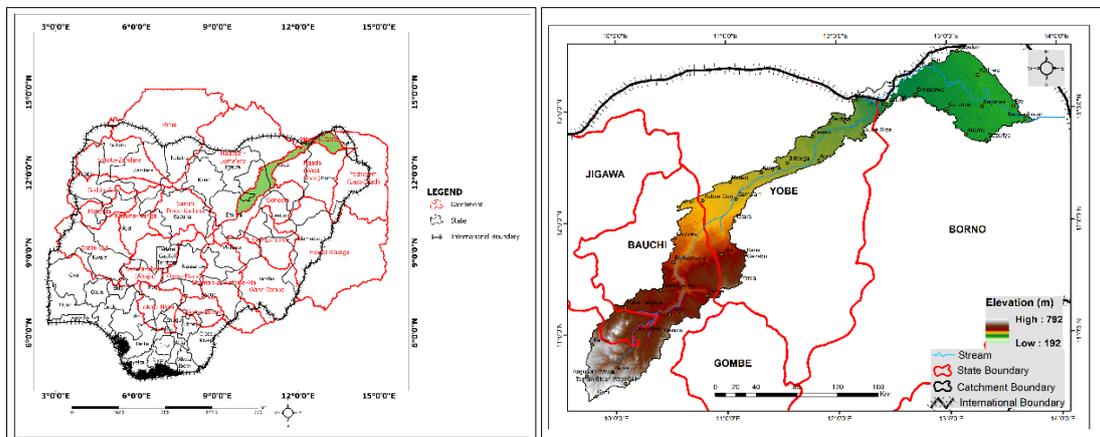


MISAU-KOMADUGU-GANA STRATEGIC CATCHMENT MANAGEMENT PLAN REPORT



MARCH, 2025

TABLE OF CONTENTS

ABBREVIATIONS AND ACRONYMS	x
EXECUTIVE SUMMARY	xiii
Chapter 1 : INTRODUCTION.....	1
1.1 Purpose for the Plan	1
1.2 Rationale for a Strategic Catchment Plan	1
1.3 Expected Outcomes	2
1.4 Sustainable Catchment Management Roles.....	2
1.5 Environmental Roles.....	2
1.6 Socio-Economic Roles.....	3
1.7 Governance and Institutional Roles	3
1.8 Catchment Policies.....	3
Chapter 2 : CHARACTERISTICS OF THE CATCHMENT	7
2.1 Location	7
2.1.1 Location and Boundary	7
2.2 Precipitation, Temperature, Sunshine, and Relative Humidity	8
2.2.1 Precipitation	8
2.2.2 Temperature	8
2.2.3 Sunshine Duration.....	10
2.2.4 Relative Humidity	11
2.3 Topography, Drainage, Geology and Soil Types	12
2.3.1 Topography	12
2.3.2 Drainage	12
2.3.3 Geology and Soil Types	16
2.4 Land Use and Land Cover	19
2.4.1 Agricultural Land Use.....	20

2.4.2 Pastoralism.....	21
2.4.3 Forest and Woodlands.....	21
2.4.4 Urban and Built-Areas.....	22
2.4.5 Wetlands and Waterbodies.....	22
2.4.6 Desertification and Land Degradation.....	22
2.4.7 Mineral Extraction.....	22
2.4.8 Biodiversity and Ecosystem Summary.....	23
2.5 Hydrology and Water Resources.....	25
2.5.1 Hydrology.....	25
2.5.2 Hydrograph/Water Budget of the Catchment.....	26
2.5.3 Water Resources Assessment Concept in the Catchment.....	30
2.5.4 Hydrogeological Disposition of the Catchment.....	32
2.6 Water Demand for Misau-Komadugu Catchment.....	35
2.6.1 Water Availability by Sub-basin.....	35
2.6.2 Rainfall Data for Misau-Komadugu Catchment.....	35
2.6.3 Water Use and Demands.....	36
2.6.4 Municipal Water Demand.....	37
2.6.5 Livestock Water Demand.....	38
2.6.6 Irrigation water demand.....	39
2.6.7 Water Demand Vs Total Available Water.....	39
2.6.8 Total Water Demand.....	41
2.6.9 Infrastructure and Assets.....	43
2.7 Water Quality.....	58
2.7.1 The Misau-K.Gana Catchment.....	58
2.7.2 Surface Water Quality.....	58
2.7.3 Groundwater Quality.....	68
2.8 Climate Change Impact on Water and Land Resources.....	72

2.8.1 Historical and Future Climatic Trend	72
2.8.2 Projected Annual Rainfall for The Misau K-Gana Catchment	75
2.8.3 Projected Mean Annual Temperature for The Misau K-Gana Catchment.....	76
2.8.4 Analysis of Downscaled Output of GCMs.....	78
2.8.5 Projected Annual Evapotranspiration for The Misau K-Gana Catchment.....	79
2.8.6 Major Impacts of Climate Change	80
2.8.7 National and International Climate Change Frameworks/Agreements	81
2.9 Flood and Drought Vulnerability	85
2.9.1 The Digital Elevation Map (DEM)	85
2.9.2 Slope map.....	86
2.9.3 Rainfall map.....	87
2.9.4 Proximity to water sources.....	88
2.9.5 LULC	89
2.9.6 Flood Risk.....	90
2.10 Socio-Economic Dynamics.....	94
2.10.1 Population Distribution and Growth.....	94
2.10.2 Demographics and Poverty	97
2.10.3 Gender Issues	103
Chapter 3 : STAKEHOLDER ENGAGEMENT AND GOVERNANCE	105
3.1 Methodology	105
3.2 Key Stakeholders Engaged	105
3.3 Major Topics for Stakeholder Discussions	107
3.4 Key Points of Stakeholder Engagement	108
3.5 Coordination Mechanisms	110
Chapter 4 : STRATEGIC VISION AND GOALS	113
Chapter 5 : STRATEGIC CHALLENGES AND PRIORITY INTERVENTIONS.....	116
5.1 Key Challenges	116

5.2 Strategic Interventions	117
5.3 Expected Outcomes and Feasibility of Implementation	132
Chapter 6 : MONITORING, EVALUATION AND LEARNING	133
6.1 Data Collection Methods	133
6.2 Feedback Mechanisms	134
6.3 Data Management and Analysis.....	134
6.4 Institutional Roles and Coordination	135
6.5 Adaptive Management Process	136
6.6 Specific Indicators for Success and Potential Reporting Framework.....	140
6.7 Annual Report Template	141
Chapter 7 : CONCLUSION AND MOVING FORWARD.....	143
7.1 Summary of Strategic Issues and Priorities	143
7.1.1 Key Priorities for 2025-2027	145
7.2 Recommendations for Aligning with Broader National and Regional Programs.....	145
7.3 Catchment Policy for Interstate River Systems	147
7.4 Catchment Management Policies and Framework	151
7.4.1 Institutional Leadership and Governance	151
7.5 High-Level Funding Strategies and Partnership Opportunities	152
7.5.1 Government Budgetary Allocations and Climate Financing	152
7.5.2 National and International Climate Funds	152
7.5.3 Public-Private Partnerships (PPP).....	152
7.5.4 International Development Grants and Loans	153
7.5.5 Partnership Opportunities for Catchment Management	153
7.5.5.1 Government Agencies.....	153
7.5.5.2 International and Development Partner Collaborations.....	153
7.5.5.3 Academic and Research Institutions	154
7.5.5.4 Private Sector and NGOs	154

