	4563.25	7659.04

Nov	187.05	1196.03	122.62	501.90
Dec	31.97	191.66	12.71	78.78
Sum	28130.78	32795.12	32795.12	63042.71

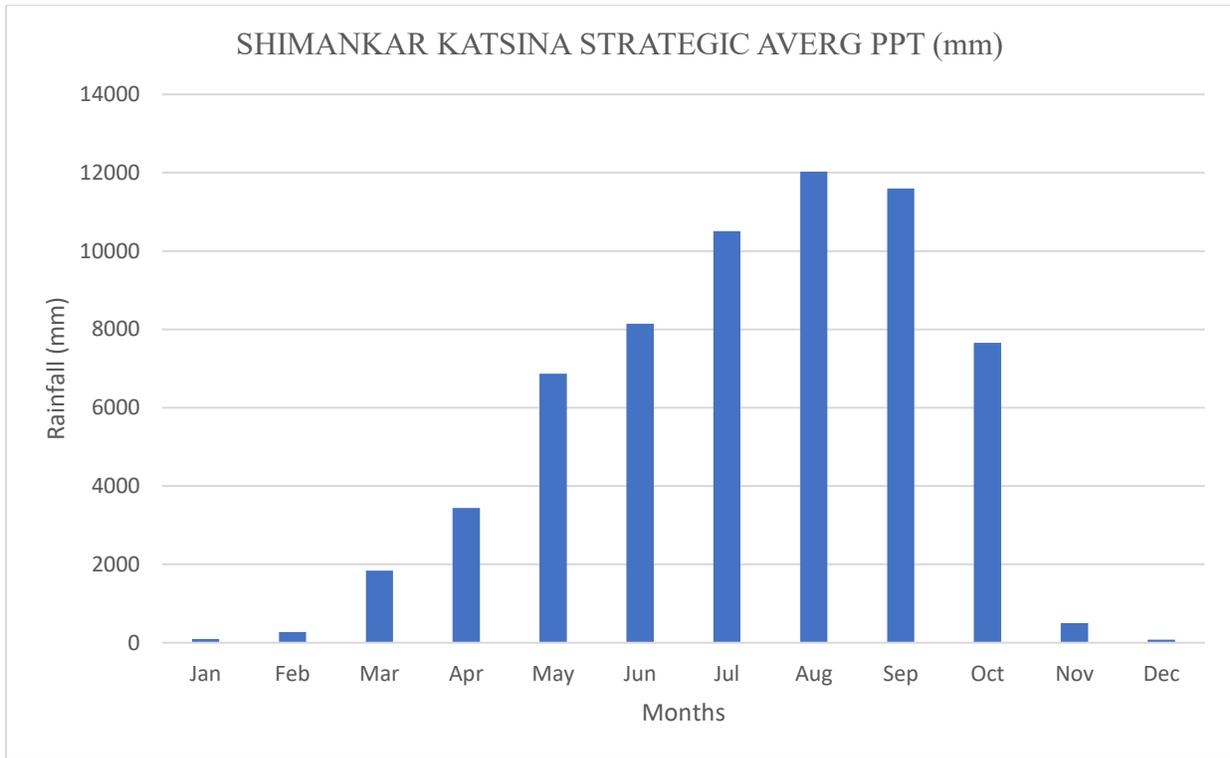


Figure 3.1: Rainfall Histogram for Shemankar - Katsina Strategic Catchment

Table 3.2: Evapotranspiration Data for Shemankar-Katsina Strategic Catchment

Month	Magama-Ankwe	Katsina Ala	Shemankar	Average
Jan	1697.64	2753.58	1066.39	1839.20
Feb	909.52	2305.84	628.71	1281.36
Mar	1246.80	3155.09	913.62	1771.84
Apr	2718.60	4061.27	2414.58	3064.82
May	5000.95	4767.36	4880.80	4883.04
Jun	4701.64	4200.44	4908.50	4603.53
Jul	4051.83	3572.71	4238.48	3954.34
Aug	3725.31	3466.42	3875.34	3689.02
Sep	4138.56	3699.53	4270.96	4036.35
Oct	4447.73	4256.57	4496.01	4400.11
Nov	3442.14	3449.98	3433.88	3442.00
Dec	2865.13	3019.90	2335.61	2740.21
SUM	28130.78	32795.12	32795.12	39705.81

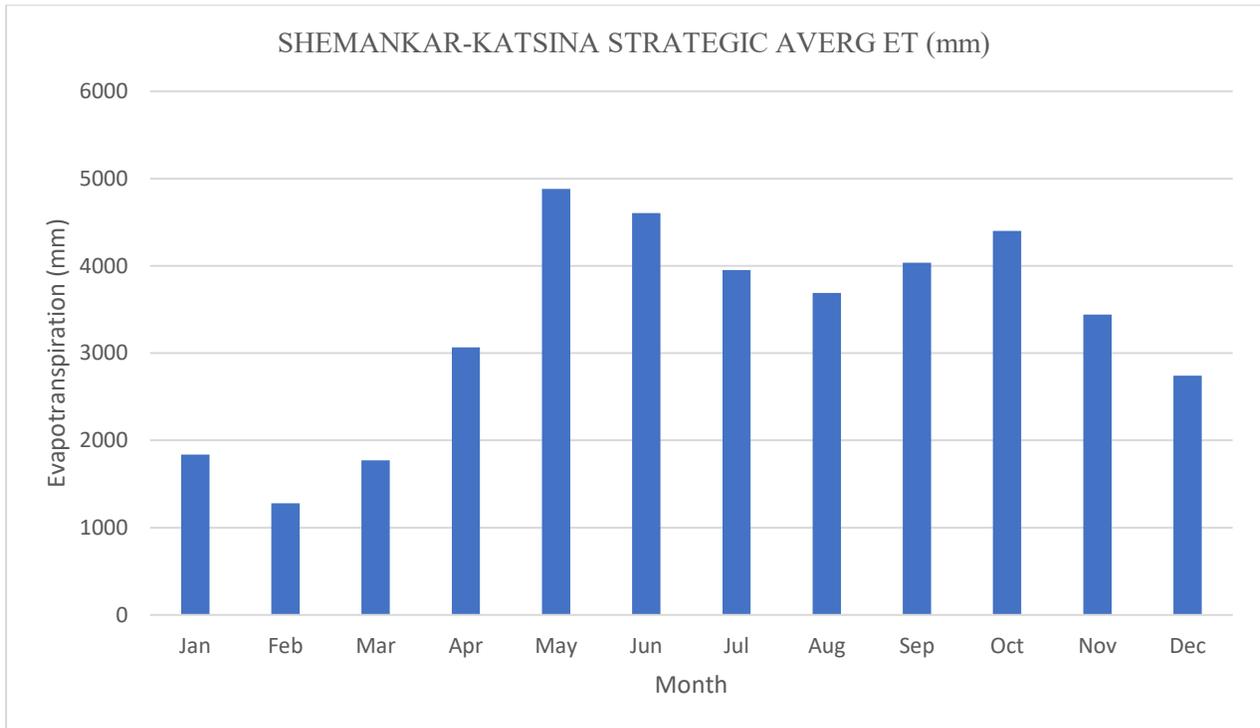


Figure 3.2: Evapotranspiration Histogram for Shemankar-Katsina Strategic Catchment

3.5 Historical and Future Climatic Trends

Temperature and rainfall trends for the Shemankar-Katsina-Ala catchment were forecast (projected) from 2023 to 2050 based on the monthly and annual data from 1981 to 2022, deploying the growth rate schema in Excel. It is of the following specifications:

$$\text{Growth Rate} = (\text{ending value} - \text{beginning value} / \text{beginning value}) \times 100.$$

This above rate is then used to extrapolate for each of the projected periods by multiplying it with the ending value. The formula is thus able to explore the data generation process by linking each value to the previous period which aids a graphical depiction of trends over time. It needs to be noted that growth may be of different forms including simple growth and exponential growth. What has been used however is the simple growth projection, given the nature of the data when explored from the point of view of period to period.

Excel was used to plot the trends indicated by the projection, just to indicate the annual increase in temperature and not for the projection.

The temperature and rainfall data were sourced from the National Aeronautics and Space Administration data-access-viewer. These are comparable with existing local data from the Nigerian Meteorological Society.

3.5.1 Temperature Trends for the Shemankar-Katsina-Ala

Table 3.3: Mean monthly temperature for Shemankar-Katsina-Ala for 1981-2022 and 2023-2050

Month	Mean monthly Temperature	Mean monthly Temperature
January	23.80	26.20
February	26.10	28.20
March	27.59	29.08
April	27.64	28.56
May	26.83	27.74
June	25.84	26.59
July	24.99	25.84
August	24.83	25.55
September	25.07	25.58
October	25.42	26.09
November	25.20	26.67
December	23.49	24.90
Mean	25.57	26.98
Maximum	27.64	29.42
Minimum	23.49	25.23

Table 3.3 presents a comparison of the mean monthly temperatures for Shemankar-Katsina-Ala between the historical period (1981-2022) and the projected period (2023-2050). Overall, the data indicate a warming trend, with the mean annual temperature rising from 25.57°C to 26.98°C. The largest increases are observed in the early months of the year, with January's temperature increasing from 23.80°C to 26.20°C, and February from 26.10°C to 28.20°C, suggesting that the warming trend will intensify during the dry season. The hottest months of March and April also show increases, with March rising from 27.59°C to 29.08°C, and April from 27.64°C to 28.56°C. This warming during the hottest months would affect agriculture and water resources, especially as they are typically associated with high heat demand. Mid-year months like June through September see more moderate increases, which aligns with the rainy season which tends to

moderate temperatures due to increased cloud cover and rainfall. For example, August, one of the wettest months, shows a slight increase from 24.83°C to 25.55°C.

The maximum monthly temperature is projected to rise from 27.64°C to 29.42°C, while the minimum monthly temperature increases from 23.49°C to 25.23°C, indicating a narrowing temperature range and overall warmer conditions throughout the year. This shift may affect seasonal temperature variation, potentially impacting ecological patterns and seasonal activities that depend on distinct temperature changes.

Overall, the projected warming trend for Shemankar-Katsina-Ala is expected to bring higher temperatures across all months, with significant warming in the dry season. These changes may challenge water availability, agriculture, and health infrastructure, as warmer temperatures are linked with increased water demand and heat-related stresses on both natural and human systems.

This pattern is presented in Figure 3.3.

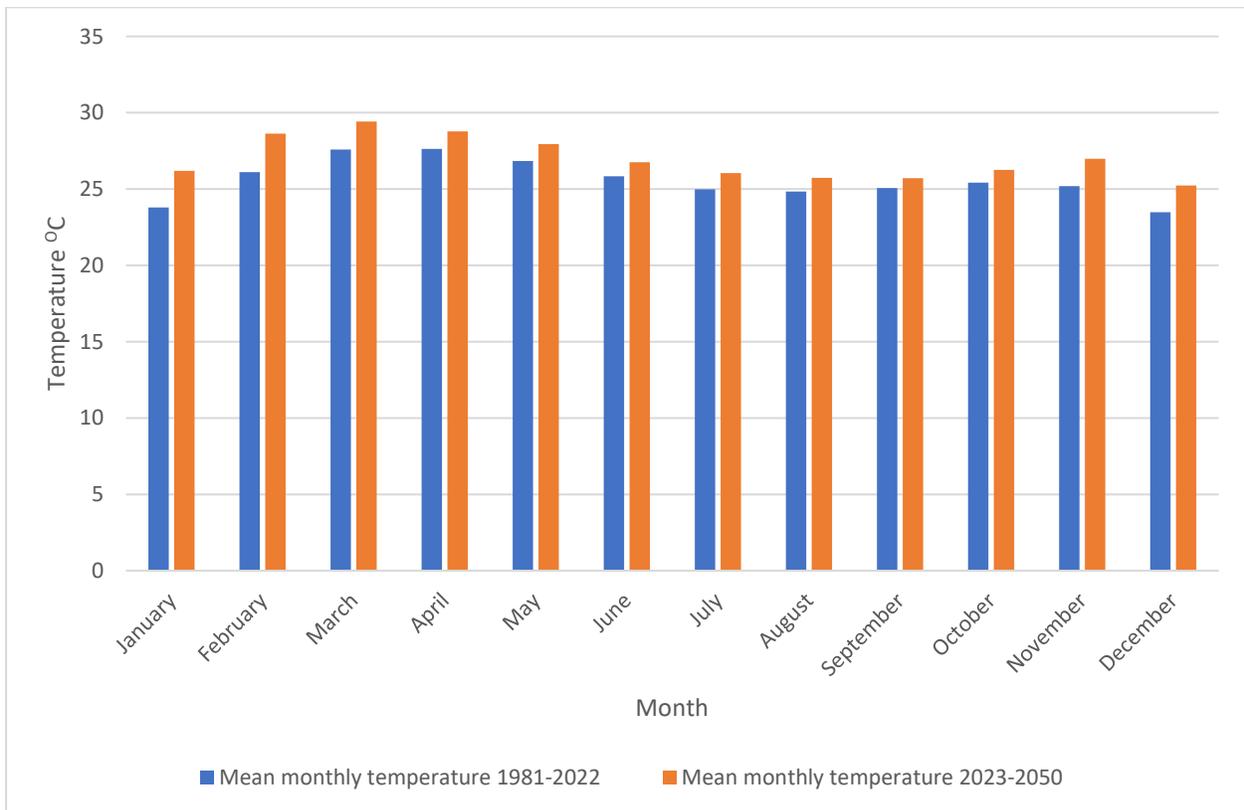


Figure 3.3: Mean monthly temperatures from 1981 to 2022 and 2023 to 2050 for Shemankar-Katsina-Ala

3.5.2 Projected Mean Annual Temperature for Shemankar-Katsina-Ala

Figure 3.4 illustrates the mean annual temperature trend for Shemankar-Katsina-Ala from 1981 to 2050, highlighting both historical and projected data.

From Figure 3.4 the mean annual temperature shows an increasing trend over time with approximate yearly increase of 0.0398°C per year, reflecting a steady warming trend. The high R^2 value of 0.8542 suggests that 85.42% of the variability in annual temperature is explained by this linear trend.

Between 1981 and around 2020, the annual temperature displayed significant interannual variability, with several peaks and dips. These fluctuations suggest natural variability influenced by regional climatic factors or extreme events, such as warmer or cooler years.

By 2050, the projected temperature will reach nearly 28°C , which is higher than most historical values. This increase implies that, if current trends continue, Shemankar-Katsina-Ala may experience warmer conditions, which could impact agriculture, water resources, and human health. The steady increase in projected temperatures suggests a need for adaptive measures to address potential impacts on the community. Prolonged warming could lead to increased heat stress, water scarcity, and challenges for temperature-sensitive sectors such as agriculture.

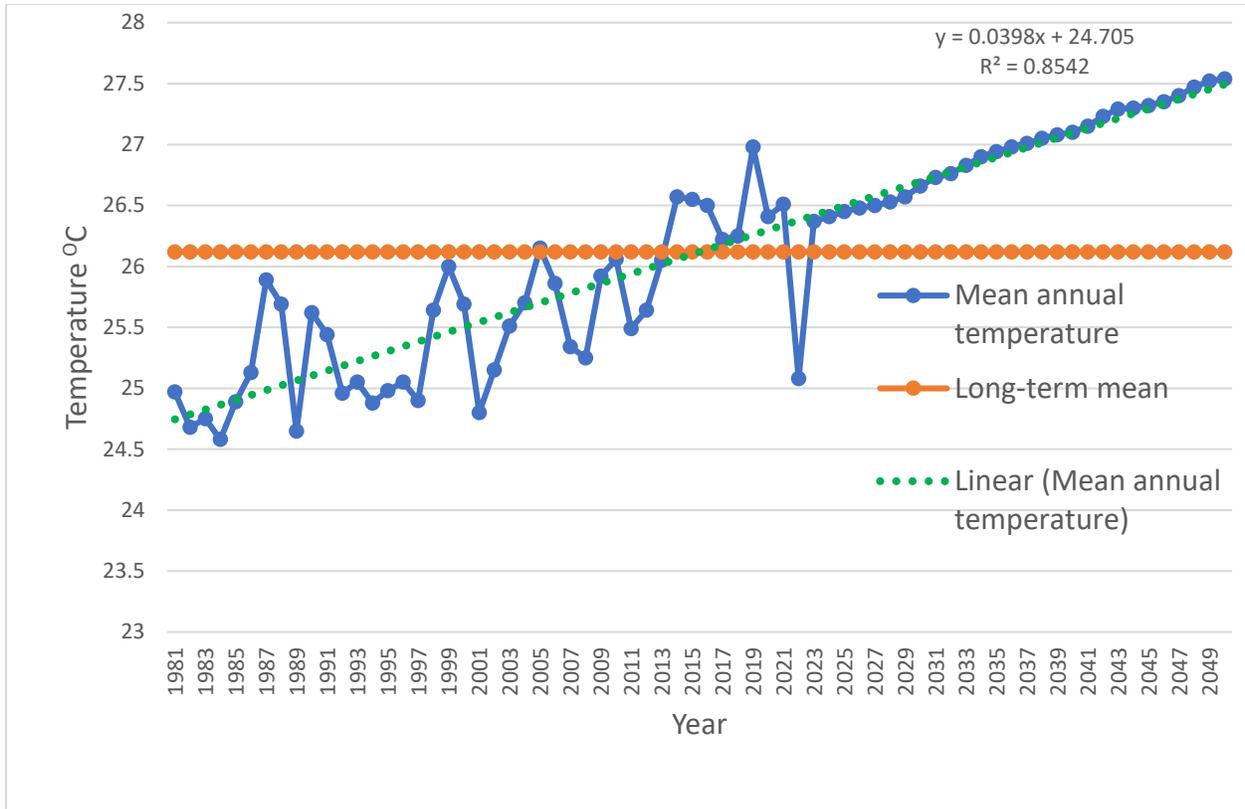


Figure 3.4: Projected Mean Annual Temperature Trend (1981-2050) for Shemankar-Katsina-Ala

3.5.3 Projected Annual Rainfall for Shemankar-Katsina-Ala

Figure 3.5 shows the projected annual rainfall trend for Shemankar-Katsina-Ala from 1981 to 2050.

The trend indicates a downward slope over time. The equation $y = -10.348x + 1520.3$ suggests an annual decrease in rainfall of approximately 10.3 mm. This downward trend implies a long-term decline in rainfall, which could have significant implications for water availability, agriculture, and ecosystems in the area.

The historical annual rainfall data (1981 to 2022), exhibits considerable fluctuations, with multiple peaks and troughs. This variability reflects natural climate variations, which could be influenced by factors like El Niño and La Niña events, as well as other regional climatic factors.

Fluctuations in annual rainfall during the projected period appear to decrease. This suggests that the projections assume a more stable but gradually declining rainfall trend.

A persistent decline in rainfall could impact agriculture, water resources, and biodiversity in Shemankar-Katsina-Ala. Lower rainfall levels may stress crops, reduce water availability, and lead to increased competition for water resources, especially in agriculture-dependent communities.

In summary, Figure 3.5 projects a decline in annual rainfall for Shemankar-Katsina-Ala, with less variability in the later years. This declining trend could present challenges for water resource management and agricultural productivity, underscoring the importance of planning for potential water scarcity in the coming decades.

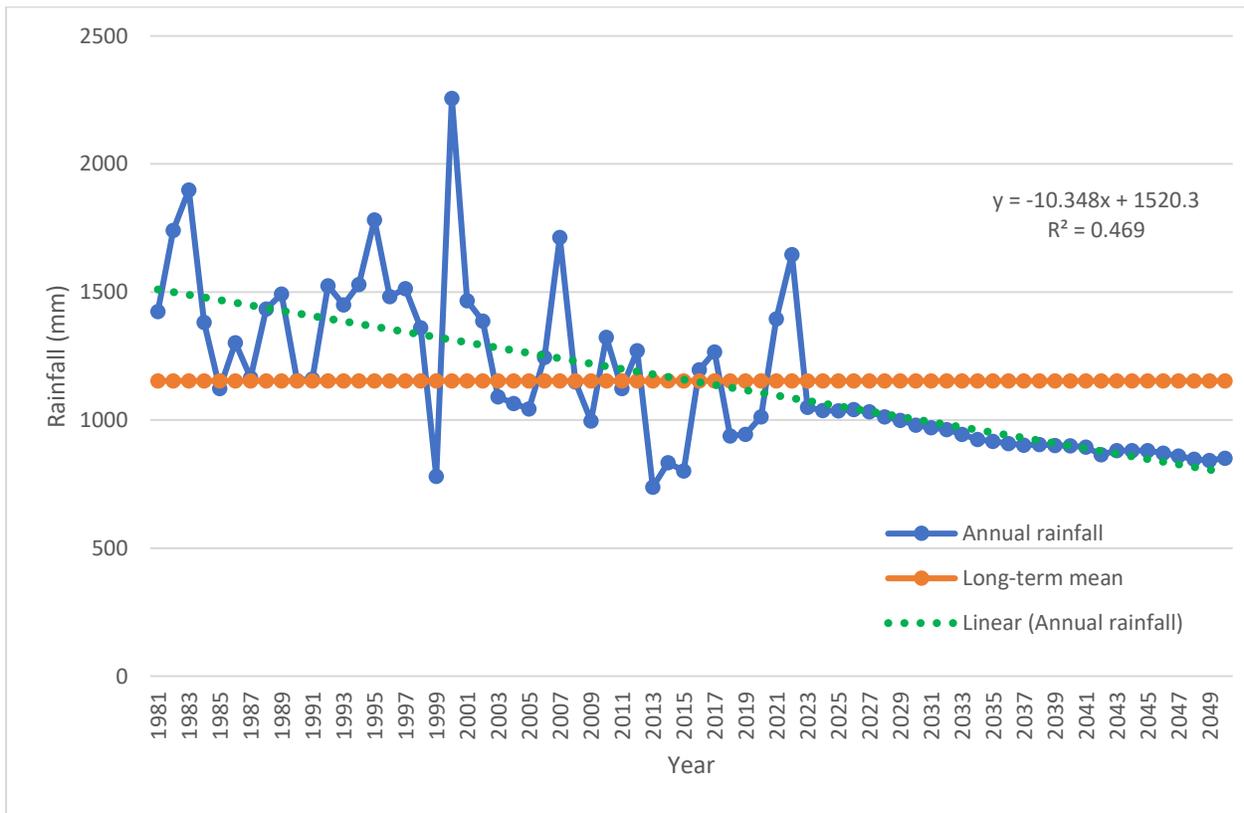


Figure 3.5: Projected Annual Rainfall Trend (1981-2050) for Shemankar-Katsina-Ala

3.4 Summary

This report examines projected temperature and rainfall trends for Shemankar-Katsina-Ala from 2023 to 2050, based on data from 1981 to 2022. Using a growth rate formula in Excel, the projections suggest a general warming trend, with mean annual temperatures expected to rise from 25.57°C to 26.98°C. The greatest temperature increases are forecasted for the dry season months of January and February, with temperatures reaching as high as 28.20°C in February. Warmer dry months may challenge water and agriculture resources due to higher heat demand. Meanwhile, mid-year rainy season months like June to August are projected to see only slight temperature increases, likely due to moderating effects of rainfall. By 2050, the projected mean annual temperature approaches 28°C, indicating increased heat stress for residents and sectors reliant on stable temperatures. The rainfall forecast shows a declining trend, with an annual decrease of approximately 10.3 mm. This reduction could impact water availability and agriculture, especially given the area's heavy reliance on rainfall for crop growth. The combined warming and drying trends may necessitate adaptation strategies to mitigate risks in agriculture and water management.

CHAPTER 4 WATER RESOURCES

4.1 Hydrograph/Water Budget of the Catchment

1 Data Source and Methodology Overview

a. The CHIRPS (Climate Hazards Group InfraRed Precipitation with Station) Data

The CHIRPS is a **high-resolution, quasi-global precipitation dataset developed by the Climate Hazards Group** at the University of California, Santa Barbara. It was designed to support climate and hydrological studies, particularly in data-scarce regions. This justifies its use for synthetic hydrograph and water budget analysis in this work. CHIRPS integrates satellite imagery, in-situ observations, and long-term climatological data to produce reliable estimates of rainfall from 1981 to the present.

Key Features of CHIRPS:

- i. **Spatial Resolution:** CHIRPS provides precipitation data at a spatial resolution of **0.05° (~5 km)**, which makes it suitable for fine-scale hydrological studies like catchment analysis.
- ii. **Temporal Resolution:** The dataset is available at daily, pentadal (5-day), and monthly time steps, allowing for both short-term event analysis and long-term climatological studies.
- iii. **Data Sources:** It merges **infrared satellite data** with ground station measurements to improve accuracy, especially in regions with limited weather station coverage.
- iv. **Coverage:** CHIRPS data covers **50°S to 50°N** latitude, making it particularly useful for studies in tropical and subtropical regions, including much of Africa.

Relevance to the Catchment Study:

For this analysis, CHIRPS data was used to generate hydrographs and water budgets for the catchment. The **high spatial resolution** of CHIRPS allows for an accurate representation of precipitation patterns across the catchment, which is critical in understanding the seasonal and inter-annual variability of water resources. Additionally, the **long-term dataset** (starting from

1981) provides a robust basis for analyzing historical trends in rainfall and the corresponding impact on water availability in the region.

By utilizing CHIRPS data, this study was able to capture both the timing and intensity of precipitation events, which are key inputs for hydrological modelling and water balance calculations.

b. *SCS Rainfall – Runoff Model Overview*

The **SCS Rainfall-Runoff Model**, developed by the **Soil Conservation Service** (now known as the **Natural Resources Conservation Service (NRCS)**), is widely used to estimate direct runoff from rainfall events. This model is based on the **Curve Number (CN) method**, which accounts for the catchment's land use, soil type, and moisture conditions to predict the volume of runoff from a given rainfall event.

Key Features of the SCS Rainfall-Runoff Model:

- i. **Curve Number (CN):** The CN is a dimensionless number ranging from 30 to 100 that represents the potential for runoff in a given catchment. It is derived based on land cover, hydrological soil group, and antecedent moisture conditions.

- **Low CN values** indicate permeable soils and low runoff potential.
- **High CN values** indicate impermeable surfaces and high runoff potential.

- ii. **Runoff Estimation:** The SCS model calculates runoff depth using the equation:

$$Q = \frac{(P - Ia)^2}{(P - Ia) + S} \quad (P \geq Ia, Q = 0)$$

Where:

- Q is the runoff (inches or mm),
- P is the total precipitation,
- Ia is the initial abstraction (typically set as 20% of the potential maximum retention, SSS),
- SSS is the potential maximum retention after runoff begins, which is related to the CN.

- iii. **Flexibility:** The model is adaptable to a wide variety of catchments and can handle both large and small watersheds with different land uses, making it a versatile tool for estimating runoff.

Relevance to the Catchment Study:

For this analysis, the **SCS Rainfall-Runoff Model** was employed in conjunction with **CHIRPS precipitation data** to estimate the volume of runoff generated in the catchment. The model's use of **land use and soil data** provided a detailed understanding of how different areas within the catchment contribute to runoff during rainfall events. By incorporating the **Curve Number approach**, the model allowed for the evaluation of the catchment's response to varying rainfall intensities, particularly the influence of land cover and soil infiltration capacity on runoff generation.

The combination of CHIRPS precipitation data and the SCS model enabled accurate estimation of runoff, which is essential for water resource planning, flood forecasting, and understanding the hydrological behaviour of the catchment.

A hydrograph is a graphical representation that illustrates the relationship between the rate of flow (discharge) of a river or stream and time. It typically displays how the discharge changes in response to precipitation events at a specific location, allowing for analysis of hydrological behaviour over time. The key features of a hydrograph are the Discharge (m^3/s) and Time: The x-axis of the hydrograph hours, days or years. Base Flow: The normal flow level of the river during dry periods, which serves as a baseline for understanding changes during rainfall events. Rising Limb: The initial increase in discharge following rainfall, indicating how quickly water enters the river system. Peak Discharge: The maximum flow rate reached during a storm event. Recession Limb: The decline in discharge after peak flow, showing how quickly the river returns to base flow. Lag Time: The delay between peak rainfall and peak discharge, which can vary based on watershed characteristics and rainfall intensity.

The Water budget, also known as hydrologic budget on the other hand, is an accounting of the inflows, outflows, and storage changes of water within a specific system, such as a watershed, river basin, or aquifer. A water budget graph is a visual representation of the various components of the water cycle for a specific river basin or watershed. It illustrates the balance between water inputs and outputs within a specific watershed or area over a certain period.

$$\Delta S \text{ (Water storage change)} = \text{Input} - \text{Output}$$

$$\Delta S = \text{Precipitation} - (\text{Runoff (R)} + \text{Evapotranspiration (ET)})$$

$$\Delta S = P - (R + ET)$$

Other important components of output are:

1. **Infiltration (I)**: Water seeping into the soil.
2. **Groundwater recharge (G)**: Water recharging aquifers.

4.2 The Strategic Catchments

The strategic catchments consist of groups of catchments, each containing two or more sub-catchments. To generate a representative synthetic hydrograph based on the SCS model and to incorporate CHIRPS rainfall and evapotranspiration data, it was necessary to perform the analysis at the sub-catchment level. By working at this finer scale, synthetic hydrographs were generated for each sub-catchment. Following this, the data from the individual sub-catchments were aggregated to represent the entire strategic catchment. This process ensured that the hydrographs accurately reflected the dynamics within each strategic catchment, while considering the variability at the sub-catchment level. The report is as follows:

4.2.1 Shemankar-Katsina-Ala Strategic Catchments

The Shemankar hydrograph and water budget analysis (Figures 4.1-4.5) reveal distinct seasonal hydrological patterns. A three-month dry period (December to February) features minimal to no rainfall, followed by a nine-month flow cycle beginning in March. Discharge shows a steady rise from March, peaks in September, and undergoes a sharp decline between September and November. Evapotranspiration exceeds precipitation for about four months, dominating the water balance during drier phases. A significant water surplus occurs from April to November (eight months), driven by seasonal rainfall, which replenishes groundwater and surface reserves. This surplus period contributes to an annual water budget of 733.66 mm, reflecting the region's reliance on monsoon-influenced recharge. The data underscores the interplay between prolonged dry spells, concentrated rainfall, and evapotranspiration in shaping water availability.

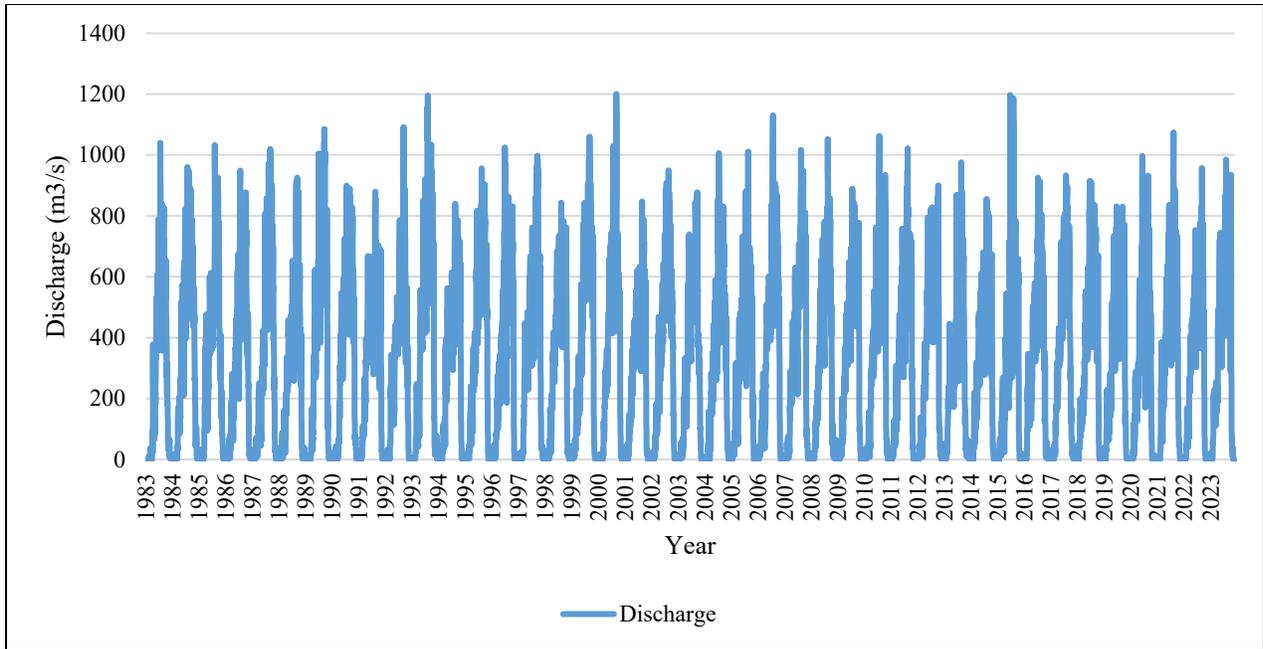


Figure 4.1: Hydrograph of Shemankar Strategic Catchment Based on HEC-HMS modelling for Strategic catchment.

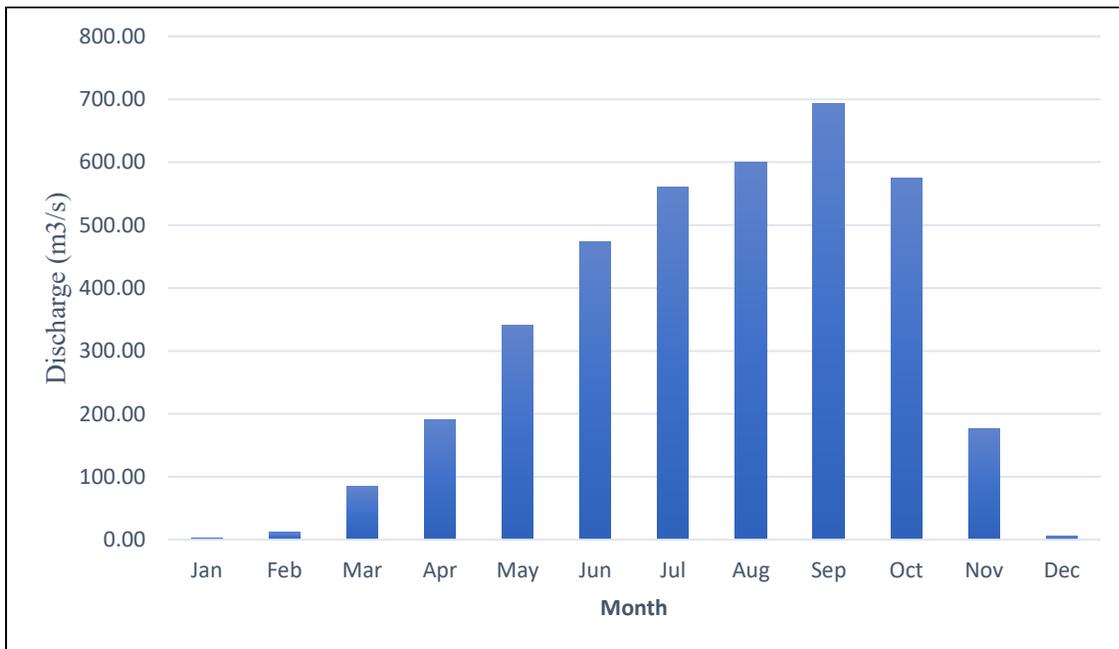


Figure 4.2: 40 - Year Summary Hydrograph of Shemankar Strategic Catchment

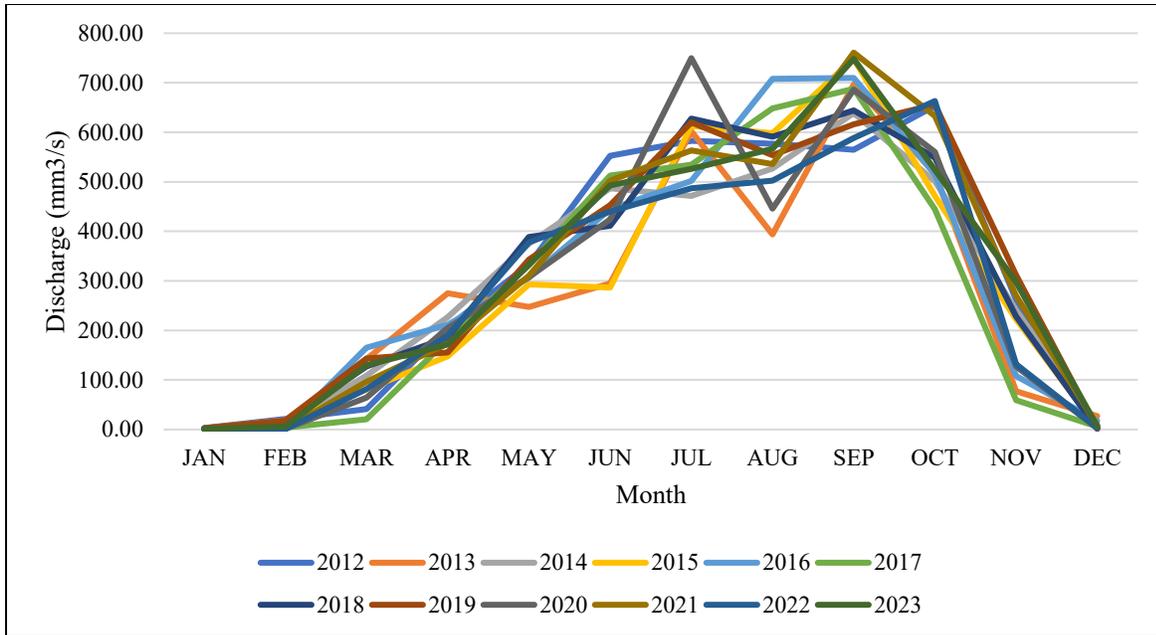


Figure 4.3: Hydrograph of Shemankar Strategic Catchment for Specific Year

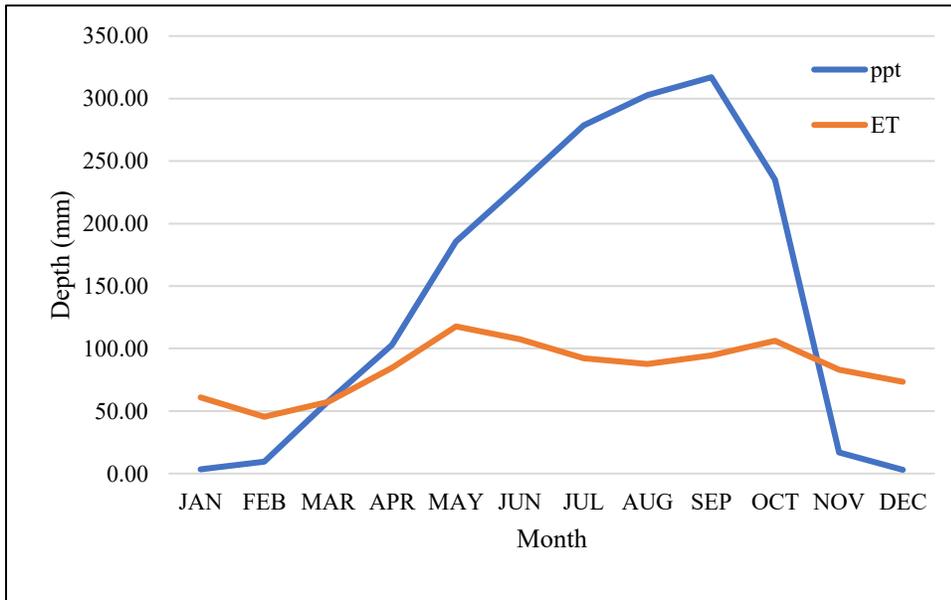


Figure 4.4: Water Budget for Shemankar Strategic Catchment

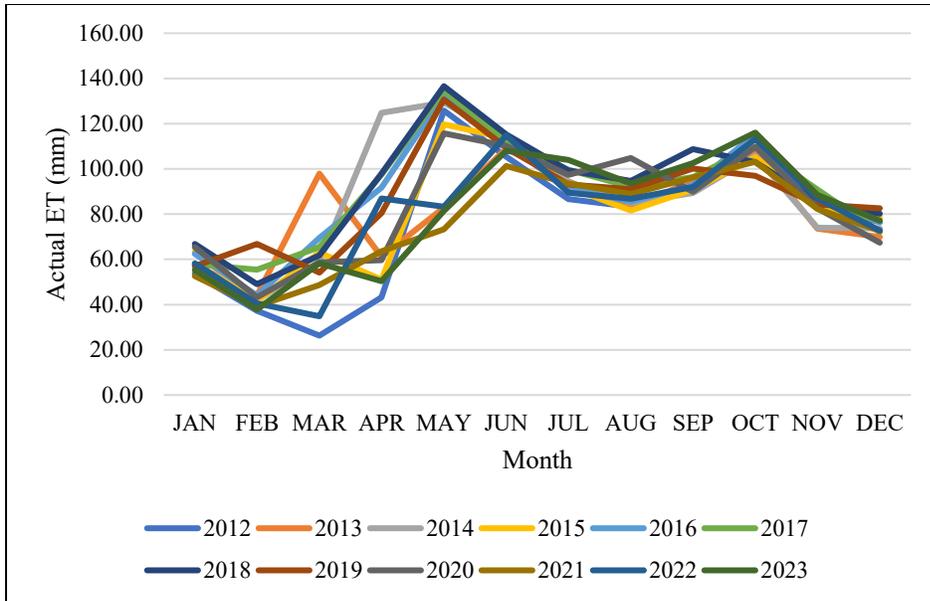


Figure 4.5: Monthly Actual Evapotranspiration Distribution for the Shemankar Catchment

Source: TerraClimate

Table 4.1: Summary of Discharge, Rainfall and Evapotranspiration Data for Shemankar Strategic catchment

MONTH	PPT	ET	Synthetic Peak Runoff (m ³ /s)
Jan	3.47	60.85	2.82
Feb	9.40	45.42	11.59
Mar	57.82	57.48	84.15
Apr	102.96	84.65	190.84
May	185.76	117.70	340.07
Jun	231.57	107.56	474.24
Jul	278.60	92.12	561.27
Aug	302.80	87.59	600.11
Sep	317.04	94.57	692.56



Oct	234.99	106.21	574.05
Nov	16.94	83.07	176.60
Dec	3.00	73.44	6.47

Prospects

The catchment’s pronounced seasonal variability—characterized by a short dry period (December–February) and an extended wet phase (April–November)—presents both challenges and opportunities for water management. Key strategies could include:

- **Storage Infrastructure:** Develop reservoirs or groundwater recharge systems to capture surplus monsoon flows (April–November) for use during the dry months, mitigating drought risks.
- **Demand Management:** Optimize agricultural practices (e.g., drought-resistant crops, irrigation scheduling) to align with water availability, reducing reliance on groundwater during low-flow periods.
- **Flood Mitigation:** The sharp post-September discharge decline suggests flashier flows; small-scale retention structures (check dams, terraces) could stabilize flow regimes and reduce erosion.
- **Climate Resilience:** Strengthen adaptive measures to address monsoon variability, as the region’s 733.66 mm annual budget hinges heavily on seasonal rainfall.
- **Ecosystem Protection:** Sustain wetlands and forests to enhance natural water retention, buffer evapotranspiration losses, and maintain baseflow during drier phases.

4.3 Surface Water Quality

Water quality in Plateau State is an important aspect of environmental and public health, given the state's reliance on surface and groundwater for drinking, agriculture, and industrial activities. The water quality in the region is influenced by natural factors such as geology and climate, as well as anthropogenic activities like agriculture, mining, and urbanization.

4.3.1 Physical Parameters

Plateau State

- i. Temperature:** Water temperature is a critical physical parameter that influences the chemical and biological characteristics of water bodies. In Plateau State, water temperatures vary significantly depending on the source and the season. Surface water bodies such as rivers, streams, and reservoirs generally experience temperature fluctuations between 20°C and 30°C, influenced by ambient air temperatures and solar radiation [Ezekiel, 2017]. Groundwater, on the other hand, tends to have more stable temperatures, typically ranging from 20°C to 25°C, as it is less affected by external climatic conditions [Oloruntoba, 2019]. Elevated water temperatures can affect the solubility of oxygen, leading to lower dissolved oxygen levels, which in turn can impact aquatic life and the overall ecological balance of water bodies.
- ii. pH:** The pH level of water is an indicator of its acidity or alkalinity, which can significantly affect both chemical reactions and biological processes in water. In Plateau State, the pH of surface water generally ranges from 6.5 to 8.5, reflecting a near-neutral to slightly alkaline condition [Oloruntoba, 2019]. This range is typical for freshwater systems and is conducive to most forms of aquatic life. Groundwater sources in the state also tend to have a similar pH range, although there can be local variations due to geological influences, such as the presence of calcareous rocks that can increase alkalinity. The pH levels are crucial for the solubility and bioavailability of nutrients and metals in the water, which can have downstream effects on water quality [Adeniyi & Olabanji, 2015].
- iii. Turbidity:** Turbidity is a measure of the cloudiness or haziness of water, caused by the presence of suspended solids, such as silt, clay, organic matter, and microorganisms. In Plateau State, turbidity levels in surface water can be highly variable, particularly during the rainy season when increased runoff from agricultural lands and urban areas introduces large amounts of suspended solids into rivers and streams [Adeoye & Abubakar, 2015]. Turbidity levels in some rivers have been recorded as high as 50 to 150 NTU (Nephelometric Turbidity Units), especially following heavy rains [Ezekiel, 2017]. High turbidity can reduce light penetration in water, affecting photosynthetic activity and the

aquatic food chain. In addition, it can complicate water treatment processes, leading to higher costs and potential health risks if not properly managed.

Benue State

Water quality in Benue State is critical due to its importance for agriculture, domestic use, and industrial activities. The state's water sources, primarily the River Benue and its tributaries, are subject to various physical, chemical, and biological factors that determine their suitability for human consumption, irrigation, and ecological health. This section will examine the general water quality in Benue State, focusing on physical, chemical, and biological parameters.

- i. Temperature:** Water temperature is an important physical parameter influencing other water quality factors, including dissolved oxygen levels, biological activity, and chemical reactions in water bodies. In Benue State, the temperature of surface waters such as the River Benue and its tributaries typically fluctuates with the seasons. During the dry season, water temperatures can rise to around 30°C due to high ambient temperatures and direct solar radiation. In contrast, the rainy season brings cooler temperatures, with water bodies recording average temperatures of around 24°C to 28°C (*Eze, 2018*). Temperature fluctuations can have direct implications for aquatic ecosystems, as higher temperatures reduce the solubility of oxygen in water, potentially leading to oxygen depletion and stress on aquatic organisms. Temperature also affects the growth rates of bacteria and algae, with higher temperatures promoting faster microbial growth, which can exacerbate water quality issues (*Obaje, 2009*).
- ii. pH:** The pH of water is a measure of its acidity or alkalinity, and it plays a crucial role in determining the suitability of water for various uses. In Benue State, surface water pH levels typically range from 6.5 to 8.5, indicating that most water bodies are neutral to slightly alkaline (*Abah & Omada, 2019*). However, localized variations in pH have been observed, particularly in areas where there is agricultural runoff or industrial effluents. Water bodies with a pH below 6.5 are considered acidic, which can affect aquatic life, particularly fish, by disrupting physiological processes such as respiration and reproduction. In contrast, water with a pH above 8.5 can lead to the precipitation of minerals such as calcium and magnesium, affecting water hardness and potentially leading to scaling in irrigation and water supply infrastructure (*Adamu, 2019*).

- iii. **Turbidity:** Turbidity refers to the cloudiness or haziness of water caused by suspended particles such as silt, clay, organic matter, and microorganisms. High turbidity reduces light penetration into the water, which can inhibit photosynthesis in aquatic plants and affect the overall health of aquatic ecosystems. In Benue State, turbidity levels are often elevated during the rainy season when surface runoff carries sediments into rivers and streams. This is particularly true for the River Benue and its tributaries, where turbidity levels can exceed 100 NTU (Nephelometric Turbidity Units) during periods of heavy rainfall (*Olapade, 2018*). High turbidity not only affects aquatic life but also poses challenges for water treatment, as it increases the cost and complexity of removing suspended solids and other contaminants. Furthermore, high turbidity can harbor pathogens, making the water unsafe for drinking without proper treatment (*Eze, 2018*).

Taraba State

Water quality is a critical factor in determining the suitability of water for various uses, including drinking, agriculture, and industrial purposes. In Taraba State, water quality is influenced by several natural and anthropogenic factors, including the region's topography, land use patterns, agricultural practices, and industrial activities. The state relies on both surface water (rivers, streams, lakes) and groundwater (boreholes, wells) for its water supply, making the assessment of water quality essential for the well-being of its population and the environment.

- i. **Temperature:** Water temperature in Taraba State varies seasonally and geographically. In the lowland areas, particularly near the Benue River and its tributaries, water temperatures tend to be higher, especially during the dry season, with average values ranging between 25°C and 32°C [*Ayoade, 2004*]. The Mambilla Plateau, owing to its elevation, experiences cooler water temperatures, which range from 18°C to 24°C. Water temperature affects dissolved oxygen levels, with cooler water generally holding more oxygen, which is critical for aquatic life [*Adakole, 2000*]. Higher temperatures during the dry season can also increase the rate of evaporation from surface water bodies, reducing the overall availability of water and concentrating pollutants in the remaining water. Temperature fluctuations, especially during harmattan (a dry, cool wind season), can further influence water quality by affecting the physical and chemical properties of water.

- ii. **pH:** The pH of water in Taraba State typically ranges from slightly acidic to neutral, with values between 6.0 and 7.5 in most surface and groundwater sources [Olorunfemi, 2000]. In regions with agricultural activities, such as the Benue River basin, the application of fertilizers and pesticides can lead to acidification of water bodies. This can lower the pH levels, making the water more acidic, which in turn affects aquatic ecosystems and water potability. Water bodies with a pH below 6.5 may become corrosive, leading to the leaching of metals from rocks and soils, further degrading water quality. Conversely, water with a pH above 8.0 can result in the precipitation of minerals such as calcium carbonate, which may lead to scaling in water infrastructure.
- iii. **Turbidity:** Turbidity, or the cloudiness of water, is a significant indicator of water quality in Taraba State, particularly in surface water sources such as rivers and lakes. Turbidity levels in the Benue River and its tributaries often increase during the rainy season due to soil erosion, surface runoff, and increased sediment loads. Turbidity levels in these water bodies can exceed 100 NTU (Nephelometric Turbidity Units) during peak flow periods [Olowolafe, 2002]. High turbidity affects aquatic ecosystems by reducing light penetration, which limits photosynthesis in aquatic plants and algae. Additionally, turbid water can harbor pathogens and reduce the effectiveness of disinfection processes in water treatment facilities. In groundwater sources, turbidity levels are generally lower, with values typically below 5 NTU. However, improper well construction or contamination from surface runoff can lead to occasional spikes in turbidity.

Nasarawa State

Water quality is a critical concern in Nasarawa State, given its importance for agriculture, domestic consumption, and industrial use. The water quality in the state is influenced by both natural and anthropogenic factors, including geology, land use, agricultural practices, and mining activities. Assessments of water quality in Nasarawa State typically focus on physical, chemical, and biological parameters, each of which provides insight into the suitability of water for different uses and potential health risks. Physical parameters of water, such as temperature, pH, turbidity, conductivity, and total dissolved solids (TDS), are key indicators of the general water quality in Nasarawa State. These parameters help determine the aesthetic and usability of water for various purposes.

- i. Temperature:** Water temperature is an important physical parameter as it affects the chemical and biological properties of water. In Nasarawa State, the temperature of surface water bodies, such as rivers and streams, generally ranges from 25°C to 30°C, with slight seasonal variations. During the rainy season, when water levels are higher, temperatures tend to be slightly cooler, while in the dry season, temperatures may rise due to increased solar radiation and reduced water flow (*Ajayi, 2020*). High temperatures can accelerate the growth of microorganisms and promote the depletion of dissolved oxygen, which is essential for aquatic life. This is particularly problematic in the dry season when water levels are low, and temperature increases are more pronounced (*Udo, 2016*).
- ii. pH:** The pH of water is a measure of its acidity or alkalinity and is critical for the health of aquatic ecosystems and the safety of water for human consumption. Water sources in Nasarawa State typically exhibit pH levels between 6.5 and 7.5, which is within the range considered acceptable for most uses, including drinking water and irrigation (*Afolayan & Popoola, 2019*). However, localized deviations from this range can occur, particularly in areas impacted by mining activities. For example, in mining zones where acidic runoff from mineral extraction occurs, the pH of nearby water bodies may be lowered, leading to increased acidity, which can harm aquatic life and reduce the suitability of water for agriculture and drinking (*Iloeje, 2017*).
- iii. Turbidity:** Turbidity is a measure of the clarity of water, with higher turbidity indicating a greater presence of suspended particles such as silt, clay, and organic matter. In Nasarawa State, turbidity levels in rivers and streams are generally higher during the rainy season due to increased runoff and soil erosion. This is particularly true in areas with intensive agriculture and deforestation, where soil particles are washed into water bodies, reducing water clarity (*Ajayi, 2020*). High turbidity can have negative effects on aquatic ecosystems by reducing light penetration, which affects photosynthesis in aquatic plants and algae. It can also carry pollutants, such as heavy metals and pathogens, that adhere to the suspended particles, thus posing risks to water quality (*Udo, 2016*).
- iv. Conductivity and Total Dissolved Solids (TDS):** Conductivity measures the water's ability to conduct electrical current, which is directly related to the concentration of dissolved ions. In Nasarawa State, conductivity values typically range from 50 to 500 $\mu\text{S}/\text{cm}$, depending on the water source and the surrounding geology. Higher conductivity

values are often associated with areas where groundwater passes through mineral-rich formations, particularly in the southern part of the state, which is dominated by sedimentary rocks (Afolayan & Popoola, 2019). High conductivity can indicate the presence of dissolved salts and minerals, which may be beneficial for agricultural irrigation but could pose challenges for drinking water quality if levels are too high. Total dissolved solids (TDS), which represent the total concentration of dissolved substances in water, generally fall within acceptable limits for most uses in Nasarawa State, typically ranging from 100 to 600 mg/L. However, in areas with significant mining activities, TDS levels can increase due to the leaching of minerals and chemicals into water sources, potentially making the water unsuitable for consumption without treatment (Iloeje, 2017).

4.3.2 Chemical Parameters

Plateau State

- i. **Nutrients:** Nutrient levels, particularly nitrogen and phosphorus, are important chemical parameters that influence the productivity of aquatic ecosystems. In Plateau State, nutrient levels in surface waters are typically moderate but can spike due to agricultural runoff, which introduces fertilizers into water bodies [Ezekiel, 2017]. Nitrate concentrations in rivers and streams range from 0.5 to 5.0 mg/L, while phosphate levels are generally between 0.1 and 1.0 mg/L [Adeniyi & Olabanji, 2015]. Elevated nutrient levels can lead to eutrophication, a process that results in excessive growth of algae and other aquatic plants, which can deplete oxygen levels and harm aquatic life. In some areas, especially near intensive agricultural zones, nutrient pollution has become a significant concern, requiring targeted management practices to reduce the input of fertilizers and other nutrient sources into water bodies [Adeoye & Abubakar, 2015].
- ii. **Heavy Metals:** The presence of heavy metals in water is a major concern in Plateau State, largely due to the state's history of mining activities. Metals such as lead (Pb), cadmium (Cd), zinc (Zn), and arsenic (As) have been detected in both surface and groundwater

sources, often at concentrations exceeding WHO guidelines for drinking water [Oloruntoba, 2019]. In areas surrounding former mining sites, particularly in the Jos Plateau region, lead concentrations in water have been recorded as high as 0.05 to 0.2 mg/L, which poses significant health risks, especially to children [Oloruntoba, 2019]. These metals can enter water bodies through leaching from mine tailings, runoff from contaminated soils, and direct discharge from mining operations. Long-term exposure to heavy metals can lead to chronic health issues, including neurological damage, kidney failure, and cancer [Adeniyi & Olabanji, 2015].

- iii. **Arsenic:** Arsenic levels in groundwater in some parts of Plateau State have been found to exceed safe limits, particularly in areas with geothermal activity. Arsenic contamination is of particular concern due to its carcinogenic properties and the potential for long-term health impacts [Ezekiel, 2017].
- iv. **Dissolved Oxygen (DO) and Biochemical Oxygen Demand (BOD):** Dissolved oxygen (DO) is a critical chemical parameter that supports aquatic life, while biochemical oxygen demand (BOD) measures the amount of oxygen required by microorganisms to decompose organic matter in water. In Plateau State, DO levels in surface waters typically range from 5.0 to 8.0 mg/L, which is generally sufficient to support most aquatic organisms [Adeoye & Abubakar, 2015]. However, BOD levels can vary widely, particularly in areas impacted by organic pollution from sewage, agricultural runoff, or industrial discharges. High BOD levels, often exceeding 5 mg/L, indicate significant organic pollution, which can lead to hypoxic conditions and fish kills [Oloruntoba, 2019].

Benue State

- i. **Nutrients (Nitrogen and Phosphorus):** Nutrient levels in water, particularly nitrogen (N) and phosphorus (P), are key indicators of water quality, as they influence the growth of algae and aquatic plants. Excessive nutrient levels, particularly from agricultural runoff, can lead to eutrophication, a process in which water bodies become overly enriched with nutrients, resulting in excessive plant and algal growth. In Benue State, nutrient pollution is a growing concern, particularly in areas with intensive agricultural activities, such as the cultivation of yams, rice, and soybeans (Ayuba, 2020). Studies have shown that nitrate (NO₃⁻) levels in surface waters in Benue State often exceed 10 mg/L, which is above the World Health Organization (WHO) limit for drinking water (Abah & Omada, 2019).

Elevated nitrate levels can cause health issues such as methemoglobinemia, also known as "blue baby syndrome," in infants. Phosphorus levels are also elevated in some areas, particularly near agricultural fields, leading to algal blooms that can deplete oxygen levels and harm aquatic life.

- ii. **Heavy Metals:** Heavy metal contamination is a critical water quality issue, particularly in regions where industrial activities, mining, and agricultural inputs contribute to the presence of toxic metals in water bodies. In Benue State, heavy metals such as lead (Pb), cadmium (Cd), chromium (Cr), and mercury (Hg) have been detected in surface and groundwater sources, although concentrations vary across different locations. Lead contamination is a particular concern due to its persistence in the environment and its ability to bioaccumulate in organisms, leading to long-term health effects. In some areas of Benue State, lead levels have been reported to exceed 0.01 mg/L, which is the WHO guideline limit for drinking water (*Adamu, 2019*). Cadmium and chromium levels have also been found to exceed permissible limits, particularly in areas close to mining activities and industries that discharge untreated waste into nearby water bodies.
- iii. **Dissolved Oxygen (DO):** Dissolved oxygen is essential for the survival of aquatic organisms, and its levels are a key indicator of water quality. In Benue State, DO levels vary seasonally, with higher levels typically observed during the rainy season due to increased water flow and aeration from rainfall. However, during the dry season, DO levels can drop significantly, particularly in stagnant or slow-moving water bodies (*Olapade, 2018*). Low DO levels can lead to hypoxia, a condition in which aquatic organisms, particularly fish, are deprived of adequate oxygen, leading to mass die-offs and disruptions to the ecosystem. DO levels below 4 mg/L are considered critical for most fish species, and in some parts of the River Benue, particularly during periods of low flow, DO levels have been recorded as low as 3 mg/L (*Abah & Omada, 2019*).

Taraba State

- i. **Nutrients:** Nutrient levels, particularly nitrogen and phosphorus, are important chemical parameters in assessing water quality. In Taraba State, nutrient levels are influenced by agricultural activities, particularly in areas where fertilizers are used extensively. Elevated concentrations of nitrate (NO_3^-) and phosphate (PO_4^{3-}) have been recorded in surface water bodies such as the Benue River and its tributaries, especially during the rainy season when

runoff from farmlands is highest [Adakole, 2000]. Excessive nutrient levels can lead to eutrophication, a process where water bodies become enriched with nutrients, leading to excessive growth of algae and aquatic plants. This, in turn, depletes dissolved oxygen levels, affecting aquatic life and leading to the development of "dead zones" where most organisms cannot survive. Nutrient levels in groundwater are generally lower than in surface water, but localized contamination from septic systems or agricultural runoff can elevate nitrate levels in wells and boreholes.

- ii. **Heavy Metals:** The presence of heavy metals in water is a significant concern for public health and environmental safety. In Taraba State, heavy metals such as lead (Pb), cadmium (Cd), and mercury (Hg) have been detected in both surface and groundwater sources, though concentrations are typically low. However, certain areas with mining activities, particularly near the Mambilla Plateau, show elevated levels of heavy metals due to runoff from mining sites and improper waste disposal [Olorunfemi, 2000]. Heavy metal contamination poses a serious risk to human health, as these metals can accumulate in the body over time, leading to chronic health problems such as kidney damage, neurological disorders, and cancer. Regular monitoring of heavy metal concentrations is essential to ensure that water remains safe for consumption and irrigation.
- iii. **Dissolved Oxygen (DO):** Dissolved oxygen (DO) is a critical parameter for assessing the health of aquatic ecosystems. In Taraba State, DO levels vary depending on temperature, flow conditions, and the presence of organic matter. During the rainy season, when water flow is high, DO levels in rivers and streams are generally sufficient to support aquatic life, with values typically ranging from 6 to 9 mg/L [Ayoade, 2004]. However, during the dry season, particularly in stagnant water bodies, DO levels can drop below 4 mg/L, leading to hypoxic conditions that stress or kill fish and other aquatic organisms. DO levels are also affected by the decomposition of organic matter, which consumes oxygen. In areas with high organic pollution, such as those receiving untreated sewage or agricultural runoff, DO levels can become critically low, leading to fish kills and the degradation of water quality.

Nasarawa State

Chemical parameters of water quality include the concentration of nutrients, heavy metals, and other chemical contaminants that can affect both human health and the environment. In Nasarawa

State, the chemical quality of water is influenced by both natural processes, such as the weathering of rocks, and human activities, including agriculture, mining, and industrial discharges.

- i. Nutrients:** Nutrient levels in water, particularly nitrogen and phosphorus, are critical for the health of aquatic ecosystems but can also lead to problems such as eutrophication if present in excessive amounts. In Nasarawa State, nutrient levels in rivers and streams are generally moderate, but there are concerns about nutrient pollution in areas with intensive agriculture. Fertilizers used in farming can introduce high levels of nitrates and phosphates into water bodies, especially during the rainy season when runoff from farmlands enters rivers and streams (Ajayi, 2020). Elevated levels of nitrates (NO_3^-) can lead to health issues such as methemoglobinemia, also known as "blue baby syndrome," in infants who consume water with high nitrate concentrations. Phosphates (PO_4^{3-}), on the other hand, contribute to the growth of algae and aquatic plants, which can cause eutrophication, leading to oxygen depletion in water bodies and harm to aquatic life. While nutrient levels in Nasarawa's water bodies are generally within acceptable limits for drinking water, localized areas with high agricultural activity have reported higher nutrient concentrations, which could pose environmental and health risks (Afolayan & Popoola, 2019).
- ii. Heavy Metals:** Heavy metal contamination is a significant concern in Nasarawa State due to its extensive mining activities. Mining operations, particularly for minerals like lead, zinc, and barite, have the potential to introduce heavy metals into nearby water bodies through runoff and leaching. Studies have reported elevated levels of heavy metals such as lead (Pb), cadmium (Cd), arsenic (As), and mercury (Hg) in water sources near mining areas, particularly in Karu, Keffi, and Akwanga (Udo, 2016). These metals are toxic to both humans and aquatic life and can accumulate in the food chain, leading to long-term health impacts. For example, lead contamination in drinking water is associated with developmental issues in children, including cognitive impairments and behavioral problems. Similarly, mercury and cadmium are linked to kidney damage and other chronic health issues. In some mining areas of Nasarawa State, heavy metal concentrations in water exceed the World Health Organization (WHO) limits for drinking water, highlighting the need for water treatment and remediation efforts (Iloeje, 2017).
- iii. Pesticides and Agricultural Chemicals:** In addition to heavy metals, agricultural chemicals such as pesticides and herbicides are another source of chemical contamination

in Nasarawa State's water bodies. Farmers often use these chemicals to boost crop yields, but improper application or overuse can result in their runoff into rivers and streams. Pesticides such as organophosphates and carbamates, which are commonly used in the region, can have detrimental effects on aquatic organisms and may pose risks to human health if they contaminate drinking water sources (Ajayi, 2020).

4.3.3 Biological Parameters

Plateau State

- i. **Bacteria:** Microbial contamination, particularly by pathogenic bacteria, is a significant concern in Plateau State, especially in surface water sources used for drinking and domestic purposes. Common indicators of bacterial contamination include *Escherichia coli* (*E. coli*) and total coliform bacteria, which are used to assess the presence of fecal contamination. Studies have shown that surface waters in Plateau State often exceed acceptable limits for *E. coli*, particularly during the rainy season when runoff can carry contaminants from agricultural fields, open defecation sites, and urban areas into rivers and streams [Adeniyi & Olabanji, 2015]. *E. coli* counts in some rivers have been reported as high as 100 to 1,000 CFU/100 mL, indicating a significant risk of waterborne diseases such as diarrhea, cholera, and typhoid fever [Oloruntoba, 2019].
- ii. **Water Treatment and Public Health:** The presence of pathogenic bacteria in water supplies underscores the need for effective water treatment and sanitation practices. In many rural areas of Plateau State, access to treated water is limited, increasing the reliance on untreated surface water and, consequently, the risk of waterborne diseases [Ezekiel, 2017].
- iii. **Algae:** Algal growth in water bodies is closely linked to nutrient levels, particularly nitrogen and phosphorus. In Plateau State, algal blooms are a common occurrence in rivers, lakes, and reservoirs, especially during the dry season when water levels are lower, and nutrient concentrations are higher due to evaporation [Adeoye & Abubakar, 2015]. The most common types of algae found in Plateau State include cyanobacteria (blue-green algae), which can produce harmful toxins that pose risks to both aquatic life and human health. Harmful algal blooms (HABs) have been reported in some water bodies, leading to fish kills and the contamination of water supplies [Oloruntoba, 2019]. Monitoring and

managing nutrient inputs into these water bodies are crucial to preventing the occurrence of HABs and protecting water quality.

- iv. **Protozoa and Parasites:** In addition to bacteria and algae, water bodies in Plateau State are also home to various protozoa and parasites, including Giardia and Cryptosporidium, which can cause gastrointestinal illnesses in humans. These pathogens are often introduced into water bodies through fecal contamination from both human and animal sources. The presence of these protozoa in water supplies is a significant public health concern, particularly in areas without adequate water treatment infrastructure [Adeniyi & Olabanji, 2015]. Studies have highlighted the need for regular monitoring of these biological contaminants and the implementation of appropriate water treatment methods, such as filtration and disinfection, to reduce the risk of waterborne diseases [Oloruntoba, 2019].

Benue State

- i. **Bacteria:** The presence of pathogenic bacteria in water is a major concern for public health, particularly in rural areas where access to treated water is limited. In Benue State, coliform bacteria, including Escherichia coli (E. coli), are commonly used as indicators of fecal contamination. Studies have shown that many water sources in Benue State, particularly surface waters and shallow wells, are contaminated with coliform bacteria, often exceeding the WHO limit of zero coliforms per 100 mL of water (Eze, 2018). The primary sources of bacterial contamination in Benue State include inadequate sanitation facilities, agricultural runoff, and the discharge of untreated sewage into rivers and streams. Consumption of water contaminated with coliform bacteria can lead to waterborne diseases such as diarrhea, cholera, and typhoid fever.
- ii. **Algae:** Algae are naturally occurring organisms in aquatic environments, but excessive algal growth can be a sign of nutrient pollution, particularly from nitrogen and phosphorus. In Benue State, algal blooms are a growing concern, particularly in areas where agricultural runoff enters rivers and streams. The presence of blue-green algae, or cyanobacteria, is particularly problematic, as these organisms can produce harmful toxins known as cyanotoxins, which pose risks to both aquatic life and human health (Ayuba, 2020). Algal blooms can deplete dissolved oxygen levels in the water, leading to hypoxic conditions that are harmful to fish and other aquatic organisms. In addition, cyanotoxins can contaminate

drinking water sources, leading to health risks such as liver damage, neurological symptoms, and, in extreme cases, death (*Adamu, 2019*).

Taraba State

- i. **Bacteria:** Microbial contamination, particularly from fecal coliform bacteria such as *Escherichia coli* (*E. coli*), is a major concern in Taraba State's water resources. Bacterial contamination is often linked to inadequate sanitation, open defecation, and improper disposal of sewage and animal waste, particularly in rural areas and around the Benue River basin. During the rainy season, bacterial counts in surface water can increase significantly due to runoff from human settlements and agricultural areas [*Adakole, 2000*]. High levels of coliform bacteria in water sources pose serious health risks, particularly for gastrointestinal diseases such as cholera, dysentery, and typhoid. Water treatment processes, including chlorination and filtration, are essential to reduce bacterial contamination in drinking water supplies.
- ii. **Algae:** Algal blooms are a seasonal issue in some of Taraba State's surface water bodies, particularly in slow-moving or stagnant sections of rivers and lakes. These blooms are often driven by high nutrient levels (particularly phosphorus) and warm water temperatures. In extreme cases, harmful algal blooms (HABs), which produce toxins, can occur, affecting both aquatic life and human health [*Olowolafe, 2002*]. Algal blooms reduce water quality by lowering dissolved oxygen levels and increasing the concentration of organic matter in the water. This can lead to the death of fish and other aquatic organisms and make water unsuitable for recreational use or drinking.
- iii. **Protozoa and Other Microorganisms:** In addition to bacteria, other microorganisms such as protozoa (e.g., *Giardia* and *Cryptosporidium*) and viruses can contaminate water sources in Taraba State. These pathogens are often introduced through fecal contamination and pose significant risks to human health, particularly for children and immunocompromised individuals. Waterborne diseases caused by these microorganisms can be severe, leading to diarrhea, dehydration, and even death in vulnerable populations [*Ayoade, 2004*].

To mitigate the risks posed by biological contaminants, it is crucial to implement effective water treatment processes, such as filtration and disinfection, and to promote improved sanitation and hygiene practices.

Nasarawa State

Biological parameters refer to the presence of living organisms in water, including bacteria, algae, and other microorganisms. These parameters are critical for assessing the health of aquatic ecosystems and the safety of water for human consumption.

- i. Bacteria:** Microbial contamination is a major concern in Nasarawa State, particularly in rural areas where water treatment infrastructure is limited. Bacteria such as *Escherichia coli* (*E. coli*), *Salmonella*, and *Vibrio cholerae* are commonly detected in water sources, particularly during the rainy season when runoff from human and animal waste enters rivers and streams (*Afolayan & Popoola, 2019*). The presence of these bacteria indicates fecal contamination, which poses serious health risks, including gastrointestinal diseases such as diarrhea, cholera, and typhoid fever. The prevalence of bacterial contamination is linked to inadequate sanitation facilities and the use of untreated surface water for drinking, particularly in rural communities. Studies have found that water sources in these areas often fail to meet WHO guidelines for microbial water quality, with significant levels of coliform bacteria detected in rivers, wells, and boreholes (*Udo, 2016*). Efforts to improve water treatment, sanitation, and hygiene practices are essential to reducing the risks of waterborne diseases in the state.
- ii. Algae and Other Aquatic Plants:** The presence of algae in water bodies is a natural occurrence, but excessive algal growth, particularly in nutrient-rich waters, can lead to algal blooms, which negatively affect water quality. In Nasarawa State, algal blooms are more common in stagnant or slow-moving water bodies, particularly during the dry season when water levels are low, and nutrient concentrations are higher due to reduced dilution (*Ajayi, 2020*). These blooms can lead to the production of harmful toxins, which can affect both aquatic life and human health. Algal blooms also contribute to eutrophication, a process where water bodies become overly enriched with nutrients, leading to oxygen depletion. This, in turn, results in the death of fish and other aquatic organisms, further degrading water quality. In Nasarawa State, eutrophication is a growing concern in areas with intensive agricultural activities, particularly in low-lying floodplains and along the Benue River, where nutrient runoff is significant (*Afolayan & Popoola, 2019*).

4.4 Hydrogeological Disposition of the Catchment

The hydrogeological disposition of the catchment and its hydrogeological units and aquiferous layers make up part of the water resources of the catchment, as seen and explained in figure 4.6

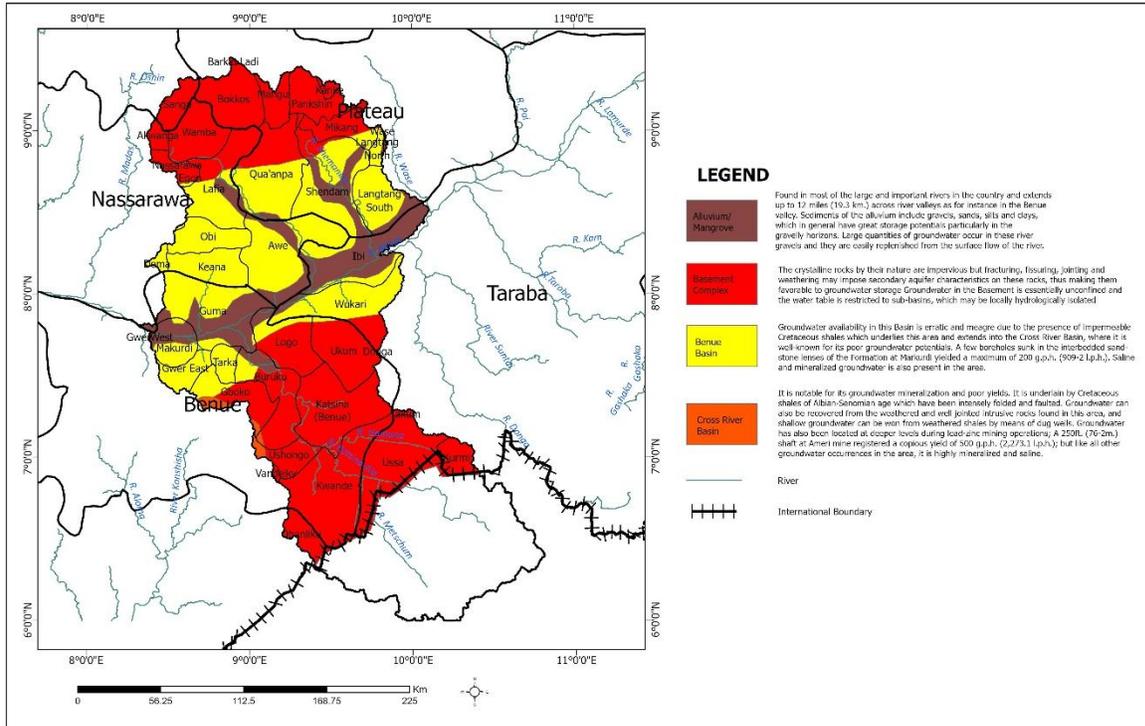


Figure 4.6: Hydrogeological provinces of the catchment (Source: MSL, 2024)

Groundwater storage is critical in the catchment, particularly in areas where surface water resources are insufficient. The catchment aquifers store a significant volume of water, which is accessed through boreholes and wells. However, over-extraction and inadequate recharge have led to concerns about the sustainability of groundwater resources. The continuous decline in groundwater levels in some areas suggests that current extraction rates may not be sustainable in the long term (Musa et al., 2020).

4.5 Water Resources Assessment Concept in the Catchment

The concept of water resources assessment is a key element in managing water resources, as it directly affects water availability, agricultural productivity, and environmental well-being. In the catchment area of northeastern Nigeria, understanding stream flow and discharge is especially important due to the region's semi-arid climate and unpredictable rainfall patterns. This report offers a comprehensive overview of the stream flow and discharge in the catchment, highlighting current conditions, challenges, and recommendations for effective management.

4.5.1 Stream Flow and Discharge

Plateau State

Plateau State is characterized by a network of rivers and streams, most of which are part of the larger Niger and Benue River basins. The state's topography, with its elevated plateaus and hills, plays a significant role in the flow characteristics of these water bodies. Rivers such as the Kaduna, Benue, and Gongola originate from the Jos Plateau and flow outward, draining the surrounding areas.

- i. **Seasonal Variations:** Stream flow in Plateau State exhibits marked seasonal variations, largely driven by the region's climatic patterns. During the rainy season, which typically lasts from April to October, stream flow increases significantly due to the high volume of rainfall. Conversely, during the dry season, from November to March, stream flow decreases, leading to reduced water availability [Adebayo, 2014]. The variability in stream flow is a critical factor in water resource management, as it affects the reliability of water supply for agriculture, industry, and domestic use.
- ii. **Stream Discharge:** The discharge of rivers and streams in Plateau State is also subject to significant seasonal fluctuations. During the peak of the rainy season, rivers can experience discharge rates that are several times higher than those observed during the dry season. For example, the Kaduna River, one of the major rivers in the state, has a discharge rate that can vary from less than 100 cubic meters per second (m^3/s) during the dry season to over 1,000 m^3/s during periods of heavy rainfall [Iloje, 2017]. These fluctuations present challenges for water storage and flood management, as the infrastructure must be capable of handling both extremes.

- iii. **Impact of Topography on Stream Flow:** The topography of Plateau State, particularly the Jos Plateau, influences the velocity and direction of stream flow. The steep gradients in some areas lead to fast-moving streams, which can result in higher rates of erosion and sediment transport. In contrast, flatter areas, particularly in the lowlands, experience slower stream flow, which can lead to sediment deposition and the formation of floodplains [Ogunleye & Ayoade, 2016].

Benue State

- i. Water quantity is a critical aspect of the hydrological system in Benue State, which has far-reaching implications for agriculture, water supply, flood control, and ecosystem health. The quantity of water available in the state is influenced by factors such as stream flow, discharge patterns, water levels, storage capacities, and the occurrence of floods and droughts. In this section, these factors will be examined in detail, with emphasis on how they shape water availability in Benue State.
- ii. The River Benue is the primary hydrological feature in Benue State and is one of the major rivers in Nigeria. It is a key tributary of the Niger River and forms an essential part of the hydrological network in the country. The stream flow and discharge patterns of the River Benue and its tributaries, such as the Katsina-Ala and Donga rivers, are heavily influenced by seasonal rainfall patterns and regional hydrological conditions.
- iii. The River Benue experiences a marked seasonal fluctuation in flow rates, with higher discharges occurring during the rainy season (typically from May to October) and lower discharges during the dry season (from November to April). During the peak of the rainy season, the River Benue's discharge can exceed 7,000 cubic meters per second (m^3/s), particularly in August and September when rainfall is highest (Adamu, 2019). In contrast, during the dry season, discharge rates can drop significantly, with recorded values as low as 200 m^3/s in some years (Abah & Omada, 2019).
- iv. The seasonal variability in stream flow and discharge has important implications for water availability, particularly for agriculture and domestic water supply. The high flows during the rainy season support irrigation activities and replenish reservoirs, while the low flows during the dry season can lead to water shortages, especially in areas that rely on surface water for agriculture and human consumption.

Taraba State

- i. Taraba State's water quantity is significantly shaped by its hydrological features, geographical diversity, and climatic variations. The state's rivers, streams, and groundwater systems play a crucial role in sustaining its population, agriculture, and ecosystems. Water quantity in the region is affected by seasonal rainfall patterns, streamflow characteristics, groundwater storage, and environmental phenomena such as flooding and drought. Understanding these aspects is crucial for the effective management of water resources, especially in the context of growing demand and environmental changes.
- ii. Streamflow in Taraba State is dominated by the Benue River and its numerous tributaries. The flow of these rivers is highly seasonal, reflecting the state's distinct wet and dry seasons. During the wet season, which occurs between May and October, rainfall contributes significantly to river discharge, leading to higher stream flows. The Benue River, in particular, experiences peak discharge during this period, with flow volumes reaching their maximum in August and September. Average streamflow rates for the Benue River at Wuro-Bokki, one of the key monitoring stations, range from 1,000 to 1,500 cubic meters per second (m^3/s) during the rainy season [Ayoade, 2004].
- iii. In contrast, the dry season (November to April) is characterized by drastically reduced streamflow. The discharge of rivers during this period often falls to as low as $200 \text{ m}^3/\text{s}$ in the case of the Benue River, while smaller rivers and streams may even dry up completely. This seasonal variability creates challenges for water availability, particularly for agriculture and domestic use in areas dependent on surface water sources.
- iv. Groundwater sources, particularly in the low-lying areas of the state, help supplement water availability during the dry season. However, excessive reliance on groundwater extraction during periods of low streamflow can lead to depletion and long-term sustainability issues.

Nasarawa State

- i. Water quantity in Nasarawa State is a function of several hydrological processes, including streamflow, discharge, water levels, storage capacities, and the region's susceptibility to both floods and droughts. Nasarawa State is located within the Benue River Basin and is significantly influenced by seasonal rainfall patterns. The quantity of available water in the state varies seasonally and spatially, affecting its utilization for agriculture, domestic use, and industrial purposes.
- ii. Stream flow in Nasarawa State is largely determined by seasonal rainfall patterns, topography, and the presence of major rivers, particularly the Benue River and its tributaries. The state's river systems are dynamic, with discharge rates fluctuating based on the season.
- iii. During the rainy season, which spans from April to October, stream flows in Nasarawa State are significantly higher due to increased rainfall and runoff. The Benue River, the most prominent water body in the state, experiences its peak discharge during this period, often reaching levels above 3,000 cubic meters per second (*Ajayi, 2020*). Smaller rivers, such as the Mada and Farin Ruwa Rivers, also experience similar trends, with discharge rates increasing sharply during the rainy months.
- iv. In contrast, the dry season, which extends from November to March, is marked by a drastic reduction in stream flow. Rivers become smaller, and many seasonal streams dry up completely during this period. The reduced flow is due to a combination of low rainfall, high evaporation rates, and reduced groundwater recharge (*Afolayan & Popoola, 2019*). The Benue River, for instance, experiences a significant decline in discharge during the dry season, often dropping to levels below 1,000 cubic meters per second.
- v. The topography of Nasarawa State, characterized by both lowland areas and highland regions, plays a critical role in shaping stream flow patterns. In the hilly northern parts of the state, such as the Akwanga and Wamba regions, steep slopes promote faster runoff and higher discharge rates in local streams during rainfall events. This rapid runoff can lead to flash floods, which are particularly common in the rainy season (*Iloeje, 2017*). On the other hand, the floodplains of the southern region near the Benue River experience slower-moving water and prolonged discharge periods due to the flatter terrain.

- vi. Land use changes, particularly deforestation and agricultural expansion, have also impacted stream flow and discharge in Nasarawa State. The removal of vegetation reduces the land's ability to absorb rainfall, increasing surface runoff and stream flow, especially during heavy rainfall events. This not only increases the risk of flooding but also contributes to soil erosion and sedimentation in rivers (*Udo, 2016*). Sedimentation can reduce the carrying capacity of rivers, further exacerbating the risk of flooding during peak discharge periods.

4.5.2 Surface Water Resource Potential

The average precipitation over the country is about 1,150mm. Only 24% of the precipitation becomes runoff and the rest are lost as evapotranspiration and/or other form of abstractions. Total internal generation of the runoff in Nigeria is 244BCM/year and the surface water resource potential are estimated at 330BCM/year. The total water resources potential was evaluated by adding the component that is lost without becoming surface runoff among recharge. The internal generation of total water resources potential is estimated at 286BCM/year and the total water resources potential with inflow from neighboring countries is estimated at 374BCM/year. 89BCM/year of water comes from neighboring countries, which roughly indicates that almost 24% of surface water resources in Nigeria relies on neighboring countries. The total groundwater resources potential is estimated at 142BCM/year as a renewable source on the basis of the estimated groundwater recharge. The table below shows the water resource potential for HA-4 of which the Shemankar-Katsina Ala catchment is a component.