7.6 Moving Forward with the Catchment Plan 155

7.7 Risks and Adaptive Management..... 157

Conclusion 158

Annexes..... 159

Annex 1: Detailed Population Statistics for the Catchment..... 159

Annex 2: Threats, Challenges, Socio-Economic and Policies Linked to Water Infrastructure in the Catchment as indicated by the Stakeholders..... 160

GLOSSARY 161

REFERENCES 166

List of Figures

Figure 2.1: Misau-Komadugu-Gana Catchment showing the LGAs (MSL, 2024)----- 7

Figure 2.2: Annual Average Precipitation for Misau-Komadugu-Gana Strategic Catchment (Source: MSL, 2024) ----- 8

Figure 2.3: Average Annual Temperatures from 2000 to 2023 for the Misau K-Gana catchment (Source: MSL, 2024) ----- 9

Figure 2.4: Annual Sunshine Duration (2000 – 2023) (MSL, 2024)-----10

Figure 2.5: Annual Average Humidity for Misau K-Gana Catchment (Source: MSL, 2024) -11

Figure 2.6: Digital Elevation Model of the Catchment (Source: MSL, 2024)-----12

Figure 2.7: Drainage Map of Misau-Komadugu-Gana Catchment (Source: MSL, 2024)-----13

Figure 2.8: Map showing the Gauging Stations within the catchment (Source: MSL, 2024)-14

Figure 2.9: Map of Meteorological stations (Source: MSL, 2024)-----15

Figure 2.10: Geologic map of the catchment area (Source: MSL, 2024) -----17

Figure 2.11: Soil Map of the catchment area (Source: MSL, 2024) -----19

Figure 2.12: Land use/Land cover map of the catchment (Source: MSL, 2024)-----20

Figure 2.13: Map showing the vegetation cover in the catchment area (Source: MSL, 2024)21

Figure 2.14: Hydrograph of Misau Strategic Catchment Based on HEC-HMS modelling for Strategic Catchment. (Source: MSL 2024) -----26

Figure 2.15: 40 Years Summary Hydrograph of Misau Strategic Catchment (Source: MSL, 2024) -----27

Figure 2.16: Hydrograph of Misau Strategic Catchment for Specific Year (Source: MSL, 2024) -----27

Figure 2.17: Water Budget for Misau Strategic Catchment (Source, MSL, 2024)-----28

Figure 2.18: Monthly Actual Evapotranspiration Distribution for the Misau Catchment ----28

Figure 2.19: Hydrogeological provinces of the catchment (Source: MSL, 2024) -----32

Figure 2.20: Misau Komadugu-Gana Catchment chart (Source: MSL, 2024) -----37

Figure 2.21: Mean monthly temperatures from 1981 to 2022 and 2023 to 2050 for the Misau K-Gana catchment-----74

Figure 2.22: Projected Annual Trend (1981-2050) for the Misau K-Gana catchment (Source: MSL, 2024)-----76

Figure 2.23: Projected Mean Annual Temperature Trend (1981-2050) for the Misau K-Gana catchment (Source: MSL, 2024) -----77

Figure 2.24: Trend in Evapotranspiration for Misau K-Gana Catchment. -----80

Figure 2.25: The flow chart of the methodology -----85

Figure 2.26: Digital Elevation Model (Source: MSL, 2024)-----86

Figure 2.27: Slope map of the catchment -----87

Figure 2.28: Rainfall map of the Catchment (Source: MSL, 2024)-----88

Figure 2.29: Distance to River Map (Source: MSL, 2024)-----89

Figure 2.30: LULC Map of the Catchment (Source: MSL, 2024) -----90

Figure 2.31: Risk Level map of the Catchment -----91

Figure 2.32: Flood Vulnerability Map of the Catchment (Source: MSL, 2024) -----92

Figure 2.33: LULC bar chart (Source MSL 2024)-----93

Figure 2.34: Population projection Graph of the Catchment (Source: MSL, 2024) -----95

Figure 5.1: Strategic Catchment Management Plan ----- 123

Figure 5.2: Component 1 (Sustainable Conservation Management and Use of Water Resources) ----- 124

Figure 5.3: Component 2 (Preservation and Restoration of Critical Ecosystems and Services for Sustainable land Use)----- 125

Figure 5.4: Component 3 (Improved Diversification for Enhanced Sustainable Livelihoods and Well-Being) ----- 126

Figure 5.5: Component 4 (Climate Resilience, Disaster Risk Management Framework and Climate Resilient Infrastructure) ----- 127

Figure 5.6: Component 5 (Strengthening Institutional Mechanisms and Project Coordination Mechanisms) ----- 128

Figure 5.7: Component 6 (Mainstreaming Gender Equality and Social Inclusion (GESI) Mechanism) ----- 129

Figure 5.8: Component 7 (Research & Extension Framework For Strategic Catchment Management Plan) ----- 130

Figure 5.9:Component 8 (Robust Monitoring and Reporting System For The Strategic Catchment Management Plan) ----- 131

List of Tables

Table 2.1: Summary table of the Biodiversity of the Catchment -----23

Table 2.2: Summary of Discharge, Rainfall and Evapotranspiration Data for Misau Strategic catchment -----29

Table 2.3: Groundwater Recharge and Groundwater Demand (2030)-----34

Table 2.4. Groundwater Recharge and Demand by effect of climate (2030) -----34

Table 2.5: Cumulative annual flow volume (million cubic meters, or MCM) for Misau-Komadugu Catchment sub-basins -----35

Table 2.6: Rainfall Data for Misau-Komadugu Strategic Catchment-----36

Table 2.7. Water supply use by 2017 in the catchment -----37

Table 2.8: Water Balance for Komadugu Catchment -----40

Table 2.9: Total water allocated Vs. Water available per resource – Komadugu Catchment--40

Table 2.10: Total water demand in the Misau-Komadugu Catchment-----41

Table 2.11: Water Balance of the Catchment-----42

Table 2.12: Catchment Infrastructure and Assets -----43

Table 2.13: Health risks of heavy metals in groundwater -----69

Table 2.14: Preliminary Conclusion of Water Quality Status of Some Rivers within the Catchment -----71

Table 2.15: Mean Monthly Temperature for the Misau K-Gana Catchment for 1981-2022 and 2023-2050. -----73

Table 2.16: Available coupled GCMs SRES runs deployed-----78

Table 2.17: Key Impacts of Climate Change -----80

Table 2.18: Flood Risk Analysis of the Catchment-----92

Table 2.19. Summary of Misau-Komadugu-Gana Catchment -----96

Table 2.20. Catchment Demographics and Poverty -----98

Table 4.1. Misau-Komadugu Gana Catchment's Strategic Goals and Objectives for Sustainable Catchment Development ----- 114

Table 6.1: Institutional Responsibilities For MEL Tasks -----	135
Table 6.2. Monitoring and Evaluation Plan for the Misau-Komadugu Gana catchment-----	137
Table 7.1: Strategic Priorities for Implementation (2025-2027)-----	145
Table 7.2: Institutional Roles and Responsibilities -----	151
Table 7.3: Conceptual Overview- Catchment Development Fund (CDF) -----	154
Table 7.4: Next steps and key actions points -----	155
Table 7.5:Roadmap for Implementation (2025-2027) -----	158

ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	Description
°C	Degree Celsius
°F	Fahrenheit
AfDB	African Development Bank
ACReSAL	Agro-Climate Resilience in Semi-Arid Landscapes
AfDB	African Development Bank
AfDP	Agriculture Development Program
AFOLU	Agriculture, Forestry, and Other Land Use
AMSL	Above Mean Sea Level
BCM	Billion Cubic Meters
BOD	Biochemical Oxygen Demand
CBOs	Community-Based Organizations
CJTF	Civilian Joint Task Force
CMCs	Catchment Management Committees
CMO	Catchment Management Offices
CMP	Catchment Management Plan
DFID	United Kingdom's Department for International Development
DO	Dissolved Oxygen
EBA	Ecosystem-Based Adaptation
EC	Electrical Conductivity
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
ET	Evapotranspiration
FGDs	Focus Group Discussions
GCF	corporate social responsibility
GESI	Gender Equality & Social Inclusion
GHG	Greenhouse Gas
HJKYB-TF	Hadejia-Jama'are-Komadugu-Yobe Basin Trust Fund
ICJ	International Court of Justice
ITCZ	Intertropical Convergence Zone
IUCN	International Union for Conservation of Nature

IWRM	Integrated Water Resources Management
JICA	Japan International Cooperation Agency
Km	Kilometer
KPIs	Key Performance Indicators
LCBC	Lake Chad Basin Commission
LGAs	Local Government Areas
LULC	Land Use and Land Cover
MAR	Mean Annual Runoff
MCM	Million Cubic Meters
MEL	Monitoring, Evaluation, and Learning
MER	Monitoring, Evaluation, and Reporting
NASRDA	National Space Research and Development Agency
NCRS	National Centre for Remote Sensing
NDVI	Normalized Difference Vegetation Index
NEMA	National Emergency Management Agency
NESREA	National Environmental Standards and Regulations Enforcement Agency
NGOs	Non-Governmental Organizations
NIHSA	Nigerian Hydrological Services Agency
NIMET	Nigerian Meteorological Agency
NIS	Nigerian Industrial Standard
NIWA	National Inland Waterway Authority
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
NWRI	National Water Resources Institute
NWRMP	National Water Resources Master Plan
OSGOF	Office of Surveyor General
PET	Potential Evapotranspiration
PIM	Participatory Irrigation Management

PPPs	Public-Private Partnerships
PRA	Participatory Rural Appraisal
PSC	Project Steering Committee
PWD	Projected Water Demand
RBDAs	River Basin Development Authorities
RUWASSA	Rural Water Supply and Sanitation Agency
SAP	Strategic Action Plan
SAPDWR	Strategic Action Plan for the Development of Water Resources
SCMP	Strategic Catchment Management Plan
SMEs	Small and Medium Enterprises
sq.km	Square Kilometer
TDS	Total Dissolved Solids
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNEP	United Nations Environment Programme
UNFCCC	United Nations Framework Convention on Climate Change
UNHCR	United Nations High Commissioner for Refugees
UNICEF	United Nations Children’s Fund
USAID	United States Agency for International Development
WFP	World Food Programme
WFP	World Food Programme
WUAs	Water User Associations

EXECUTIVE SUMMARY

The Misau-Komadugu Gana catchment, which covers approximately 23,419 km² (2,341,900 hectares) in northeastern Nigeria, plays a crucial hydrological role in supporting regional socio-economic activities such as agriculture, aquaculture, and animal husbandry. It is an integral part of the Komadugu-Yobe Basin river system, which runs through Bauchi, Borno, Jigawa, and Yobe states in the Komadugu-Yobe Basin.

The Misau-Komadugu Gana Catchment Management Plan aims for sustainable management of water and land resources by enhancing climate resilience and improving socio-economic conditions. The strategic plan, developed from a thorough assessment of hydrological, environmental, and socio-economic factors, highlights key challenges such as growing socio-economic pressures from population growth, climate change vulnerabilities leading to droughts and floods, and increasing environmental degradation, including deforestation and soil erosion. Additionally, the catchment faces water resource constraints affecting availability and quality.

The overall vision of the Misau-Komadugu Gana Catchment Management Plan is to establish a climate-resilient, inclusive, and sustainably managed catchment that ensures equitable access to land and water resources, supports livelihoods and ecosystems, and promotes long-term resilience through integrated planning and stakeholder partnerships. The Misau-Komadugu Gana Catchment Management Plan can be achieved through the following objectives:

- i. Enhanced water resource availability through improved conservation, storage, and efficiency.
- ii. Ecosystem restoration and protection, including sustainable land use, reforestation, and wetland conservation.
- iii. Climate resilience strategies, integrating disaster risk management, adaptive farming, and resilient infrastructure.
- iv. Strengthened governance and stakeholder cooperation to support integrated water resources management.
- v. Sustainable livelihoods, promoting capacity building, alternative income opportunities and equitable allocation of resources.

To achieve these objectives, the plan outlines the following key interventions:

Water resources management involves effective irrigation techniques, groundwater monitoring to prevent over-extraction, and infrastructure development for water collection and storage.

Ecosystem protection includes large-scale reforestation, sustainable land use practices, and safeguarding wetlands to maintain biodiversity. Enhancing climate resilience entails implementing flood protection, early warning systems, climate-friendly farming, and durable infrastructure against extreme weather. Community engagement is vital, with catchment management committees for inclusive decision-making, policy frameworks for sustainable resource use, and capacity-building programs for local communities and stakeholders.

The plan aims to improve water security through better resource management, reduce environmental degradation with sustainable land practices, enhance climate resilience against floods and droughts, boost socio-economic conditions for sustainable livelihoods, and foster governance for long-term sustainability of catchment areas.

The methodologies in this plan can be scaled and adapted to other northern Nigeria watersheds under the ACREsAL Project, enhancing regional sustainability. Below are past and ongoing initiatives by government and development partners in the Misau Komadugu-Gana catchment.

Past and ongoing interventions in the catchment area.

To put things in the right context, table ES1 and figure ES1 and ES2 showcase various past and current development initiatives undertaken by the different partners involved in the Misua Komadugu Gana.

Table ES 1: Past and Ongoing Initiatives by Governments and Development Partners in Misau-Komadugu Gana Catchment

LOCATION	PAST INITIATIVE	ONGOING INITIATIVE
Komadugu Yobe	<p>Project: Komadugu Yobe Basin (KYB) project Agency: Nigerian government, UNDP and other partners Focus: Addressing water resource challenges, including conflict resolution among water users, improving water flow regulation, and enhancing agricultural productivity</p>	<p>Project: Agroclimatic Resilience in Semi-Arid Landscapes (ACReSAL) Agency: Federal and state governments, world bank. Focus: Enhancing agro-climatic resilience, improving water resource management, reforestation, and sustainable land use practices</p>
Within the entire catchment	<p>Project: National Fadama Development Project (NFDP) Agency: Federal Ministry of Agriculture and Food Security with World Bank Focus: Community-driven agricultural development, irrigation schemes, and improving rural livelihoods through sustainable land and water management.</p>	
Damaturu (Yobe State)	<p>Project: Strategic Action Plan for Water Resource Development in the Komadugu-Yobe Basin Agency: African Water Facility, Hadejia-Jama'are-Komadugu-Yobe Basin Trust Fund, Nigeria Integrated Water Resources Management Commission Focus: Integrated water resources management, reoperation of Tiga and</p>	