Table 4.2: Resource Potential for HA4 (Source: JICA project Team)

HA-4		
Water Resources Potential		
Total Water Resources Potential ¹⁾		
Including inflow from outside Nigeria	(BCM /year)	47.7
Only internal generation in Nigeria	(BCM /year)	32.6
Surface Water Resources Potential		
Including inflow from outside Nigeria	(BCM/year)	46.1
Only internal generation in Nigeria	(BCM/year)	31
Groundwater Resources Potential		
Groundwater Recharge	(BCM/year)	14.6
Runoff Condition (Only internal generation in Nigeria)		
Precipitation (P)	(mm/year)	1,341
Total Runoff (RO)	(mm/year)	416
Groundwater Recharge (GRE)	(mm/ year)	196
Loss of Recharge (LOS)	(mm/year)	22
Runoff Rate (RO/P)	(%)	31
Recharge Rate (GRE/P)	(%)	14.6
Loss Rate (LOS/P)	(%)	1.6
Total Water Res. Rate ((RO+LOS)/P)	(%)	32.6



4.5.2.1 Run off Yield

Table 4.3: Runoff Yield for SHAs in HA-4

HA	SHA	SHA divided by National Boundary	SN	Area (km2)	Average Monthly Runoff Yield (Height) (mm/month)												Average Annual Runoff Yield (mm/year)	Average Annual Preci- pitation (mm/year)	Average Runoff Rate (%)
					1	2	3	4	5	6	7	8	9	10	11	12			
406	406_e		114	10,331.5	14.0	7.2	19.9	56.4	108.5	159.3	217.8	252.7	282.4	226.8	90.1	34.9	1,470	1,915	76.8
	406_l		115	12,618.8	10.2	4.2	4.7	14.4	63.6	113.6	131.1	160.7	194.6	169.5	62.8	25.1	954	1,553	61.5
410	410		119	4,839.1	4.5	2.2	1.0	0.5	2.8	7.6	18.2	63.3	87.0	43.5	19.6	9.3	260	1,161	22.4

4.5.3 Ground water potential

Table 4.4: Amount of Groundwater by Newly Drilled Boreholes and Borehole Rehabilitation.

State		Amount of groundwater to be developed by 2030		Amount of groundwater by rehabilitated boreholes		Amount of groundwater by newly drilled boreholes		
		Urban/semi-urban/town	Rural	Urban/semi-urban/town	Rural	Urban/semi-urban/town	Rural	
							Motorized pump	Motorized pump
		M3/day	M3/day	M3/day	M3/day	M3/day	M3/day	M3/day
1	Benue	146,595	86,034	73,298	24,723	73,298	36,786	24,524
2	Cross River	121,148	63,719	60,574	31,859	60,574	19,116	12,744
3	Kaduna	110,091	91,901	55,045	45,951	55,045	27,570	18,380
4	Nasarawa	94,527	31,785	47,263	13,051	47,241	11,241	7,494
5	Plateau	173,722	67,490	54,851	8,978	118,870	35,107	23,405
6	Taraba	143,180	51,001	5,609	1,599	137,571	29,641	19,761
	TOTAL	789,263	391,930	296,640	126,161	492,599	159,461	106,308

Source: National Water Resources Master Plan (JICA)

4.5.4 Groundwater Recharge

Groundwater recharge seems to reduce due to influence of the Climate Change. Amount of decrease in groundwater recharge is different area by area. It should be noticed that area with smaller groundwater recharge will have larger influence than the area with higher groundwater recharge even though amount of the decrease in groundwater recharge is the same.

Lowering of groundwater level due to reduce in groundwater recharge will be small around river because groundwater level will be almost constant at river beds. However, decrease in groundwater level will become larger in place far from rivers. Therefore, inland area in the plateau far from rivers will affect more influence by decrease in groundwater recharge. Countermeasures against the Climate Change will take account of such a condition mentioned above.

4.5.4.1 Balance of Demand and Supply by Groundwater

Balance between groundwater recharge and demands are shown in Table 4.5. Ratio of groundwater demand/recharge is 5% in national average. However, it is 1 to 86% state by state showing large difference among states. This is because of difference in groundwater recharge state by state. Ratio of groundwater demand/recharge is higher in the northern part of Nigeria, where there are sedimentary rocks distributed, and groundwater recharge is smaller than the other area. However, aquifer expands in wide area crossing state boundary, where groundwater can be extracted from boreholes collecting groundwater from large surrounding area to meet groundwater demand.

Table 4.5: Groundwater Recharge and Groundwater Demand (2030)

No	State	Groundwater Recharge (MCM/year)	Groundwater demand (2030) (MCM/year)					Groundwater Demand/recharge
			Water Supply	Private irrigation	Live stock	Aquaculture	Total	
1	Benue	10,655	152	50	1	3	206	2%
2	Cross river	14,620	84	24	0	52	160	1%
3	Kaduna	8,446	157	53	7	8	225	3%
4	Nasarawa	4,657	67	29	2	11	109	2%
5	Plateau	3,917	113	31	10	27	181	5%
6	Taraba	13,147	81	41	4	0	127	1%
Total		55,442	654	228	24	101	1,007	2%

Source: National Water Resources Master Plan (JICA)

Balance of groundwater recharge and demand is shown in Table 13 in case of the Climate Change (scenario case-1). Ratio of groundwater demand/recharge is 2% in catchment average. Effect of the Climate Change will make difference lager in water balance among states.

Table 4.6: Groundwater Recharge and Demand by effect of climate (2030)

NO.	State	Groundwater Recharge (MCM/year)	Groundwater demand (2030) (MCM/year)					Groundwater Demand/recharge
			Water Supply	Private irrigation	Live stock	Aquaculture	Total	
1	Benue	9,182	152	55	1	3	211	2
2	Cross river	13,067	84	26	0	52	162	1
3	Kaduna	6,511	157	61	7	8	233	4
4	Nasarawa	3,349	67	32	2	11	112	3%
5	Plateau	2,945	113	34	10	27	184	6%
6	Taraba	10,723	81	46	4	0	132	1%
	Total	124,178	5,964	1,409	241	875	8,486	2%

4.5.5 Water Uses and Demands For Shemankar-Katsina-Ala Catchments

Current and future water demands were estimated for the States covering Sub-Basin area of Wase-Taraba Catchment using the methodology applied in the NWRMP (JICA Team, 2014). The demand-related data obtained were based on the State level. The States considered are Benue, Cross River, Kaduna, Nasarawa, Plateau and Taraba.

The water demand is divided into the following categories:

- Municipal water demand (including domestic, commercial, and industrial).
- Irrigation water demand.
- Livestock water demand.
- Aquaculture water demand.
- Hydropower water demand.
- Environmental water demand.

4.5.5.1 Municipal water use

Municipal water demand is mostly met by groundwater throughout the basin, this is due to heavy pollution of the surface rivers. However, there are existing schemes covering the municipal supply of some portion of the catchment.

4.5.6 Population

The Project estimates the population by Sub-Catchment Areas as the smallest unit.

Population Projection

Population was projected using the 2006 census data for a duration up to 2050 by utilizing the projection growth rate in the table 16 below

Table 4.7: Average annual rate of population growth (UN, 2012)

2010 -2015	2015-2020	2020-2025	2025-2030	2030-2035	2035-2040
2.78%	2.71%	2.65%	2.60%	2.54%	2.35%

4.5.6.1 Population Projection

Table 4.8 below shows the population projection of local government areas within Shemankar catchments;

Table 4.8: Population of local government areas covered by the catchment

State	LGA	2006	2022	2025	2030	2035	2040	2045	2050
Benue	Buruku	206,215	297,700	319653	359897	405208	456224	513662	578333
Benue	Gboko	361,325	521,700	560171	630697	710101	799503	900160	1013490
Benue	Guma	194,164	280,300	300970	338862	381525	429559	483640	544530
Benue	Gwer East	168,660	243,500	261456	294373	331435	373163	420144	473040
Benue	GwerWest	122,313	176,600	189623	213496	240375	270639	304712	343075
Benue	Katsina (Benue)	225,471	325,500	349503	393505	443048	498827	561630	632339
Benue	Kwande	248,642	359,000	385473	434004	488645	550166	619432	697418
Benue	Logo	169,570	244,800	262852	295945	333204	375155	422387	475565
Benue	Makurdi	300,377	433,700	465682	524311	590322	664643	748322	842535
Benue	Tarka	79,280	114,500	122943	138422	155849	175471	197562	222436



Benue	Ukum	216,983	313,300	336403	378756	426442	480131	540579	608638
Benue	Ushongo	191,935	277,100	297534	334993	377169	424655	478118	538314
Benue	Vandeiky	234,567	338,700	363676	409463	461015	519056	584405	657982
Cross River	Obanliku	109,633	167,000	179315	201891	227309	255927	288148	324426
Kaduna	Sanga	151,485	223,800	240303	270558	304621	342973	386153	434769
Nassarawa	Akwanga	111,902	172,800	185543	208902	235203	264815	298155	335693
Nassarawa	Awe	113,083	174,600	187475	211078	237653	267574	301261	339190
Nassarawa	Doma	138,991	214,600	230425	259435	292098	328874	370279	416897
Nassarawa	Keana	81,801	126,300	135614	152687	171911	193554	217923	245359
Nassarawa	Lafia	329,922	509,300	546857	615706	693223	780500	878765	989401
Nassarawa	Nassarawa Egon	148,405	229,100	245994	276965	311835	351095	395298	445065
Nassarawa	Obi	148,977	230,000	246961	278053	313060	352474	396850	446814
Nassarawa	Wamba	72,687	112,200	120474	135641	152719	171946	193594	217967
Plateau	Barkin Ladi	179,805	264,500	284005	319761	360019	405345	456378	513836



Plateau	Bokkos	179,550	264,100	283575	319277	359474	404732	455688	513059
Plateau	Kanke	124,268	182,800	196280	220992	248814	280140	315410	355120
Plateau	Langtang North	142,316	209,400	224842	253149	285021	320905	361306	406795
Plateau	Langtang South	105,173	154,700	166108	187021	210567	237077	266925	300531
Plateau	Mangu	300,520	442,100	474701	534466	601755	677516	762816	858854
Plateau	Mikang	96,388	141,800	152257	171426	193008	217308	244667	275470
Plateau	Pankshin	190,114	279,700	300326	338137	380708	428639	482605	543364
Plateau	Qua'anpa	197,276	290,200	311600	350830	395000	444730	500722	563763
Plateau	Shendam	205,119	301,800	324055	364854	410789	462507	520737	586297
Plateau	Wase	159,861	235,200	252544	284339	320138	360443	405823	456916
Taraba	Donga	133,105	209,400	224842	253149	285021	320905	361306	406795
Taraba	Ibi	84,302	132,600	142378	160304	180486	203209	228793	257598
Taraba	Kurmi	91,282	143,600	154189	173602	195458	220066	247773	278967
Taraba	Takum	134,576	211,700	227311	255930	288151	324429	365275	411263



Taraba	Ussa	90,889	143,000	153545	172876	194642	219147	246737	277802
Taraba	Wukari	238,283	374,800	402438	453105	510151	574379	646694	728112
TOTAL		6,779,215	10,067,500	10,809,896	12,170,861	13,703,171	15,428,399	17,370,833	19,557,819

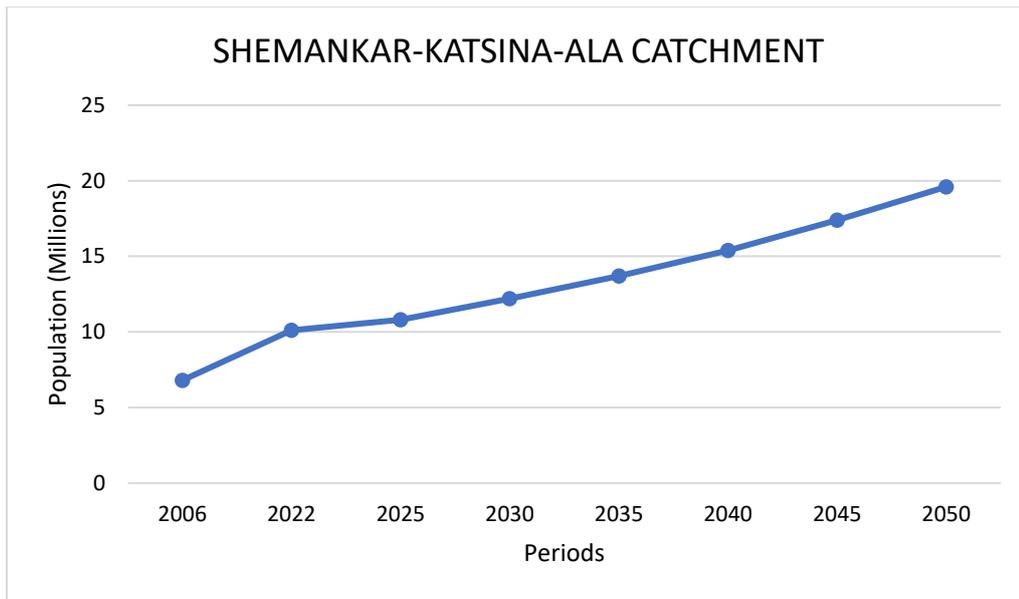


Figure 4.7: Graphical Representation of the Projected Population Shemankar-Katsina-Ala Catchment



Table 4.9 below shows the projected water demand 2006 to 2050 for Shemankar-Katsina-Ala Catchment

Per Capita Demand = 70 L/Day

Table 4.9: Municipal Water demand 2006 - 2050 for Shemankar-Katsina-Ala catchment

State	LGA	Water Demand m3/d 2006	2022	2025	2030	2035	2040	2045	2050
Benue	Buruku	14435	20839	22376	25193	28365	31936	35956	40483
Benue	Gboko	25293	36519	39212	44149	49707	55965	63011	70944
Benue	Guma	13591	19621	21068	23720	26707	30069	33855	38117
Benue	Gwer East	11806	17045	18302	20606	23200	26121	29410	33113
Benue	GwerWest	8562	12362	13274	14945	16826	18945	21330	24015
Benue	Katsina (Benue)	15783	22785	24465	27545	31013	34918	39314	44264
Benue	Kwande	17405	25130	26983	30380	34205	38512	43360	48819
Benue	Logo	11870	17136	18400	20716	23324	26261	29567	33290



Benue	Makurdi	21026	30359	32598	36702	41323	46525	52383	58977
Benue	Tarka	5550	8015	8606	9690	10909	12283	13829	15570
Benue	Ukum	15189	21931	23548	26513	29851	33609	37841	42605
Benue	Ushongo	13435	19397	20827	23450	26402	29726	33468	37682
Benue	Vandeiky	16420	23709	25457	28662	32271	36334	40908	46059
Cross River	Obanliku	7674	11690	12552	14132	15912	17915	20170	22710
Kaduna	Sanga	10604	15666	16821	18939	21323	24008	27031	30434
Nassarawa	Akwanga	7833	12096	12988	14623	16464	18537	20871	23499
Nassarawa	Awe	7916	12222	13123	14775	16636	18730	21088	23743
Nassarawa	Doma	9729	15022	16130	18160	20447	23021	25920	29183
Nassarawa	Keana	5726	8841	9493	10688	12034	13549	15255	17175
Nassarawa	Lafia	23095	35651	38280	43099	48526	54635	61514	69258
Nassarawa	Nassarawa Egon	10388	16037	17220	19388	21828	24577	27671	31155



Nassarawa	Obi	10428	16100	17287	19464	21914	24673	27780	31277
Nassarawa	Wamba	5088	7854	8433	9495	10690	12036	13552	15258
Plateau	Barkin Ladi	12586	18515	19880	22383	25201	28374	31946	35969
Plateau	Bokkos	12569	18487	19850	22349	25163	28331	31898	35914
Plateau	Kanke	8699	12796	13740	15469	17417	19610	22079	24858
Plateau	Langtang North	9962	14658	15739	17720	19951	22463	25291	28476
Plateau	Langtang South	7362	10829	11628	13091	14740	16595	18685	21037
Plateau	Mangu	21036	30947	33229	37413	42123	47426	53397	60120
Plateau	Mikang	6747	9926	10658	12000	13511	15212	17127	19283
Plateau	Pankshin	13308	19579	21023	23670	26650	30005	33782	38036
Plateau	Qua'anpa	13809	20314	21812	24558	27650	31131	35051	39463
Plateau	Shendam	14358	21126	22684	25540	28755	32376	36452	41041
Plateau	Wase	11190	16464	17678	19904	22410	25231	28408	31984



Taraba	Donga	9317	14658	15739	17720	19951	22463	25291	28476
Taraba	Ibi	5901	9282	9966	11221	12634	14225	16016	18032
Taraba	Kurmi	6390	10052	10793	12152	13682	15405	17344	19528
Taraba	Takum	9420	14819	15912	17915	20171	22710	25569	28788
Taraba	Ussa	6362	10010	10748	12101	13625	15340	17272	19446
Taraba	Wukari	16680	26236	28171	31717	35711	40207	45269	50968
TOTAL		474,545	704,725	756,693	851,960	959,222	1,079,988	1,215,958	1,369,047

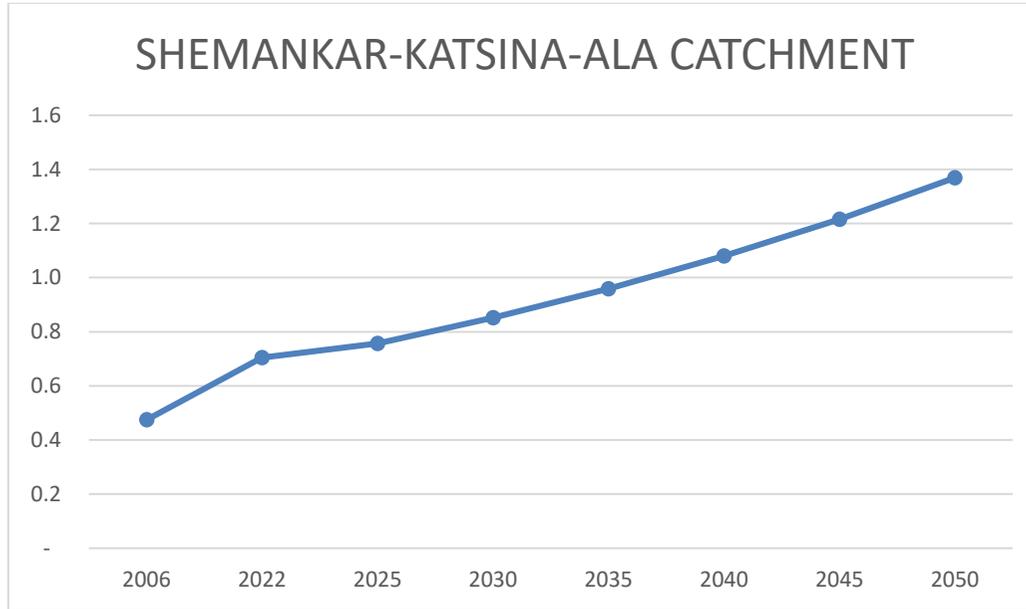


Figure 4.8: Graphical representation of Municipal Water demand 2006 - 2050 for Shemankar-Katsina-Ala catchment



Table 4.10: Water Capacity of the Catchment

State	LGA	Water Capacity m3/d 2006	2022	2025	2030	2035	2040	2045	2050
Benue	Buruku	18766	27091	29088	32751	36874	41516	46743	52628
Benue	Gboko	32881	47475	50976	57393	64619	72755	81915	92228
Benue	Guma	17669	25507	27388	30836	34719	39090	44011	49552
Benue	Gwer East	15348	22159	23793	26788	30161	33958	38233	43047
Benue	GwerWest	11130	16071	17256	19428	21874	24628	27729	31220
Benue	Katsina (Benue)	20518	29621	31805	35809	40317	45393	51108	57543
Benue	Kwande	22626	32669	35078	39494	44467	50065	56368	63465
Benue	Logo	15431	22277	23920	26931	30322	34139	38437	43276



Benue	Makurdi	27334	39467	42377	47712	53719	60483	68097	76671
Benue	Tarka	7214	10420	11188	12596	14182	15968	17978	20242
Benue	Ukum	19745	28510	30613	34467	38806	43692	49193	55386
Benue	Ushongo	17466	25216	27076	30484	34322	38644	43509	48987
Benue	Vandeiky	21346	30822	33095	37261	41952	47234	53181	59876
Cross River	Obanliku	9977	15197	16318	18372	20685	23289	26221	29523
Kaduna	Sanga	13785	20366	21868	24621	27720	31210	35140	39564
Nassarawa	Akwanga	10183	15725	16884	19010	21403	24098	27132	30548
Nassarawa	Awe	10291	15889	17060	19208	21626	24349	27415	30866
Nassarawa	Doma	12648	19529	20969	23609	26581	29927	33695	37938
Nassarawa	Keana	7444	11493	12341	13895	15644	17613	19831	22328
Nassarawa	Lafia	30023	46346	49764	56029	63083	71025	79968	90036
Nassarawa	Nassarawa Egon	13505	20848	22385	25204	28377	31950	35972	40501



Nassarawa	Obi	13557	20930	22473	25303	28488	32075	36113	40660
Nassarawa	Wamba	6615	10210	10963	12343	13897	15647	17617	19835
Plateau	Barkin Ladi	16362	24070	25844	29098	32762	36886	41530	46759
Plateau	Bokkos	16339	24033	25805	29054	32712	36831	41468	46688
Plateau	Kanke	11308	16635	17861	20110	22642	25493	28702	32316
Plateau	Langtang North	12951	19055	20461	23037	25937	29202	32879	37018
Plateau	Langtang South	9571	14078	15116	17019	19162	21574	24290	27348
Plateau	Mangu	27347	40231	43198	48636	54760	61654	69416	78156
Plateau	Mikang	8771	12904	13855	15600	17564	19775	22265	25068
Plateau	Pankshin	17300	25453	27330	30770	34644	39006	43917	49446
Plateau	Qua'anpa	17952	26408	28356	31926	35945	40470	45566	51302
Plateau	Shendam	18666	27464	29489	33202	37382	42088	47387	53353
Plateau	Wase	14547	21403	22982	25875	29133	32800	36930	41579



Taraba	Donga	12113	19055	20461	23037	25937	29202	32879	37018
Taraba	Ibi	7671	12067	12956	14588	16424	18492	20820	23441
Taraba	Kurmi	8307	13068	14031	15798	17787	20026	22547	25386
Taraba	Takum	12246	19265	20685	23290	26222	29523	33240	37425
Taraba	Ussa	8271	13013	13973	15732	17712	19942	22453	25280
Taraba	Wukari	21684	34107	36622	41233	46424	52269	58849	66258
TOTAL		616,909	916,143	983,701	1,107,548	1,246,989	1,403,984	1,580,746	1,779,762

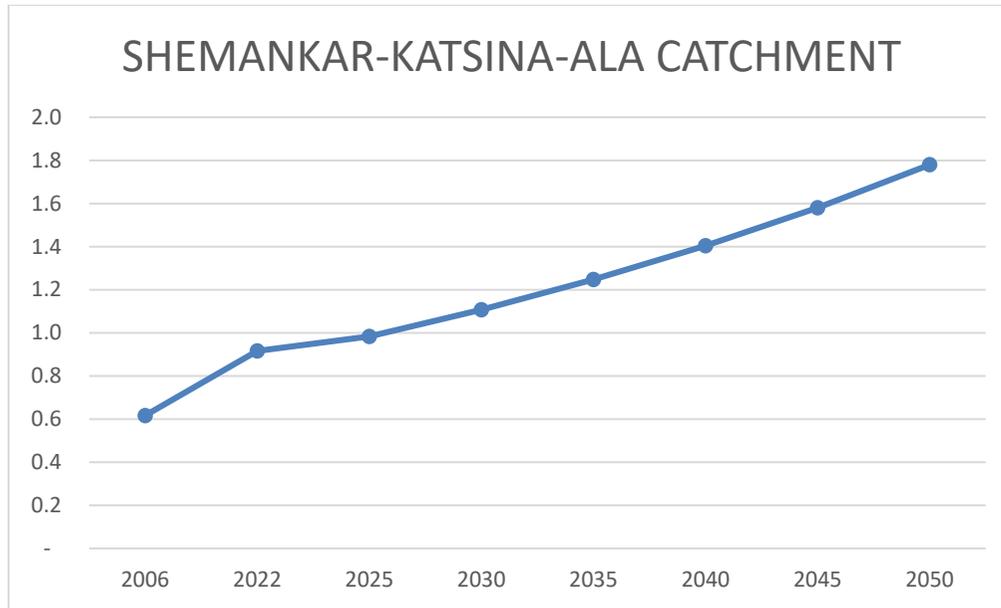


Figure 4.9: Graphical Representation of the Water Capacity of the Catchment

4.5.7 Calculated Model for Water Demand in the Shemankar-Katsina-Ala Catchment

The projected livelihood water requirements for the years 2022, 2025, 2030, 2035, 2040, 2045, and 2050 across the Shemankar-Katsina-Ala Catchment. This region is vital for sustaining agricultural activities, domestic needs, and other water-dependent livelihoods, are increasingly impacted by environmental changes, population growth, and evolving socio-economic dynamics.

The analysis is structured to provide a comprehensive understanding of the water demands anticipated over this timeline. It considers factors such as population projections, agricultural expansion, industrial activities, and climate variability. The goal is to provide stakeholders, including policymakers, planners, and local communities, with actionable insights to promote sustainable water resource management and ensure the resilience of livelihoods within the catchment. The findings emphasize the urgency of forward-looking water resource planning to address potential challenges and optimize the sustainable use of available water supplies.

The aim of this report is to estimate and project the average livelihood water requirements for the years 2022, 2025, 2030, 2035, 2040, 2045, and 2050 across the Shemankar-Katsina-Ala catchment, providing critical data for sustainable water resource management and planning.

METHODOLOGY

Human Domestic Water Requirement

When estimating human domestic water requirements in the catchments, factors like population size, per capita water consumption (typically 50 liters per person per day in rural areas, 100 liters in peri-urban areas, and 200 liters in urban areas), and water source availability (surface or groundwater) were considered. Using the estimated population for each catchment, the domestic requirement was calculated by multiplying it by the average daily water requirement ranging from 70 to 116 liters per person per day and then multiplying by 365 days to obtain the annual water demand for each catchment.

Animals Water Requirement

Factors that determine water quantity requirements

A combination of some of the factors listed below determine the quantity of water intake by animals:

- i. Kind & size of animal. Camels for instance, can drink about one-third (1/3) of their body weight, around 30 gallons or more of water, in a single sitting depending on the body size. These large amounts of water are stored in the camels' digestive and circulatory systems; they have oval-shaped red blood cells that double in size when hydrated.
- ii. Physiological state of animal. Lactating cows for instance require an extra litre of water per litre of milk. Lactating cows require up to twice the water of dry (non-lactating) cows. Water consumption in pregnant and growing animals also increases by some percentages.
- iii. Level of animal activity. Activity by the animal is directly proportional to water intake. The more the activity, the more the water requirement.
- iv. Type of diet & dry matter intake. Dry diets such as hay, require more water than moist diets such as silage or lush pasture with higher moisture contents. Also, dry matter intake is linked to water. That is, reducing water intake will reduce feed intake.
- v. Water Temperature. Water with lower temperature / not hot, is most desirable.
- vi. Water trough number and space. In adequate number of troughs and animals crowding at a trough may limit water to some of them.
- vii. Air temperature / season/ temperature around the animals. Water consumption by animals will increase on hot/sunny days. Water requirements on very hot days can double their requirements in cool weather.

Data Source

The data on the State by State population of poultry and livestock was obtained from the Federal Department of Animal Husbandry Services, Abuja, Nigeria (NASS, 2011). Those for beef cattle (21.5 litres/day), sheep (5.68 litres/day) and goat ((5.68 litres/day)) were according to Mourad *et al.* (2019); 0.22 litres/day for chickens (Obioha, 1992); 18.9 litres/day for pigs (NDSU, 2015); 0.6 litres/day, 50 litres/day, 48 litres/day and 16 litres/day for turkeys, camels, horses and donkeys

respectively (Pallas, 1986); 0.39 litres/day for rabbits (Ward and McKague, 2007); 0.8 litres/day for duck (Veltman and Sharlin, 1981).

Procedures

- i. The annual water consumption (m^3) for the animals under consideration was obtained as a product of the animal population, the daily water requirement and 365 (number of days in a year) divided by 1,000.
- ii. The unit of measurement is cubic metres.
- iii. Several percentages were used for the various States in the catchment area as presented on the maps. This is due to the fact that there are no figures for the animal population based on catchment area. The information available is only on State-by-State basis.
- iv. Although the data from the Federal Department of Animal Husbandry Services did not record any value for horse population, results from the interview with indigenes of Bauchi showed that there are horses in Bauchi. The population of horses used for this projection was therefore based on the information obtained from key informant interview conducted in Bauchi State.
- v. In order to cater for the water requirements for pets which are not covered in the mainstream animals covered by the data from the Federal Department of Animal Husbandry Services, a 10% addition to the total water requirement has been recommended.
- vi. The respective animal growth rate was determined from the data for 2020 and 2021 obtained from the Federal Department of Animal Husbandry Services using the arithmetic growth formular expressed by equation 1.

$$\text{Animal Growth Rate, } K = \frac{P_2 - P_1}{t_2 - t_1} \quad (1)$$

Where,

K = Animal Growth Rate, P_2 = Animal population in 2021 P_1 = Animal Population in 2020, t_2 and t_1 are 2021 and 2020 respectively.

4.5.8 Livestock

The number of livestock in the northern part of the country is significantly larger than in the south. This trend is largely due to northern inhabitants often facing droughts, which makes them overly reliant on livestock production rather than crop farming. The low annual precipitation results in particularly scarce surface water during the dry season, and even during the rainy season, streams rarely have enough water. Consequently, livestock must depend on well water as a last resort.

The water consumption of livestock depends on atmospheric temperature, body weight, and the availability of grazing grass. Since approximately 80% of the weight of grazing grass is water, if a cattle grazes on 20 kg of grass per day, it effectively consumes about 16 liters of water, adequate to sustain an adult cow weighing 240 kg (which requires 0.15 liters of water per kg of live weight) for one day.

In extreme drought years, when annual rainfall is 400 mm or less, grass cover in grazing fields becomes so sparse that adult cattle can only graze on about 5 kg of grass per day. In this scenario, it would need at least 11 liters of water daily from watering spots to maintain its body condition. Additionally, moving livestock require more water—approximately double the amount needed by stationary ones. This is why adult cattle generally need between 25 to 35 liters of water per day, depending on their body weight and activity level.

The water needs of other ruminants, such as goats and sheep, are similar to those of cattle. The following table outlines the standard water requirements for livestock in tropical zones, as referenced in a livestock guidebook published by the FAO in the 1960s. It is important to note that domestically kept livestock and nomadic livestock have different water requirements.

Table 4.11: Water Requirements (Litre /Animal/Day)

Cattle	Sheep	Goat	Pig	Chicken	Guinea fowl	Duck	Turkey	Pigeon	Donkey	Rabbit	Camel	Horses
21.5	5.68	5.68	18.9	0.22	0.22	0.8	0.6	0.2	16	0.39	50	48

Table 4.12: Case of water requirement per head of livestock

Livestock specie	Live Weight(kg)	Maintaining * (L/day)	Uptake from grazing (L/day)	from Grass/ feeds	Gross water Drink (L/day)	Annual (m ³) requirement
Cattle	250	60	38.4		21.6	7.9
Goat	30	6.6	4.3		2.3	0.8
Sheep	40	8.8	6.8		2.0	0.7
Pig	90	20	16.7		3.3	1.2
Donkey	110	24	15.6		8.4	3.1
Camel	350	80	55.4		24.6	9.0
Horse	300	70	47.8		22.2	8.1
Fowl	2	0.4	0.292		0.108	0.039

Source: FAO Live stock Guide-book in Tropical African Countries, 1960

Table 4.13: Number of livestock heads/ fowls in 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	40,279	154,212	33,957	130,420	1,245,597	3,175	872	872
Cross River	8,000	319,966	21,674	22,800	1,017,489	907	907	907
Kaduna	520,983	2,175,857	971,336	351,506	3,920,317	2,542	0	0
Nasarawa	58,329	617,583	125,878	567,961	1,950,636	0	2,646	0
Plateau	643,059	1,421,192	362,633	2,197,599	2,889,871	0	0	0
Taraba	224,104	1,226,332	232,746	935,817	3,435,021	0	0	1,065
Total	1,494,754	5,915,142	1,748,224	4,206,103	14,458,931	6,624	4,425	2,844

Table 4.14: Corresponding livestock water requirement n 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	317,117	130,772	25,196	155,721	48,578	9,769	7,830	7,002
Cross River	62,984	271,331	16,082	27,223	39,682	2,791	8,144	7,283
Kaduna	4,101,699	1,845,127	720,731	419,698	152,892	7,822	0	0
Nasarawa	459,224	523,710	93,401	678,145	76,075	0	23,758	0
Plateau	5,062,804	1,205,171	269,074	2,623,933	112,705	0	0	0
Taraba	1,764,371	1,039,930	172,698	1,117,365	133,966	0	0	8,552
Total l	11,768,199	5,016,041	1,297,182	5,022,085	563,898	20,382	39,732	22,837

Table 4.15: Estimated growth rate of livestock heads during the period 2010 ~ 2030

Specie	Formula of linear regression	Annual growth rate
Cattle:	Y= 121.3 X + 15,470.2	0.681%/year
Goats:	Y= 1352.2 X + 41,466.8	2.011%/year
Sheep:	Y= 1372.3 X + 20,327.7	3.000%/year
Pigs:	Y= 268.3 X + 7,411.7	2.154%/year
Fowls:	Y= 1265.9 X + 79,006.1	1.227%/year

The growth was then used to project the animal populations for 2022, 2030, 2040 and 2050 using the arithmetic growth model expressed by equation 2.

$$P_x = P_{2020} + K(t_x - 2020) \quad (2)$$

Table 4.16: Number of livestock heads/ fowls projected in 2030

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	46,114	230,243	60,205	199,484	1,508,315	3,175	872	872
Cross River	9,159	477,718	38,427	34,874	1,232,095	907	907	907
Kaduna	596,459	3,248,617	1,722,152	537,646	4,747,179	2,542	0	0
Nasarawa	66,779	922,069	223,178	868,725	2,362,059	0	2,646	0
Plateau	736,221	2,121,881	642,938	3,361,337	3,499,394	0	0	0
Taraba	256,571	1,830,949	412,652	1,431,379	4,159,526	0	0	1,065
Total	1,711,303	8831477	3,099,552	6,433,445	17,508,568	6,624	4,425	2,844

Table 4.17: Corresponding livestock water requirement projected in 2030

Livestock Water	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	363,565	193,404	43,950	240,378	58,824	9,735	7,830	7,066
Cross River	72,209	401,284	28,052	42,023	48,052	2,781	8,144	7,349
Kaduna	4,702,484	2,728,839	1,257,171	647,863	185,140	7,794	0	0
Nasarawa	526,488	774,538	162,920	1,046,813	92,120	0	23,758	0
Plateau	5,804,364	1,782,380	469,345	4,050,411	136,476	0	0	0
Taraba	2,022,802	1,537,997	301,236	1,724,811	162,222	0	0	8,630
Total	13,491,912	7,418,442	2,262,674	7,752,299	682,834	20,310	39,732	23,045

Table 4.18: Number of livestock heads/ fowls projected in 2050

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	51,949	306,274	86,453	268,548	1,771,033	3,175	872	872
Cross River	10,318	635,470	55,180	46,948	1,446,701	907	907	907
Kaduna	671,935	4,321,377	2,472,968	723,786	5,574,041	2,542	0	0
Nasarawa	75,229	1,226,555	320,478	1,169,489	2,773,482	0	2,646	0
Plateau	829,383	2,822,570	923,243	4,525,075	4,108,917	0	0	0
Taraba	289,038	2,435,566	592,558	1,926,941	4,884,031	0	0	1,065
Total	1,927,852	11,747,812	4,450,880	8,660,787	20,558,205	6,624	4,425	2,844

Table 4.19: Corresponding livestock water requirement projected in 2050

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Benue	410,013	256,036	62,704	325,035	69,070	9,701	7,830	7,130
Cross River	81,434	531,237	40,022	56,823	56,422	2,771	8,144	7,415
Kaduna	5,303,269	3,612,551	1,793,611	876,028	217,388	7,766	0	0
Nasarawa	593,752	1,025,366	232,439	1,415,481	108,165	0	23,758	0
Plateau	6,545,924	2,359,589	669,616	5,476,889	160,247	0	0	0
Taraba	2,281,233	2,036,064	429,774	2,332,257	190,478	0	0	8,708
Total	15,215,625	9,820,843	3,228,166	10,482,513	801,770	20,238	39,732	23,253

Table 4.20: Breakdown of water requirement into hydrological area (HA)

HA	Water Demand (MCM)		
	2010	2030	2050
4	7.7	10.3	12.9

4.5.9 Inland Fishery

Basic Data for 2030 projection: Area of farm ponds by Fishery Statistics of Nigeria, Inventory of Private and Government Fish Farm and Hatcheries (Dec. 2004) published in 2007

Table 4.21: Fish Farm Pond

State	Number of Fish Farm	Water Area of Farm Pond (ha)	Brackish Water Area of Farm Pond (ha)
BENUE	198	19.3	0.0
CROSS RIVER	191	386.2	0.0
KADUNA	10	59.2	0.0
NASSARAWA	39	78.5	0.0
PLATEAU	18	186.7	0.0
TARABA	8	2.8	0.0
TOTAL	464	732.7	0.0

Annual water supply per hectare of water surface is calculated as groundwater replacing bottom 50cm of spoiled water with fish excretes (ammonia) and remained feed every 2 months or 6 times a year per 1 ~ 2 batches of fish culture. Totalled 0.03 MCM per ha per year. 75 ~ 85% of the pond water is supplied from shallow wells and the rest is filled by surface runoff, running water, stagnant water in lakes/ Fadama etc. Only if water quality satisfies quality requirement, water from any source can be used for partial water replacement. The requirement is free from detergent and agricultural chemicals, neutral pH and dissolved oxygen above 4 ppm. The colder the water temperature, the more oxygen content can be realized, and this is the reason why groundwater is preferred for water replacement.

The above table implies that the envisaged inland fish farming supplies 1.73 kg/ year / person assuming that national population in 2030 will be 257 million, slightly higher than the current level of per capita consumption of sweet water fish (1.62 kg) and the growth rate expected in 2030 is positive. 0.75%. The target yield, 10 t/ha in 2030 is evidently higher than rice yield per ha, but fish farming is just as a manufacturing factory where such fish feeds as offal from slaughterhouses and low-grade fish meal can be converted into raw fish meat in a short period. Initial investment is also

much higher than the cases observed in ordinary irrigation projects, higher return should be expected from crop farming. It is often referred to that 1.4 million ha of water surface in Nigeria is suitable for developing fish culture from where 2.5 million ton of cultured fish harvest is possible, this projection suggests only less than 40 thousand ha and less than 500 thousand ton/year of fish-farm output. This divergence comes from two limitations, high level of initial investment and marketing convenience of the place where fish farming is developed.

Table 4.22: Projected Water Demand for Inland Aquaculture

HA	Water Demand (MCM)		
	2010	2030	2050
4	22.4	35.9	49.4

4.5.10 Fresh water aquaculture Water Demand Projections

Annual fish yield increase $Y=0.163e^{-0.04336.t}$ (where $t= x^{th}$ year – 2007).

Production $P=P_{t-1} + (projected\ demand\ in\ 2030 - production\ in\ 2007)/23$ (where: P_{t-1} is the production in the previous year)

Aquaculture area = Production/yield

4.5.11 Aquaculture Water Requirement

The data for aquaculture were sourced from official publications by the Federal Department of Fisheries (FDF, 2008). These data included projections for human population, fish demand, and supply in Nigeria between 2000 and 2015 (Table 4.23). The correlation between fish demand and supply in relation to population growth helped estimate and project the fish demand for each catchment area, as the predicted population figures were already available. The water demands for aquaculture were derived from reputable sources such as the Food and Agriculture Organization

(FAO, 2024) and empirical studies on aquaculture and water use conducted by Obassi and Adeoye (2022). The formula used for estimating water requirements is:

$$\text{Water required} = \text{Quantity of fish} \times 10,000 \text{ cubic meters per tonne}$$

This calculation method assumes that traditional pond systems require approximately 10,000 cubic meters of water per tonne of fish produced.

Table 4.23: Projected Human Population, Fish Demand and Supply in Nigeria (2000-2015)

Year	Projected Population (Million)	Projected Fish Demand (Tonnes)	Projected Domestic Fish Supply (Tonnes)	Deficit (Tonnes)
2000	114.4	1,430.00	467.098	962.902
2001	117.6	1,470.00	480.163	984.836
2002	121.0	1,412.50	507.928	1,004.572
2003	124.4	1,555.00	522.627	1,063.082
2004	128.0	1,600.00	536.917	1,063.072
2005	131.5	1,643.75	552.433	1,091.317
2006	135.3	1,691.25	567.948	1,23.301
2007	139.1	1,732.75	583.872	1,154.873
2008	143.0	1,782.30	600.612	1,186.887
2009	147.1	1,838.75	617.353	1,221.397
2010	151.2	1,810.00	634.500	1,255.440
2011	155.5	1,943.75	652.606	1,291.143
2012	160.0	2,000.00	689.958	1,328.508
2013	164.0	2,113.75	709.683	1,365.042
2014	169.1	2,175.00	730.248	1,404.067
2015	174.0	2,055.00	671.492	1,444.752

Source: (FDF, 2008) (Tonnes × 1000)

4.5.12 Irrigation Water Demand Projection

The irrigation water demand was computed as a product of gross irrigation water requirement multiplied by cropped area for that particular crop. In the computation of the irrigation water demand, an irrigation efficiency of 50% is assumed. This was applied to the whole basin. Assuming that all irrigation schemes are equipped with drainage systems, then half of the water abstracted re-joins the surface water.

Table 4.24: Crop patterns were recommended in the Agriculture Thematic Report (SMEC, 2017)

As in the table below:

No	*Irrigated Crop Pattern	Dry Season		Wet Season					Dry Season					
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
1	CropPattern1			Green Manure	TPR/WSR/DSR Rice					Sow wheat on residual soil moisture				
2	CropPattern2			Green Manure	TPR/WSR/DSR Rice					Vegetable (bulb onions, green onions tomatoes ,leafy vegetables, sweet peppers, chilli papers, eggplant)				
3	CropPattern3			Green Manure	Rice + Groundnut + Maize					Vegetables Eggplants				
4	CropPattern4	Perennial Fruits												
**	Rainfed Agriculture													
No	*Irrigated Crop Pattern	Dry Season		Wet Season					Dry Season					
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar	
5	Cropping Pattern5			Millet + sorghum + maize										
6	Cropping Pattern6			Millet + sorghum + Cowpea										
7	Cropping Pattern7			Millet + sorghum + Cowpea or groundnut										
8	Cropping Pattern8			Millet + sorghum + sesame										
9	Cropping Pattern9			Upland rice + millet + Sorghum										
10	Cropping Pattern10			Millet +cowpea + maize										
<p>*TRP=transplanted rice,WSR= wet seeded pre-germinated rice broadcast onto the field,DSR= dry seeded rice broadcast on the field as in a wheat. The rainfall pattern for a given year determines the planting method. TPR when heavy rains come in July, WSR can also be same but is a way of reaching quickly say when rains come early, and the farmer wants to sow the field quickly without a seedbed. DSRisforyearswheretherainsarelateandthefarmersowsdependingonacalendar date.</p>														
<p>**Farmer soften have a number of small field sand these cropping patterns may be in different fields.</p>														

4.5.13 Irrigation Water (Net Irrigation Requirement)

Estimation of the net irrigation requirements in the catchments considered factors like crop water requirements, effective rainfall, evapotranspiration rates, and soil characteristics (e.g., water retention capacity). The equation generally used (Allen et al., 1998) is:

$$\text{Total water requirement (TWR)} = \text{ET rate} \times \text{Catchment Area} \times \text{Crop factor}$$

$$\text{Net irrigation requirement (NIR)} = \text{TWR} / \text{Irrigation efficiency}$$

RESULTS

The results which comprises the estimation of water requirements for Human Domestic Water, Animals, aquaculture and Irrigation are presented in Tables 4.25 – 4.28 based on the catchments

The water demand for livelihood in the Shemankar-Katsina-Ala Catchment presented in Table 4.26, shows varying distribution across human domestic use, livestock, aquaculture, and irrigation from 2022 to 2050. Human domestic water requirements represent a minimal but consistent share, beginning at 4,491.20 cubic meters in 2022 and reaching 8,724.91 cubic meters by 2050. This steady increase reflects the population growth in the catchment, although the demand remains small compared to other sectors. Livestock water demand, particularly for cattle, goats, pigs, and sheep, takes up a more significant portion. For instance, cattle water demand starts at 14.09 million cubic meters in 2022 and rises to 17.46 million cubic meters by 2050, while goat water demand grows from 15.56 million cubic meters to 25.93 million cubic meters in the same period. Pig water requirements also see a substantial increase, reaching 34.83 million cubic meters by 2050, indicating the growing importance of livestock in the region.

Aquaculture and irrigation, however, dominate the water demand in this catchment. Aquaculture water demand starts at 1.19 million cubic meters in 2022 and rises to 2.31 million cubic meters by 2050, reflecting the increasing role of fish farming in supporting livelihoods. Nevertheless, irrigation remains the most significant contributor to overall water demand, with an initial requirement of 721.26 million cubic meters in 2022, growing to 1.40 billion cubic meters by 2050. The increasing water needs for irrigation underscore the heavy reliance on agriculture, particularly crop cultivation, in the Shimankar Catchment. Overall, while human domestic and aquaculture demands grow moderately, livestock and irrigation water requirements show the largest increases, highlighting their critical roles in sustaining the livelihoods of the region.



Table 4.25: Estimated Shemankar Catchment Livelihood Water Required in Cubic Meter (M³) for 2022 to 2050

	Year	2022	2025	2030	2035	2040	2045	2050
SN	Projected Human Being Population	4,491,200.00	4,822,389.28	5,429,527.64	6,113,104.67	6,882,743.97	7,749,280.80	8,724,914.53
1	Human Domestic Water Reqmt	4,491.20	4,822.39	5,429.53	6,113.10	6,882.74	7,749.28	8,724.91
2	Cattles Water Requirement	14,086,870.95	14,448,250.28	15,050,549.16	15,652,848.05	16,255,146.94	16,857,445.82	17,459,744.71
3	Sheep Water Requirement	6,877,497.35	7,368,747.16	8,187,496.84	9,006,246.52	9,824,996.21	10,643,745.89	11,462,495.58
4	Goat Water Requirement	15,560,914.42	16,672,408.31	18,524,898.12	20,377,387.93	22,229,877.74	24,082,367.56	25,934,857.37
5	Pig Water Requirement	17,100,127.28	19,000,141.42	22,166,831.66	25,333,521.90	28,500,212.14	31,666,902.37	34,833,592.61
6	Chicken Water Requirement	1,218,286.17	1,456,646.51	1,853,913.74	2,251,180.97	2,648,448.20	3,045,715.44	3,442,982.67
7	Guinea Fowl Water Requirement	73,151.42	83,126.62	99,751.94	116,377.26	133,002.59	149,627.91	166,253.23
8	Duck Water Requirement	313,444.13	356,186.51	427,423.82	498,661.12	569,898.42	641,135.73	712,373.03
9	Turkey Water Requirement	96,197.97	109,315.87	131,179.05	153,042.22	174,905.40	196,768.57	218,631.74
10	Pigeon Water Requirement	9,202.58	10,457.47	12,548.97	14,640.46	16,731.96	18,823.45	20,914.95
11	Donkey Water Requirement	10,443.78	10,475.05	10,527.17	10,579.28	10,631.40	10,683.51	10,735.63
12	Rabbit Water Requirement	16,200.30	18,000.33	21,000.38	24,000.44	27,000.49	30,000.55	33,000.60
13	Camel Water Requirement	-	-	-	-	-	-	-
14	Horse Water Requirement	-	-	-	-	-	-	-
15	Aquaculture Water Requirement	1,189,006.47	1,276,685.97	1,437,420.62	1,618,391.74	1,822,147.11	2,051,555.26	2,309,845.87
16	Irrigation (Net Irrigation Reqmt)	721,261,975.44	774,449,149.09	871,952,224.82	981,730,928.70	1,105,330,761.16	1,244,491,801.02	1,401,173,202.84
Total Water Demand for Livelihood		777,817,809.46	835,264,412.99	939,881,195.82	1,056,793,919.71	1,187,550,642.50	1,333,894,322.36	1,497,787,355.74

Table 4.26: Water Demand Projections for HA 4 2030 (Source: JICA, 2014)

PROJECTION 2030 HA 4	ITEM		AMOUNT
Water Demand FOR	Livestock	Surface water	3.0 mcm/per year
		Groundwater	8.0 mcm/per year
	Fresh Water Aquaculture	Surface water	9.0 mcm/per year
		Groundwater	27 mcm/per year
	Municipal	Surface water	147 mcm/per year
		Groundwater	292 mcm/per year
	Irrigation	Surface water	568 mcm/per year
		Groundwater	93 mcm/per year
	Sources	Surface water	727 mcm/per year
		Groundwater	420 mcm/per year
	Annual Precipitation		1,341 mm/per year
	Annual PET		1,338 mm/per year

4.6 Existing Cropping Pattern

The following table shows cropping seasons in hydrological basins of Nigeria, which are gained from various materials and interview surveys.

Table 4.27: Cropping Seasons

Area	HA	Crop	Cropping Season	Wet Period
Central	2 / 3 / 4	Rice (wet season) Rice (dry season) Tomato Maize Sorghum Cassava	May – Sep. ⁴⁾ Nov. - March ⁵⁾ Dec. - March ⁶⁾ June – Sep. June – Sep. April – Dec.	Eastern: April – Oct. Western: April – Oct.

Source: 1)Bakalori 2)Jibiya 3)Swashi 4)Tada Shonga 5)Geriyon 6)Svannah 7)Lower Anambra, Isi Uzo

4.6.1 Currently practiced cropping pattern in public irrigation schemes

The central part including HA – 2, HA – 3 and HA – 4, irrigated rice cropping is not active both in rainy and dry seasons. Several limiting factors are considered in this inactiveness, above all fuel for driving pumps is too expensive to purchase, spare-parts for them are hardly procured, irrigation facilities do not function well due to maintenance management has not properly practiced etc.

Table 4.28: HAs-2/3/4 Existing Cropping Pattern

Scheme	Crop	Wet season Area (ha)	Dry season Area (ha)	Crop intensity		Developed Area (ha)
				Wet (%)	Dry (%)	
Kampe dam (Omi I.P.) (HA-2)	Rice	40	0	4	0	1,000
	Others	710	250	71	25	
Oke-Oyi (HA-2)	Rice	1	0	2	0	50
	Others	21	24	42	48	
Tada-shonga (HA-2)	Rice	43	0	10	0	435
	Others	392	100	90	23	
Lake Geriyo (HA-3)	Rice	0	150	0	43	350
	Others	0	170	0	49	
Dadin Kowa (HA-3)	Rice	70	0	70	0	100
	Others	30	70	30	70	
Total	Rice	154	150	8	8	1,935
	Others	1,153	614	60	32	

Source: Inventory survey, Data collected from UBRBDA, Interview at Project site

CHAPTER 5 WATER QUALITY DATA FOR SURFACE AND GROUNDWATER

5.1 Surface Water Quality

Preliminary Evaluation for Northern Zone

Presents the preliminary evaluation on water quality for the Northern Zone. The major points to be highlighted in terms of water quality in the northern zone are as follows:

- Generally, the water quality of rivers is good in the wet season judging from the fact that the concentrations of BOD and DO are maintained within the standards to support the aquatic living environment.
- Generally, the water quality of rivers tends to be diminished in the dry season which can be attributable among others reasons to the lower self-purification efficiency due to the low flow of the watercourses.
- Presence of heavy metals had been detected in some rivers that call to a detailed further water monitoring research in order to understand their causes and to promote a sound management of the water quality of those affected rivers.
- Since the samplings were limited to only two times, the trends of the found values cannot be assessed and they should be considered as preliminary results only. It is recommended strongly to continue on sustainable manner the monitoring of these watercourses to arrive to a solid conclusion about the water quality.

Table 5.1: Preliminary Conclusion of Water Quality Status of Some Rivers in the Northern States of Nigeria

N	State	River Name	Code	Wet Season	Dry Season	NFA
1	Katsina	River Sokoto at Ajiwa Dam	SW/001	Good	Poor	Ni
2		River Challawa at Chalawa WTP	SW/001	Good	Poor	-
3	Kano	River Challawa at Challawa George Dam	SW/004	Poor	Poor	Cu, Cd
4		River Kano a Tiga Dam	SW/003	Moderate	Moderate	-
5		River Sokoto at Gusau WTP	SW/002	Good	Poor	Ni
6	Zamfara	River Gagre at intake Kaura Namoda WTP	SW/003	Good	Poor	Ni, Zn
7	Jigawa	River Ogwala at Birnin Kudu	SW/001	Good	Poor	Cu
8		River Kaduna at outlet of Shiroro Dam	SW/001	Good	Poor	Cd
9	Niger	River Chanchaga at Mina	SW/003	Good	Poor	-
10		River Gurara at Izon	SW/004	Good	Poor	Ni
11		River Gbako at Bida WTP	SW/006	Good	Poor	Cd
12		River Kaduna at Wuya	SW/005	Good	Poor	Zn, Pb, Cd
13		River Niger at Jebba Bridge	SW/007	Good	Poor	Cd
14		River Niger at New Bussa WTP	SW/002	Good	Poor	-
15	Sokoto	River Rima at Sokoto WTP	SW/001	Good	Poor	-
16		River Sokoto at Sokoto WTP	SW/002	Good	Poor	Fe, Ni
17	Kebbi	River Sokoto at Kebbi WTP	SW/001	Good	Poor	-
18		River Zamfara at Bunza	SW/003	Good	Poor	-
19		River Ka at Fokku	SW/005	Good	Poor	-
20	Nassarawa	River Mada at Mada WTP	SW/005	Good	Good	Zn, Pb
21		River Galma at Chika Dam	SW/001	Good	Good	Zn, Pb, Cd
22	Kaduna	River Kaduna at intake to Kaduna North WTP	SW/004	Good	Poor	Ni, Pb
23	Plateau	Lamingo Dam at JOS WTP	SW/001	Good	Poor	Ni, Pb, As, Cd
24	F.C.T.	River Usman at Jabi Dam	SW/001	Good	Good	Cu, As
25		River Usman at Usman WTP	SW/002	Good	Good	Cu
26	Kogi	River Niger at Koton Karfi	SW/001	Poor	Poor	Fe, Ni
27	Benue	Yandev Dam	SW/002	Good	Moderate	Cu, Ni, Pb, Cd
28		River Benue at Makurdi	SW/001	Good	Poor	Fe, As, Cd
29		River Katsina Ala at Katsina Ala	SW/003	Good	Moderate	Ni, As, Cd
30	Gombe	River Dindima at Nafada Bridge	SW/001	Moderate	To be confirmed	As, Pb, Cd
31		River Gongola at Dadin- Kowa WTP	SW/003	Moderate	To be confirmed	As
32		River Gaidan Maiwa at the Bridge	SW/001	Good	To be confirmed	As, Pb, Cd
33	Bauchi	Wikki spring at Yankari Game Reserve	SW/001	Poor	Moderate	Fe, As
34		Gubi Dam at intake to Bauchi WTP	SW/003	Good	Moderate	As, Cu, Ni
35	Adamawa	River Benue at intake to Yola WTP	SW/003	Moderate	Poor	Fe, As, Cd
36		River Gongola at Kiri Dam	SW/001	Moderate	Moderate	Cd, Pb
37		River Ibi at intake to Ibi WTP	SW/004	Poor	Poor	Pb
38	Taraba	River Donga at Donga Bridge	SW/003	Moderate	Moderate	-
39		River Taraba at A4 Bridge, Tella	SW/001	Poor	Poor	Pb
40	Borno	River Ngadda at Alau Dam intake to Maiduguri WTP	SW/001	Good	Good	
41		River Banki at Banki town	SW/001	Good	Good	Ni, Zn
42	Yobe	River Komadugu-Gana at Gashua	SW/002	Moderate	Poor	Ni, As

Note: Sampling was undertaken twice, one in the rainy season and the other in the dry season. This table shows only preliminary evaluation based on the results of these limited samples.

Criteria:

Good quality : BOD = < 3 and 6 ≤ DO (based on Nigeria Standard Values for surface water- recreation & fisheries) Moderate : 3 < BOD = < 6 and 4 ≤ DO < 6 (based on Nigeria Standard Values for surface water- irrigation & reuse) Poor : BOD > 6 or DO < 4 (proposed by JICA Project Team)

NFA: need further assessment because of the presence of higher values in the samples than the standard

Table 5.2: Water Balance Analysis of the Catchment

WATER BALANCE ANALYSIS FOR SHEMANKAR CATCHMENT		
WATER DEMAND (CUBIC METER)	2025	2050
MUNICIPAL	276,192,838.03	499,702,277.30
LIVESTOCK	29,624,588	44,134,635
AQUACULTURE	20,143,190	23,261,473
IRRIGATION	40,400,000	412,500,000
TOTAL	366,360,616	979,598,385
AVAILABLE WATER RESOURCES (CUBIC METER)	33,973,178,500	33,973,178,500
WATER BALANCE (CUBIC METER)	33,606,817,884	32,993,580,115

Source: JICA 2014 MP and SMEC 2019 as Analysed

CHAPTER 6 CLIMATE CHANGE

The NWRMP (JICA, 2014) carried out investigation into the climate change effects for Nigeria. The long-term trend of rainfall and air temperature in the past in Nigeria has been considered based on meteorological datasets collected from NIMET and was summarized as follows:

There is a linear tendency of increase in air temperature in the last 50 years;

There is a linear tendency of decrease in rainfall in the last 50 years. However, the variation by decades is much larger than the linear decreasing rate;

Generally, most parts of the country showed evidence of long-term temperature increase;

Annual rainfall showed a decrease of 2 to 8 mm/year across many parts of the country.

According to JICA studies 2014 it was found that the annual rainfall does not change over the coming 35 years. However, the temperature changes by 2.6°C over time frame.

6.1 Climate Change Scenarios

For the possible future climate conditions, climate change scenarios in Nigeria have been discussed as shown below.

4th IPCC Report

According to the 4th IPCC report (2007)², it is expected that the increase of air temperature in West Africa area in 2100 would be about 3-5 degree Celsius in the case of A1B scenario, which is about 1.5 times higher than the average in the world.

As for the precipitation, the predictions of precipitation by different GCM models vary very much. It is difficult to conclude the general tendency for the change in precipitation.

6.2 Nigeria's First National Communication on Climate Change

In the Nigeria's First National Communication (2003)³, the climate change scenarios in Nigeria have been discussed based on several GCM model output. The following findings were noted.

- The most significant changes are with respect to temperature and temperature related parameters.
- There has been an observed trend towards aridity in Sub Saharan West Africa. This trend will be put on hold or reversed as the century progresses. There are possibilities, however, that the additional water need created by higher temperatures may not be met by the increases in precipitation.

- The difference of climate condition from coastal area to the northern part of the country could become more significant.

6.3 Nigeria's Second National Communication on Climate Change

Nigeria's Second National Communication (SNC) on Climate Change represents a critical milestone in the country's ongoing efforts to assess, address, and communicate the impacts and challenges of climate change on a national scale in accordance with the Paris Agreement and the United Nations Framework Convention on Climate Change (UNFCCC) requirements, which provides a comprehensive analysis of greenhouse gas (GHG) emissions, climate vulnerability, and adaptive and mitigation strategies tailored to Nigeria's unique socio-economic and environmental contexts.

The findings of the SNC highlight the escalating risks posed by climate change to Nigeria's ecosystems, economy, and communities, particularly vulnerable populations. Some of the key findings are listed below;

- i. Greenhouse Gas (GHG) Inventory and Emissions Trends
- ii. Vulnerability and Impacts of Climate Change
- iii. Adaptation Measures and Challenges
- iv. Mitigation Strategies and Potential
- v. Barriers to Climate Action
- vi. International Cooperation and Support Needs

Some of the outcomes and Future Steps are also presented below;

- i. Strengthening Policy Frameworks
- ii. Public Awareness and Community Engagement
- iii. Focus on Renewable Energy Expansion
- iv. Capacity Building and Research Development

6.4 Nigeria's Third National Communication on Climate Change

To build on the insights successes from the previous communications and to provide an updated assessment of the country's greenhouse gas (GHG) emissions, climate vulnerabilities, and strategies for adaptation and mitigation, the Third National Communication on climate change was held to also reflects Nigeria's ongoing commitment to climate action and sustainable development, presenting a comprehensive review of its climate policies, measures undertaken, and future directions for a climate-resilient and low-carbon economy. It was noted that emissions in Nigeria are primarily driven by the Agriculture, Forestry, and Other Land Use (AFOLU) sector, which contributed 60.1% of emissions,

followed by the energy sector at 33.9%. Without intervention, emissions were projected to increase by over 58% by 2035. Nigeria faces significant climate vulnerabilities, including risks of drought, desertification, flooding, water scarcity, and reduced agricultural productivity.

Key findings and outcomes were similar to the second National Communication with some improvement such as;

- i. Capacity Building, Technology Transfer, and Financial Needs
- ii. Enhanced Policy Framework and Institutional Coordination
- iii. Scaling Up Renewable Energy and Green Economy Initiatives
- iv. Strengthening Community Engagement and Resilience Building
- v. Research, Innovation, and Monitoring Systems

6.5 The Paris Agreement

Since becoming a member of the United Nations Framework Convention on Climate Change (UNFCCC) in 1994, Nigeria has ratified the Kyoto Protocol in 2004 and the Paris Agreement in 2007.

The Paris Agreement is a legally binding international treaty on climate change. It was adopted by 196 Parties at the UN Climate Change Conference (COP21) in Paris, France, on the 12th of December, 2015. It came into effect on the 4 of November, 2016

Its overarching goal is to cease “the increase in the global average temperature to well below 2°C above pre-industrial levels” and pursue efforts “to limit the temperature increase to 1.5°C above pre-industrial levels.”

CHAPTER 7 FLOOD VULNERABILITY AND RISK

The Flood Vulnerability was performed through GIS analysis to determine the vulnerable locations dependent on applied criteria using the weighted Overlay process. Weighted vulnerability analysis allows one to answer questions that are impacted by many factors and assign varying weights to each of the factors. The result gives more information than binary analysis, as it ranks locations based on the vulnerability rather than giving only a vulnerable/not vulnerable result. We need to identify the problem (Flood vulnerability), and break it down into smaller sub-models.

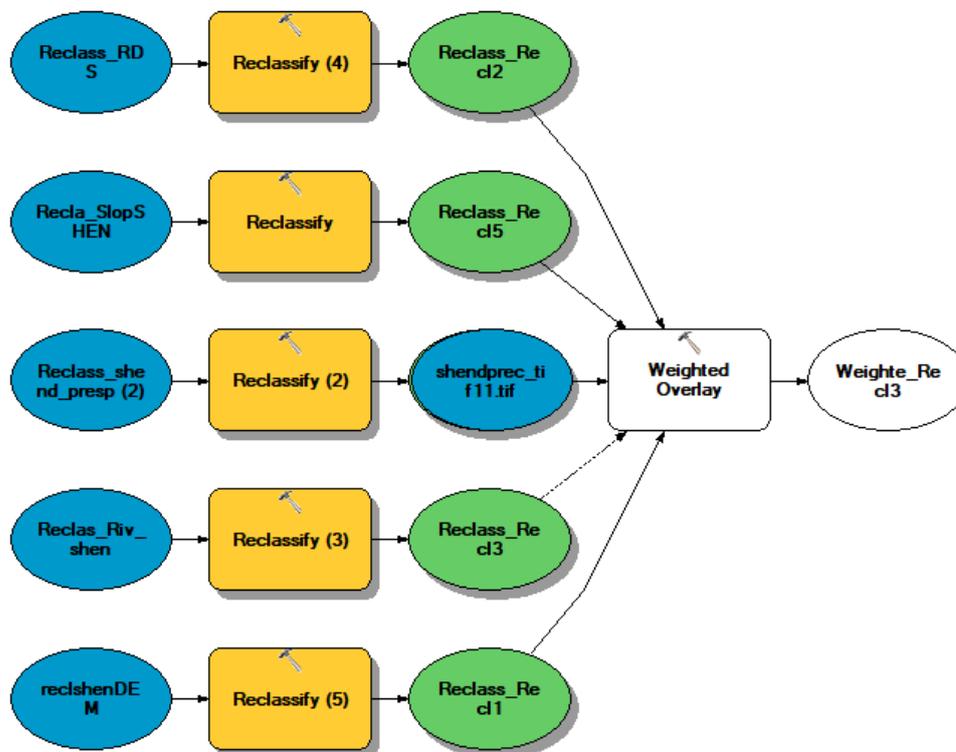


Figure 7.1: The flow chat of the methodology

Then we determine which factors are more important in determining vulnerable areas. For this study, slope, elevation, proximity to rivers, Land use/Land cover and rain fall datasets were used. Before performing the weighted overlay, standardization is carried out by reclassifying each layer. This gives the layers a common scale (i.e. 1 to 5, 1 to 9, etc.) that will be preserved in the final overlay. Figure 7.1 shows the selection factors and the reclassification criteria on a 1 to 3 scale. Finally, the weight of each layer is assigned, the layers are combined in a weighted overlay, and the results are analyzed. See Fig. 7.1 for a graphical depiction of the model used to carry out the flood vulnerability model exercise.

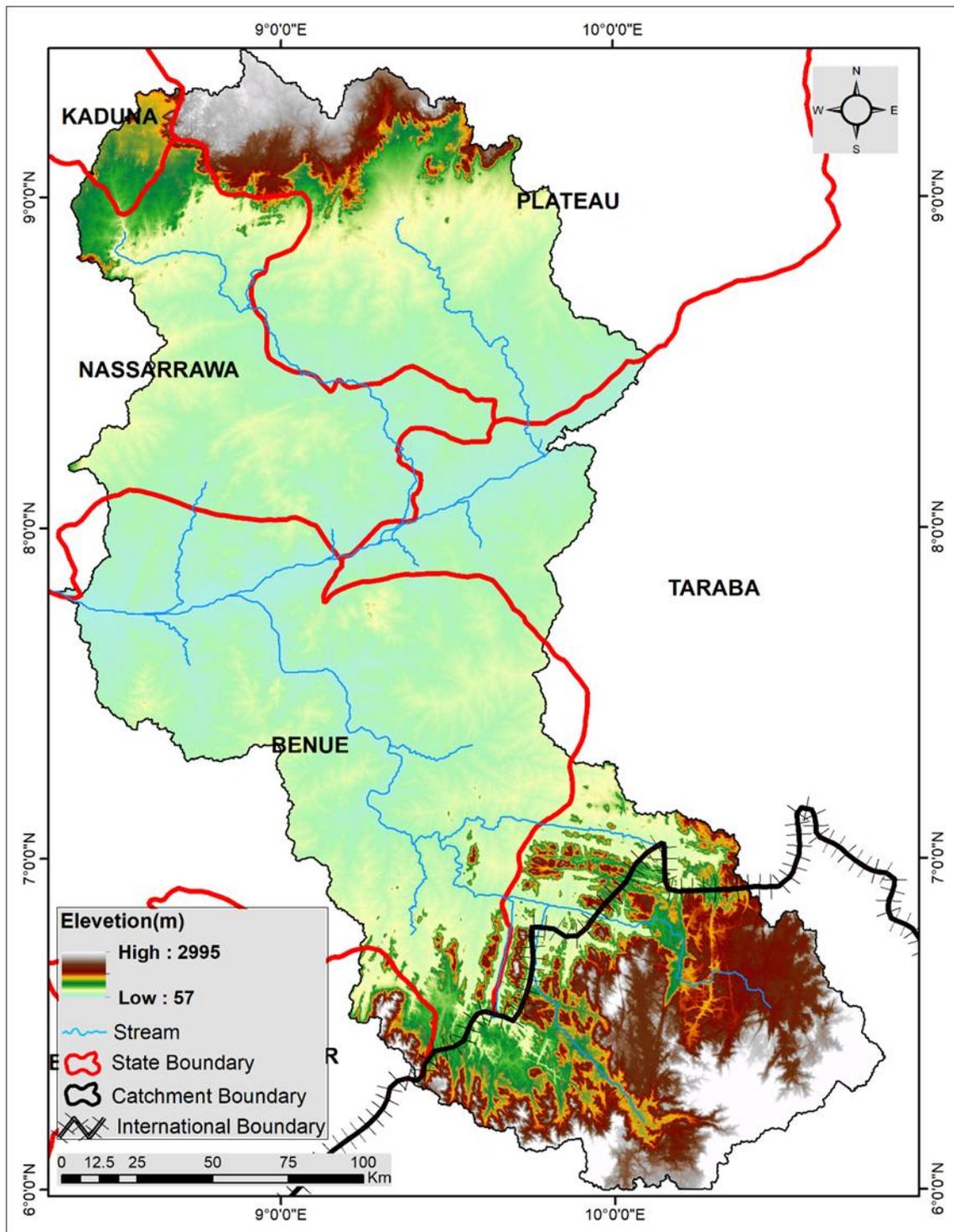


Figure 7.2: Digital Elevation Model of Shemankar-Katsina Ala catchment (Source: MSL, 2024)

The digital elevation model (DEM) displayed a grayscale shaded relief map of the Shemankar-Katsina Ala catchment, clearly showing elevation differences (Figure 31). Higher elevations are represented

by white to grey tones, while lower elevations appear in shades of green to light green. The map highlights the rugged topography, with elevations ranging from 57 meters to 2,995 meters above sea level, particularly around the Mambilla and Jos Plateaus.

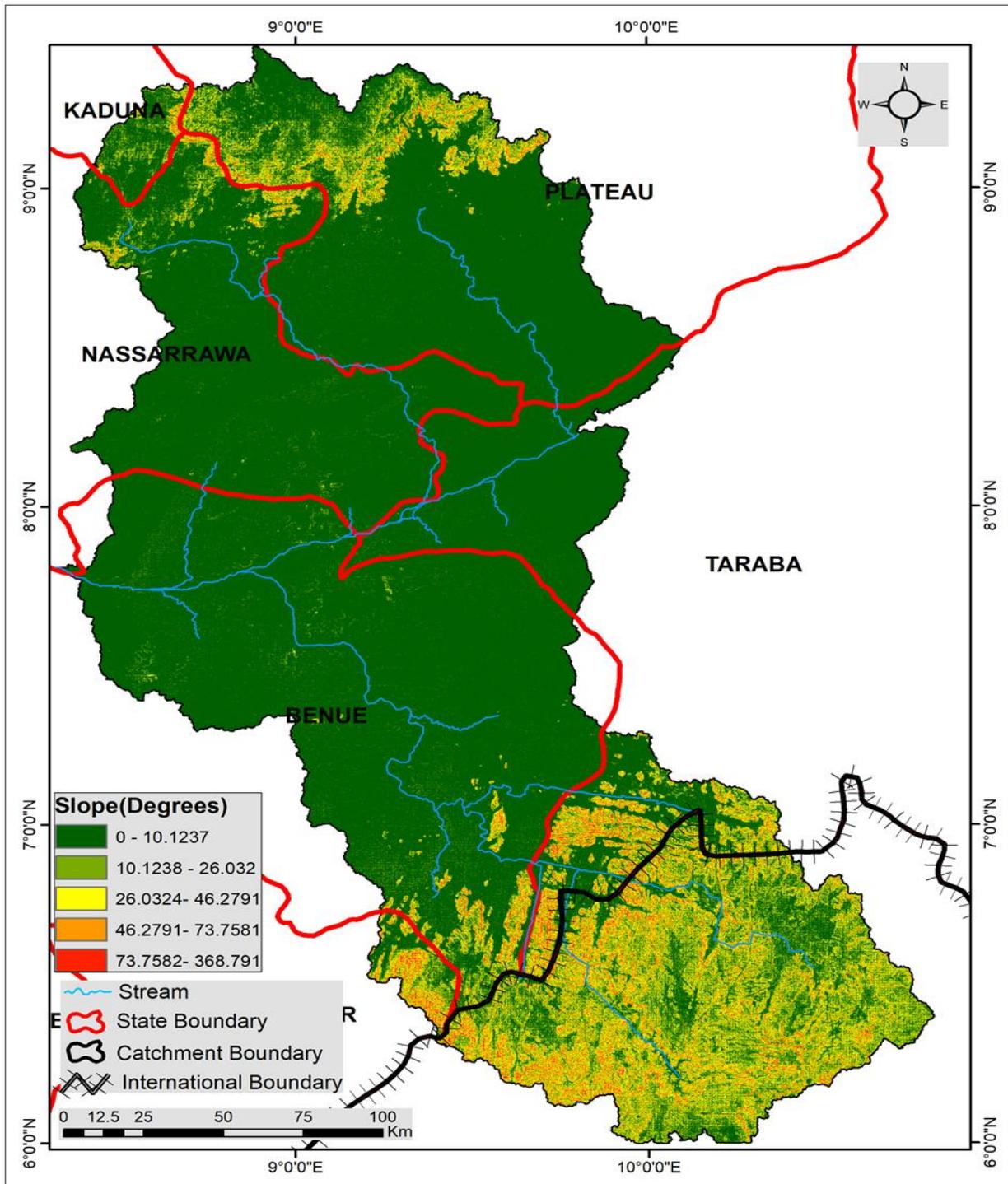


Figure 7.3: Slope map of Shemankar-Katsina Ala catchment (Source: MSL, 2024)

The slope map is crucial for comprehending the catchment's topography. The map delineates various levels of inclination in the terrain, providing insights into the landscape's characteristics. Areas with flat to very gentle slopes ($0-4^{\circ}$) are predominantly flat, increasing the likelihood of water pooling and slower drainage, potentially leading to flooding during heavy rainfall. Regions with gentle slopes ($4-6^{\circ}$) facilitate better water runoff compared with flatter areas but still pose a moderate risk of water accumulation. Areas with moderate slopes ($7-13^{\circ}$) exhibit a moderate steepness, promoting more rapid surface runoff, reducing water retention, and heightening the risk of soil erosion.

Steep slopes ($14-22^{\circ}$) are susceptible to swift runoff and increased erosion, potentially causing the displacement of sediment and accelerated downstream water flow. Very steep slopes ($25-65^{\circ}$) represent the steepest gradients in the area where the velocity of runoff is at its maximum (figure 7.3)

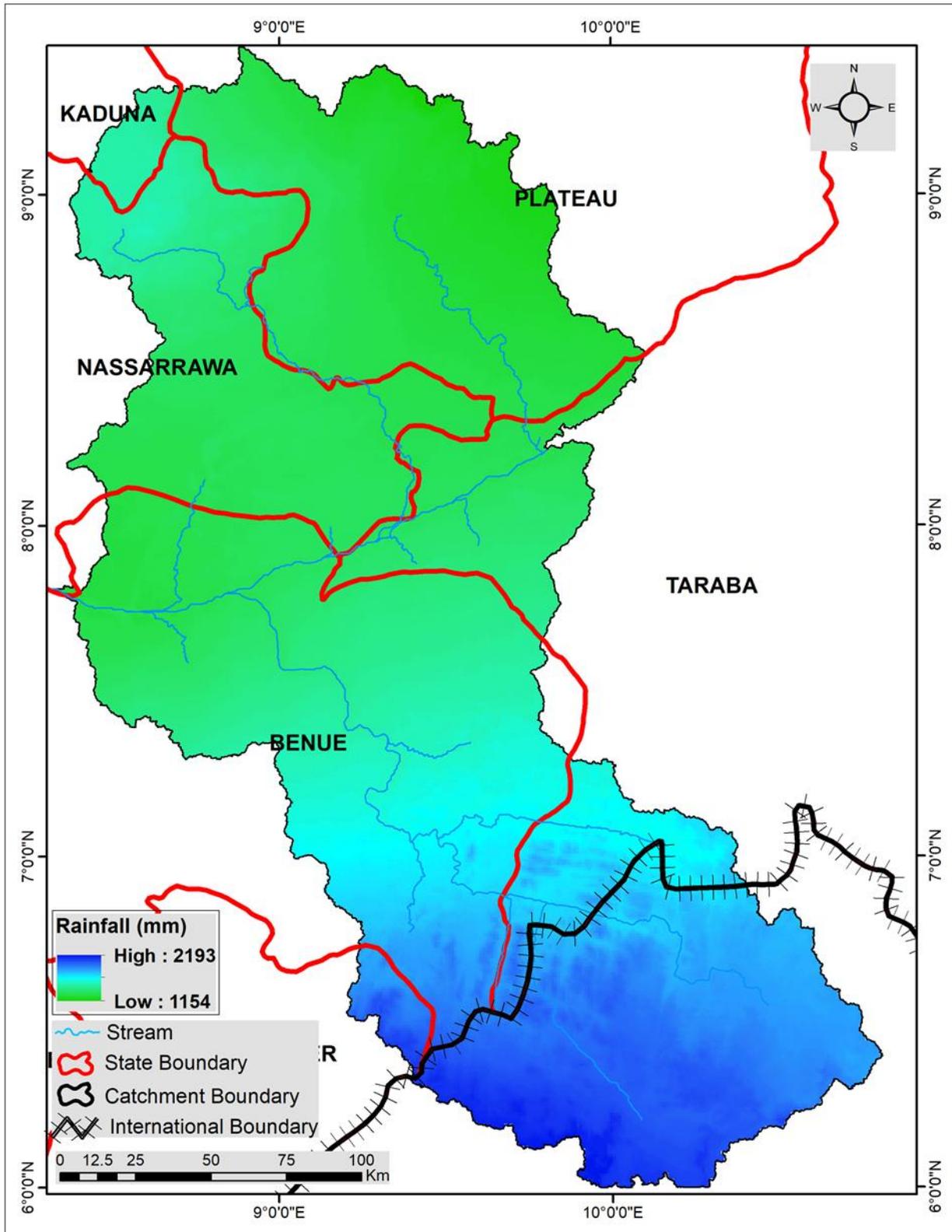


Figure 7.4: Rainfall map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)

The rainfall map of the catchment area indicated significant variation in rainfall distribution across the city. Rainfall measurements showed a sharp spatial contrast, with amounts around 1154mm near the Jos Plateau and Nasarawa states, while the southern region of the map recorded higher rainfall levels, reaching up to 2193mm in the catchment.

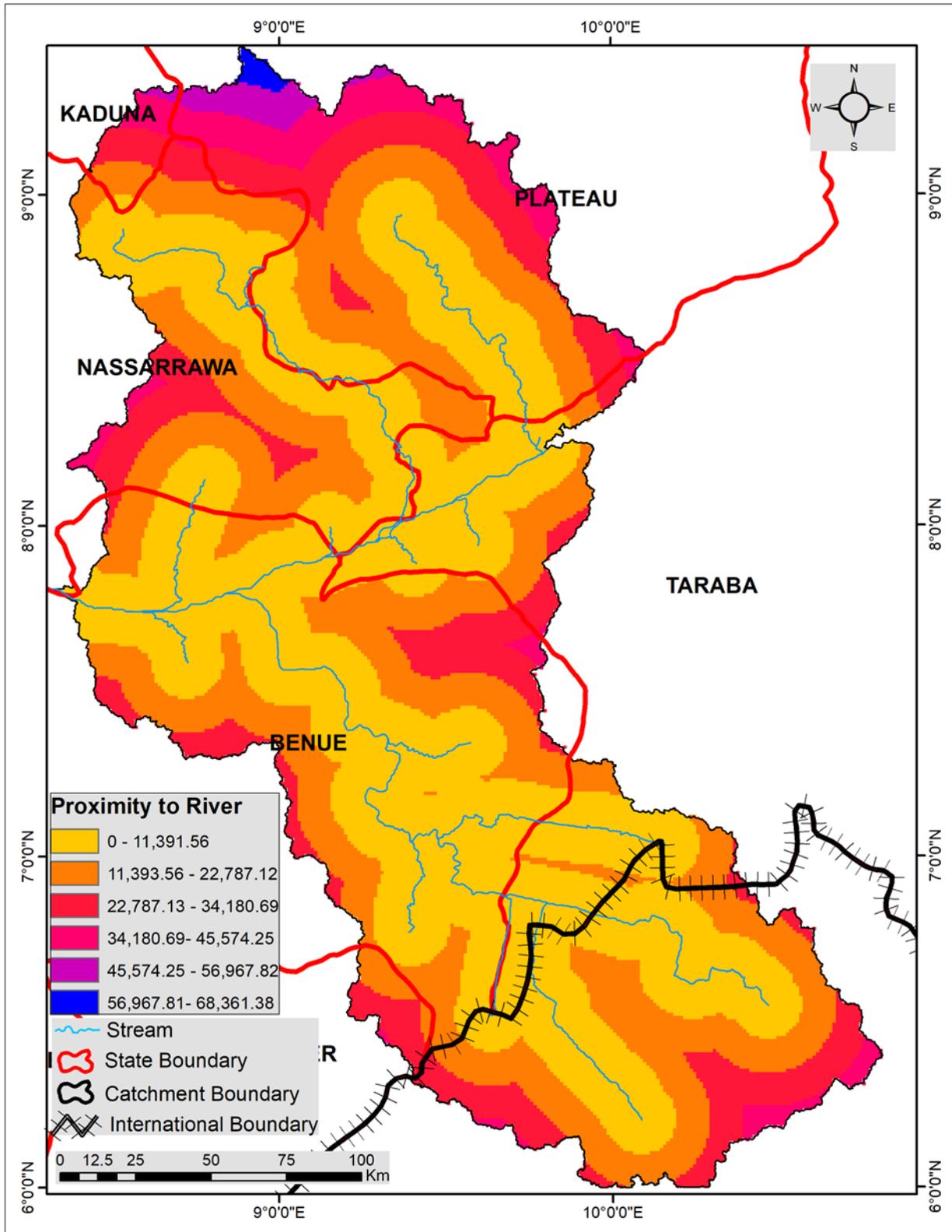


Figure 7.5: Distance to River Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)

Proximity to streams is also a very important variable to consider in flood vulnerability analysis because nearness to streams/rivers mean high probability to the risk of flooding. This depicts uniform distances away from the river and for this study about 0-15km shows areas closest to the river while about 95-111km depicts areas far away from the river.