	Challawa Gorge dams, urban water supply, agriculture water management, aquaculture, rangeland management, and ecosystem restoration	
Yobe, Jigawa, kano and Borno states		<p>Project: Hadejia-Jama'are Komadugu-Yobe Basin Trust Fund (HJKYBTF)</p> <p>Agencies: Nigerian government and international partners.</p> <p>Focus: Promoting integrated water resource management in the Komadugu-Yobe Basin, including Hadejia-Jama'are</p>
Rigar-Jeji, Hardawa Community, Misau Local Government Area, Bauchi State	<p>Project: Rural Water Project under the Sustainable Climate Resilient WASH Programme</p> <p>Agency: WaterAid Nigeria, Global Supply Chains, and DP World</p> <p>Focus: Enhancing access to safe drinking water, sanitation, and hygiene (WASH), promoting women's economic empowerment, and improving public health through solar-powered boreholes and sanitation facilities.</p>	
Bauchi, Bauchi State	Project: Bauchi Township Water Supply Project	

	<p>Agency: African Development Bank (ADB), Bauchi State Water Board (BSWB), Federal Government of Nigeria</p> <p>Focus: Expansion of potable water supply, construction of a 45,500m³/day treatment plant, installation of pipelines and pumping stations, institutional strengthening of BSWB, and improving water accessibility and sanitation in Bauchi town.</p>	
<p>Chad Basin Development Authority: Kano, Jigawa, Yobe, Borno, Bauchi, Plateau, Adamawa Hadejia-jama'are</p> <p>River basin Development Authority: kano, Jigawa, Yobe, Borno, Bauchi, Plateau, Adamawa</p>		<p>Project: Integrated River Basin Development Programs Agencies: NEMA, SEMA, and international partners. Focus: Reducing disaster risks from floods and droughts through improved early warning systems and disaster preparedness</p>
<p>Gwange 1, 2, 3, Maiduguri Metropolitan Council (MMC), Borno State</p>	<p>Project: Borehole Drilling Project for Improved Water Access</p> <p>Agency: Borno State Government, Borno State Rural Water Supply and Sanitation Agency (RUWASSA)</p> <p>Focus: Providing safe and adequate water supply through new boreholes, benefiting local</p>	

	communities and IDPs, as part of a statewide water project.	
Tungushe Community, Konduga L.G.A, Borno State	<p>Project: Borehole Drilling Project</p> <p>Agency: Borno State Government, Borno State Rural Water Supply and Sanitation Agency (RUWASSA)</p> <p>Focus: Providing safe and reliable water supply to the community through borehole drilling.</p>	
Maiduguri, Borno State		<p>Project: Borno State Water Supply Project</p> <p>Agency: World Bank, Borno State Water Corporation (BSWC), Federal Government of Nigeria.</p> <p>Focus: Expansion of water supply infrastructure by drawing water from Lake Alau, construction of treatment and distribution facilities, strengthening BSWC, and developing a sanitation master plan for Maiduguri.</p>

<p>Gajiram, Nganzai, Borno State</p>	<p>Project: Completion of Nganzai Water Supply Project Agency: Borno State Government Focus: Provision reliable water supply to Gajiram through the completion of water infrastructure to improve access to clean water.</p>	
<p>Buni Gari, Buni Yadi, and Damaturu, Yobe State</p>	<p>Project: Buni Gari Water Treatment Plant & Buni Yadi/Damaturu Flood and Erosion Control Project Agency: Yobe State Government Focus: Provision of safe drinking water, mitigating flood and erosion impacts, supporting agriculture through irrigation, and ensuring water quality monitoring with a new Water Quality Laboratory.</p>	
<p>Gashua, Zango, and Sabon Garin Lamido, Yobe State</p>	<p>Project: Gashua Water Supply Project (Phase II) Agency: Federal Ministry of Water Resources Focus: Expansion of water supply services, installation of boreholes and solar panels, rehabilitation of water treatment plants and storage tanks, and improving water quality to address health concerns such as kidney disease prevalence in the region.</p>	
<p>Yobe</p>		<p>Project: Rural Water Supply and Sanitation Sub-Programmes Agency: African Development Fund (ADF) in partnership with the Government of Nigeria Focus: Increase access to safe drinking water and sanitation services in rural areas, strengthen institutional capacity for effective water resource management, Improve hygiene and water quality monitoring systems and enhance livelihoods through integrated water use for cattle watering and gardening</p>

<p>Potiskum, Yobe State</p>	<p>Project: Small Water Scheme in Potiskum Agency: Federal Ministry of Water Resources, Chad Basin River Basin Development Authority (RBDA) Focus: Providing improved water access through a small-scale water supply system, aimed at enhancing safe drinking water availability in Potiskum.</p>	
<p>Gorgaram, Yobe State</p>		<p>Project: Completion of Gorgaram Minor Irrigation Scheme Agency: Federal Ministry of Water Resources, Upper Benue River Basin Development Authority (RBDA) Focus: Enhancing agricultural productivity through minor irrigation infrastructure, supporting water access for farming, and promoting sustainable water resource management.</p>
<p>Dutse, Jigawa State</p>		<p>Project: Dutse Greater Water Project Agency: Jigawa State Government, Federal Government of Nigeria Focus: Providing long-term water supply solutions by drawing water from Sintilmawa River to Dutse, enhancing water distribution infrastructure, and addressing decades-long water shortages in the state capital and surrounding areas.</p>
<p>Dutse, Jigawa State</p>	<p>Project: Greater Dutse Water Supply Project Agency: Federal Government of Nigeria, Jigawa State Government, Federal Ministry of Water Resources and Sanitation Focus: Enhancing potable water access through a ₦59.5 billion water supply project, including tube wells, pumping stations, transmission pipelines, and water reservoirs, to address longstanding water scarcity and improve public health in Dutse and surrounding communities.</p>	

<p>Dutse, Jigawa State</p>		<p>Project: Greater Dutse Water Supply Project Agency: Federal Government of Nigeria, Jigawa State Government, Federal Ministry of Water Resources and Sanitation Focus: Providing clean and reliable water for over 1.5 million residents by constructing tube wells, pumping stations, water reservoirs, and a 56km water transmission network from Sintilmawa to Dutse, aimed at reducing waterborne diseases and improving socio-economic growth</p>
<p>Unguwar Tsamiya, Jigawa State</p>		<p>Project: Water Supply Scheme at Unguwar Tsamiya Agency: Federal Ministry of Water Resources, Hadejia-Jama'are River Basin Development Authority (RBDA) Focus: Improving access to clean water through the development of a water supply scheme, ensuring safe and sustainable water resources for the community.</p>
<p>Dutse, Jigawa State</p>		<p>Project: Greater Dutse Water Supply Project Agency: Federal Executive Council (FEC), Federal Ministry of Water Resources and Sanitation Focus: Providing sustainable water supply to 1.5 million residents in Jigawa</p>
<p>Within the entire catchment</p>	<p>Projects: Private Sector and Community-Based Interventions Agencies: NGOs and private organizations like Oxfam, ActionAid, and Dangote Foundation. Focus: Supporting local livelihoods, providing microfinance for women, and promoting community-led resource management</p>	<p>Projects: UN Women's Gender and Social Inclusion Projects Agencies: UN Women, Federal Ministry of Women Affairs. Focus: Promoting gender equality in resource management and empowering women in rural communities.</p>

Despite the aforementioned initiatives, there remains a widespread concern that most of the interventions within the catchment did not effectively address the development challenges in a cohesive manner. Numerous projects appeared to lack the necessary integrated approach to tackle the interconnected issues that arise from the same environmental and socio-economic development challenges. As a result, the catchment continues to face various biophysical and social problems, some of which are noteworthy as highlighted below.