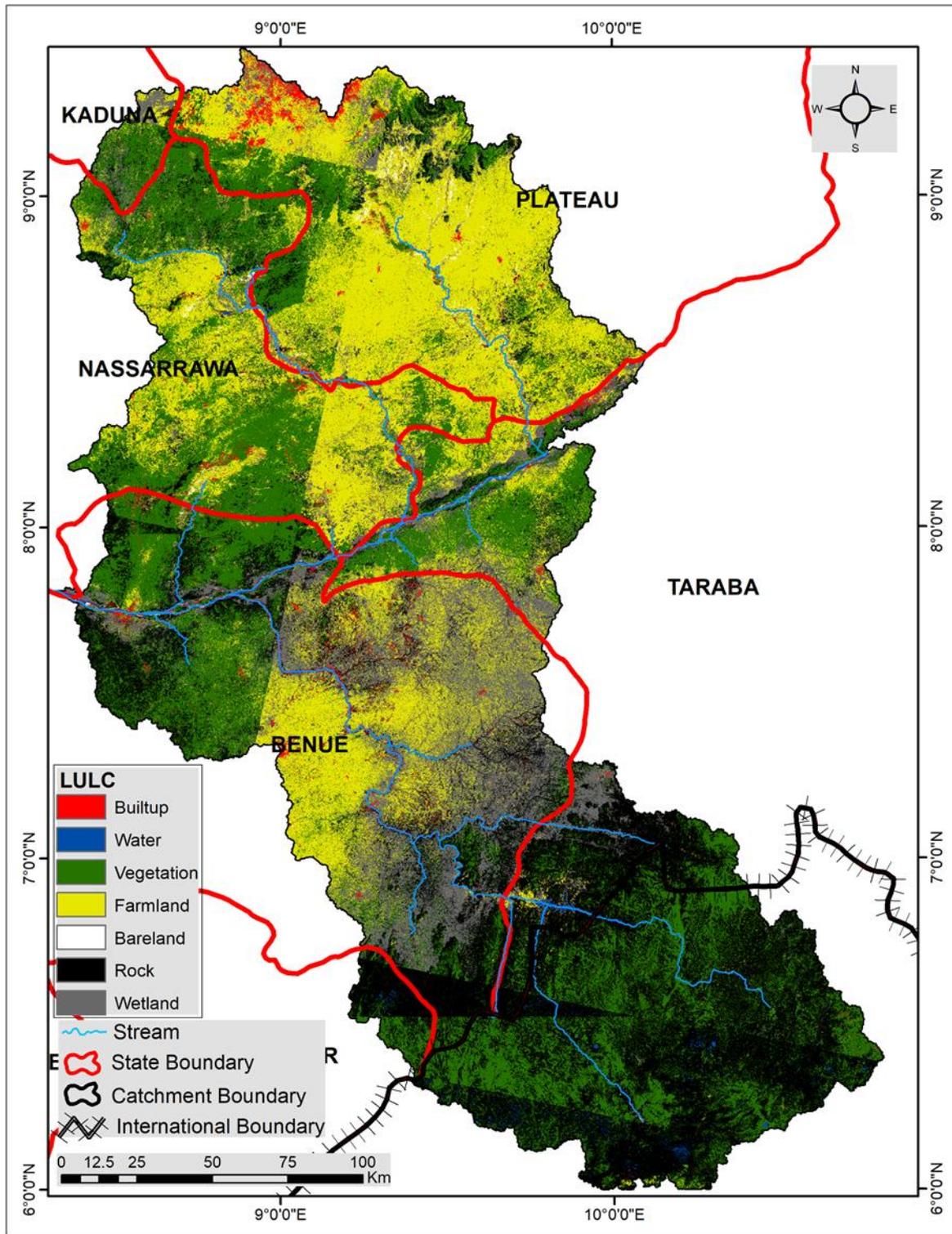


Figure 7.6: LULC Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)

Water bodies are highly susceptible to flooding, rated as extremely vulnerable (5), especially during heavy rainfall due to direct water involvement and overflow risk. Riparian or wetland areas also carry extreme vulnerability (5) because they are naturally waterlogged and prone to flooding. Settlements or built-up areas have a high vulnerability (4) as impermeable surfaces contribute to

increased runoff, raising flood risk. Croplands are moderately vulnerable (3); while they can absorb some water, large-scale runoff is still possible. Bare surfaces, with a moderate vulnerability (3), have limited vegetation, leading to higher runoff and erosion risks. Shrublands exhibit low vulnerability (2) as some vegetation reduces runoff, though not as effectively as forests. Vegetation and forested areas, rated least vulnerable (1), have dense vegetation and root systems that significantly improve water absorption and minimize runoff.

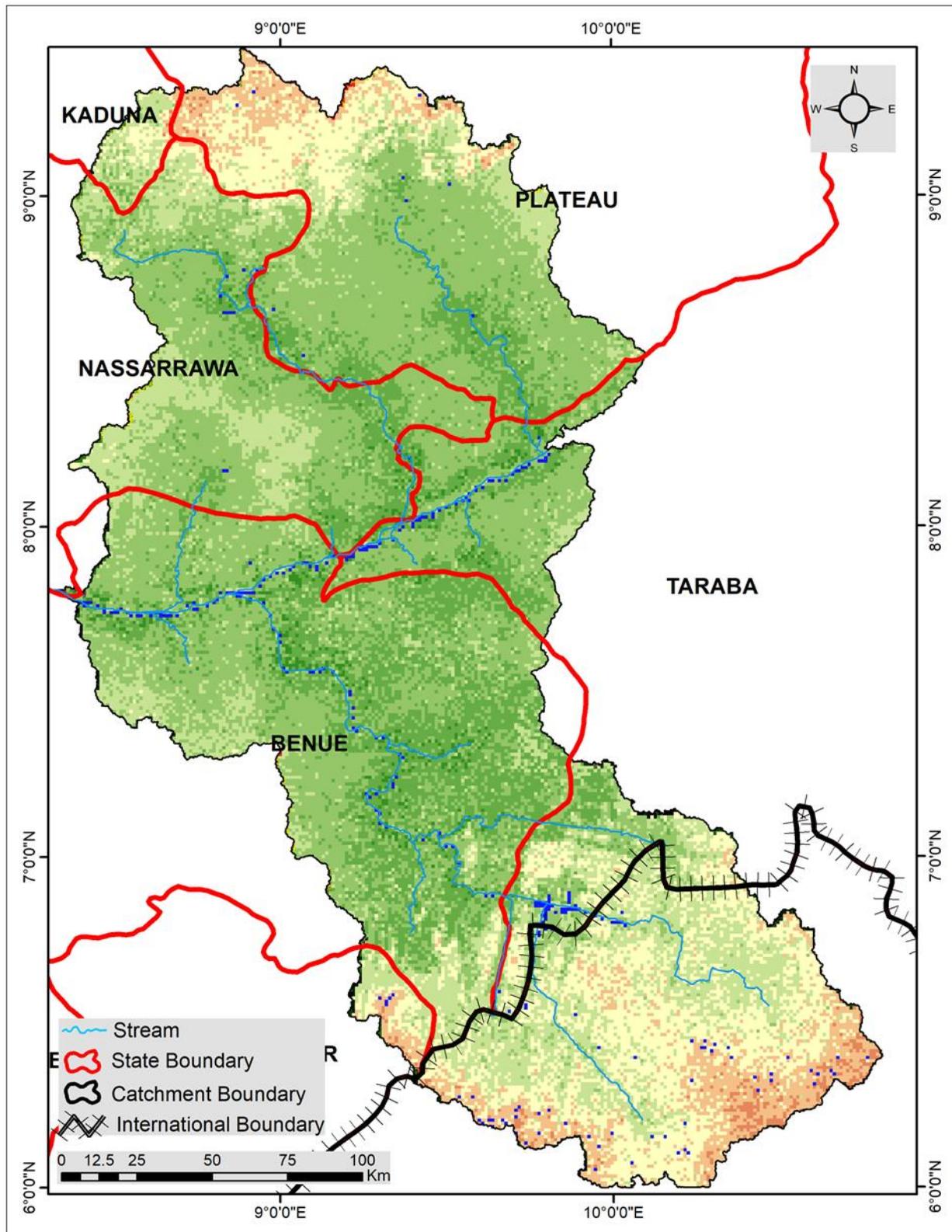


Figure 7.7: Flood Vulnerability Map of Shemankar-Katsina Ala Catchment (Source: MSL, 2024)

7.1 Flood Vulnerability

A weighted overlay analysis was conducted to evaluate potential flood vulnerabilities within the catchment area. The resulting flood vulnerability map was created by combining datasets such as Digital Elevation Model (DEM), proximity to rivers, precipitation, slope, and land use/land cover. Before the overlay, the data layers were categorized, weighted, and scored on a scale of 1 to 9. Proximity to rivers received the highest weight, followed by elevation, precipitation, slope, and land use. The flood risk map identifies different zones within the catchment, classified into five risk levels: Highly Not Vulnerable, Not Vulnerable, Moderate, Vulnerable, and Highly Vulnerable (figure 7.8).

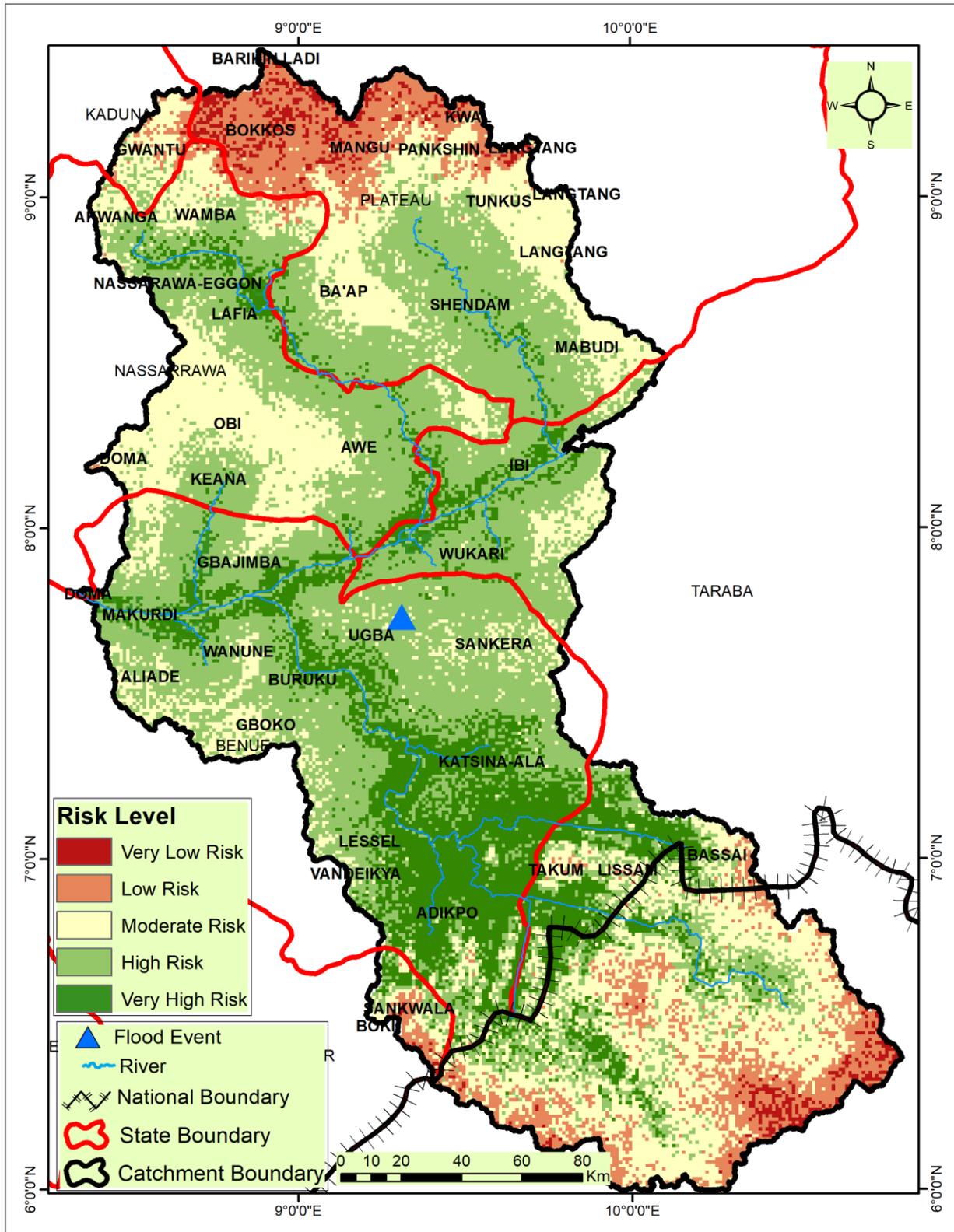


Figure 7.8: Flood Risk Map of the Catchment (Source: MSL, 2024)

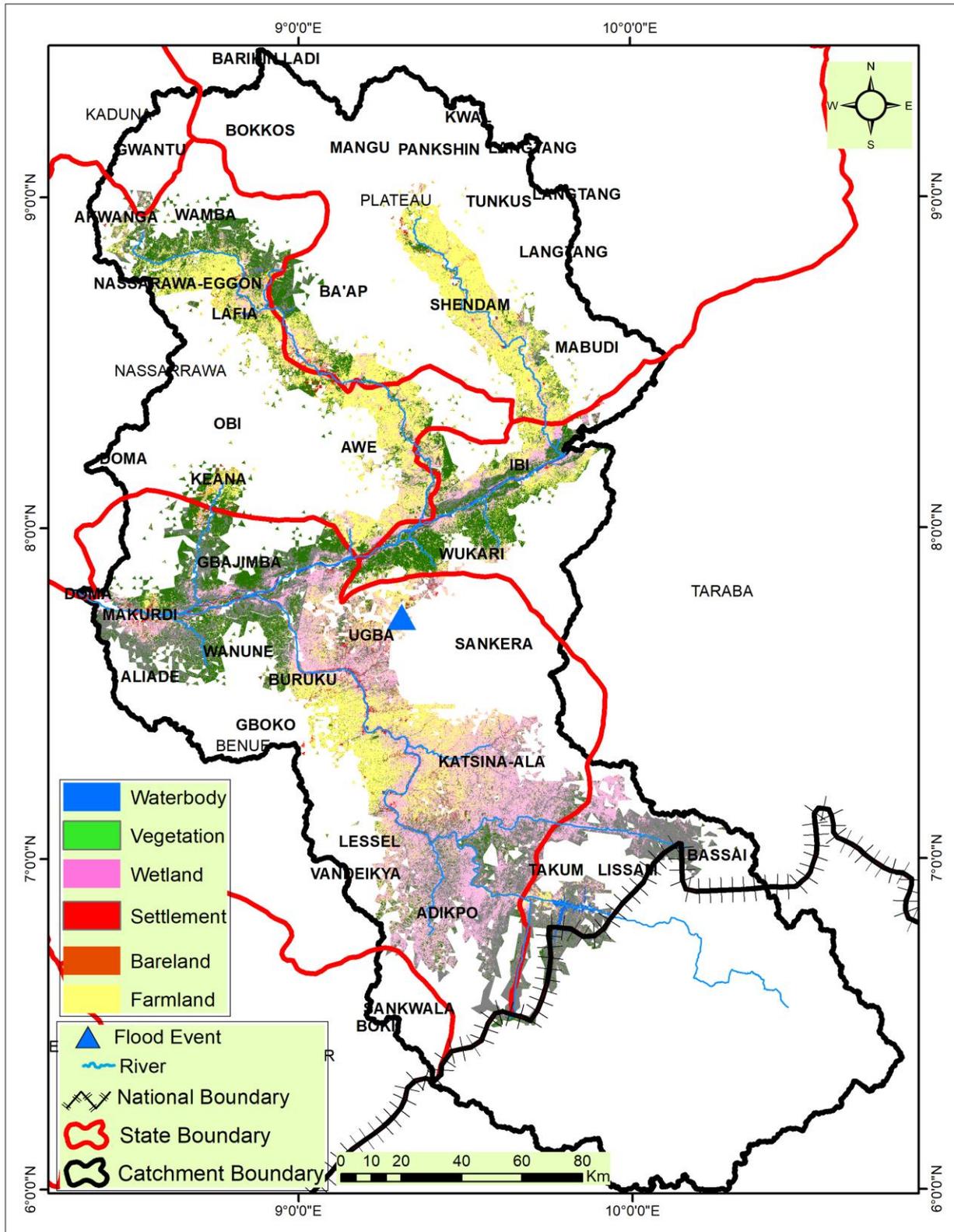


Figure 7.9: Flood Event Map of the Catchment (Source: MSL, 2024)

Table 7.1: Class name Parameters for LULC analysis (Source: MSL, 2024)

Class Name	HA	%
builtup	32128.92	2.03
water	22005.63	1.39
vegetation	313485.5	19.81
farmland	449105	28.37
bareland	6614.01	0.42
rock	344459.3	21.76
wetland	414965	26.22

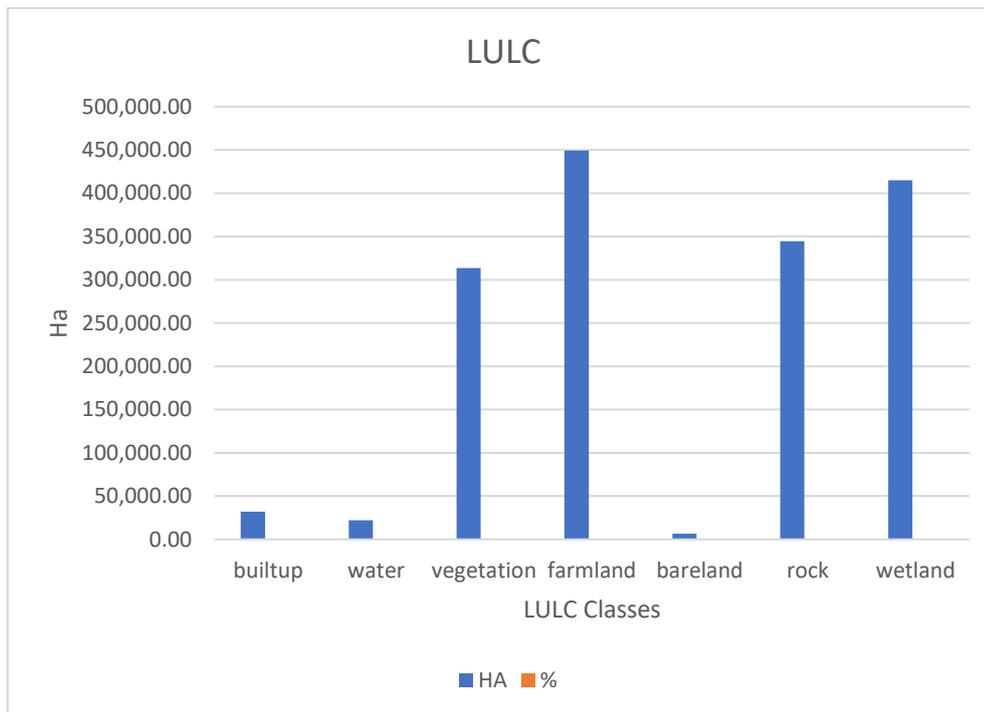


Figure 7.10: Graphical Representation of the LULC Analysis (Source: MSL, 2024)

Flooding in this catchment is an annual event particularly along the River Shemankar of Plateau state which flows into the River Benue and around River Katsina-Ala and Makurdi areas of Benue state. The flooding event of August, 2017 caused by prolonged and heavy rainfall led to the overflowing of the River Benue, displacing over 100,000 people and significantly damaging vital infrastructure and creating humanitarian crises for displaced families.

The flood risk analysis shows farmland of 449,105Ha at 28% at high-risk and a significant vegetation of up at 313,485.5Ha representing about 20% of the entire land use/land cover at risk. The built up stood at 32,129Ha (2%). This shows that the urban/settlement areas are at high risk to flooding in this catchment area hence most settlements are along the river channels because of the fertile alluvium deposits for farming purposes.

CHAPTER 8 THE CONCEPTUAL FRAMEWORK OF THE STAKEHOLDER ENGAGEMENT UNDER CONSIDERATION

For the purpose of this study, the stakeholder engagement concepts that have been employed are as follows:

- Natural Resources
 - Threats and Challenges
 - Socio-economics
 - Policies
- Water Resources
Natural Resources (Forestry,
Mineral Resources, etc)

To develop the strategic catchment management plan at a macro level, the study entailed the engagement of institutional stakeholders:

Plateau State

- i. Plateau Rural Water Supply and Sanitation Agency (RUWASA)
- ii. Plateau State Ministry of Environment, Climate Change & Mineral Development
- iii. Plateau State Ministry of Agriculture and food Security
- iv. Plateau State Ministry of Water Resources
- v. Plateau State Ministry of Lands
- vi. Plateau State Ministry of Tourism (Jos Wild Life Park)
- vii. Plateau State Ministry of Women Affairs
- viii. Plateau State Ministry of Solid Mineral Development
- ix. Plateau State Miners Association

Taraba State

1. Taraba Rural Water Supply and Sanitation Agency (RUWASA)
- ii. Taraba State Ministry of Water Resources
- iii. Taraba State Ministry of Lands
- iv. Taraba State Ministry of Women Affairs
- v. Taraba State Ministry of Solid Mineral Development

- vi. Taraba State Miners Association
- vii. Ministry of waste Management and resources Innovation
- viii. Taraba Farmers Association

Benue State:

- i. Rural Water Supply and Sanitation Agency (RUWASA)
- ii. State Ministries of Environment,
- iii. State Ministry of Agriculture and food security
- iv. State Ministry of Water Resources,
- v. State Ministry of Min of Lands,
- vi. State Ministry of Women Affairs,
- vii. State Ministry of Solid Mineral Development
- viii. State Miners Association
- ix. Farmers association/ pastoralists of the State
- x. Lower Benue River Basin Authority-Benue.

Nasarawa State:

- i. Rural Water Supply and Sanitation Agency (RUWASA)
- ii. State Ministries of Environment,
- iii. State Ministry of Agriculture and food security
- iv. State Ministry of Water Resources,
- v. State Ministry of Min of Lands,
- vi. State Ministry of Women Affairs,
- vii. State Ministry of Solid Mineral Development
- viii. State Miners Association
- ix. Farmers association/ pastoralists of the State
- x. Center for Environmental and Sustainable Development Studies, Nasarawa State University Keffi.

The above stakeholders were considered as the institutions that could influence and impact the development of the strategic catchment management plan.

8.1 Natural Resources

The Shemankar Katsina-Ala catchment area spans multiple states in Nigeria, primarily Plateau, Benue, Taraba, and Nasarawa States. These states are rich in diverse natural resources. The area's water resources, forests, minerals, and agricultural potential play a critical role in the local economy. However, sustainable management of these resources is essential to address environmental challenges and ensure long-term prosperity for the region. Below is a detailed breakdown of the natural resources found in each state within the Shemankar Katsina-Ala catchment area.

8.1.1 Forestry resources

Shemankar-Katsina-Ala Catchment is home to forest reserves and a variety of tree species that are vital for both environmental stability and economic activities. The catchment has designated forest reserves aimed at conserving biodiversity and protecting the environment, although deforestation is a challenge due to logging and agricultural expansion. Forests and conservation areas in the catchment area include:

- Pandam National Park
- Mahari National Park
- Shinge Forest Reserve
- Gidan Waya Forest Reserve
- Pidan Lake in Mangu

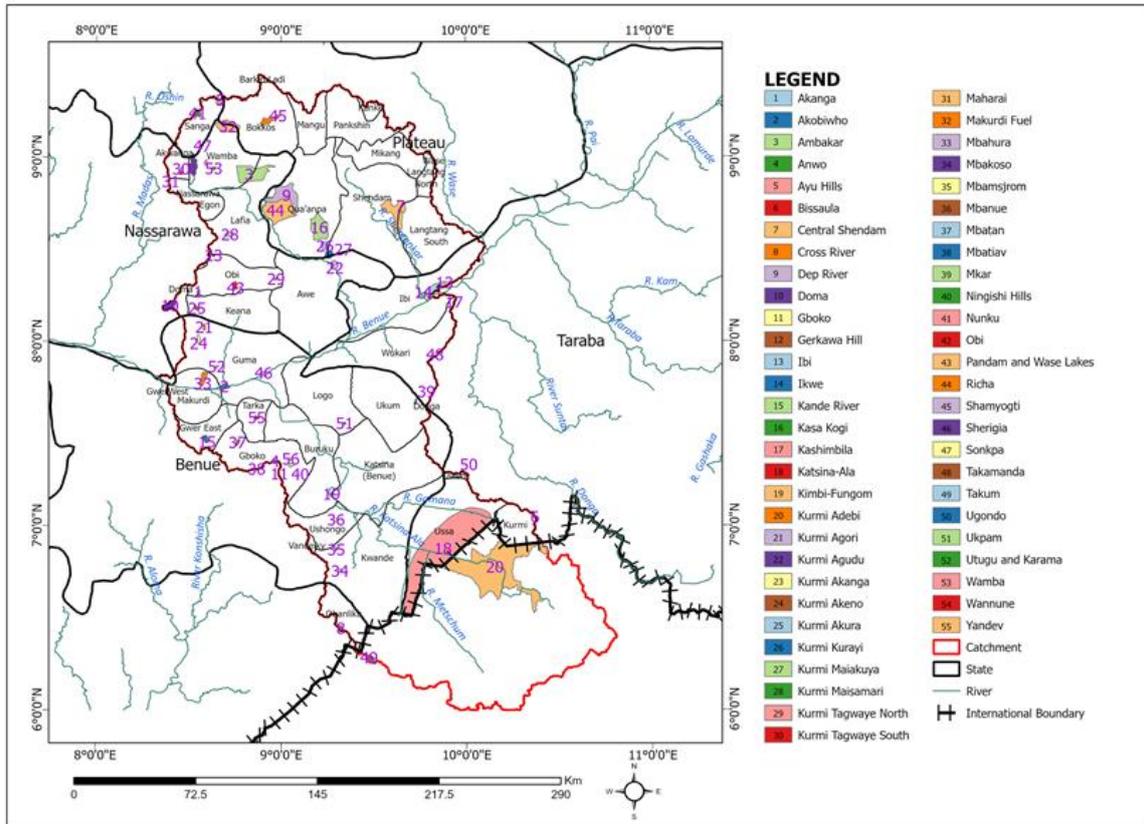


Figure 8.1: Forest Reserves in Shemankar-Katsina-Ala Catchment (Source: MSL, 2024)

8.1.2. Water Resources

8.1.2.1 Water Levels and Storage

Plateau State

- i. **Surface Water Levels:** The water levels in rivers, streams, and reservoirs in Plateau State are primarily influenced by seasonal rainfall patterns. During the rainy season, surface water levels rise due to the influx of rainwater, while during the dry season, these levels drop as a result of reduced inflows and increased evaporation.
- ii. **Reservoirs and Dams:** Plateau State has several reservoirs and dams that are used for water storage, irrigation, and hydroelectric power generation. Notable among these are the Lamingo Dam, Kura Falls Dam, and the Wase Dam. These reservoirs play a crucial role in regulating water levels and ensuring a steady water supply throughout the year [Adebayo, 2014]. However, during periods of prolonged drought, water levels in these reservoirs can drop significantly, affecting water availability for various uses.
- iii. **Groundwater Levels:** Groundwater is an important source of water in Plateau State, particularly in rural areas. The state's groundwater levels are influenced by both natural factors, such as rainfall and recharge rates, and human activities, such as groundwater abstraction for agriculture and domestic use. In some parts of the state, over-extraction of groundwater has led to a decline in water levels, raising concerns about the sustainability of this resource [Ojo et al., 2015].
- iv. **Water Storage Capacity:** The storage capacity of water bodies in Plateau State is a critical factor in managing water resources, particularly in the face of climate variability and increasing demand. The state's reservoirs and dams are designed to store large volumes of water during the rainy season, which can then be released during the dry season to maintain water supply.
- v. **Challenges of Water Storage:** One of the challenges of water storage in Plateau State is the loss of storage capacity due to sedimentation. Rivers and streams in the state carry significant amounts of sediment, which are deposited in reservoirs, reducing their capacity over time. This sedimentation problem is exacerbated by deforestation and poor land management practices in the watershed areas [Ogunleye & Ayoade, 2016]. Addressing this issue requires ongoing maintenance and dredging of reservoirs, as well as the implementation of soil conservation measures to reduce sediment load in rivers.

Benue State

- i. Water levels in the River Benue and its tributaries are closely linked to the region's rainfall patterns and vary significantly between the wet and dry seasons. The river's water levels are at their highest during the peak rainy months (July to September), and this period corresponds to maximum water storage in natural and artificial reservoirs across the state. The lower sections of the River Benue, including areas near Makurdi, experience significant rises in water levels during this time, which supports floodplain agriculture but also poses flood risks (*Olapade, 2018*).
- ii. Artificial water storage in Benue State is primarily achieved through reservoirs and dams, which are crucial for both water supply and flood control. However, the storage capacity of these infrastructures is often limited by siltation and poor maintenance. Reservoirs such as the Katsina-Ala and Oweto dams serve irrigation schemes and hydroelectric projects, but during periods of low rainfall, water storage levels can drop dramatically, reducing their effectiveness for sustained water supply and agricultural support (*Adamu, 2019*).
- iii. In contrast, during the dry season, water levels in rivers and reservoirs fall significantly, often to critical levels that affect not only agriculture but also water supply for domestic and industrial use. The declining water levels during this period emphasize the need for effective water management strategies, including the construction of additional storage infrastructure and improvements in water use efficiency (*Ayuba, 2020*).

Taraba State

- i. Water levels in Taraba State's rivers, streams, and reservoirs fluctuate widely based on seasonal rainfall patterns and the volume of surface runoff. The Benue River, which serves as a major waterway and source of water for irrigation and domestic use, experiences significant changes in water levels between the rainy and dry seasons. During the peak of the wet season, the water level of the Benue River rises by up to 4 meters, with extensive flooding in low-lying areas [*Olaniran, 1983*]. This rise in water level provides opportunities for irrigation but also poses risks of inundation to settlements and farmlands.
- ii. In terms of water storage, Taraba State has several small dams and reservoirs that help manage water supply, especially during the dry season. However, the state lacks large-scale water storage infrastructure, making it vulnerable to seasonal water shortages. Reservoirs and small dams such as the Kashimbilla Dam provide crucial storage, capturing rainfall and runoff during the wet season and releasing it during the dry months to support irrigation, power generation, and domestic water supply [*Olanrewaju, 2017*].

- iii. Groundwater storage in the region is highly variable. In areas with basement complex rock formations, such as the Mambilla Plateau, groundwater recharge rates are lower, and water storage is limited. Conversely, in areas with sedimentary rock formations, particularly along the Benue River valley, aquifers have higher storage capacities, supporting borehole and well-water supplies throughout the year [Olorunfemi, 2000].

Nasarawa State

The water levels in Nasarawa State's rivers and streams are closely linked to rainfall patterns and vary significantly between the rainy and dry seasons. In addition to surface water, groundwater storage plays a crucial role in maintaining water availability throughout the year, especially during the dry season.

Surface Water Levels

The water levels in Nasarawa State's major rivers, particularly the Benue River, fluctuate seasonally. During the peak of the rainy season, water levels rise significantly, often leading to flooding in low-lying areas. Water levels in the Benue River can rise by several meters during this period, inundating floodplains and affecting settlements along its banks (Afolayan & Popoola, 2019). The rise in water levels also impacts the smaller rivers and streams that feed into the Benue, with many seasonal streams becoming fully flowing rivers during the wet months. In the dry season, water levels drop dramatically. The reduced rainfall and increased evaporation lead to lower river levels, with some smaller streams drying up completely. This seasonal variation in water levels is a critical factor for agricultural planning, as the availability of water for irrigation depends on the flow in rivers and streams (Ajayi, 2020). In some areas, particularly in the northern parts of the state, water scarcity during the dry season is a significant challenge for both farmers and rural communities.

Groundwater Storage

Groundwater is an essential component of water storage in Nasarawa State, particularly in areas where surface water availability is limited during the dry season. The state's geology, which includes both sedimentary formations and Basement Complex rocks, influences groundwater recharge and storage capacities. In the southern parts of the state, where sedimentary rocks dominate, groundwater storage is more abundant due to the higher porosity of the formations. Boreholes and wells are commonly used to access groundwater for domestic and agricultural use, particularly during the dry season when surface water sources are depleted (Iloeje, 2017). In the northern parts of the state, where crystalline Basement Complex rocks are prevalent, groundwater availability is more limited. The low permeability of these rocks restricts groundwater recharge, and communities in these areas often face

water scarcity during the dry season. Shallow wells and rainwater harvesting are common strategies used to cope with the limited groundwater availability in these regions (Udo, 2016).

Plateau State

Plateau State is a highland region with rich natural resources, including minerals, forests, and water resources. The Shemankar River originates here, contributing to the Katsina-Ala catchment.

- **Shemankar River:** Originating in the Jos Plateau, this river plays a key role in the local hydrology and supports agriculture and communities as it flows into Taraba State.
- **Springs and Streams:** Numerous small rivers and springs flow from the Jos Plateau, feeding into larger rivers like the Shemankar and Katsina-Ala.

Benue State

- **Katsina-Ala River:** This river is a major waterway in Benue State and supports irrigation, fishing, and local agriculture. It flows into the Benue River, one of Nigeria's largest rivers.
- **Groundwater:** Wells and boreholes are common, especially in rural areas, supporting both agricultural and domestic water needs.

Taraba State

- **Shemankar River:** An essential river for irrigation and water supply, originating from Plateau and passing through Taraba.
- **Benue River:** Another significant water body that influences the state's agricultural activities.

Nasarawa State

Nasarawa State has several rivers and streams that feed into larger water systems, indirectly contributing to the broader hydrology of the Shemankar Katsina-Ala catchment.

- **River Benue:** Flows along the southern border of Nasarawa State, playing a significant role in the region's water system and contributing to the agricultural and fishing activities.
- **Other Rivers:** The state is also drained by smaller rivers like Mada, Farin Ruwa, and Dep River, which provide water for domestic use, agriculture, and fishing.
- **Groundwater:** Groundwater resources are also tapped via boreholes and wells, serving rural communities and farms for irrigation.

There are water resources within the Shemankar catchment: Farin Ruwa Falls in Wamba LGA Pepper Ruwa in Lafia which has wide biodiversity Table: There are also Dams within the catchment as follows:

8.1.3 Soils

There is widespread fertile land across Shemankar-Katsina-Ala Catchment, as well as widespread food resources such as Yams, Citrus, Mangoes, Shea Butter, Water melons, Irish Potatoes etc. the soil in the catchment is characterized Alluvial Soils, Lateritic Soils and Hydromorphic Soils

Agricultural Activities

Plateau State

- Crops: Plateau's cool climate makes it ideal for growing potatoes, tomatoes, onions, and other vegetables. It also produces maize, millet, and sorghum.
- Tree Crops: Fruits such as mangoes and guavas are cultivated, along with shea and locust beans.
- Livestock: Plateau State is known for cattle rearing, and dairy farming is a significant activity, with milk and beef production.
- Fishing: Though less prominent than in other states, fishing occurs in some of the rivers and reservoirs.

Benue State

- Crops: Benue is a major producer of crops such as yams, cassava, maize, rice, and groundnuts.
- Tree Crops: Shea and locust beans are valuable for both local consumption and export.
- Livestock: Cattle, goats, and poultry are raised in significant numbers. Benue also supports fish farming, especially in areas around the rivers.

Taraba State

- Crops: Taraba is known for producing crops such as maize, rice, cassava, yam, and vegetables.
- Livestock: Cattle and goats are commonly raised, with a focus on both meat and dairy production.
- Fishing: Rivers such as the Shemankar and Benue provide opportunities for fishing, contributing to food security.

Nasarawa State

Agriculture is the backbone of Nasarawa State's economy, with the majority of the population engaged in farming. The state's fertile soil and ample rainfall support the cultivation of various crops.

Crops:

- Yam, cassava, and maize: These staple crops are widely grown across Nasarawa State and contribute to food security.
- Rice: Irrigated rice farming is common, particularly in areas near the Benue River.
- Millet and sorghum: Drought-resistant crops that thrive in Nasarawa's semi-arid regions.
- Groundnuts and soybeans: Cash crops that are important for local and commercial markets.
- Sesame seeds: Nasarawa is one of the leading producers of sesame seeds in Nigeria, which are exported internationally.
- Vegetables: Farmers in the state grow tomatoes, onions, and leafy greens, which are sold locally and regionally.

8.1.4 Mineral Resources

The catchment is home to a variety of minerals as indicated in figure 8.2 below, hence attracts some mining activity that holds promise for the development of future economic activity.

Mineral Resources

Plateau State

- Tin: Plateau State is historically known for its tin mining industry. The Jos Plateau was one of the world's largest producers of tin and columbite during the 20th century.
- Zinc and Lead: Also mined in the state for industrial use.
- Gypsum: Found in Plateau State and used for making cement and other construction materials.
- Clay: Used in the production of ceramics and pottery.

Benue State

- Limestone: Found in commercial quantities, particularly in the northern parts of Benue State, used in cement manufacturing.
- Barite: Important for the oil and gas industry.
- Gypsum: Available and used in construction and agriculture.

Taraba State

- Limestone: Found in some parts of Taraba, used for cement production.
- Barite: Present in deposits, used in drilling operations.
- Lead and Zinc: Extracted from certain parts of the state, these minerals are important for industrial use.

Nasarawa State

Nasarawa State is famously known as the "Home of Solid Minerals" because of the abundance of mineral resources found within the state. Some of these minerals include:

- Tin: Deposits of tin can be found in Nasarawa, which historically was an important region for tin mining.
- Columbite: Often found alongside tin, columbite is used in the production of heat-resistant alloys.
- Bauxite: A significant resource for aluminium production.
- Limestone: Found in large deposits and used in cement production.
- Barite: Used in the oil and gas industry as a drilling fluid.
- Lead and Zinc: Extracted in significant quantities and used in industrial applications.
- Gypsum: Utilized in the construction industry, particularly for the production of plaster and drywall.
- Marble: Found in various locations and used for construction and sculpture.
- Uranium: Though not extensively mined, there have been reports of uranium deposits in the state.
- Clay and Kaolin: Used in ceramics, pottery, and brick-making industries.

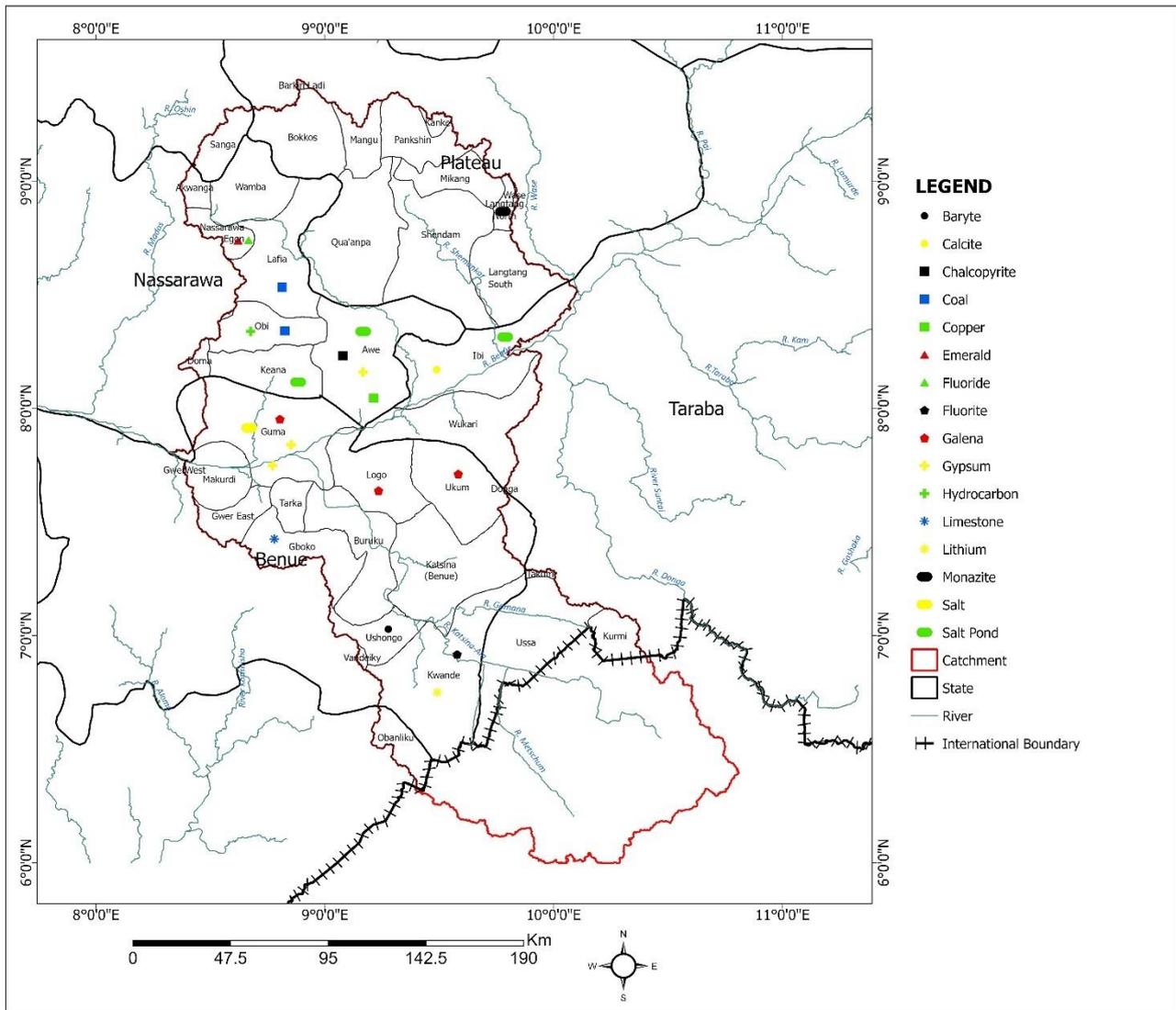


Figure 8.2: Map showing the mineral resources in the catchment area (Source: MSL, 2024)

8.1.5 Biodiversity Resources

Shemankar-Katsina-Ala catchment is home to a variety of ecosystems, including savannas, wetlands, forest reserves, and national parks. Despite facing challenges such as conflict, climate change, and environmental degradation, the region continues to thrive in terms of biodiversity. This rich biodiversity plays a vital role in providing essential ecosystem services, which are critical to the livelihoods, health, and well-being of the local communities.

Biodiversity of the Catchment

Plateau State

Plateau State is a biodiversity hotspot in Nigeria, with a wide variety of plant and animal species. The state's unique highland ecosystems, particularly those on the Jos Plateau, support species that are not found in other parts of the country.