Key Biophysical and Socioeconomic Challenges

Stakeholder engagement and biophysical assessments indicate that the Misau-Komadugu Gana catchment is confronted with the following significant biophysical and socioeconomic challenges.

1. Biophysical Challenges

- **Land degradation and desertification:** extensive deforestation, overgrazing and poor land management have led to increased soil erosion and declining soil fertility. Areas in Yobe and Bauchi states are experiencing accelerated desertification, leaving less land available for agriculture and pasture.
- **Depletion of Water Resources and Hydrological Variability:** long-term water security is at risk due to over-extraction and declining groundwater recharge rates brought on by climate change. Irrigation, domestic use, and livestock are all impacted by seasonal fluctuations in surface water availability, which also increases user competition.
- **Impacts of climate change:** rising temperatures and irregular rainfall patterns increase the risk of droughts and floods and destabilize agricultural productivity. Increased evaporation rates reduce overall water retention capacity in soils and wetlands and exacerbate desertification.

2. Socioeconomic Challenges

- **Conflict over land and water resources:** increasing competition between farmers and pastoralists has intensified land use conflicts, particularly in Borno and Jigawa states. These disputes are likely to worsen and endanger regional stability in the absence of better framework conditions for land administration.
- **Economic vulnerability and livelihood restrictions:** The region remains heavily dependent on rain-fed agriculture, leaving communities exposed to climate shocks. In

addition, limited access to alternative sources of income, financial support, and agricultural technology prevents economic diversification.

- **Socio-economic disparities and unsustainable livelihood practices:** High poverty rates, weak governance, and limited infrastructure access hinder the catchment's sustainable development. Over 70% of local government areas (LGAs) in the catchment experience high or very high poverty levels.
- **Weak governance:** Weak institutional frameworks, lack of coordinated water management, ineffective policy enforcement, and insufficient funding for infrastructure hinder the sustainable development of the Misua Komadugu Gana Catchment. There is also limited stakeholder engagement and inadequate involvement of traditional governance structures. Although institutions aim for inclusivity, they fail to empower women and marginalized groups to challenge existing power structures and gender norms. For sustainable development, the active participation of all stakeholders is essential, requiring effective coordination during implementation. Additionally, improved upstream and downstream linkages within the watershed could serve as a model for other river basins in the country.

Inadequate infrastructure and weak governance hinder agricultural productivity and economic growth, with inefficient irrigation systems, poor road networks, and limited access to clean water. Additionally, weak institutional frameworks and ineffective enforcement of water policies challenge resource management.

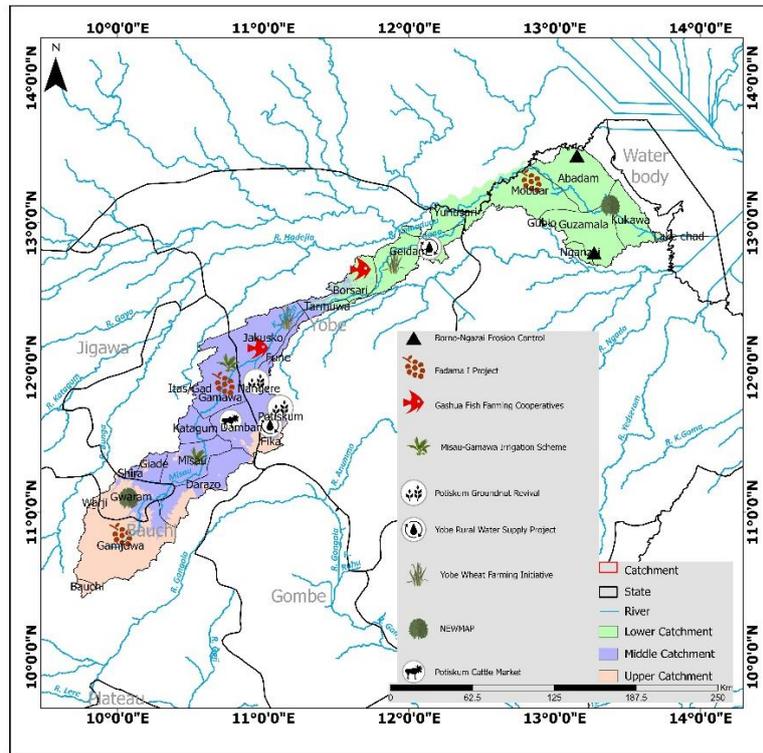


Figure E.S 1: Misau-Komadugu-Gana catchment Showing the Past Interventions (Source: MSL, 2024)

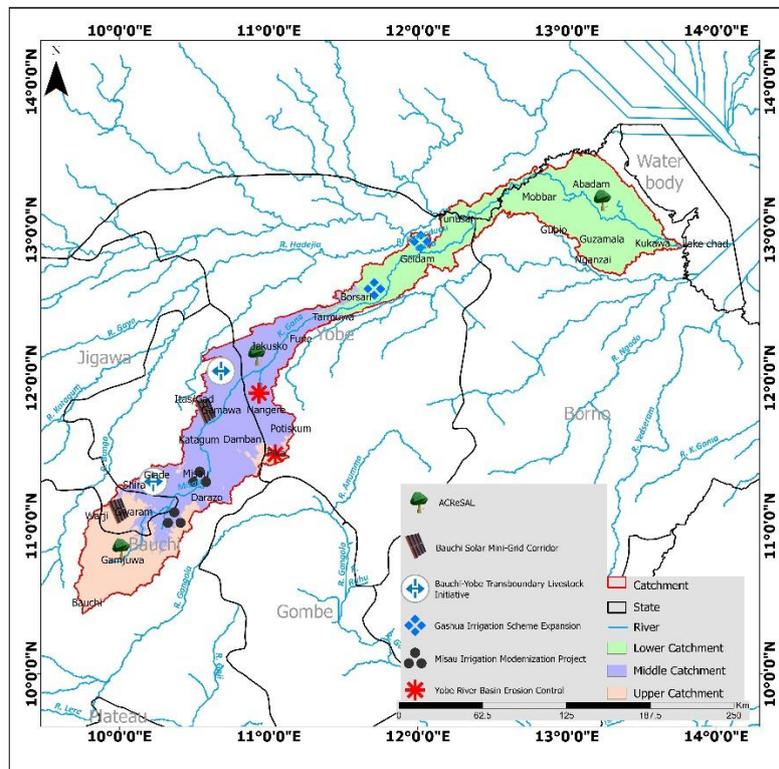


Figure E.S 2: Misau-Komadugu-Gana catchment Showing the Ongoing Interventions (Source: MSL, 2024)

Elements of the Catchment Management Plan

The strategic vision and objectives are reflected in the following components of the Misau-Komadugu Gana catchment management plan.

1. Strategic Vision

The strategic vision of the catchment management plan is to establish a climate-resilient, inclusive, and sustainably managed catchment that ensures equitable access to land and water resources, supports livelihoods and ecosystems, and promotes long-term resilience through integrated planning and stakeholder partnerships.

2. Strategic Objectives

To achieve this vision of the catchment plan, the following strategic objectives are outlined:

- i. A sustainable use of the natural resources free of conflict for use by present and future generation.
- ii. Livelihood enhancement and food security.
- iii. Environmental Management and Climate Change Adaptation.
- iv. **Water Management:** Equitable water management and monitoring system put in place to address pollution, availability, and quality of surface and ground water. Put in place Integrated Water Resources Management System to address the following:
 - Surface and ground water management.
 - Equitable water allocation
 - Water pollution control
 - River diversion
 - Invasive weed control
 - Community engagement
 - Gender Inclusivity
 - Pest management
 - Water conservation
 - Water for efficient irrigation systems and integrated farming methods
 - Monitoring stations for ground and surface water.
- v. **Land Use:** Review existing land use laws to address urbanization, women exclusion, and conservation of the environment to address;

- Indiscriminate bush burning
 - Illegal tree felling
 - Gully erosion
 - Desert encroachment
 - Over grazing
- vi. **Environmental Protection:** Carry out stakeholder’s engagement on habitat restoration, nature conservation and sustainable use of the environment to encourage use of renewable energy to reduce carbon emission and climate change.
- vii. **Community Benefits:** Put in place empowerment programmes for the benefit of both male and female members of the catchment area, including the development of Primary Health Care Centres, rehabilitation and construction of women development centres and ensure gender balance in all the development programmes and activities.
- viii. **Economic Development:** Establishment of skill acquisition centres, provision of infrastructure, provision of micro credit scheme, training and provision of post-harvest facilities to improve value-chain. Introduce back to school programmes for out of schools’ children.
- ix. **Climate Change Resilience:** Establishment of community tree nurseries, community and private woodlots, orchards, and home-based eco-friendly cottage industries, develop climate smart agriculture through the use of solar powered machines and promote drought resistant crops, as well as introducing awareness programmes on climate change adaptation.
- x. **Monitoring And Evaluation/ Alignment of Policies on Catchment Basis:** Putting in place result-based M&E mechanisms in the catchment area. Furthermore, the riparian States of ACREsAL to form a monitoring committee of the representatives of the line ministries, departments, and agencies, including stakeholder farmers to be supported by ACREsAL and be supervised and advised by the Trust fund and the Northeast Development Commission (NEDC). Whenever ACREsAL winds up, the NEDC should then facilitate the activities of the committee. This is to ensure effective management of the catchment for sustainable use and development.

Catchment Policies

It is necessary to recognize and further domesticate the following treaties, policies, and laws in order to foster harmonious relationships and stakeholder engagement regarding the equitable use of interstate water resources. The key Catchment Policies, Treaties, and Laws are:

1. National and International Treaties Governing Catchment Management

- Lake Chad Basin Commission (LCBC) Treaty: Governs transboundary water resource management between Nigeria, Chad, Cameroon, and Niger. Provides a framework for coordinated water allocation, flood risk management, and conservation efforts.
- Nigeria-Niger Joint Commission (NNJC): Facilitates bilateral cooperation in water use and conservation between Nigeria and Niger, particularly for shared river basins. Encourages joint monitoring of groundwater depletion and pollution control.

2. National Laws and Policies on Water Resource Management

- Water Resources Act (2004): Provides the legal framework for managing water resources across Nigeria, including in the Misau-Komadugu Gana Catchment. Establishes principles for water use regulation, pollution control, and conservation strategies.
- National Water Resources Policy (2016): Adopts Integrated Water Resources Management (IWRM) principles, emphasizing stakeholder participation and conservation-based management. Supports the development of catchment management plans at the state and local levels.

3. Land Use and Environmental Policies

- Land Use Act (1978): Governs land ownership, allocation, and use at the state level. Requires government approval for large-scale land development projects, ensuring environmental sustainability.
- National Environmental Standards and Regulations Enforcement Agency (NESREA) Act (2007): Provides environmental protection standards for pollution control, waste management, and impact assessments. Regulated catchment-based environmental management, requires compliance with sustainability guidelines.

4. State-Level Catchment and Water Resource Management Policies

- Bauchi State Environmental Protection Agency (BASEPA) Law: Mandates pollution control, waste management, and enforcement of environmental standards. Ensures catchment conservation and protection of water quality.

- Yobe State Environmental Protection Law (2012): Establishes guidelines for water conservation, wetland protection, and sustainable land use. Aligns with national frameworks such as the Water Resources Act (2004) and NESREA Act (2007).
- Borno State Urban and Regional Planning Law (2012): Regulates urban expansion, zoning, and land use in flood-prone areas. Supports resettlement planning for communities displaced by climate change and land degradation.

Other treaties, policies, and laws are outlined below.

5. Treaties

- Vienna Convention on the Law of Treaties on principle of binding nature of treaty once signed, ratified and inforce (pacta sunt servanda),
- UN Watercourses Convention on non-navigational use of shared watercourses, application to surface water and connected groundwater,
- UNECE Water Convention on relevance to both surface and ground water as well as application to all uses of the shared watercourse,
- Niger Basin Water Charter as principal treaty of the Niger River Basin,

International Policies That Affect Water Resources

- 1971 Stockholm Declaration on Human Environment
- 1992 Dublin principles on water and sustainable Development,
- 1992 Rio Declaration on Environment and Development and Agenda 21
- 2008 ECOWAS Water Resources Policy
- Draft Articles on the Law of Transboundary Aquifer

National Laws and Policies

- 1999 Constitution of Federal Republic of Nigeria
- 1993 National Water Resources Act
- 2016 National Water Resources Policy
- 2016 National Policy on Environment
- National Climate Change Policy for Nigeria (2021-2030)

Plan Components

To address the challenges in the catchment, the following strategic components or intervention areas are identified in order to achieve the aim and objective of the Catchment Management Plan

Component 1: Sustainable Conservation, Management, and Use of Water Resources

Long-term water security and ecological balance in the Misau-Komadugu Gana Catchment depend on sustainable water resource management. This calls for a coordinated strategy that incorporates policy-driven interventions, community involvement, and scientific data analysis. Sustainable conservation, management, and use of water resources involves key strategies such as: integrated watershed management, water use efficiency, rainwater harvesting, water recycling and reuse, ground recharge strategies, community involvement in water governance and climate-adaptive water planning.

Component 2: Preservation and Restoration of Critical Ecosystems

To sustain biodiversity, improve environmental resilience, and promote sustainable livelihoods in the Misau-Komadugu Gana Catchment, it is imperative that critical ecosystems be preserved and restored. This includes proactive intervention techniques meant to reverse deterioration and advance ecological balance. Wetland protection and rehabilitation, riparian buffer zones, agroforestry and sustainable land-use practices, reforestation and afforestation initiatives, erosion control measures, policy enforcement and incentives, community-based conservation initiatives, and habitat restoration for endangered species are some of the key strategies.

Component 3: Improved Diversification for Sustainable Livelihoods

To increase economic resilience, lessen reliance on climate-sensitive activities, and advance sustainable development, it is imperative to improve livelihood diversification. Agro-based businesses, climate-resilient farming methods, sustainable livestock management, microfinance and credit availability, community-led entrepreneurship programs, market connections and value chains, alternative revenue-generating activities, and sustainable fisheries development are important strategies for accomplishing this component.