- **Flora:** The vegetation of Plateau State is diverse, ranging from savannah grasslands in the lowland areas to montane forests and woodlands on the Jos Plateau. The montane forests are particularly important for conservation, as they contain several endemic plant species that are adapted to the cooler, wetter conditions of the highlands. These forests also provide important habitat for wildlife and play a crucial role in maintaining the ecological balance of the region [Buba & Nwokocho, 2015].
- **Fauna:** The fauna of Plateau State includes a range of mammals, birds, reptiles, and amphibians. Notable species include the Nigerian mole-rat, the Plateau indigo snake, and various species of antelopes and primates. The state is also home to several bird species, some of which are considered endangered or vulnerable. The Jos Wildlife Park, one of the key conservation areas in the state, provides a refuge for many of these species and is a focal point for biodiversity conservation efforts [Obot et al., 2016].

Benue State

Benue State is endowed with a rich variety of plant and animal species, a reflection of its location within the Guinea Savannah zone of Nigeria. This zone is characterized by a mixture of grasslands, woodlands, and scattered trees, creating a conducive environment for a diverse range of flora and fauna. The biodiversity in Benue is vital for the provision of essential ecosystem services, including food production, water regulation, and climate stabilization, which are critical for the well-being of local communities.

- **Flora and Fauna:** The flora of Benue State consists primarily of savanna grasslands, interspersed with patches of forest along riverbanks and protected areas. Common tree species include *Isoberlinia doka*, *Terminalia glaucescens*, and *Vitellaria paradoxa* (shea butter tree), which have significant economic and ecological importance. The presence of these species supports traditional agriculture and provides non-timber forest products like fruits, medicinal plants, and firewood (Ajeigbe, 2019).
- Benue State is home to various wildlife species, although many are under pressure due to deforestation, poaching, and habitat degradation. Species of mammals, birds, reptiles, and

amphibians thrive in the state's forests and savannas. Some notable fauna include antelope, baboons, warhogs, and several species of birds like the grey heron and African fish eagle. The presence of these animals contributes to the state's ecological balance and offers potential for eco-tourism (Enokela, 2021).

Taraba State

- Taraba State is endowed with a rich diversity of flora and fauna, attributed to its varied climatic zones and topographical features. The state lies within the transition zone between the Sudan savanna and the rainforest, resulting in a unique blend of species from both ecosystems. According to the Nigerian Conservation Foundation (2017), Taraba is home to numerous plant and animal species, including several that are endemic to the region.
- The diverse habitats in Taraba support a variety of wildlife, including elephants, antelopes, monkeys, and numerous bird species. The Mambilla Plateau, in particular, is known for its rich biodiversity, including unique species like the Mambilla monkey (*Cercopithecus campbelli*). The state's vegetation is primarily made up of grasslands, forests, and shrubs, which contribute to the overall ecological health of the region [Nigerian Conservation Foundation, 2017].

Nasarawa State

- Nasarawa State is home to a variety of flora and fauna, thanks to its diverse habitats ranging from grasslands and savannahs to forests and wetlands. The state's biodiversity includes numerous plant species, mammals, birds, reptiles, and amphibians, some of which are endemic to the region. Notable wildlife includes the West African manatee, various antelope species, and numerous bird species that migrate through the region (Ede et al., 2020).
- The rich biodiversity in Nasarawa State is essential for maintaining ecological balance and resilience. It supports food security through agriculture, contributes to the livelihoods of local communities, and provides essential resources such as timber, medicinal plants, and non-timber forest products.

8.1.6 Tourism Resources

- i. **Pandam Natinal Park:** in Plateau State, Nigeria, is a rich tourism resource with diverse attractions. It is home to a variety of wildlife, including antelopes, warthogs, monkeys, and numerous bird species, making it ideal for wildlife viewing and birdwatching. The park's scenic landscape includes Pandam Lake, popular for boating and fishing. Its ecosystems range from savannas to wetlands, offering nature lovers a variety of experiences. The park also has cultural significance, providing insight into local traditions. Additionally, it supports conservation efforts and serves as a research site for biodiversity and environmental sustainability.
- ii. **Mahari National Park in Wamba LGA** offers diverse ecosystems, wildlife viewing, and eco-tourism activities. Visitors can enjoy guided tours, nature trails, and camping while engaging with local cultures. The park also supports educational programs and research opportunities, making it a valuable destination for nature enthusiasts and eco-tourists.

8.1.7 Ecosystem Services in the Catchment

Plateau State

The ecosystems of Plateau State provide a range of vital services that support both human well-being and environmental health. These ecosystem services include provisioning services, such as the supply of food, water, and raw materials; regulating services, such as climate regulation, water purification, and erosion control; cultural services, such as recreation, tourism, and spiritual value; and supporting services, such as soil formation and nutrient cycling [Usman et al., 2017].

- **Provisioning Services:** Agriculture, which is the mainstay of Plateau State's economy, depends heavily on the ecosystem services provided by the natural environment. Fertile soils, adequate rainfall, and a favorable climate contribute to the production of crops and livestock. Additionally, the forests and woodlands provide timber, fuelwood, and non-timber forest products, such as medicinal plants and wild fruits [Adebayo & Usman, 2016].
- **Regulating Services:** The state's ecosystems play a critical role in regulating local and regional climate patterns, particularly through the maintenance of forest cover and the management of water cycles. Forests and wetlands in Plateau State act as carbon sinks, helping to mitigate the effects of climate change by sequestering carbon dioxide. They also help regulate water flow,

reduce the risk of flooding, and maintain water quality by filtering pollutants [Usman *et al.*, 2017].

- **Cultural Services:** The natural landscapes of Plateau State, including its mountains, rivers, and forests, hold significant cultural and spiritual value for the local communities. These areas are often associated with traditional beliefs and practices, and they serve as important sites for cultural activities and rituals. In addition, the state's scenic beauty and unique biodiversity attract tourists, contributing to the local economy and raising awareness about the importance of conservation [Buba & Nwokocho, 2015].

Benue State

- The ecosystem services provided by the natural environment in Benue State are crucial for human livelihoods. The provisioning services, such as crop production and livestock grazing, are the most significant for local economies, particularly in rural areas where agriculture is the primary occupation. The state's forests and wetlands offer habitat for pollinators and natural pest control agents, enhancing agricultural productivity. Regulating services, such as water filtration and erosion control provided by riparian vegetation, help maintain water quality and reduce soil degradation, a common issue in the region (Agbese, 2020).
- In addition, the cultural services provided by the environment, such as recreational opportunities and the maintenance of cultural heritage linked to natural landscapes, are vital for the social fabric of Benue's communities. Sacred groves and rivers play essential roles in the spiritual lives of the people, particularly the Tiv and Idoma ethnic groups, where certain areas are protected due to their cultural and religious significance (Dukor, 2017).

Taraba State

- Ecosystem services provided by Taraba's biodiversity are essential for the livelihoods of local communities. These services include provisioning services (such as food, water, and raw materials), regulating services (such as climate regulation, flood control, and disease regulation), supporting services (like nutrient cycling and soil formation), and cultural services (including recreational and spiritual benefits) [Millennium Ecosystem Assessment, 2005]. The agricultural sector heavily relies on these ecosystem services for crop production and livestock rearing, underscoring the importance of conserving biodiversity for food security.
- Additionally, the forests in Taraba serve as crucial carbon sinks, helping to mitigate climate change impacts. The diverse plant species contribute to carbon sequestration, which is vital in addressing global warming [Adefalu & Adeola, 2014]. Furthermore, the state is involved in

various conservation initiatives aimed at protecting its unique biodiversity and ensuring sustainable utilization of its natural resources.

Nasarawa State

- Ecosystem services in Nasarawa State can be categorized into provisioning, regulating, cultural, and supporting services. These services are vital for the well-being of the population and include the following:
- **Provisioning Services:** This includes the supply of food, water, timber, and medicinal resources. Agriculture, which is the primary economic activity in the state, relies heavily on the rich biodiversity found in local ecosystems (*Ajayi, 2020*).
- **Regulating Services:** Ecosystems play a crucial role in regulating climate, controlling floods, and maintaining water quality. Forested areas in the state help to stabilize soil, reduce erosion, and mitigate the impacts of flooding, particularly in the rainy season.
- **Cultural Services:** The natural landscapes and biodiversity in Nasarawa State are integral to the cultural identity of its people. Traditional practices, festivals, and beliefs often revolve around the natural environment, promoting conservation and sustainable use of resources (*Jibunoh, 2020a*).
- **Supporting Services:** These include nutrient cycling, soil formation, and primary production, which are fundamental for maintaining ecosystem functions and supporting agricultural productivity.

8.1.8 Water-Dependent Ecosystems and Habitats

Plateau State

- **Rivers and Wetlands:** Plateau State is rich in water resources, with numerous rivers, streams, and wetlands that play a crucial role in supporting biodiversity and providing ecosystem services. The state is the source of several major rivers, including the Kaduna, Gongola, and Benue rivers, which drain into larger river systems in Nigeria.
- **Riparian Ecosystems:** The riparian ecosystems along these rivers are characterized by lush vegetation, which provides habitat for a variety of wildlife, including fish, amphibians, birds, and mammals. These areas are particularly important for species that depend on aquatic and semi-aquatic environments, such as the African clawless otter and various species of kingfishers and herons [*Obot et al., 2016*]. Riparian zones also play a critical role in maintaining water quality by filtering runoff and preventing soil erosion.

- **Wetlands:** Wetlands in Plateau State, including floodplains, swamps, and marshes, are among the most productive ecosystems in the region. They provide essential services such as water purification, flood control, and groundwater recharge. Wetlands also support a high diversity of plant and animal species, many of which are adapted to the unique conditions of these habitats. However, these ecosystems are under threat from human activities such as agriculture, urbanization, and pollution, which have led to the degradation of many wetland areas [Usman et al., 2017].
- **Lakes and Reservoirs:** Plateau State is home to several natural and artificial lakes and reservoirs, which are important for water supply, irrigation, fisheries, and recreation. Notable among these are the Lamingo Dam, Kura Falls Dam, and the Jos Plateau Reservoirs.
- **Ecological Importance:** These water bodies provide critical habitats for aquatic species, including fish, amphibians, and aquatic plants. They also serve as important stopover sites for migratory birds, making them key areas for bird conservation. The ecological health of these lakes and reservoirs is closely linked to the surrounding land use and water management practices [Obot et al., 2016].
- **Threats to Water-Dependent Ecosystems:** The health of water-dependent ecosystems in Plateau State is threatened by a range of factors, including pollution from agricultural runoff, industrial discharges, and domestic wastewater. The introduction of invasive species, overfishing, and water abstraction for irrigation and domestic use also pose significant risks to the biodiversity and functioning of these ecosystems [Adebayo & Usman, 2016]. Effective management and conservation strategies are needed to protect these vital resources and ensure their sustainability.

Benue State

Water-dependent ecosystems in Benue State include rivers, wetlands, and floodplains, which are critical to maintaining biodiversity and supporting human livelihoods. The state is named after the Benue River, which runs through its landscape and serves as a central feature of the state's water systems.

- **Rivers and Wetlands :**The Benue River and its tributaries, including the Katsina-Ala and Okpokwu rivers, form the lifeblood of the state's hydrological network. These rivers support a wide range of aquatic species, including fish, amphibians, and aquatic plants. Wetlands, especially those along the riverbanks and floodplains, provide critical habitat for migratory birds, fish, and other aquatic organisms. These wetlands also act as natural water filters, absorbing pollutants and improving water quality (Ajeigbe, 2019).

- The wetlands in Benue State, particularly around the lower Benue Basin, are important for fisheries, agriculture, and groundwater recharge. Local communities rely on these wetlands for fishing and dry-season farming, especially as water levels drop during the dry season. However, these ecosystems face threats from unsustainable agricultural practices, water pollution, and changes in land use, which could reduce their capacity to provide essential ecosystem services (*Enokela, 2021*).

Importance for Agriculture and Livelihoods

- Water-dependent ecosystems in Benue State play a vital role in agricultural activities, particularly in rice and vegetable farming, which thrive in floodplain areas. These ecosystems also support livestock rearing by providing grazing lands during the dry season, when other areas may be less productive. Additionally, the rivers and wetlands are sources of water for irrigation, helping farmers sustain agricultural activities throughout the year (*Agbese, 2020*).

However, the unsustainable exploitation of water resources, including over-extraction for irrigation and the diversion of watercourses, threatens the long-term sustainability of these ecosystems. Efforts to promote sustainable water management practices and protect wetlands are essential to preserving the biodiversity and ecosystem services of Benue State.

Taraba State

Water-dependent ecosystems, particularly rivers, wetlands, and lakes, are integral to the ecological and economic landscape of Taraba State. The Benue River, which flows through the state, provides essential water resources for both humans and wildlife. It serves as a critical habitat for various aquatic species, including fish, crustaceans, and amphibians, which are important for local diets and livelihoods [*Taraba State Government, 2020a*].

Wetlands in Taraba, such as the Wase Wetlands, are vital for biodiversity conservation and water management. These areas act as natural buffers, helping to filter pollutants, regulate water flow, and support a variety of plant and animal life. The wetlands also provide essential services such as flood control, groundwater recharge, and habitat for migratory birds [*Akinola et al., 2018*]. The unique ecosystems found in these wetlands contribute to the overall health of the environment and offer significant opportunities for eco-tourism and sustainable fisheries.

The state also features several man-made reservoirs and dams, such as the Tunga Dam, which provide water for irrigation, drinking, and hydroelectric power generation. These water bodies not only support human activities but also play a crucial role in maintaining local ecosystems. Proper management of

these water resources is essential to ensure the sustainability of both human and ecological needs [Nigerian Meteorological Agency, 2019].

Nasarawa State

Wetlands and Rivers

Nasarawa State is endowed with several rivers, lakes, and wetlands that are vital for both ecological and human communities. The Benue River, which forms part of the state's southern boundary, supports diverse aquatic ecosystems and is essential for irrigation, fishing, and transportation. Wetlands in Nasarawa, such as the floodplains along the Benue River, serve as critical habitats for various species of birds, fish, and other wildlife. These wetlands also play a crucial role in flood control, water purification, and providing breeding grounds for fish species, which are important for the livelihoods of local fishing communities (Ede et al., 2020).

Terrestrial Ecosystems

The terrestrial ecosystems in Nasarawa State include savannahs, grasslands, and forests, each supporting unique biodiversity. The state's vegetation is primarily composed of Guinea savannah, characterized by grasses interspersed with scattered trees and shrubs. These ecosystems provide habitat for numerous animal species, including herbivores and their predators. Forests, particularly in the southern regions, are rich in timber and non-timber forest products. They also serve as crucial carbon sinks, helping to mitigate climate change impacts. The conservation of these ecosystems is vital for maintaining biodiversity and the services they provide (Ajayi, 2020).

8.2 Threats and Challenges

The Shemankar-Katsina-Ala catchment area, spanning Plateau, Taraba, and Benue States, faces multiple agricultural challenges that affect productivity, food security, and economic stability. Here are the primary challenges and potential solutions:

8.2.1 Agricultural Challenges

Farmer-Herder Conflicts: The recurrent conflicts between farmers and herders, particularly in Benue and Taraba, disrupt agricultural activities, reduce available grazing land, and lead to crop destruction. This conflict is exacerbated by issues such as encroachment on farmlands and inadequate grazing management

Land Degradation and Soil Erosion: Plateau and Taraba states suffer from land degradation due to overgrazing, deforestation, and unsustainable farming practices, leading to reduced soil fertility and agricultural productivity

Climate Variability: With inconsistent rainfall patterns and extended dry seasons, climate variability impacts crop yields, especially for rain-fed crops. Drought-prone areas and excessive flooding further disrupt farming cycles in these regions

Traditional Farming Techniques: Many farmers in this catchment area rely on traditional, low-efficiency farming tools, which limits their productivity. The lack of modern machinery and technology hinders optimal land use and crop yield potential

Limited Market Access: Poor road infrastructure and insufficient storage facilities limit farmers' ability to transport and store produce, increasing post-harvest losses and reducing market prices for their products

8.2.2 Proposed Solutions

Promotion of Sustainable Grazing and Farming Practices: Establishing designated grazing reserves and educating herders on rotational grazing can help reduce farmer-herder tensions. Introducing sustainable land management practices, such as agroforestry and conservation agriculture, will reduce land degradation and restore soil health

Climate-Resilient Agriculture: Supporting farmers with climate-resilient seeds and techniques, such as drought-resistant crops and efficient water management systems, can help mitigate climate impacts.

Initiatives like the Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) project in Plateau, which uses greenhouse and drip irrigation systems, can also enhance crop resilience and increase yields

Access to Modern Agricultural Tools: Introducing affordable machinery and modern farming techniques will improve labor efficiency and yields. Government-backed programs to supply machinery on a loan or rental basis could help small-scale farmer's access necessary tools

Improved Infrastructure and Market Access: Investing in better roads and cold storage facilities will reduce post-harvest losses and ensure produce reaches markets in good condition. Cooperative groups could help farmer's pool resources to transport and sell products at fair prices.

Implementing these solutions requires collaboration between government agencies, local communities, and agricultural organizations to effectively address the diverse challenges facing the Shemankar-Katsina-Ala catchment area.

8.2.3 Challenges of water resource management

Climate Change

Climate change is expected to affect stream flow and discharge patterns in the Shemankar-Katsina-Ala catchment, resulting in increased variability and possible reductions in water availability. Alterations in rainfall patterns and temperature may influence both the volume and timing of stream flow.

Human Activities

- i. **Agricultural Practices:** Irrigation and land use changes can alter natural flow regimes and affect discharge rates.
- ii. **Water Withdrawal:** Increased demand for water for agriculture, industry, and domestic use can reduce stream flow and discharge.

Data Gaps

Limited monitoring infrastructure and insufficient data collection can hinder effective water resource management. Expanding and maintaining hydrological monitoring networks are essential for accurate assessments.

8.2.4 Water levels and storage

One of the challenges of water storage in Shemankar-Katsina-Ala catchment is the loss of storage capacity due to sedimentation. Rivers and streams in the state carry significant amounts of sediment, which are deposited in reservoirs, reducing their capacity over time. This sedimentation problem is exacerbated by deforestation and poor land management practices in the watershed areas [Ogunleye & Ayoade, 2016]. Addressing this issue requires ongoing maintenance and dredging of reservoirs, as well as the implementation of soil conservation measures to reduce sediment load in rivers.

8.2.4.1 Water Levels in the Catchment

i. Seasonal Variability:

The water levels in rivers, streams, and reservoirs in catchment area are primarily influenced by seasonal rainfall patterns. During the rainy season, surface water levels rise due to the influx of rainwater, while during the dry season, these levels drop as a result of reduced inflows and increased evaporation. The river's water levels are at their highest during the peak rainy months (July to September), and this period corresponds to maximum water storage in natural and artificial reservoirs across the state. The lower sections of the River Benue, including areas near Makurdi, experience significant rises in water levels during this time, which supports floodplain agriculture but also poses flood risks (Olapade, 2018).

ii. Groundwater Levels

Groundwater is an important source of water in the particularly in rural areas. The state's groundwater levels are influenced by both natural factors, such as rainfall and recharge rates, and human activities, such as groundwater abstraction for agriculture and domestic use. In some parts of the state, over-extraction of groundwater has led to a decline in water levels, raising concerns about the sustainability of this resource [Ojo et al., 2015].

iii. Impact of Climate Change:

Climate change has been identified as a significant factor affecting water levels in the catchment. Increased temperatures and changing precipitation patterns have contributed to the reduction in water availability, particularly in the dry season. This has exacerbated the challenges of maintaining adequate water levels for agriculture and human consumption (Yusuf et al., 2021).

8.2.5 Challenges in Water Storage:

One of the challenges of water storage in the catchment is the loss of storage capacity due to sedimentation. Rivers and streams in the state carry significant amounts of sediment, which are deposited in reservoirs, reducing their capacity over time. This sedimentation problem is exacerbated by deforestation and poor land management practices in the watershed areas [Ogunleye & Ayode, 2016]. Addressing this issue requires ongoing maintenance and dredging of reservoirs, as well as the implementation of soil conservation measures to reduce sediment load in rivers.

8.2.6 Flood and Drought Patterns

Plateau State

Flood Patterns

Flooding is a recurrent issue in Plateau State, particularly during the rainy season when rivers and streams can overflow their banks. Floods in the state are primarily driven by heavy rainfall, rapid runoff, and inadequate drainage systems.

- **Types of Floods:** The state experiences both riverine floods, caused by the overflow of rivers, and flash floods, which occur as a result of intense, localized rainfall. Riverine floods are more common along major rivers such as the Kaduna and Gongola, where the natural floodplains are prone to inundation during periods of heavy rainfall [Iloeje, 2017]. Flash floods, on the other hand, are more frequent in urban areas like Jos, where the combination of impervious surfaces and inadequate drainage infrastructure can lead to rapid water accumulation and flooding.
- **Impacts of Flooding:** The impacts of flooding in Plateau State are wide-ranging, affecting agriculture, infrastructure, and communities. Floods can destroy crops, erode soils, and damage roads and bridges, leading to significant economic losses. In addition, floods pose a threat to public health by contaminating water supplies and increasing the risk of waterborne diseases [Ojo et al., 2015]. Managing flood risk in the state requires a combination of structural measures, such as the construction of levees and floodwalls, and non-structural measures, such as improved land use planning and early warning systems.

Drought Patterns

Drought is another significant hydrological challenge in Plateau State, particularly during the dry season when rainfall is scarce and water demand is high. Droughts in the state are characterized by prolonged periods of below-average rainfall, leading to reduced water availability for agriculture, industry, and domestic use.

- **Frequency and Severity:** The frequency and severity of droughts in Plateau State have increased in recent years, a trend that is likely linked to climate change [Ogunleye & Ayoade, 2016]. Droughts are more common in the northern parts of the state, where rainfall is typically lower and evapotranspiration rates are higher. These droughts can lead to significant reductions in stream flow, groundwater recharge, and reservoir levels, exacerbating water scarcity issues.

- **Drought Impacts:** The impacts of drought in Plateau State are most severe in the agricultural sector, where reduced water availability can lead to crop failure and food insecurity. Livestock farming is also affected, as drought reduces the availability of water and pasture for animals. In addition, prolonged droughts can strain the state's water supply systems, leading to water rationing and increased competition for water resources [Adebayo, 2014]. Addressing the challenges posed by drought requires the implementation of water conservation measures, improved irrigation efficiency, and the development of drought-resistant crops.

Benue State

Flood Patterns

- Flooding is a recurring challenge in Benue State, particularly along the floodplains of the River Benue. The state experiences seasonal flooding, which typically occurs during the rainy season, particularly between August and September. These floods are caused by heavy rainfall combined with high discharge levels in the River Benue and its tributaries. The flooding is often exacerbated by poor drainage infrastructure and the inability of existing dams and reservoirs to control the excess water flows.
- The floods in Benue State are characterized by both riverine and flash flooding. Riverine floods result from the overflow of the River Benue and its tributaries, inundating low-lying areas and floodplains. Flash floods, on the other hand, occur due to intense and short-duration rainfall events, especially in urban areas with inadequate drainage systems. The 2012 and 2017 floods in Benue State were particularly severe, displacing thousands of residents and damaging farmland and infrastructure (Eze, 2018).
- Floods in Benue State have significant socio-economic and environmental consequences. They destroy crops, homes, and infrastructure, disrupt livelihoods, and lead to the contamination of water sources with sediment and pollutants. Flooding also contributes to the loss of lives and the spread of waterborne diseases. Addressing these challenges requires a combination of flood forecasting, improved drainage systems, and better floodplain management (Ayuba, 2020).

Drought Patterns

While Benue State is more commonly associated with seasonal flooding, it is also vulnerable to drought conditions, particularly during years of below-average rainfall. Droughts in Benue State

typically occur during extended dry seasons or in years when the onset of the rainy season is delayed. These droughts can have devastating effects on agriculture, which is the primary economic activity in the state.

- Droughts reduce water availability in rivers, streams, and reservoirs, leading to water shortages for irrigation, domestic use, and livestock. The 2007 drought in Benue State, for instance, led to significant agricultural losses, as farmers were unable to irrigate their crops, resulting in reduced yields of staple crops such as yams, maize, and rice (*Obaje, 2009*). In addition to affecting crop production, droughts also lead to soil degradation and desertification, further reducing the state's agricultural productivity (*Abah & Omada, 2019*).
- Droughts in Benue State also have social and economic impacts, including food insecurity, increased poverty levels, and migration of rural populations to urban areas in search of alternative livelihoods. The increasing frequency and intensity of droughts due to climate change pose a growing threat to the state's water resources and food security. To mitigate these impacts, there is a need for improved water storage infrastructure, drought-resistant crop varieties, and better water conservation practices (*Olapade, 2018*).

Taraba State

Flood Patterns

- Flooding is a recurrent issue in Taraba State, particularly in the riverine areas adjacent to the Benue River. The state's flood patterns are primarily influenced by seasonal rainfall, the topography of the river valleys, and the limited capacity of drainage systems to handle excessive runoff. During the peak of the rainy season (July to September), heavy rainfall results in significant surface runoff, which can overwhelm rivers and cause them to overflow their banks. The Benue River, due to its extensive drainage basin, is particularly prone to flooding, with annual flood events affecting communities in Gassol, Wukari, and other low-lying areas [*Ayoade, 2004*].
- Flash floods also occur in hilly areas, such as the Mambilla Plateau, where steep slopes lead to rapid accumulation of runoff during intense rainfall events. These flash floods can cause significant soil erosion, damage to infrastructure, and loss of agricultural land.
- Efforts to manage flooding in Taraba State include the construction of flood defenses, such as levees and embankments along the Benue River. However, the state's capacity to mitigate

flooding is limited, and the impacts of climate change, including more intense and unpredictable rainfall, are likely to exacerbate flood risks in the future [Olaniran, 1983].

Drought Patterns

- Droughts, though less frequent than floods, pose a significant challenge to water quantity in Taraba State, particularly during prolonged dry seasons. Drought conditions are characterized by extended periods of low rainfall, which can lead to reduced water levels in rivers and reservoirs, diminished groundwater recharge, and water shortages for agriculture and domestic use. The southern part of the state, where rainfall is more abundant, is less vulnerable to drought compared to the northern and central regions, where rainfall is more variable.
- The most severe droughts in Taraba State are typically associated with the harmattan, a dry and dusty trade wind that blows from the Sahara between November and March. During these months, river flows are at their lowest, and water levels in reservoirs and aquifers diminish. The impact of drought is particularly severe on rainfed agriculture, which depends on reliable seasonal rainfall for crop production [Ayoade, 2004].
- Droughts also contribute to food insecurity, as water shortages limit the ability of farmers to irrigate crops and water livestock. Prolonged droughts can lead to the failure of staple crops such as maize, sorghum, and millet, which are widely cultivated in the state. Efforts to mitigate drought impacts include the promotion of water conservation practices, the expansion of irrigation infrastructure, and the development of drought-resistant crop varieties [Olanrewaju, 2017].

Nasarawa State

Flood Patterns

Flooding is a recurrent issue in Nasarawa State, particularly during the rainy season when rivers and streams experience high discharge rates. Floods are most common in low-lying areas along the Benue River and its tributaries, where floodplains are regularly inundated.

- **Flooding in the Benue River Basin:** The Benue River, which forms part of Nasarawa State's southern boundary, is prone to flooding during the peak of the rainy season. This flooding is often exacerbated by the topography of the floodplain and the large volume of water flowing from upstream regions. Floods in the Benue River Basin can cover large areas of farmland and displace communities living along the river's banks. These floods are typically seasonal, occurring between July and September when the river reaches its highest levels (*Afolayan & Popoola, 2019*). The impact of flooding is particularly severe in agricultural areas, where crops are often destroyed by rising waters. Farmers in flood-prone areas have adapted by planting crops that are more resistant to waterlogging or by shifting to flood-resilient agricultural practices. However, despite these adaptations, flooding remains a significant threat to food security and livelihoods in the region (*Ajayi, 2020*).
- **Flash Flooding in Hilly Areas:** In the northern and central parts of Nasarawa State, where the terrain is hillier, flash flooding is a common occurrence during intense rainfall events. The steep slopes in areas such as Akwanga and Wamba lead to rapid runoff, which can overwhelm local streams and drainage systems. Flash floods in these areas are typically short-lived but can cause significant damage to infrastructure, particularly roads and bridges (*Iloeje, 2017*). In addition, flash floods contribute to soil erosion and the degradation of agricultural lands, further impacting water quality and agricultural productivity.
- **Flood Management Strategies:** The government and local communities have implemented several flood management strategies to mitigate the impact of floods in Nasarawa State. These include the construction of embankments along major rivers, such as the Benue, to protect flood-prone areas. Additionally, early warning systems have been introduced in some areas to alert communities of impending floods, allowing them to evacuate and take precautionary measures (*Udo, 2016*). However, more comprehensive flood management measures, including improved land use planning and reforestation efforts, are needed to reduce the long-term risks of flooding in the state.

Drought Patterns

In contrast to the flooding experienced during the rainy season, Nasarawa State is also vulnerable to droughts during the dry season. Droughts are characterized by prolonged periods of water scarcity, which affect agriculture, livestock, and domestic water supplies.

- **Dry Season Droughts:** Droughts in Nasarawa State are most pronounced during the dry season, particularly from December to March. During this period, the absence of rainfall and the high rate of evaporation lead to a significant reduction in available water resources. Rivers and streams dry up, and groundwater levels drop, making it difficult for farmers to irrigate their crops and for communities to access clean water (*Ajayi, 2020*). The effects of drought are particularly severe in the northern parts of the state, where water scarcity is more pronounced due to the limited availability of groundwater. In these areas, droughts can lead to crop failures and food shortages, exacerbating poverty and food insecurity. Livestock are also affected, as the lack of water and pasture leads to reduced animal productivity and higher mortality rates (*Afolayan & Popoola, 2019*).
- **Coping with Droughts:** To cope with droughts, farmers in Nasarawa State have adopted several strategies, including the use of drought-resistant crop varieties and the implementation of irrigation systems where possible. Rainwater harvesting is also common in areas where groundwater is scarce, allowing communities to store water during the rainy season for use during the dry months (*Iloeje, 2017*). However, these strategies are often insufficient to fully mitigate the impact of droughts, particularly in years when rainfall is below average.

8.2.7 Challenges to Biodiversity and Ecosystem Services

Floods and droughts pose significant challenges to biodiversity in the Shemankar catchment. Here are some key challenges:

- i. **Habitat Disruption:** Intense flooding can destroy natural habitats, such as wetlands and forests, displacing plant and animal species and reducing biodiversity.
- ii. **Soil Erosion:** Floodwaters can lead to severe soil erosion, which degrades the quality of habitats for many species and reduces the availability of nutrients for plants.

- iii. **Water Quality Degradation:** Floods often carry pollutants, sediments, and debris into water bodies, negatively affecting aquatic ecosystems and reducing the survival of sensitive species.
- iv. **Water Scarcity:** Prolonged droughts reduce water availability in rivers and streams, affecting both aquatic and terrestrial species that rely on these water sources for survival.
- v. **Habitat Degradation:** Droughts can dry up wetlands, ponds, and streams, causing loss of habitats that are crucial for amphibians, fish, and water-dependent plants.
- vi. **Reduction in Vegetation:** Drought leads to the decline of plant species, reducing food availability and shelter for herbivores and other animals, which can lead to a decline in biodiversity.

8.2.8 Security Challenges:

- i. **Farmer-Herder Conflicts:** In all four states, particularly Benue and Plateau, violent clashes between farmers and nomadic herders over grazing land and water resources are prevalent. These conflicts have led to loss of lives, displacement, and destruction of property.
- ii. **Ethno-Religious Tensions:** Plateau, in particular, has experienced repeated clashes between ethnic and religious groups, often exacerbated by political and resource-based disputes. This has created a cycle of violence and retaliation that threatens social cohesion.
- iii. **Banditry and Kidnapping:** Kidnapping for ransom and armed banditry are rampant in Nasarawa and Taraba states. Criminal groups target both local residents and travelers, creating widespread insecurity and fear in rural and urban areas.
- iv. **Cattle Rustling:** Cattle rustling, the theft of livestock by armed gangs, is a persistent issue across all four states. This crime affects herders and often leads to violent reprisals, contributing to ongoing insecurity in rural communities.

8.2.9 Economic Challenges:

1. **Poverty and Unemployment:** High rates of poverty and joblessness fuel instability.
2. **Limited Infrastructure:** Inadequate roads, ports, and energy infrastructure hinder economic growth.
3. **Dependence on Oil:** Economic vulnerability due to reliance on oil exports.
4. **Corruption:** Widespread corruption undermines economic development.

8.2.10 Social Challenges:

1. **Health Concerns:** Limited access to healthcare, malaria, and other diseases.
2. **Education Shortfalls:** Low enrollment rates, inadequate infrastructure, and teacher shortages.
3. **Human Rights Abuses:** Reports of human rights violations, including forced displacement and violence.
4. **Gender Inequality:** Limited opportunities and rights for women.

8.2.11 Political Challenges:

1. **Weak Governance:** Institutional weaknesses and lack of transparency.
2. **Border Disputes:** Territorial disputes between countries.
3. **Electoral Violence:** Tensions and violence surrounding elections.
4. **Regional Instability:** Conflicts in neighboring countries impact regional stability.

8.2.12 Other Challenges:

Despite the abundance of natural resources in the catchment area, there are threats and challenges in sustainably managing these resources:

- **Jalingo Floodplain:** During heavy rains, the low-lying areas surrounding Jalingo, the capital, are frequently inundated, displacing residents and causing damage to homes and businesses. This disrupts daily life and can lead to outbreaks of waterborne diseases due to contaminated water sources.
- **Sedimentation in Mambilla Hydropower Project:** Heavy rains can cause excessive erosion in the catchment area of the Mambilla Hydropower Project on the Donga River. This can lead to increased sedimentation in the dam reservoir, reducing its capacity and potentially impacting power generation in the future.
- **Jos Erosion Corridor:** Heavy rains exacerbate soil erosion along the Jos Plateau, threatening public buildings, farmlands, and critical infrastructure like the Rikkos–Miango Road, a vital transportation link within the state. This erosion can also lead to increased sedimentation in rivers, impacting downstream water quality
- **Landslide Risk in Bokkos:** The mountainous terrain in Bokkos Local Government Area makes it susceptible to landslides triggered by heavy rains. These landslides can destroy homes, block roads, and endanger lives
- **Yola Water Treatment Plant Vulnerability:** Located along the Benue River, the Yola Water Treatment Plant faces challenges during floods. Increased turbidity and pollution from floodwaters can overwhelm the plant's capacity to provide clean drinking water to the city, posing a public health risk
- **Pollution from Artisanal Gold Mining:** In Taraba, artisanal gold mining activities introduce mercury and other toxic substances into water bodies, harming aquatic life and human health.
- Extensive mining activities for tin, lead, and other minerals release harmful chemicals and heavy metals into rivers and streams, degrading water quality.
- Unregulated mining practices have led to environmental degradation, including erosion, and loss of arable land.
- **Water Scarcity during Dry Seasons:** Extended dry seasons cause severe water shortages, affecting agriculture, domestic use, and overall water availability.

- **Conflict over Water Resources:** Competition among agriculture, industry, and urban settlements for limited water resources often leads to conflicts and unsustainable water extraction practices.
- **Seasonal Variability in Water Availability:** Significant seasonal fluctuations in rainfall and water availability impact agriculture, domestic water supply, and overall water resource management.
- **Depletion of Surface Water:** Over-extraction of surface water for irrigation and other uses reduces river flow and negatively affects aquatic ecosystems and downstream water availability.
- **Lack of Comprehensive Water Management Plans:** The absence of integrated water management plans results in fragmented and inefficient water use and conservation efforts.
- **Inadequate Water Storage Facilities:** Limited investment in reservoirs and storage facilities leads to inefficient water capture during the rainy season and shortages during dry periods.
- **Livestock Overgrazing:** Overgrazing by livestock near water sources leads to the destruction of vegetation, increased erosion, and contamination of water bodies with animal waste.
- **Contamination from Agro-Chemicals:** Runoff from farms using pesticides and fertilizers contaminates rivers and streams, affecting water quality and aquatic ecosystems.
- **Flooding in Low-Lying Areas:** Seasonal flooding in low-lying areas causes displacement of communities, damage to infrastructure, and contamination of water sources.
- **Weak Water Governance Structures:** Poor enforcement of water management policies and regulations leads to unsustainable water use and pollution.
- **Encroachment on Water Catchment Areas:** Unauthorized agricultural and urban development within water catchment areas reduces natural filtration and increases sedimentation in water bodies.
- **Invasive Plant Species:** Proliferation of invasive aquatic plants like Typha grass clogs waterways, disrupts natural water flow, and affects water quality and biodiversity.
- **Limited Access to Clean Drinking Water:** Many rural communities lack access to safe and clean drinking water, forcing them to rely on contaminated sources, which poses health risks.
- Deforestation due to agricultural expansion, logging, and fuelwood collection is a significant issue.

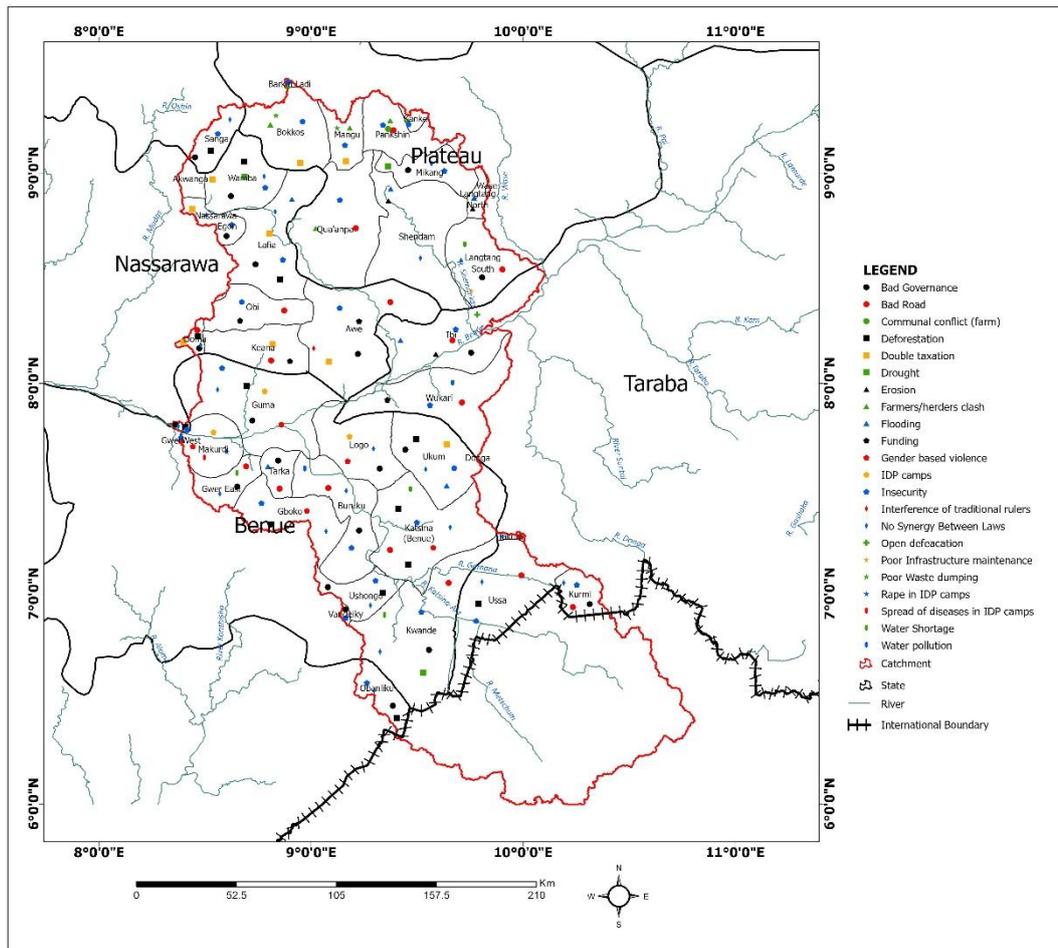


Figure 8.3: Threats and Challenges map of Shemankar-Katsina-ala catchment (Source: MSL, 2024)

8.3 Socio-Economic Data

8.3.1 Population Demographics and Growth in the Catchment

Plateau State

Plateau State has a diverse and growing population, which is estimated to be over 4 million people as of the latest census. The population is unevenly distributed across the state, with a higher concentration in urban areas such as Jos, the state capital, and its environs. Rural areas, while less densely populated, still account for a significant portion of the state's inhabitants, many of whom are engaged in agriculture and other primary economic activities [National Population Commission, 2018].

Urbanization: The state has experienced a steady increase in urbanization, particularly in the Jos metropolitan area. This urbanization is driven by factors such as migration from rural areas in search of better economic opportunities, as well as the state's role as a commercial and administrative hub in the region. Urban growth has led to the expansion of infrastructure, housing, and services, but it has also brought challenges such as congestion, unemployment, and pressure on public services [Bello & Mundi, 2016].

Population Growth Rate

The population growth rate in Plateau State is relatively high, averaging around 2.8% per annum. This growth is influenced by both natural increase (births minus deaths) and migration. High fertility rates, which are common across much of Nigeria, contribute significantly to the population growth in Plateau State. Migration, both from within Nigeria and from neighboring countries, also plays a role, particularly in urban areas where economic opportunities are more abundant [National Population Commission, 2018].

Youthful Population: Plateau State has a predominantly youthful population, with over 60% of its residents under the age of 25. This demographic structure presents both opportunities and challenges. On one hand, a youthful population can drive economic growth through increased labor supply and innovation. On the other hand, it requires significant investment in education, healthcare, and employment opportunities to harness this potential [Adeyemi & Oseni, 2017].

Benue State

Benue State is home to an estimated population of over 5 million people, according to the most recent national census figures, making it one of the more populous states in Nigeria. The population is characterized by a high rate of growth, which is reflective of both natural increase (birth rate exceeding

death rate) and rural-to-urban migration trends. The annual population growth rate of Benue State hovers around 2.9%, which aligns with the national average in Nigeria. This growth is putting increasing pressure on the state's resources, infrastructure, and social services (*National Population Commission, 2018*).