Component 4: Climate Change Adaptation and Disaster Risk Reduction

Preserving the Misau-Komadugu Gana Catchment from the growing risks of climate variability requires disaster risk reduction and climate change adaptation. Early warning systems, climate-

resilient infrastructure, sustainable land and water management, disaster preparedness and emergency response plans, ecosystem-based adaptation (EbA), capacity building and awareness initiatives, integrating climate adaptation into policies, promoting renewable energy, and financial mechanisms for adaptation are some of the strategies required to reduce risks and improve resilience.

Component 5: Strengthening Institutional & Project Coordination Mechanisms

The successful application of sustainable water resource management strategies depends on efficient institutional and project coordination mechanisms. Stakeholder collaboration, enhanced accountability, and effective decision-making are all guaranteed by strengthening governance frameworks. Important strategies like interagency cooperation, institutional capacity building, multi-stakeholder platforms, legislative reforms and policy strengthening, measures for accountability and transparency, harmonizing development projects, financial and technical assistance, and dispute resolution procedures.

Component 6: Mainstreaming Gender Equality & Social Inclusion (GESI)

Promoting sustainable development, empowering marginalized groups, and guaranteeing fair access to resources all depend on mainstreaming gender equality and social inclusion (GESI). Inclusive decision-making, building the capacity of women and vulnerable groups, equal access to resources, developing gender-responsive infrastructure, raising community awareness and advocacy, economic empowerment programs, monitoring and evaluation frameworks, and policy integration are some of the key strategies.

Component 7: Research and Extension for Data-Driven Decision-Making

Improving ecosystem management, climate resilience, and the sustainability of water resources all depend heavily on research and extension services. Through the integration of scientific research and real-world applications, decision-makers can put data-driven strategies that support sustainable development into action. Advanced hydrological and climate research, the use of remote sensing and GIS technologies, the formation of research partnerships, the creation of extension services for farmers and local communities, community-based monitoring and citizen science initiatives, the integration of indigenous knowledge systems, policy-oriented research for adaptive management, and digital platforms for data sharing and knowledge exchange are some of the crucial steps that must be taken in order to implement this strategy.

Component 8: Effective Monitoring, Evaluation & Reporting Systems

Adaptive management, impact assessment, and progress tracking all depend on a strong monitoring, evaluation, and reporting (MER) system. This system will encourage accountability among all stakeholders and make evidence-based decision-making easier. Frameworks for tracking performance, real-time monitoring of water quality and usage, periodic impact assessments, stakeholder feedback mechanisms, transparent data sharing and reporting, building capacity for monitoring teams, integrating artificial intelligence and predictive analytics, and adjusting policies and improving adaptive management are all important parts of this strategy.

Table ES2 below shows a summary of components, activities, key indicators and responsibilities of the different stakeholders in the Misau-Komadugu Gana Catchment Management Plan.

Table ES 2: Summary of Components and Activities of the Misau-Komadugu Gana Catchment Plan

S/No.	Component	Activities		Key Indicators	Responsibility/ Partners	Stakeholders Engagement	Recommendations
1	Sustainable Conservation, Management, and Use of Water Resources	Expand hydrological monitoring systems	2024-2026	50% increase in monitoring stations	State Water Boards, Research Institutes	Enhanced decision-making for water allocation	Upgrade hydrometric networks and install real-time sensors
2	Preservation and Restoration of Critical Ecosystems	Rehabilitate wetlands and riparian buffers	2025-2030	10,000 ha of restored ecosystems	Environmental Agencies, NGOs	Community participation and conservation incentives	Implement buffer zone policies and wetland conservation programs
3	Climate Change Adaptation and Disaster Risk Reduction	Develop climate-resilient water infrastructure	2024-2028	Increased capacity of flood-resistant infrastructure	Ministry of Water Resources, Local Governments	Inclusion of local communities in planning	Prioritize sustainable, eco-friendly engineering solutions
4	Improved Diversification for Sustainable Livelihoods	Support alternative livelihoods for climate adaptation.	2024-2030	40% increase in community-based enterprises	Ministry of Agriculture, NGOs, Private Sector	Microfinance access and business training	Diversify income streams beyond agriculture.

5	Strengthening Institutional & Project Coordination Mechanisms	Strengthening institutional capacity for integrated governance	2024-2027	Policy coherence and improved enforcement	Federal & State Governments, Water Agencies	Cross-sectoral collaboration and capacity-building	Align national policies with SDGs and best practices.
6	Mainstreaming Gender Equality & Social Inclusion (GESI)	Establish gender-sensitive water governance frameworks.	2025-2030	50% increase in women-led water governance roles	Local Water User Associations, Community Leaders	Women's leadership training and legal empowerment	Ensure gender-responsive budgeting and policies.
7	Research and Extension for Data-Driven Decision-Making	Promote research and technological innovation in water management.	2025-2035	Adoption of new water-saving technologies	Universities, Innovation Hubs, Private Sector	Public-private partnerships and research funding	Scale up pilot programs based on research outcomes.
8	Effective Monitoring, Evaluation & Reporting Systems	Implement a robust monitoring and evaluation framework	2024-2035	Annual assessment reports and policy revisions	Catchment Authorities, Research Bodies	Stakeholder reviews and feedback mechanisms	Ensure adaptive management and policy adjustments based on data.