The population of Benue State is predominantly rural, with more than 75% of the people living in rural areas and relying on subsistence agriculture. The major urban centers in the state include Makurdi (the state capital), Otukpo, Gboko, and Katsina-Ala, which are witnessing increasing urbanization. This urbanization is spurred by the migration of young people from rural areas in search of better economic opportunities, education, and healthcare services (*Eze, 2020*).

The population is also ethnically diverse, with the Tiv people constituting the largest ethnic group, followed by the Idoma and Igede ethnic groups. These ethnic communities have distinct languages, traditions, and cultural practices that significantly influence social dynamics in the state. The Tiv people are concentrated mainly in the northern and central parts of the state, while the Idoma and Igede people reside primarily in the southern regions (*Ajaero, 2019*).

The age structure of Benue State's population is predominantly youthful, with more than 60% of the population under the age of 30. This youthful demographic provides potential for a vibrant labor force but also presents challenges in terms of employment, education, and healthcare services. The state's high fertility rate contributes to the youthful population, but this also exacerbates issues such as unemployment and the strain on social infrastructure (*National Population Commission, 2018*).

Taraba State

Taraba State is home to a diverse population with significant ethnic and cultural heterogeneity. According to the National Population Commission of Nigeria, the state had an estimated population of 2.3 million people as of the 2006 census, but more recent estimates place the population at over 3 million in 2021, reflecting a steady annual growth rate of about 2.5% [NPC, 2006]. The state's population is predominantly rural, with a high percentage of the populace engaged in subsistence farming and other agricultural activities. Urbanization is relatively low compared to other Nigerian states, with the major urban centers being Jalingo (the state capital), Wukari, and Gembu.

The population is characterized by a youthful age structure, with a median age of around 18 years. This youthful demographic presents both opportunities and challenges. On one hand, it offers a large potential labor force for the state's agriculture and emerging sectors. On the other hand, the state faces significant pressure to provide education, healthcare, and employment opportunities for its growing population. Population growth in Taraba State is driven by high fertility rates, which are common

across northern Nigeria. The total fertility rate in the region is estimated at around 5.5 children per woman, contributing to the rapid expansion of the population [UNFPA, 2017].

Ethnically, Taraba is highly diverse, with more than 80 different ethnic groups. The major ethnic groups include the Jukun, Mumuye, Fulani, Tiv, Kuteb, and Chamba. Each ethnic group maintains distinct cultural practices, languages, and traditions, which contribute to the cultural richness of the state. The multi-ethnic nature of Taraba has implications for governance and resource allocation, as the state government must balance the needs of different communities and ethnic groups.

Nasarawa State

As of the latest census, Nasarawa State has an estimated population of about 2.5 million people, making it one of the less populous states in Nigeria compared to its neighbors. The population is predominantly rural, with over 70% of residents living in rural areas. This demographic composition is largely influenced by traditional agricultural practices, which dominate the local economy (*National Population Commission, 2021*). The population density varies across the state, with urban areas like Lafia, the state capital, experiencing higher density levels compared to rural regions.

Ethnic Composition

Nasarawa State is home to a diverse array of ethnic groups, including the Gwandara, Alago, and Eggon, among others. This ethnic diversity contributes to the state's rich cultural heritage but can also lead to challenges related to ethnic tensions and resource allocation. The interplay of these various groups shapes the social fabric of the state and influences political and economic decisions (*Jibunoh, 2020a*).

Population Growth Rate

The population growth rate in Nasarawa State is significant, with estimates suggesting an annual growth rate of about 2.5%. This growth is driven by high fertility rates, as well as migration patterns from neighboring states in search of better economic opportunities. The increasing population places pressure on the state's resources, particularly in terms of land, water, and social services (*National Population Commission, 2021*). Addressing the needs of this growing population is essential for sustainable development in the state.

8.3.2 Economic Activities and Development Plans in the Catchment

Economic Activities

- **Agriculture:** Agriculture is the backbone of Plateau State's economy, employing the majority of the population, particularly in rural areas. The state is known for its favorable climate and fertile soils, which support the cultivation of a variety of crops, including potatoes, maize, millet, and tomatoes. Plateau State is also a major producer of fruits such as apples, strawberries, and mangoes, which thrive in the cooler highland climate of the Jos Plateau [Agwu & Uzochukwu, 2015].
- **Livestock Farming:** In addition to crop production, livestock farming is a significant economic activity in Plateau State. The state is home to a large population of cattle, goats, sheep, and poultry. Livestock farming provides income for many households and contributes to food security through the production of meat, milk, and eggs [Bello & Mundi, 2016].
- **Agricultural Challenges:** Despite its potential, the agricultural sector in Plateau State faces several challenges, including poor infrastructure, limited access to credit, and the effects of climate change. Farmers often struggle with inadequate storage facilities, which leads to significant post-harvest losses, particularly for perishable crops like fruits and vegetables. The state government has initiated various programs aimed at improving agricultural productivity, such as the provision of improved seeds, fertilizers, and training for farmers [Odeh, 2018].
- **Mining:** Plateau State has a long history of mining, particularly of tin and columbite, which were major exports during the colonial period. Although mining activity has declined in recent years due to the depletion of easily accessible deposits and environmental concerns, it remains an important economic activity in certain areas of the state [Ayuba & Shehu, 2016]. The state government has been exploring opportunities to revive the mining sector through partnerships with private investors and the introduction of modern mining techniques.
- **Environmental Impact:** The legacy of mining in Plateau State has had significant environmental impacts, including land degradation, deforestation, and water pollution. Efforts are being made to rehabilitate abandoned mining sites and promote sustainable mining practices to mitigate these effects [Ayuba & Shehu, 2016].
- **Tourism:** Tourism is an emerging sector in Plateau State, capitalizing on the state's natural beauty, cool climate, and rich cultural heritage. The Jos Wildlife Park, the National Museum in Jos, and scenic locations like the Shere Hills and Kurra Falls are popular tourist destinations. The state government has identified tourism as a key area for economic diversification and has

developed plans to improve infrastructure, promote cultural festivals, and attract both domestic and international tourists [Bello & Mundi, 2016].

Development Plans

Plateau State's development plans are centered on diversifying the economy, improving infrastructure, and enhancing the quality of life for its residents. The state government's strategic development blueprint includes investments in road networks, education, healthcare, and renewable energy projects. Additionally, there are initiatives to promote small and medium-sized enterprises (SMEs) and create an enabling environment for private sector investment [Odeh, 2018].

Benue State

Benue State is predominantly agrarian, and agriculture forms the backbone of its economy. Known as the "Food Basket of the Nation," Benue is a major producer of crops such as yams, cassava, maize, rice, soybeans, and groundnuts. The state also produces fruits like oranges, mangoes, and guava, which are key export commodities. Livestock farming, including poultry, cattle rearing, and pig farming, is also a significant economic activity in the state (Okpanachi & Aiyede, 2021).

The agricultural sector in Benue is mostly subsistence-based, but there are efforts to transition towards commercial farming. The state government has initiated several development plans aimed at improving agricultural productivity through mechanization, improved seed varieties, and better access to fertilizers and credit. One such initiative is the Benue Agricultural Revolution Plan (BARP), which seeks to boost agricultural output and increase farmers' incomes by providing modern farming inputs and training (Benue State Government, 2019).

In addition to agriculture, the state has abundant natural resources, including limestone, lead, zinc, and clay, which hold potential for mining and industrial development. However, the mining sector remains underdeveloped, and efforts are being made to attract investment to this sector. Benue State's development plans include establishing industrial zones to promote agro-processing, which would add value to its agricultural products and create employment opportunities (Agbo & Yahaya, 2020).

The state government has also recognized the need for infrastructural development as a catalyst for economic growth. Key sectors such as transportation, energy, and water supply are being targeted for investment. The construction of roads and bridges to improve connectivity between rural and urban areas is one of the state's top priorities. Furthermore, the Makurdi Cargo Airport project, aimed at facilitating the export of agricultural products, is a significant part of the state's long-term economic development strategy (Benue State Government, 2019).

Taraba State

Agriculture is the dominant economic activity in Taraba State, employing about 80% of the population. The state's fertile land, varied topography, and favorable climate make it a prime area for agricultural production. Key crops grown in Taraba include maize, millet, yams, rice, groundnuts, and sorghum. The state is also known for its production of cash crops such as cotton, coffee, and cocoa, which contribute to both local livelihoods and national economic output. The agricultural sector benefits from the seasonal rainfall patterns, with irrigation becoming increasingly important in regions that experience extended dry seasons [World Bank, 2019].

Livestock farming is another vital component of the state's economy, particularly among the Fulani, who are predominantly pastoralists. Cattle, goats, and sheep are raised across the state, with cattle herding being a significant source of livelihood for many rural communities. The state also has a thriving fishing industry, particularly in the riverine areas around the Benue and Taraba rivers. Fisheries provide both food security and income for local populations [Olaniyi, 2015].

Despite its agricultural potential, Taraba State faces challenges in terms of infrastructure and market access. Poor road networks and inadequate storage facilities limit farmers' ability to transport and store their produce, leading to post-harvest losses. To address these issues, the state government has developed various agricultural development plans aimed at improving infrastructure, access to markets, and modern farming techniques. The Taraba State Agricultural Development Programme (TADP) focuses on increasing agricultural productivity through the provision of improved seedlings, fertilizers, and training for farmers [Taraba State Government, 2020b].

In addition to agriculture, the state has untapped potential in mining. Taraba is endowed with several mineral resources, including limestone, bauxite, and marble. The development of the mining sector is a key part of the state's economic diversification strategy, as outlined in the Taraba State Economic Development Plan (TSEDP). The state government aims to attract private investment into the mining sector and improve regulatory frameworks to ensure the sustainable exploitation of mineral resources [Taraba State Government, 2020c].

Nasarawa State

Economic Activities

Nasarawa State's economy is predominantly agrarian, with agriculture serving as the backbone of economic activities. Major crops include maize, yams, cassava, and rice, which are cultivated by a significant portion of the population. The state is also known for its production of livestock, including cattle, goats, and poultry, contributing to the food supply and income generation for local farmers (Ajayi, 2020).

In addition to agriculture, Nasarawa State is rich in mineral resources, including limestone, granite, and dolomite. The mining sector has the potential to significantly contribute to the state's economy, yet it remains underdeveloped compared to other regions of Nigeria. The state government has initiated efforts to attract investment in mining and to improve regulatory frameworks to enhance the sector's productivity (Jibunoh, 2020b).

Development Plans

The government of Nasarawa State has implemented various development plans aimed at fostering economic growth and improving living standards. The Nasarawa State Development Plan, a comprehensive framework outlining strategic priorities for economic development, emphasizes infrastructure development, education, healthcare, and agricultural productivity.

Key initiatives include improving road networks to facilitate trade and access to markets, enhancing healthcare facilities to address public health challenges, and investing in education to improve literacy rates and skill acquisition (Nasarawa State Government, 2022a). Additionally, the state government is focusing on public-private partnerships to leverage resources for infrastructure development and service delivery.

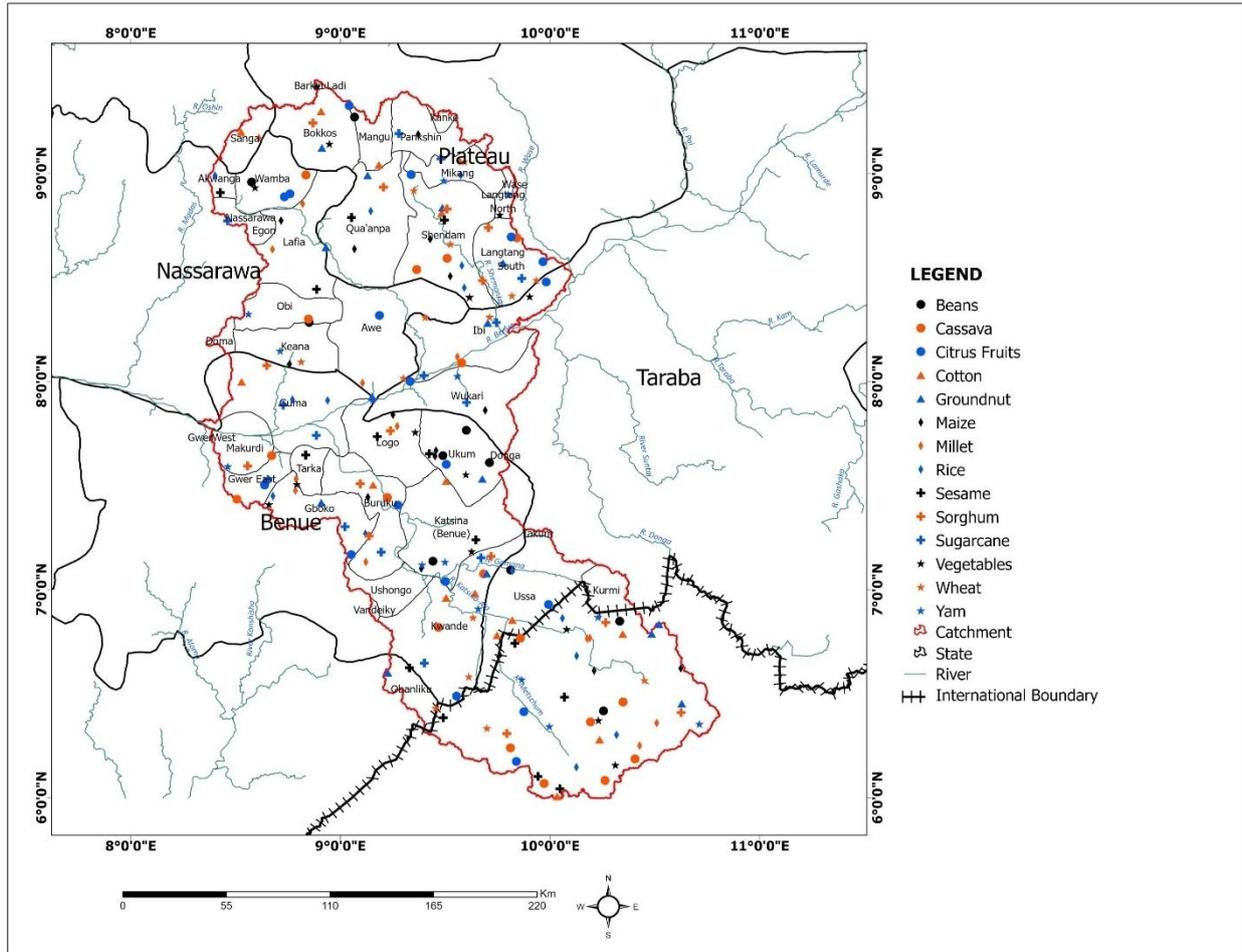


Figure 8.4: Crops grown in the Catchment (Source: MSL, 2024)

8.3.3 Social Values and Norms

Plateau State

- **Cultural Diversity:** Plateau State is one of the most culturally diverse states in Nigeria, home to over 50 ethnic groups, including the Berom, Afizere, Anaguta, Mwaghavul, and Tarok. Each of these groups has its own distinct language, traditions, and customs, which contribute to the state's rich cultural tapestry. This diversity is celebrated through various cultural festivals, traditional dances, and crafts, which are an integral part of the social fabric of Plateau State [Bawa & Ogbonna, 2015].
- **Language and Tradition:** The indigenous languages and traditions of Plateau State are highly valued by the local communities. Efforts to preserve and promote these cultural elements

include the teaching of indigenous languages in schools, the documentation of oral histories, and the organization of cultural events [Bawa & Ogbonna, 2015].

- **Religion:** Religion plays a significant role in the social and cultural life of Plateau State. The state has a diverse religious landscape, with Christianity and Islam being the dominant religions, alongside traditional African beliefs. The state has witnessed religious tensions in the past, but efforts at promoting interfaith dialogue and understanding have been made to foster peaceful coexistence among the different religious communities [Adeyemi & Oseni, 2017].
- **Social Values:** Social values in Plateau State are deeply rooted in communal life and respect for tradition. The extended family system is prevalent, with strong kinship ties that provide social security and support networks. Community solidarity, mutual aid, and respect for elders are highly regarded values that influence social interactions and community development efforts [Bawa & Ogbonna, 2015].
- **Education and Social Mobility:** Education is highly valued in Plateau State, with a strong emphasis on formal education as a means of social mobility and economic advancement. The state has a relatively high literacy rate compared to other parts of Nigeria, partly due to the presence of numerous educational institutions, including the University of Jos, colleges of education, and vocational training centers [Bello & Mundi, 2016]. However, challenges such as inadequate infrastructure, teacher shortages, and disparities in access to education between urban and rural areas remain.
- **Conflict and Peacebuilding:** Plateau State has experienced periodic outbreaks of violence, often linked to competition over land, resources, and political power. These conflicts, which sometimes take on ethnic or religious dimensions, have had a significant impact on the social cohesion and economic development of the state [Bawa & Ogbonna, 2015]. In response, various peacebuilding initiatives have been implemented, focusing on promoting dialogue, reconciliation, and the restoration of trust among the different communities.
- **Role of Traditional Rulers:** Traditional rulers and community leaders play a crucial role in conflict resolution and peacebuilding in Plateau State. They act as mediators in disputes, facilitate dialogue between conflicting parties, and help to enforce local customs and laws that promote social harmony [Adeyemi & Oseni, 2017].

Benue State

Benue State's social and cultural values are deeply rooted in the traditions of its ethnic groups, particularly the Tiv, Idoma, and Igede peoples. These values influence various aspects of life, including family structure, religion, and communal interactions.

Family remains the central social unit in Benue State, with extended families playing a crucial role in social organization. The people of Benue place a high value on communal living, where family members, including extended kin, work together to support each other both economically and socially. The Tiv people, for instance, practice a communal land tenure system where families own land collectively and distribute it for agricultural purposes based on need (*Dukor, 2017*). This system reflects the broader cultural value of collectivism, where the community's welfare is prioritized over individual interests.

Religious beliefs also play an essential role in shaping the social life of Benue's people. Christianity is the dominant religion, with the majority of the population adhering to various Christian denominations. However, traditional religious practices and beliefs, such as the worship of ancestral spirits and nature gods, coexist with Christianity, particularly in rural areas. These traditional beliefs influence rituals, festivals, and local governance structures (*Ajaero, 2019*).

Festivals and cultural events are an integral part of life in Benue State, reflecting the rich cultural heritage of its people. The Tiv people, for example, celebrate the Kwagh-Hir festival, which combines storytelling, dance, and drama to showcase their historical and cultural identity. Similarly, the Idoma people celebrate the Alekwu festival, which honors their ancestors and reinforces communal bonds. These festivals serve not only as cultural celebrations but also as platforms for social cohesion and inter-ethnic relations (*Agbo & Yahaya, 2020*).

Social values in Benue State also emphasize respect for elders and authority. Elders play a crucial role in decision-making within families and communities, and their advice is often sought on important matters, including land disputes, marriage, and religious practices. This respect for elders is deeply ingrained in the social fabric and contributes to the preservation of cultural traditions and values.

Taraba State

The social fabric of Taraba State is woven from its rich cultural heritage and traditions. The state is home to numerous ethnic groups, each with its distinct customs, languages, and social norms. These groups coexist peacefully, but ethnic identity remains a central aspect of social life in Taraba. Traditional leadership structures, such as the roles of local chiefs and community leaders, are still highly respected and play a critical role in mediating conflicts and maintaining social order within communities [*Gundu, 2018*].

Religiously, Taraba is divided between Islam and Christianity, with Islam being predominant in the northern parts of the state, particularly among the Fulani, while Christianity is more prevalent in the southern and central regions. Despite this religious divide, Taraba has historically experienced

relatively harmonious inter-religious relations. Traditional African religions are also practiced by a minority of the population, often in conjunction with Islam or Christianity.

Social values in Taraba State are deeply rooted in communal living and collective responsibility. Extended family systems are common, with family members sharing resources and responsibilities. Marriage and kinship ties are highly valued, and social status is often linked to one's family background and contribution to the community. In rural areas, traditional festivals and ceremonies, such as the Nwonyo Fishing Festival in Ibi and the Purma Festival in Jalingo, play a crucial role in fostering social cohesion and cultural identity [Gundu, 2018].

The state's cultural diversity is celebrated through music, dance, and art. Traditional crafts, such as weaving, pottery, and leatherwork, are still practiced in many communities and serve as a source of income for artisans. Cultural festivals provide an opportunity for different ethnic groups to showcase their heritage and promote social unity.

Nasarawa State

- **Cultural Diversity:** Nasarawa State is characterized by a rich cultural heritage, with numerous festivals, traditional practices, and languages reflecting the diversity of its population. Major festivals, such as the Gwandara Cultural Festival and the Eggon Festival, serve as platforms for showcasing traditional music, dance, and art. These cultural events foster community cohesion and promote tourism, which has the potential to contribute to the local economy (Jibunoh, 2020b).
- **Social Values and Community Structure:** Social values in Nasarawa State are deeply rooted in communalism and traditional governance structures. The extended family system plays a vital role in providing social support and maintaining social order. Elders in the community often hold significant authority, guiding decisions and conflict resolution within families and clans. This structure has been crucial in maintaining peace and harmony among the diverse ethnic groups in the state.
- **Education and Literacy:** Education is highly valued in Nasarawa State, with ongoing efforts to improve literacy rates and educational access. However, challenges remain, particularly in rural areas where schools may be under-resourced or difficult to reach. The state government has implemented programs aimed at improving educational infrastructure and providing incentives for teachers to work in underserved areas (Nasarawa State Government, 2022b). Community involvement in education is also encouraged, with local organizations supporting schools through funding and volunteer efforts.

8.3.4 Poverty Index

The Shemankar - Katsina Ala Catchment area, spanning local governments across Benue, Nasarawa, Plateau, and Taraba States, Nigeria, presents a complex landscape of poverty and development challenges. This catchment is characterized by diverse geographical and socio-economic conditions, yet many of its local governments share similar experiences of poverty, food insecurity, and vulnerability to socio-political and environmental factors. Understanding the patterns of poverty in this catchment is essential for designing targeted interventions and policies aimed at alleviating poverty and improving livelihoods.

Overview of Poverty Levels

The classification of local governments in the Shemankar - Katsina Ala Catchment reveals four main categories of poverty, namely **Moderate Poverty (31% - 50%)**, **High Poverty (51% - 70%)**, and **Very High Poverty (71% and above)**. No local governments were categorized in the very low or low poverty ranges, highlighting the severity of the poverty situation in this catchment.

1. Moderate Poverty Local Governments:

- Local governments such as **Makurdi, Akwanga, Keana, Lafia, Vandeikya, and Shendam** fall into the moderate poverty category, with poverty rates ranging between 31% and 50%. These areas face challenges in access to services, economic development, and infrastructure but have relatively better poverty levels compared to other areas in the catchment.
- In **Makurdi**, the capital of Benue State, moderate poverty levels are largely driven by rapid urbanization, rising population densities, and limited job opportunities outside the government sector. Meanwhile, local governments like **Akwanga, Keana, and Lafia** in Nasarawa State show signs of moderate poverty largely due to a reliance on subsistence agriculture and limited access to critical infrastructure like roads and healthcare facilities. **Shendam** in Plateau State also shares similar characteristics, with agriculture being the mainstay of the local economy and providing a modest livelihood for many households.

2. High Poverty Local Governments:

- A large proportion of the local governments in the catchment, including **Gboko, Gwer East, Gwer West, Kwande, Tarka, Awe, Doma, Obi, Barkin Ladi, Bokkos, Kanke, Langtang North, Langtang South, Mangu, Mikang, Pankshin, Qua'an Pan, Wase,**

Donga, Kurmi, Takum, Ussa, and Wukari, fall under the high poverty category, with poverty rates ranging from 51% to 70%. These areas face significant economic and development challenges, characterized by low access to basic services, insufficient infrastructure, and high levels of food insecurity.

- In **Gboko** and **Kwande** in Benue State, poverty is exacerbated by the over-dependence on smallholder agriculture and poor market access, limiting farmers' ability to generate substantial incomes. In the **Awe, Doma, and Obi** local governments in Nasarawa State, pastoral farming plays a significant role in the local economy. However, recurrent conflicts between farmers and herders over land use and water resources disrupt livelihoods, driving up poverty levels.
- The high-poverty local governments in Plateau State, such as **Barkin Ladi, Bokkos, Langtang North, and Wase**, have been severely affected by inter-communal conflicts, which disrupt agricultural production and trade. These conflicts lead to displacement and further exacerbate food insecurity and poverty. **Bokkos** and **Kanke** experience challenges related to limited infrastructure, which hinders the delivery of social services and economic opportunities. In Taraba State, local governments like **Donga, Kurmi, Takum, and Wukari** face similar issues, including weak infrastructure and poor healthcare systems.

3. Very High Poverty Local Governments:

- The local governments categorized under extreme poverty, with rates exceeding 71%, include **Buruku, Guma, Katsina-Ala, Logo, Ukum, and Ibi**. The poverty rates in these areas are alarmingly high due to various structural and environmental factors that limit economic development and access to essential services.
- **Katsina-Ala, Logo, and Ukum** in Benue State are predominantly agricultural communities that have faced persistent violence and conflict. The insecurity has led to the displacement of residents and the abandonment of farmlands, severely affecting agricultural productivity. In these areas, the combination of conflict, poor access to markets, and limited governmental intervention has trapped many households in extreme poverty.
- In **Ibi**, located in Taraba State, extreme poverty is driven by a combination of political instability, poor access to education, and limited economic diversification. Ibi's reliance on subsistence farming, coupled with climatic variations, makes it particularly vulnerable to environmental shocks.

Several interrelated factors contribute to the high and extreme poverty levels observed in the Shemankar - Katsina Ala Catchment area:

1. **Insecurity and Conflict:** Conflict remains a major driver of poverty across the catchment. Ethnic, religious, and communal clashes in Plateau and Benue States, coupled with herder-farmer conflicts in Nasarawa and Taraba States, have destabilized agricultural activities and displaced many communities. This leads to the abandonment of farmlands, disruption of livelihoods, and increased dependency on external aid.
2. **Agricultural Dependence and Low Productivity:** Most local governments within the catchment are heavily reliant on subsistence farming, with limited access to modern agricultural inputs, technology, and markets. The low productivity levels prevent families from earning sufficient income to meet their basic needs. Poor infrastructure, such as roads and storage facilities, exacerbates these challenges, reducing the profitability of agricultural activities.
3. **Environmental Degradation and Climate Change:** Environmental degradation, caused by deforestation, soil erosion, and poor land management practices, is prevalent in many local governments within the catchment. This has led to declining soil fertility and reduced crop yields, further worsening poverty levels. Climate change, manifesting in erratic rainfall and prolonged droughts, also poses a threat to agriculture and food security.
4. **Inadequate Infrastructure and Services:** Many of the local governments suffer from inadequate social infrastructure, such as schools, hospitals, and clean water supply systems. This limits the residents' access to essential services, undermining their health and educational outcomes. Poor road networks hinder trade and market access, further trapping communities in poverty.
5. **Limited Economic Diversification:** A lack of economic diversification across most of the local governments exacerbates poverty. With a heavy reliance on small-scale agriculture, local economies are unable to create alternative employment opportunities, particularly for the youth. This limited diversification restricts income generation and economic growth.

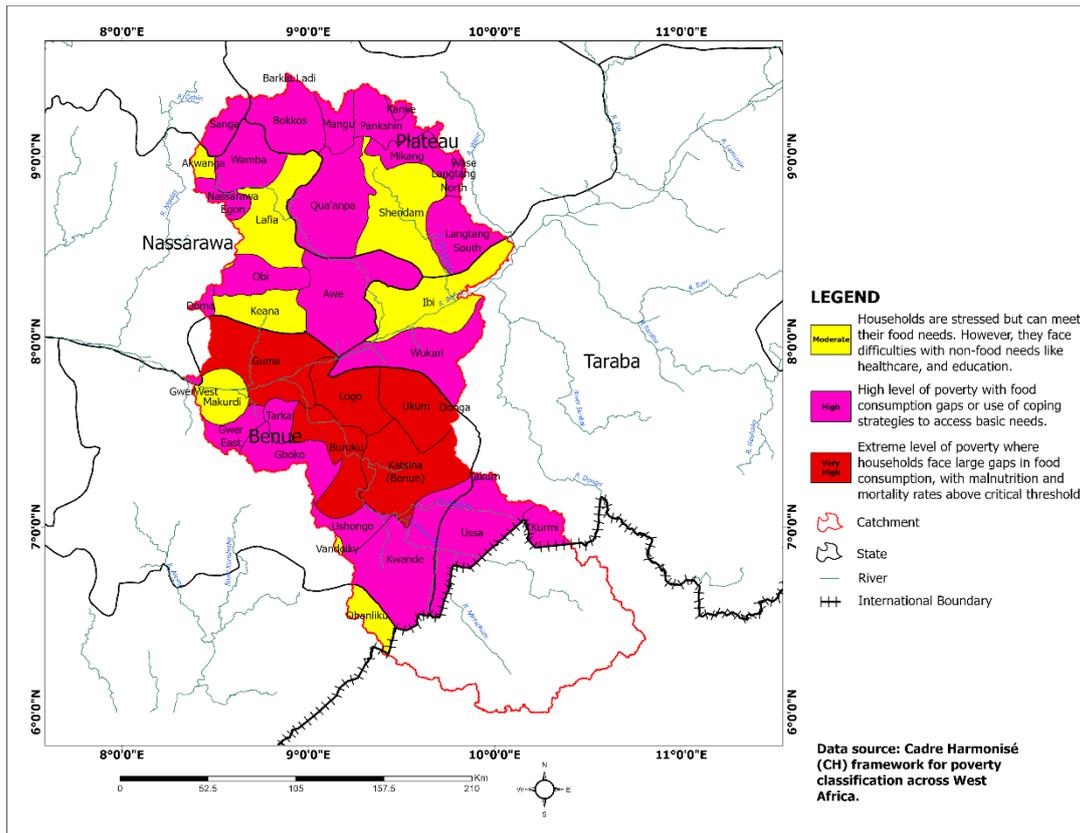


Figure 8.5: Poverty Levels Map of the Catchment (Source: MSL, 2024)

8.4 Policies

8.4.1 Relevant laws and Policies

The regulatory framework is a crucial aspect of governance and development, guiding the management of natural resources, environmental protection, and the delivery of public services. The framework consists of relevant laws and policies, institutional arrangements, governance structures, and standards and guidelines for catchment management. This section provides a comprehensive overview of these components, highlighting their significance and implementation in the catchment area.

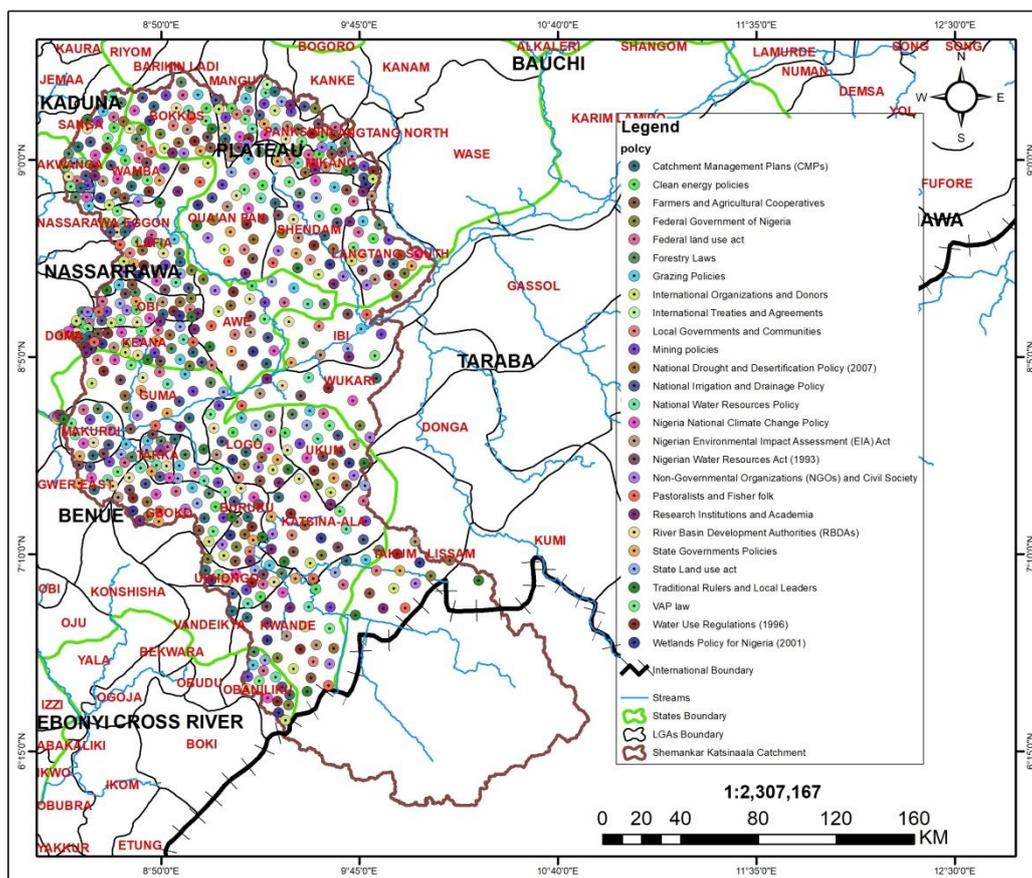


Figure 8.6: Policy map of Shemankar-Katsina-Ala catchment (Source: MSL, 2024)

Plateau State

Environmental Laws and Policies

Plateau State has adopted several environmental laws and policies aimed at protecting its rich natural resources and addressing environmental challenges such as deforestation, land degradation, and pollution.

- **Environmental Protection and Management Law (1996):** This law is the cornerstone of environmental regulation in Plateau State. It establishes guidelines for the protection of air, water, and land resources and sets out provisions for waste management, pollution control, and the conservation of biodiversity. The law empowers the Plateau State Environmental Protection Agency (PEPA) to enforce environmental regulations and monitor compliance [Adebayo & Usman, 2017].
- **Forestry Law (2004):** The Forestry Law regulates the management and conservation of forest resources in Plateau State. It includes provisions for the sustainable harvesting of timber, the protection of forest reserves, and the prevention of illegal logging. The law also promotes reforestation and afforestation initiatives to combat desertification and restore degraded lands [Buba & Nwokocho, 2015].
- **Plateau State Water Law (2010):** This law governs the management of water resources in the state, including the use, conservation, and protection of surface and groundwater. The law mandates the creation of water catchment management plans and establishes the Plateau State Water Board as the authority responsible for overseeing water supply and sanitation services [Obot et al., 2016].
- **Mining and Mineral Resources Policy (2015):** Given Plateau State's history of mining activities, this policy was introduced to regulate the extraction of mineral resources and mitigate the environmental impacts of mining. The policy emphasizes the need for sustainable mining practices, environmental impact assessments (EIAs), and the rehabilitation of mined lands [Ayuba & Shehu, 2016].

Land Use and Planning Laws

Land use and planning laws in Plateau State are designed to guide the development and management of land resources, ensuring that land is used efficiently and sustainably.

- **Urban and Regional Planning Law (2007):** This law provides the legal framework for urban and regional planning in Plateau State. It establishes guidelines for land use zoning, building

regulations, and the development of infrastructure. The law also mandates the preparation of master plans for urban areas and the protection of green spaces [Odeh, 2017].

- **Land Use Act (1978):** Although this is a federal law, it has significant implications for land management in Plateau State. The Land Use Act vests all land in the state in the hands of the governor, who holds it in trust for the people. The law regulates land allocation, ownership, and use, and is administered by the Plateau State Ministry of Lands and Survey [Adebayo & Usman, 2017].

Benue State

Benue State operates within Nigeria's broader legal and policy framework, but it also implements state-specific regulations to address its unique environmental, economic, and social challenges. The legal framework governing the state is largely influenced by national legislation, such as the Nigerian Constitution, environmental laws, and specific policies tailored for sustainable resource use.

Environmental Protection Laws

One of the cornerstone legal frameworks for environmental management in Benue State is the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act, which regulates the protection of the environment across Nigeria. This federal law applies to Benue State, where it sets standards for pollution control, waste management, and ecosystem conservation. NESREA ensures compliance with these standards through inspections, environmental audits, and enforcement actions when regulations are violated (*NESREA Act, 2007*). Additionally, Benue State has adopted local environmental policies that complement federal efforts. For instance, the Benue State Environmental Protection Agency Law establishes the Benue State Environmental Protection Agency (BENSEPA), which is tasked with monitoring and regulating environmental practices in the state. The law provides guidelines for air and water quality, waste disposal, and environmental conservation (*BENSEPA Law, 2015*).

Land Use and Planning Laws

Benue State's land use is regulated under the Land Use Act of 1978, which governs the allocation, acquisition, and management of land across Nigeria. In Benue State, this act is applied by local land allocation committees and the governor's office, which oversees the issuance of Certificates of Occupancy (C of O) for both private and public land use. The Land Use Act serves as a tool to regulate urban planning, rural development, and agricultural activities in the state (*Land Use Act, 1978*). At the state level, the Benue State Urban Development Board (BSUDB) is responsible for ensuring that land use conforms to state-approved development plans. The BSUDB enforces zoning laws and ensures

that land development aligns with environmental sustainability goals, urban growth, and agricultural land preservation.

Water Resources Laws

Benue State's water resources are governed by both federal and state-level regulations. The Water Resources Act of 1993 is the primary federal law that applies to water resources in Benue, ensuring the management and allocation of surface and groundwater resources. The law regulates water abstraction for agricultural, industrial, and domestic uses, and it mandates the protection of water bodies from pollution (*Water Resources Act, 1993*). At the state level, the Benue State Water Board Law oversees water supply and distribution in urban and semi-urban areas. This law establishes the Benue State Water Board, which is responsible for providing potable water and managing water treatment facilities (*Benue State Water Board Law, 2008*).

Taraba State

Taraba State operates within the broader context of Nigerian laws and regulations pertaining to environmental protection and resource management. The most significant legislation impacting the regulatory framework includes the National Water Policy (2004), the Environmental Impact Assessment (EIA) Act (1992), and the National Environmental Standards and Regulations Enforcement Agency (NESREA) Act (2007). These national policies provide a foundation for state-specific regulations and guidelines [*Federal Ministry of Water Resources, 2013*].

At the state level, Taraba has enacted various laws to address environmental challenges and regulate resource use. The Taraba State Water Supply and Sanitation Law (2005) was established to govern the provision of water services, promote hygiene, and ensure the sustainability of water resources. This law emphasizes the need for equitable access to water supply and the importance of maintaining the quality of water resources [*Taraba State Government, 2005*].

Furthermore, the Taraba State Environmental Protection Agency (TSEPA) Law (2008) mandates the agency to oversee environmental monitoring and enforcement of environmental standards, thereby enhancing the state's capacity to manage environmental issues effectively [*Taraba State Government, 2008*]. These laws collectively underscore the commitment of Taraba State to align with national objectives while addressing local environmental concerns.

Nasarawa State

Environmental Laws

Nasarawa State operates under several environmental laws that are aligned with federal legislation and international standards. The Environmental Impact Assessment (EIA) Act of 1992 is a cornerstone of environmental regulation in Nigeria, mandating that all major development projects undergo an assessment of their potential environmental impacts before approval (*Ogunbode et al., 2020*). The state has also enacted specific regulations tailored to its unique environmental challenges, including the Nasarawa State Environmental Protection Agency (NSEPA) Law, which aims to safeguard the environment and promote sustainable resource management. In addition, the Nasarawa State Forestry Law regulates the management and conservation of forest resources. This law is designed to combat deforestation, promote reforestation, and ensure the sustainable harvesting of timber and non-timber forest products (*Jibunoh, 2020a*).

Water Resource Management Policies

The management of water resources in Nasarawa State is governed by the National Water Policy, which aims to ensure the sustainable use and management of water resources across the country. In line with this policy, the state government has developed the Nasarawa State Water Policy, which focuses on improving water supply, ensuring equitable access to water resources, and enhancing water quality (*Nasarawa State Government, 2022a*). This policy emphasizes community involvement in water management and seeks to align with federal policies to promote integrated water resource management.

8.4.2 Institutional Arrangements and Governance

Plateau State

Environmental Governance Structures

The governance of environmental resources in Plateau State is managed through various institutions and agencies that are responsible for implementing laws and policies, monitoring compliance, and ensuring sustainable development.

- **Plateau State Environmental Protection Agency (PEPA):** PEPA is the primary agency responsible for environmental regulation and management in Plateau State. It enforces environmental laws, conducts environmental assessments, and implements programs aimed at reducing pollution, conserving biodiversity, and promoting sustainable development [*Adebayo*

& Usman, 2017]. PEPA also collaborates with other government agencies, non-governmental organizations (NGOs), and international bodies to address environmental challenges.

- **Plateau State Ministry of Environment and Natural Resources:** This ministry oversees the management of natural resources, including forests, water bodies, and wildlife. It is responsible for formulating environmental policies, coordinating conservation efforts, and implementing reforestation and land rehabilitation projects [Buba & Nwokocha, 2015]. The ministry also works with local communities to promote sustainable land use practices and protect natural ecosystems.
- **Plateau State Water Board:** The Plateau State Water Board is the agency responsible for water supply and sanitation services in the state. It manages water treatment plants, distribution networks, and wastewater facilities, ensuring that residents have access to clean and safe water. The board also develops and implements water management plans to protect water resources from overexploitation and pollution [Obot et al., 2016].

Governance Challenges

Despite the existence of these institutions, governance in Plateau State faces several challenges, including inadequate funding, lack of technical capacity, and overlapping mandates among agencies. These challenges often hinder the effective implementation of environmental laws and policies, leading to issues such as illegal logging, unregulated mining, and water pollution [Ayuba & Shehu, 2016]. Addressing these challenges requires strengthening institutional capacity, improving coordination among agencies, and ensuring that environmental governance is inclusive and participatory.

Benue State

Benue State has established several key institutions to manage its natural resources, enforce environmental laws, and oversee sustainable development. These institutions operate at both state and federal levels, often in collaboration to ensure effective governance of the environment, water resources, and land use.

- **Benue State Environmental Protection Agency (BENSEPA):** BENSEPA plays a central role in regulating environmental practices within the state. It is responsible for enforcing environmental standards, managing pollution, and promoting sustainable development initiatives. BENSEPA works with the Nigerian Ministry of Environment and NESREA to align state regulations with national policies. It also conducts public awareness campaigns,

environmental education, and capacity-building programs for local communities (*BENSEPA Law, 2015*).

- **Benue State Water Board:** The Benue State Water Board is responsible for managing water supply and treatment infrastructure in the state. It operates under the regulatory framework set by the state government, ensuring the distribution of potable water, maintaining water treatment plants, and managing water tariffs. The board also collaborates with the Federal Ministry of Water Resources to implement national water policies within the state (*Benue State Water Board Law, 2008*).
- **Benue State Urban Development Board (BSUDB):** The BSUDB oversees land use planning, urban development, and zoning regulations in the state. Its mandate includes ensuring that urban expansion adheres to state development plans and that environmental sustainability is incorporated into the planning process. The BSUDB is also tasked with approving land development projects, particularly in rapidly growing areas like Makurdi, Gboko, and Otukpo (*BSUDB Act, 2012*).
- **Collaboration with Federal Agencies:** In addition to state-level institutions, federal agencies such as the Federal Ministry of Environment, National Inland Waterways Authority (NIWA), and National Agency for the Great Green Wall collaborate with Benue State to implement national environmental policies. NIWA, for instance, oversees the regulation and protection of the Benue River and its tributaries, ensuring that activities such as sand mining, fishing, and transportation do not degrade water quality (*NIWA Act, 1997*).

Taraba State

Effective governance in Taraba State hinges on a well-defined institutional framework that includes various agencies and bodies responsible for environmental management and resource regulation. The Taraba State Ministry of Environment plays a critical role in formulating policies, implementing environmental programs, and coordinating the activities of various agencies involved in environmental protection and resource management [*Taraba State Government, 2019b*].

- The Taraba State Water Supply Agency (TSWSA) is another key institution responsible for managing water resources in the state. The TSWSA implements policies related to water supply, sanitation, and hygiene while ensuring compliance with the state's water laws. The agency collaborates with local governments to facilitate community-level water management initiatives [*Taraba State Government, 2020a*].
- Additionally, the Taraba State Environmental Protection Agency (TSEPA) is tasked with enforcing environmental regulations and conducting environmental assessments for projects

that may impact the environment. This agency is vital in promoting public awareness and stakeholder engagement in environmental governance [Umar *et al.*, 2021].

- Local government authorities also play a significant role in the implementation of environmental policies at the community level. They are responsible for local environmental management, waste disposal, and ensuring that local development initiatives comply with environmental regulations [Taraba State Government, 2020b].
- In recent years, there has been a push for enhanced collaboration among governmental institutions, NGOs, and community-based organizations to foster integrated resource management approaches that consider the diverse needs of the population while promoting sustainable practices [Federal Ministry of Environment, 2019a].

Nasarawa State

Institutional Framework

- The governance of environmental and natural resource management in Nasarawa State involves various institutions at both state and local levels. The Nasarawa State Environmental Protection Agency (NSEPA) is responsible for implementing environmental policies, conducting environmental assessments, and monitoring compliance with environmental regulations. NSEPA works in collaboration with other agencies, such as the Nasarawa State Ministry of Environment and Natural Resources, which oversees the formulation and implementation of environmental policies (Ogunbode *et al.*, 2020).
- Additionally, the state has established local government environmental units that facilitate the implementation of environmental policies at the grassroots level. These units are tasked with monitoring local environmental conditions, raising public awareness about environmental issues, and enforcing compliance with state regulations (Jibunoh, 2020b).

Governance Structures

Effective governance structures are essential for coordinating the activities of various institutions involved in environmental management. The state government has established inter-agency committees that bring together relevant stakeholders, including government agencies, non-governmental organizations (NGOs), and community representatives, to discuss and address environmental challenges (Nasarawa State Government, 2022b). These committees foster



collaboration and information sharing, enhancing the effectiveness of environmental governance in Nasarawa State.

CHAPTER 9 INFRASTRUCTURE AND ASSETS

9.1 Water Supply and Treatment Infrastructure in the Catchment

Water Supply and Treatment Infrastructure

Plateau State

Water supply infrastructure in Plateau State is vital for ensuring access to clean and potable water for its population. The state's water resources are primarily derived from surface water sources, including rivers, streams, and dams, as well as groundwater sources. The Plateau State Water Board (PSWB) is responsible for the provision and management of public water supply across the state.

- **Water Sources:** The main sources of water supply in Plateau State include the Lamingo Dam, Kura Falls Dam, and the Jos Plateau Reservoirs, which provide water for domestic, agricultural, and industrial use. Groundwater is also an important source, particularly in rural areas, where boreholes and wells are commonly used [Adeoye *et al.*, 2019]. The availability of water varies across the state, with some areas facing challenges due to the uneven distribution of water resources and infrastructure.
- **Water Treatment Facilities:** The water treatment infrastructure in Plateau State includes several treatment plants that are responsible for treating raw water to meet the standards for safe drinking water. The treatment process typically involves coagulation, sedimentation, filtration, and disinfection. The Lamingo Water Treatment Plant, for example, serves the city of Jos and its environs, providing treated water to a significant portion of the state's population [Ojo & Ayodele, 2020]. However, the capacity of these facilities is often strained due to increasing demand and aging infrastructure.
- **Challenges in Water Supply:** One of the key challenges in water supply infrastructure in Plateau State is the inadequate and aging distribution network, which results in frequent water shortages and disruptions. In many rural areas, access to clean water is limited, leading to reliance on untreated surface water, which poses health risks. Additionally, the state's water supply infrastructure is vulnerable to environmental factors such as drought and pollution, which can affect the quantity and quality of available water [Adebayo & Usman, 2017].

Benue State

Water supply infrastructure in Benue State remains underdeveloped, especially in rural areas where access to clean water is limited. Most residents in the state rely on rivers, streams, and shallow wells for water supply. The Benue River, which runs through the state, is a major source of water, but treatment facilities are limited. The urban areas, particularly Makurdi, the state capital, have a more developed water supply infrastructure, but even these systems are often insufficient to meet the growing demands of the population.

Urban Water Supply

In urban areas like Makurdi, water supply is managed by the Benue State Water Board, which operates a few major water treatment plants. One of the main treatment facilities is the Greater Makurdi Water Works, which draws water from the Benue River. This facility, with a capacity of 50,000 cubic meters per day, provides treated water to Makurdi and its environs. However, challenges such as frequent breakdowns, aging infrastructure, and power outages limit its efficiency (*Ogah, 2019*). The treatment process in these plants involves filtration, sedimentation, and chlorination to ensure water quality before distribution. However, due to insufficient funding and maintenance issues, the distribution network is often plagued with leakages and water loss, reducing the availability of potable water to urban households (*Ajene, 2020*). Consequently, many residents rely on private boreholes, sachet water, or untreated river water, which raises concerns about water quality and public health.

Rural Water Supply

Rural water supply in Benue State is largely informal and community-based. The state government, along with development partners, has implemented several projects aimed at improving rural water access, such as the construction of boreholes and hand-dug wells. The Benue State Rural Water Supply and Sanitation Agency (BERWASSA) plays a key role in these initiatives, often working with international NGOs to drill boreholes in hard-to-reach areas (*Ogunbiyi, 2021*). Despite these efforts, many rural communities still lack access to clean water, and seasonal water shortages during the dry season exacerbate the situation.

Taraba State

Water supply in Taraba State is primarily sourced from surface water bodies, groundwater aquifers, and boreholes. The state government, in collaboration with various non-governmental organizations (NGOs) and international partners, has made significant investments in water supply infrastructure to enhance access to clean and potable water. The Taraba State Water Supply Agency (TSWSA) is the

principal body responsible for the development and management of water supply services in the state [Taraba State Government, 2019a].

The major towns, including Jalingo, the state capital, and Wukari, have centralized water treatment plants that process water from nearby rivers and boreholes. For instance, the Jalingo Water Treatment Plant has the capacity to supply approximately 15 million liters of water per day, catering to the needs of urban residents and institutions [Nigerian Urban Water Sector Reform Project, 2016]. Despite these efforts, water supply remains a challenge in rural areas, where access to potable water is still limited. Many rural communities rely on untreated surface water sources, which pose health risks due to contamination from agricultural runoff and other pollutants [Taraba State Government, 2019b].

The effectiveness of water treatment facilities is often hindered by inadequate funding, maintenance issues, and a lack of technical expertise. This has led to frequent breakdowns of infrastructure, limiting the capacity to meet the growing demand for water in the state [Akinola & Adeola, 2014]. Furthermore, the distribution network within urban centres is often outdated and inefficient, leading to water losses due to leaks and illegal connections, further complicating the situation [World Bank, 2018].

Nasarawa State

Access to clean water is a fundamental necessity for public health and economic productivity. In Nasarawa State, the primary sources of water supply include rivers, boreholes, and wells. The state government has recognized the critical need to improve water supply systems, particularly in rural areas where access to potable water remains a challenge. According to the Nasarawa State Water Board, various initiatives have been implemented to expand and upgrade the water supply infrastructure (Nasarawa State Government, 2021).

Water Treatment Facilities

Water treatment is vital to ensuring that water supplied to residents is safe for consumption. Nasarawa State operates several water treatments plants, the most notable being the Lafia Water Treatment Plant, which processes water from the Doma Dam. This facility has a capacity to supply over 100,000 liters of treated water daily, serving urban and peri-urban areas (Okanlawon, 2020). However, many rural communities still rely on untreated sources, leading to health concerns related to waterborne diseases.

Challenges in Water Supply and Treatment

Despite the progress made, several challenges hinder effective water supply and treatment in Nasarawa State. Aging infrastructure, inadequate funding, and maintenance issues often lead to inconsistent

water supply. Additionally, seasonal variations in water availability and pollution from agricultural runoff impact the quality of water sources (*Nasarawa State Government, 2021*). The state government continues to seek partnerships and investments to enhance water treatment facilities and expand access to clean water.

9.2 Wastewater Management Infrastructure

Plateau State

Wastewater management in Plateau State is a critical component of the state's environmental and public health infrastructure. Proper management of wastewater is essential for preventing water pollution, protecting public health, and preserving the environment.

Sewerage Systems: The sewerage infrastructure in Plateau State is primarily concentrated in urban areas such as Jos, where centralized sewer systems exist to collect and transport wastewater for treatment. However, these systems are often inadequate to meet the needs of the growing population, and many areas still rely on septic tanks, soak-away pits, and open drains for wastewater disposal [*Ojo & Ayodele, 2020*]. The lack of a comprehensive and modern sewerage system contributes to environmental pollution and health hazards.

Wastewater Treatment Facilities: The state has a limited number of wastewater treatment facilities, most of which are outdated and operate below capacity. The Jos Central Sewage Treatment Plant, for instance, was designed to treat wastewater from the city's central areas but has faced operational challenges due to insufficient maintenance and funding. As a result, untreated or partially treated wastewater is often discharged into rivers and streams, leading to contamination of water sources [*Adeoye et al., 2019*].

Challenges in Wastewater Management: The main challenges in wastewater management in Plateau State include inadequate infrastructure, poor maintenance, and lack of investment in modern treatment technologies. The reliance on informal and unregulated wastewater disposal methods exacerbates environmental pollution, particularly in peri-urban and rural areas. Moreover, the state's hilly terrain and scattered settlements complicate the development of a comprehensive wastewater management system [*Adebayo & Usman, 2017*].

Benue State

Wastewater management in Benue State is underdeveloped, with limited infrastructure for the collection, treatment, and disposal of wastewater. In both urban and rural areas, much of the wastewater generated is untreated, leading to environmental contamination and public health risks.

Open defecation and the use of pit latrines are common, particularly in rural areas, while urban areas also struggle with inadequate sewage systems.

Urban Wastewater Systems

Makurdi, the capital city, has some rudimentary wastewater management infrastructure, but it is far from adequate. Most households rely on septic tanks for waste disposal, which are often poorly constructed or maintained. There is no centralized sewage system in the city, and wastewater is typically discharged into open drains or directly into the Benue River, causing pollution and degrading water quality (*Abah, 2018*). In some areas, informal wastewater treatment methods are used, such as the use of oxidation ponds or constructed wetlands, but these are limited in scope and often not properly managed. The lack of proper wastewater treatment facilities contributes to the contamination of surface and groundwater sources, posing risks to public health and the environment (*Ajene, 2020*).

Rural Wastewater Management

In rural areas, wastewater management is even more challenging. The majority of households rely on pit latrines, which are often poorly constructed and can lead to groundwater contamination. Open defecation remains a significant issue in many rural communities, despite efforts by the government and development partners to promote sanitation practices through the Community-Led Total Sanitation (CLTS) program (*Ogunbiyi, 2021*). The absence of proper sanitation and wastewater infrastructure has far-reaching consequences for public health, particularly in areas where communities rely on untreated water sources. Waterborne diseases such as cholera and typhoid are prevalent, particularly during the rainy season when floodwaters can carry contaminants into drinking water sources.

Taraba State

The management of wastewater in Taraba State is an area that requires significant attention. Currently, there is limited infrastructure for wastewater treatment, particularly in urban areas. The majority of wastewater generated from households, industries, and commercial establishments is discharged untreated into the environment, leading to pollution of water bodies and adverse health implications for residents [*Nigerian Environmental Study Action Team, 2019*].

Efforts to improve wastewater management have included the establishment of some decentralized treatment systems, particularly in Jalingo, where a pilot project was launched to demonstrate the feasibility of constructed wetlands for treating domestic wastewater [*Umar et al., 2019*]. However, these initiatives are few and often face challenges such as inadequate funding, lack of technical expertise, and limited public awareness of the importance of proper wastewater management.

The absence of a comprehensive wastewater management policy and regulatory framework further complicates the situation. Without strict regulations and enforcement mechanisms, the improper disposal of wastewater continues to pose environmental and health risks. The Taraba State Government has recognized the need for improved wastewater management systems and is in the process of developing a strategy that includes public-private partnerships to enhance service delivery [Taraba State Government, 2020a].

Nasarawa State

Current Wastewater Management Systems

Wastewater management is an essential component of urban planning and public health. In Nasarawa State, wastewater management systems are underdeveloped, particularly in rural areas where sewage treatment facilities are scarce. Most urban areas have rudimentary systems that often discharge untreated wastewater into nearby rivers, posing significant environmental and health risks (Adewumi, 2021).

Wastewater Treatment Facilities

The state government has initiated projects to improve wastewater management by constructing treatment facilities in major urban centers. The Lafia Sewage Treatment Plant, for example, was established to treat sewage from households and industries in the state capital. This facility employs biological treatment methods to reduce pollution and improve the quality of effluent released into the environment (Okanlawon, 2020). However, these facilities often operate below capacity due to limited funding and inadequate maintenance, resulting in the discharge of untreated or partially treated wastewater.

Challenges in Wastewater Management

The primary challenges in wastewater management in Nasarawa State include insufficient infrastructure, a lack of public awareness regarding sanitation practices, and inadequate regulatory frameworks. Many residents resort to open defecation due to the absence of proper sanitation facilities, exacerbating public health issues. Addressing these challenges requires a comprehensive approach that includes investment in infrastructure, community engagement, and the establishment of robust regulatory frameworks (Adewumi, 2021).

9.3 Transportation and Communication Networks

Plateau State

Transportation Networks

The road network is the backbone of transportation infrastructure in Plateau State, facilitating the movement of people, goods, and services within and beyond the state. The state's road network comprises federal, state, and local roads, which vary in condition and accessibility.

- **Major Highways and Roads:** Plateau State is served by several major highways, including the A3 highway, which connects the state to other parts of Nigeria, and the A234, which links Jos to Bauchi and other north-eastern states. These roads are critical for economic activities, particularly the transportation of agricultural produce and minerals [Ibrahim & Ahmed, 2018]. However, many of the state's roads are in poor condition due to inadequate maintenance, erosion, and heavy traffic, leading to frequent accidents and delays.
- **Rural Roads:** Rural Road networks in Plateau State are generally less developed and maintained compared to urban roads. Many rural areas are accessible only by dirt roads, which become impassable during the rainy season. The poor state of rural roads hampers agricultural productivity and access to markets, healthcare, and education [Ibrahim & Ahmed, 2018]. The state government has initiated several road rehabilitations projects, but progress has been slow due to funding constraints and logistical challenges.

Rail Networks

Rail transport in Plateau State has historically played a significant role in the transportation of goods, particularly minerals such as tin and columbite. However, the state's rail infrastructure has deteriorated over the years due to neglect and lack of investment.

- **Jos Railway Station:** The Jos Railway Station was once a hub for the transportation of minerals and agricultural products to other parts of Nigeria and for importation of goods into the state. Today, rail services in Plateau State are limited, and the existing rail lines are in poor condition, reducing their viability as a transportation option [Usman & Alhaji, 2019]. The revitalization of the rail network has been identified as a priority for enhancing economic development and reducing pressure on road infrastructure.
- **Future Prospects:** There are ongoing discussions about the potential for reviving rail transport in Plateau State, particularly through the rehabilitation of existing lines and the construction of

new ones. These efforts are part of broader national initiatives to revitalize Nigeria's rail sector and improve connectivity between regions [Usman & Alhaji, 2019].

Communication Networks

Telecommunications Infrastructure

Telecommunications infrastructure in Plateau State has seen significant development in recent years, driven by the expansion of mobile networks and internet services. This infrastructure is essential for connecting the state's population to the rest of Nigeria and the world, facilitating communication, business, and access to information.

- **Mobile Networks:** The majority of Plateau State's population relies on mobile networks for communication, with coverage provided by major telecommunications companies such as MTN, Glo, Airtel, and 9mobile. Mobile penetration in the state is relatively high, particularly in urban areas like Jos, where network coverage is robust [Ayo & Ojo, 2019]. However, rural areas often experience poor network coverage and connectivity issues, which limit access to mobile services and the internet.
- **Internet Access:** Internet access in Plateau State has been growing, driven by the expansion of mobile broadband services. In urban areas, there is increasing access to 4G networks, enabling faster internet speeds and better connectivity. However, rural areas still face challenges in accessing reliable and affordable internet services, which impacts education, business, and access to information [Ayo & Ojo, 2019]. Efforts to improve internet access in these areas include the expansion of network infrastructure and the promotion of digital literacy.

Media and Broadcasting

The media and broadcasting infrastructure in Plateau State includes radio and television stations, as well as print and online media outlets. These platforms play a crucial role in disseminating information, educating the public, and providing entertainment.

- **Radio and Television:** Radio is the most widely accessed medium in Plateau State, with numerous local stations broadcasting in English, Hausa, and other local languages. Television services are also available, with the Plateau Radio Television Corporation (PRTVC) being the state-owned broadcaster [Usman & Alhaji, 2019]. These media outlets are important for reaching a broad audience, particularly in rural areas where internet access is limited.
- **Print and Online Media:** Print media in Plateau State includes several local newspapers and magazines that cover regional news, politics, and social issues. In recent years, online media platforms have become increasingly popular, particularly among younger populations. These

platforms provide news, entertainment, and social interaction, contributing to the state's media landscape [Ayo & Ojo, 2019].

Benue State

Transportation Networks

Transportation infrastructure is a critical aspect of Benue State's economic development, as the state is a major agricultural hub and a transit route for goods and people. The transportation network in Benue comprises roads, bridges, and, to a lesser extent, rail and air transport. However, the state faces significant challenges in maintaining and expanding its transportation infrastructure, which hampers economic activities and access to essential services.

- **Road Networks:** The road network in Benue State is extensive, connecting major towns such as Makurdi, Gboko, Otukpo, and Katsina-Ala. However, many of these roads are in poor condition due to inadequate maintenance and the effects of seasonal flooding. The federal and state governments have made efforts to rehabilitate some major roads, such as the Makurdi-Gboko and Makurdi-Lafia highways, but many secondary and rural roads remain in a dilapidated state (Terna, 2019). The poor condition of roads in rural areas makes it difficult for farmers to transport their produce to markets, limiting their economic potential. During the rainy season, some roads become impassable due to flooding and erosion, further isolating rural communities and reducing access to healthcare, education, and other services (Ajene, 2020).
- **Bridges and River Crossings:** Given the prominence of the Benue River and its tributaries in the state's landscape, bridges are essential for maintaining connectivity. The Old Bridge and New Bridge in Makurdi are critical infrastructure for linking the northern and southern parts of the state. However, these bridges are under significant strain due to increasing traffic volumes, and there are concerns about their structural integrity (Terna, 2019). In rural areas, river crossings are often made using small wooden bridges or ferries, which are unreliable, particularly during the rainy season when rivers swell. The lack of proper river crossings hampers economic activities and contributes to the isolation of rural communities (Abah, 2018).
- **Rail Transport:** Benue State has some access to rail transport, with the Nigerian Railway Corporation's Eastern Line passing through Makurdi. However, the rail network is underutilized due to outdated infrastructure and irregular service. Efforts to revive the rail system as part of Nigeria's broader railway modernization program could improve transportation of goods, particularly agricultural produce, and reduce pressure on the road network (Ogah, 2019).

Communication Networks

Communication infrastructure in Benue State has improved significantly in recent years, particularly with the expansion of mobile telecommunications services. However, challenges remain in extending reliable and affordable communication services to rural areas, where network coverage is often limited.

- **Mobile and Internet Connectivity:** Benue State is served by major telecommunications providers, including MTN, Airtel, and Glo, which offer mobile voice and data services. Urban areas like Makurdi, Gboko, and Otukpo have relatively good network coverage, with 3G and 4G services available. However, in many rural areas, network coverage is weak or non-existent, limiting access to mobile communication and internet services (*Ogah, 2019*). The expansion of internet connectivity is crucial for economic development, particularly in sectors such as agriculture, where farmers can benefit from access to market information, weather forecasts, and agricultural advice through digital platforms. Efforts to expand broadband infrastructure, particularly under the National Broadband Plan, are aimed at improving internet penetration in underserved areas (*Ogunbiyi, 2021*).
- **Postal and Courier Services:** Postal services in Benue State are provided by the Nigerian Postal Service (NIPOST) and private courier companies. However, the postal system is often unreliable, particularly in rural areas where delivery services are limited. Many residents rely on private courier services for sending and receiving parcels, but these services are more expensive and less accessible in remote areas (*Abah, 2018*).

Taraba State

Transportation network

The transportation network in Taraba State is crucial for facilitating economic activities and ensuring the movement of goods and people. The state is traversed by several federal and state roads that connect major towns and facilitate trade. The Jalingo-Wukari road and the Jalingo-Takum road are among the key routes that enhance accessibility to agricultural and commercial hubs [*Nigerian Federal Roads Maintenance Agency, 2020*]. Despite the presence of these road networks, the condition of many roads in Taraba is poor, particularly during the rainy season when flooding and erosion exacerbate infrastructural decay. The lack of adequate maintenance and investment in road infrastructure has

limited economic activities, especially in rural areas, where poor access hinders farmers from transporting their produce to markets [Taraba State Government, 2020a]. In addition to road transport, Taraba State has several local airports, with the Jalingo Airport serving as the primary hub for air travel. Although it provides limited domestic flights, the airport is crucial for facilitating business and tourism within the state [Nigeria Civil Aviation Authority, 2021]. However, air transport in the state is underutilized due to insufficient investment in infrastructure and marketing efforts.

Communication infrastructure

Communication infrastructure in Taraba State has improved significantly over the past decade, with the expansion of mobile telecommunications services. Major telecommunications companies have established networks that provide mobile coverage to urban and rural areas, enhancing communication and access to information for residents [Nigerian Communications Commission, 2021]. However, internet access remains a challenge, particularly in rural areas where connectivity is often limited or non-existent. Efforts are underway to expand broadband infrastructure to improve internet access and facilitate digital inclusion across the state. The Taraba State Government is collaborating with private sector stakeholders to enhance telecommunications infrastructure and promote the use of information and communication technology (ICT) in education, health, and business sectors [Taraba State Government, 2020a].

Nasarawa State

Transportation Infrastructure

Transportation is critical for economic development, trade, and connectivity. Nasarawa State boasts a network of roads that facilitate movement within the state and connect it to neighboring regions. The state has a mix of federal, state, and local roads, with major highways such as the Akwanga-Lafia Road and the Lafia-Keffi Road serving as critical transport corridors (Jibunoh, 2020b). The state government has prioritized road construction and rehabilitation to enhance access to rural communities and improve economic opportunities. However, many rural roads remain unpaved and in poor condition, limiting access to markets and essential services (Okanlawon, 2020).

Public Transportation

Public transportation in Nasarawa State primarily relies on taxis, motorcycles (popularly known as "Okada"), and buses. While these modes of transport provide essential services, the lack of regulation and oversight often leads to safety concerns and inefficiencies. The government is working to improve public transportation systems by introducing measures to enhance safety and accessibility (Nasarawa State Government, 2021).

Communication Networks

Effective communication is vital for economic growth and social interaction. In Nasarawa State, telecommunication services have expanded significantly in recent years, with several mobile network providers operating in the region. However, access to reliable internet services remains limited, particularly in rural areas where connectivity is poor (*Adewumi, 2021*). The state government has initiated efforts to improve communication infrastructure by partnering with telecommunications companies to expand network coverage and enhance internet access.

CHAPTER 10 SHARED VISION

SHEMANKAR-KATSINA-ALA CATCHMENT

GOAL

To establish a harmonized mechanism for resource utilization driving collective actions towards sustainable development

OBJECTIVES

1. To improve water quality by enhanced technology on periodic water analysis on the catchment area by 2029
2. To promote sustainable land use mechanisms relatable to the catchment area
3. To adopt clean behavioral techniques to preserve catchment area biodiversity and ecological integrity
4. To improve the livelihoods of the communities through shared prosperity and empowerment
5. To achieve climate change impact resilience on the catchment area through enhancing traditional ecological knowledge
6. To ensure gender considerations are integrated onto catchment management through equal rights to information, knowledge and rights on decision making.

STAKEHODLER ENGAGEMENT

Relevant MDAs, Local Communities, Private organisations, NGOs, and Academic Institutions

MDAs:

- a. Relevant MDAs on the catchment area will foster effective resource management by enhancing developed policies through funding, technical support and periodic efficient monitoring
- b. Local communities will be involved actively in decision making and support conservation measures with traditional and indigenous practices.
- c. Private businesses will be expected to adopt sustainable practices on their activities and also invest on collaborative strategies in their host catchment areas.
- d. Existing NGOs will be engaged in raising awareness, conducting research and advocating for policy changes and provision of technical assistance
- e. Academic institutions will be engaged on research, technical expertise and professional trainings.

WATER MANAGEMENT

- a. Water management strategies should be domesticated in the catchment area such as the Clean Nigeria Campaign.
- b. Stakeholders should be involved in strategy implementations
- c. Watershed protection should be enhanced and reviewed so as to prevent conflict.
- d. Water treatment facilities should be provided to reduce pollution
- e. Capturing rainwater through water harvesting should be harnessed for irrigation and household utilization.
- f. The catchment area can explore inter basin transfers to meet demand of areas that lack water
- g. Water pricing will be considered for cost benefit incentive to foster efficient use
- h. The adoption of more efficient irrigation systems will be promoted through drip irrigation or sprinkler systems
- i. Construction of hydro dam at Kamwai (Bokkos LGA), Agro Dam at Kwa (Quan Pan LGA)

LAND USE

- a. Constant review and formalization of artisanal miners on the catchment area will be adopted
- b. Mechanisms to check the quality of agro chemicals to reduce the cases of fake products
- c. Agro-ecology to be adopted to mimic natural ecosystems and enhance biodiversity and improve soil quality
- d. The use of technology to optimize resource use, reduce waste and increase yields.
- e. Habitat restoration through afforestation programs and protection of wetlands.
- f. Implement measures to reduce impact of climate change by adaptation mechanisms that are community based
- g. To enhance green implementation of programs such as green spaces, urban forestry and green infrastructure.

ENVIRONMENTAL PROTECTION

- a. Effective land reclamation strategies will be insisted on through awareness campaigns, stakeholder engagement and regulations.
- b. Establishing and managing green areas, special ecosystems, and biodiversity.
- c. Endangered and threatened species through habitat conservation and community based initiatives.
- d. Ex-situ conservation where species can be conserved through genetic material seeds, botanical gardens.

- e. Preserving wetlands on the catchment area to provide habitat variety and regulate water flows.
- f. Tree planting strategies
- g. Special ecosystem at Takas (Pankshin LGA) where Cycad bee specie has thrived for millions of years.
- h. Investment in reusable solar energy at Anguwan Kuda at Shendam LGA
- i. Creation of state parks at shendam and Mikang LGAs.

COMMUNITY BENEFITS

- a. Cooperate social responsibilities should be demanded for mining communities and other establishments hosted by the catchment area.
- b. Environmental protection measures should include ecotourism and sustainable agriculture to stimulate local economies.
- c. Apply sustainable strategies for clean environment so as to improve health
- d. Community based shared responsibility initiatives to effect sustainability
- e. Environmental protection should involve cultural heritage preservation.
- f. Gender inclusion for equity and effectiveness will be enhanced.

ECONOMIC DEVELOPMENT

- a. To adapt improved technologies for dam construction in the catchment area so as to manage water resources effectively.
- b. Rural economies will be stimulated through construction of accessible road infrastructure
- c. International market informations should be shared to rural producers
- d. Invest in ICT infrastructure to facilitate business operations, education and communication.
- e. School, tourism, renewable energy should be improved and invested on.

CLIMATIC CHANGE RESILIENCE

- A. Smart agricultural practices such as precision agriculture will be harnessed
- B. Construction of flood control infrastructure should be enhanced, drainages, dams and barricades.
- C. Adopting a holistic approach to water management that considers supply demand and quality
- D. Leveraging local knowledge and traditional practices to develop
- E. Early warning syatems
- F. Using climate resilient crop varieties that are tolerant
- G. Awareness and enlightenment

MONITORING AND EVALUATION

- a. The catchment area will define measurable targets for key outcomes
- b. M and E results will be used to inform decision making and adjustments to policies
- c. Consistent evaluation of policies to fit into global standards
- d. Involve local communities on the implementation of policies
- e. Identifying and resolving conflicts to endure a coherent and effective approach
- f. Reduce burning of hydroactive materials in the environment e.g. Tyres through campaign and awareness creation
- g. Inclusiveness with people living with disabilities.

ENDORSEMENT PAGE

SHEWAN/AN - KAGIWA-ALA ATTACHMENT
SHARED VISION 21/04/24

Sr	NAME	STATE INSTITUTION	Gsm LINE
1.	Angbashim Y. Ishaku	Nasarawa	08066879235
2	Agbu BULUS	Treba Acre	07032646644
3	Bitrus K. Hasea	Plateau state Tourism Corporation.	09052445004
4.	Simon Jafra Nathaniel	Plateau state Acrend farmers Group	08038320054
5	Dashhat Geoffrey D	Plateau state Acrend	08066025552
5	Gwang Mafwata Sunday	Plateau state MWRSE	08035758895
6	Solomon David Kaze	Plateau RUWASSA	08036514747
7	Abasi Mammen Joseph	Nasarawa RUWASSA	07036623879
8	Pem Edward	PLS - ACREND - GIS	08037837338
9.	Salamat Abubakar Ekp	FONGO - NAS	08069079508
10	Jafar Usman	MT-yeti A/G NAS/staff	07036329115
11.	Ibrahim Aminu Abuballi	FONGO - NAS STATE	08143033117

STAKEHOLDER ENGAGEMENT PHOTOS





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GLOSSARY

Glossary of Key Terms

Term	Definition
Adaptive Management	A flexible approach to resource management that allows for adjustments based on monitoring results, stakeholder feedback, and changing environmental or socio-economic conditions.
Afforestation	The process of planting trees in areas where there were no forests previously, often to restore ecosystems, sequester carbon, or prevent soil erosion.
Agroforestry	A land-use system that integrates trees and shrubs with crops and/or livestock to enhance productivity, biodiversity, and sustainability.
Aquifer	An underground layer of water-bearing rock or sediment from which groundwater can be extracted for use.
Baseflow	The portion of streamflow that comes from groundwater seepage into streams, maintaining flow during dry periods.
Best Management Practices (BMPs)	Techniques or measures used to reduce pollution and manage water resources sustainably, such as buffer strips or sediment traps.
Biochemical Oxygen Demand (BOD)	A measure of the amount of oxygen consumed by microorganisms decomposing organic matter in water, indicating pollution levels.
Biodiversity	The variety of plant and animal life in a particular habitat or ecosystem, essential for maintaining ecological balance and resilience.
Buffer Zone	A designated area of vegetation or land that acts as a barrier to reduce pollution, control erosion, and protect water bodies from contaminants.
Capacity Building	The process of strengthening the skills, knowledge, and abilities of individuals, organizations, or communities to achieve their goals effectively.
Carbon Sequestration	The process of capturing and storing atmospheric carbon dioxide, often through reforestation, afforestation, or soil management, to mitigate climate change.
Carrying Capacity	The maximum population size of a species that an environment can sustain indefinitely, given the available resources.
Catchment Delineation	The process of defining the boundaries of a watershed using topographic and hydrological data.

Catchment Management Plan (CMP)	A strategic document outlining actions to manage land, water, and other natural resources within a specific catchment area, balancing environmental, social, and economic needs for sustainable development.
Channelization	The artificial straightening or modification of a river or stream, often to control flooding but sometimes leading to ecological harm.
Climate Adaptation	Actions taken to adjust to the impacts of climate change, such as building flood defenses, developing drought-resistant crops, or improving water management systems.
Climate Mitigation	Efforts to reduce or prevent greenhouse gas emissions, such as using renewable energy, improving energy efficiency, or reforestation.
Climate Resilience	The ability of a system, community, or ecosystem to anticipate, prepare for, and adapt to climate-related risks and recover from their impacts.
Community-Based Organizations (CBOs)	Local groups or associations that work to address community needs and challenges, often playing a key role in implementing development projects.
Desertification	The process by which fertile land becomes desert, typically due to drought, deforestation, or inappropriate agriculture.
Discharge	The volume of water flowing through a river or stream per unit of time (e.g., cubic meters per second).
Ecological Footprint	A measure of human demand on Earth's ecosystems, comparing the resources consumed to the planet's capacity to regenerate them.
Ecosystem Services	The benefits that humans derive from ecosystems, such as clean water, air, food, and climate regulation.
Environmental Degradation	The deterioration of the environment through depletion of resources, destruction of ecosystems, and pollution, often caused by human activities.
Environmental Impact Assessment (EIA)	A process used to evaluate the potential environmental effects of a proposed project or development before it is carried out.
Erosion	The process by which soil and rock are removed from the Earth's surface by natural forces such as wind, water, or human activities, often leading to land degradation.
Eutrophication	The excessive growth of algae and other plants in water bodies due to nutrient pollution, often leading to oxygen depletion and harm to aquatic life.
Evapotranspiration (ET)	The combined process of water evaporation from soil and transpiration from plants, a key component of the water cycle.

Floodplain	A flat area of land adjacent to a river or stream that is prone to flooding, often rich in biodiversity and fertile soil.
Geographic Information System (GIS)	A computer-based tool for mapping and analyzing spatial data, widely used in catchment management.
Greenhouse Gas (GHG)	Gases that trap heat in the atmosphere, contributing to global warming and climate change. Examples include carbon dioxide (CO ₂), methane (CH ₄), and nitrous oxide (N ₂ O).
Groundwater Recharge	The process by which water from precipitation or surface water percolates into the ground, replenishing aquifers and maintaining water availability.
Gully Erosion	Severe erosion where water cuts deep channels into the soil, often due to poor land management.
Hydraulic Conductivity	A measure of how easily water can move through soil or rock, important for groundwater studies.
Hydrological Cycle	The continuous movement of water on, above, and below the Earth's surface, including processes such as evaporation, condensation, precipitation, and runoff.
Hydrological Modeling	The use of mathematical models to simulate and predict the movement and distribution of water within a catchment or watershed.
Infiltration	The process by which water soaks into the soil from the surface.
Instream Flow	The water flow required to maintain aquatic ecosystems and downstream water needs.
Integrated Catchment Management (ICM)	A holistic approach to managing land, water, and other natural resources within a catchment, considering social, economic, and environmental factors.
Integrated Water Resources Management (IWRM)	A holistic approach to managing water resources that considers social, economic, and environmental factors, promoting sustainable and equitable use.
Land Degradation	The decline in land quality caused by human activities, such as deforestation, overgrazing, and poor agricultural practices, leading to reduced productivity and ecosystem health.
Land Tenure	The system of rights and institutions that govern access to and use of land, including ownership, leasing, and communal arrangements.
Land Use/Land Cover (LULC)	Categories describing how land is utilized (e.g., forest, agriculture, urban) and its surface characteristics.

Livelihood Diversification	The process by which households or communities expand their income sources to reduce dependence on a single activity, enhancing resilience to economic and environmental shocks.
Livelihood Resilience	The ability of households or communities to withstand and recover from economic, environmental, or social shocks, often through diversified income sources and adaptive strategies.
Microcredit	Small loans provided to low-income individuals or groups to support income-generating activities, often used to promote entrepreneurship and poverty alleviation.
Multidimensional Poverty Index (MPI)	A measure of poverty that considers multiple deprivations in health, education, and living standards, providing a comprehensive understanding of poverty beyond income levels.
Non-Governmental Organizations (NGOs)	Non-profit organizations that operate independently of government, often focused on social, environmental, or developmental issues.
Normalized Difference Vegetation Index (NDVI)	A remote sensing indicator used to assess vegetation health and density by measuring the difference between near-infrared (NIR) and red light reflectance. Higher values indicate healthier vegetation.
Participatory Approach	A methodology that involves stakeholders in decision-making processes, ensuring their perspectives and needs are considered.
Peak Flow	The highest discharge rate in a stream or river during a rainfall or snowmelt event.
Permeability	The ability of soil or rock to allow water to pass through it.
Public-Private Partnership (PPP)	A collaborative arrangement between government agencies and private sector entities to deliver public services or infrastructure projects.
Rainwater Harvesting	The collection and storage of rainwater for later use, such as irrigation, drinking water, or groundwater recharge.
Reforestation	The process of replanting trees in areas where forests have been depleted or degraded, aiming to restore ecosystem functions and biodiversity.
Resilience	The capacity of a system, community, or ecosystem to absorb disturbances, adapt to change, and continue to function effectively.
Riparian Zone	The interface between land and a river or stream, often rich in biodiversity and critical for water quality and ecosystem health.
Rotational Grazing	A livestock management practice where animals are moved between different grazing areas to allow vegetation recovery and prevent overgrazing.

Runoff	Water that flows over the land surface rather than infiltrating into the soil, often carrying pollutants.
Sediment Load	The amount of sediment carried by a river or stream, affecting water quality and aquatic habitats
Sedimentation	The deposition of soil, sand, and other particles carried by water, which can reduce water quality, clog waterways, and harm aquatic ecosystems.
Socio-Economic Indicators	Metrics used to measure the social and economic conditions of a population, such as income levels, education, health, and employment rates.
Soil Conservation	Practices aimed at preventing soil erosion and degradation, such as contour plowing, terracing, and cover cropping.
Soil Fertility	The ability of soil to sustain plant growth by providing essential nutrients, water, and a suitable physical structure.
Stakeholder Engagement	The process of involving individuals, groups, or organizations affected by or interested in a project or decision, ensuring their input and participation in planning and implementation.
Stakeholder Forum	A platform for dialogue and collaboration among stakeholders, often used to share knowledge, discuss challenges, and develop solutions.
Stakeholder Mapping	The process of identifying and analyzing stakeholders to understand their interests, influence, and potential impact on a project.
Streamflow	The flow of water in a natural channel, influenced by precipitation, groundwater, and land use.
Subsidence	The sinking of land due to groundwater over-extraction or soil compaction.
Sustainable Agriculture	Farming practices that meet current food needs without compromising the ability of future generations to meet theirs, often emphasizing soil health, water conservation, and biodiversity.
Sustainable Development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs, balancing economic, social, and environmental goals.
Traditional Knowledge	Knowledge, practices, and beliefs developed by indigenous and local communities over generations, often used to manage natural resources sustainably.
Total Dissolved Solids (TDS)	A measure of the combined content of inorganic and organic substances dissolved in water, affecting quality.

Transboundary Water Management	Cooperative management of shared water resources (e.g., rivers, aquifers) between countries or regions.
Water Allocation	The regulated distribution of water resources among competing users (e.g., agriculture, industry, households).
Water Balance	An accounting of all water inputs (precipitation) and outputs (evapotranspiration, runoff) in a catchment.
Water Footprint	The total volume of freshwater used to produce goods and services consumed by an individual, community, or organization.
Water Quality	The chemical, physical, and biological characteristics of water, determining its suitability for specific uses such as drinking, irrigation, or ecosystem health.
Water Scarcity	A condition where the demand for water exceeds the available supply, often exacerbated by population growth, climate change, and poor water management.
Water Table	The upper surface of the zone of saturation in the ground, where the soil or rocks are permanently saturated with water.
Water Use Efficiency (WUE)	The ratio of beneficial water use (e.g., crop yield) to total water applied, indicating sustainable practices.
Watershed	An area of land that drains all precipitation and surface water into a common outlet, such as a river, lake, or ocean. Synonymous with "catchment."
Wetland	An area of land that is saturated with water, either permanently or seasonally, supporting unique ecosystems and providing services such as flood control and water filtration.
Wetland Restoration	The process of returning a degraded wetland to its natural state to improve water quality and biodiversity.
Zoning	The process of dividing land into areas with specific land-use regulations, such as residential, agricultural, or conservation zones.