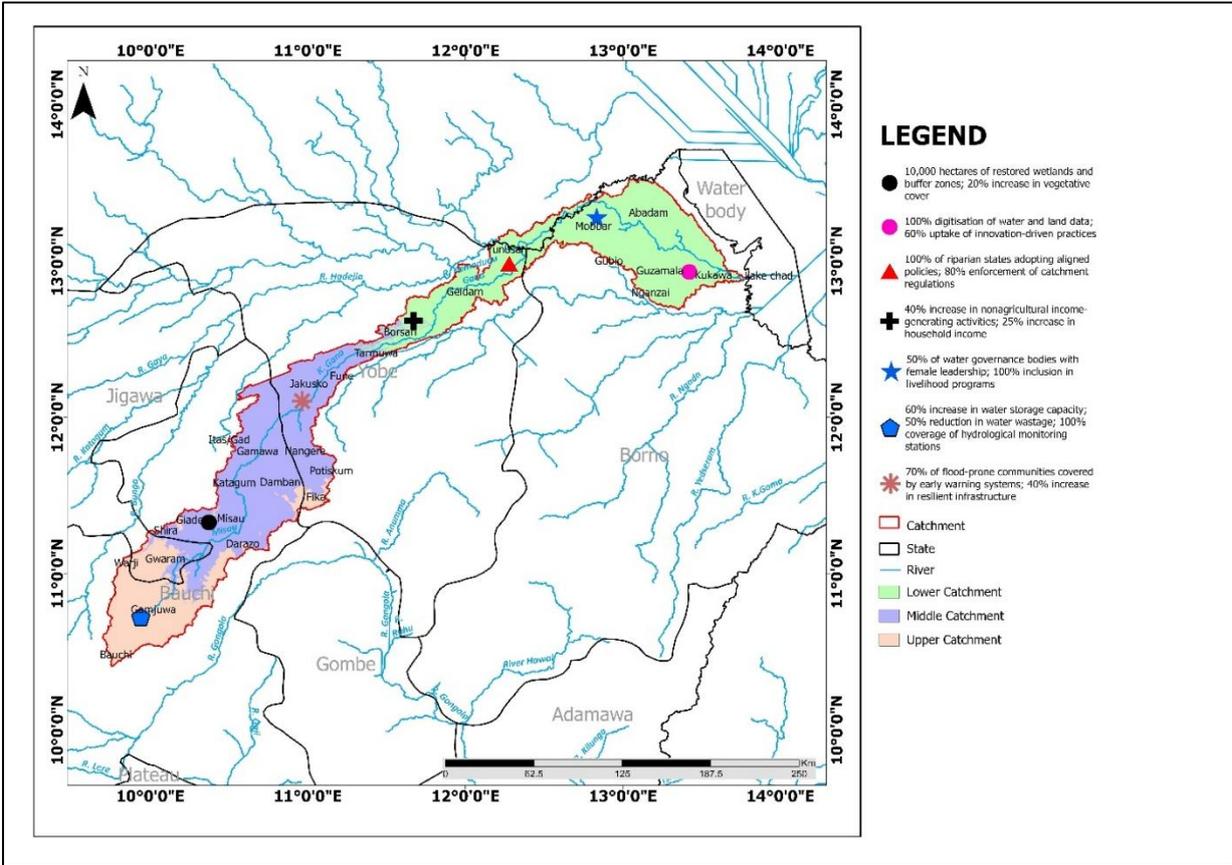


Figure E.S.3: Misau-Komadugu Gana Catchment showing the Recommended Interventions (Source: MSL, 2024)

Table E.S.3: Lower Catchment of the Misau-Komadugu-Gana Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Towns	Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Lower Catchment	Abadam, Kukawa	Lake Chad shrinkage & declining fisheries	Wetland restoration, fishery co-management, water harvesting schemes	Satellite monitoring of lake, community fishery councils	Lake Chad Basin Commission, NIWA	Revived fisheries, improved water ecosystem health
	Mobbar, Yunusari	Desert encroachment & sand dune movement Biodiversity Loss	Shelterbelt planting, community woodlots, sand dune stabilization Biodiversity Conservation	Aerial imagery, community-based afforestation. NDVI satellite imagery, urban planning GIS	FMEnv, State Forestry Dept. ACReSAL. NIWRMC, IWRM	Halted desertification, restored arable land
	Gubio, Guzamala	Water scarcity for agriculture	Drilling of boreholes, small-scale irrigation schemes	Geophysical survey, Conduct hydrogeology mapping	RUWASSA, Agric Ministry, WASH sector agencies, NIHSA, NIWRMC.	Improved water access, enhanced dry season farming
	Nganzai, Borsari	Frequent farmer-pastoralist clashes	Grazing reserves demarcation, dialogue platforms, early warning systems	Conflict mapping, participatory land use planning	Min. of Interior, Agric Ministry, Peace Committees	Reduced conflict, secured livelihoods

	Geidam	Seasonal flooding (near Komadugu-Yobe River)	Flood embankments, drainage improvement, early warning systems	Flood risk modeling, community alert system	NIHSA, NEMA, Yobe State Emergency Agencies	Reduced flood risk, safeguarded settlements
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Table E.S.4: Middle Catchment of the Misau-Komadugu-Gana Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Towns	Challenge	Propose Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Middle Catchment	Tarmuwa, Fune, Jakusko	Sheet erosion on gentle slopes	Contour bunding, agroforestry, gully plugging	GIS slope mapping, community agroforestry plots	NEWMAP, State Ministry of Environment	Reduced soil loss, improved land productivity
	Itas/Gad, Dambam	Farmer-pastoralist conflict over land use	Grazing corridor demarcation, water points for livestock,	Participatory mapping, GPS boundary marking	Min. of Agriculture, Local Govt, Peacebuilding NGOs,LGA	Peaceful land sharing, secured livelihoods

			dialogue forums			
Gamawa, Katagum, Giade	Declining groundwater levels for farming	Construction of solar-powered boreholes, rainwater harvesting structures	Hydrogeological surveys, solar pumping systems	RUWASSA, Agric Extension Services, NIWRMC, NIHSA, ACREsAL, FWMR	Enhanced water supply, resilient dry-season farming	
Potiskum, Nangere	Flash flooding in peri-urban zones	Stormwater drainage channels, flood early warning systems	Hydrological models, flood risk maps GIS slope analysis, drone surveillance, erosion mapping.	NIHSA, NEMA, Local Emergency Agencies, ACREsAL, NIWEMC, HJRBDA,	Reduced flood risk, protected communities	
Misau, Darazo, Shira	Land degradation & deforestation due to fuelwood	Community woodlots, alternative energy promotion (e.g. clean cookstoves)	Remote sensing for forest cover, community nursery programs Consistent Soil testing (NDVI, and periodic land use land cover)	FMEnv, State Forestry, Energy Commission, ADP, FMAFS ACReSAL, LGA	Restored tree cover, reduced pressure on natural forests	

				drone monitoring, GIS maps		
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Table E.S.5: Upper Catchment of the Misau-Komadugu-Gana Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	Towns	Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Upper catchment	Gwaram	Gully erosion on steep slopes	Check dams, re-vegetation, contour bunding	GIS erosion risk maps, drone monitoring	ACReSAL, State Min. of Environment FMEnv, FMWR	Stabilized land, protected infrastructure
	Warji	Soil erosion from unsustainable farming	Terracing, agroforestry, farmer training	Satellite imagery, agroforestry demo plots	Agric Extension, State Min. of Agriculture, LGA	Improved soil stability, sustainable farming
	Gamjuwa	Flash flooding during peak rains	Construction of retention basins, stormwater drains	Hydrological flood modeling, flood risk maps	NIHSA, NEMA, ACReSAL, FWMR, NIWRMC,	Reduced flood damage, protected settlements
	Fika	Deforestation and biodiversity loss	Community woodlots, alternative livelihood (beekeeping, NTFPs)	Remote sensing, community nursery programs	FMEnv, State Forestry, Nat. Park Service, Ministry of Tourism. LGA	Restored vegetation cover, enhanced biodiversity

				Consistent Soil testing (NDVI, and periodic land use land cover) drone monitoring, GIS maps		
	Bauchi	Rapid urban expansion causing land degradation	Urban planning enforcement, greenbelt creation	Urban land use maps, participatory planning tools	State Urban Dev. Board, Min. of Lands, State Ministry of Env't	Controlled urban sprawl, preserved green spaces

Expected Outcomes

These strategic interventions, developed by the Misau-Komadugu Gana Catchment Management Plan, will, if fully implemented, lead to the following outcomes:

- i. Groundwater recharge and water source sustainability, increased policy enforcement that results in equitable water distribution, and improved water use efficiency and decreased waste.
- ii. Improved biodiversity conservation, restoration of important habitats, decreased soil erosion and land degradation, increased carbon sequestration, and increased climate resilience.
- iii. improved food security through climate-adaptive farming methods, higher household incomes and economic resilience, and greater financial inclusion for farmers and small business owners.
- iv. Enhanced community readiness through early warning systems, decreased climate-induced vulnerabilities and disaster effects, and more funding for climate-resilient infrastructure.
- v. Strengthened institutional frameworks for coordinated resource management, improved enforcement and coherence of policies, and increased investment in water governance through partnerships.

CHAPTER 1 : INTRODUCTION

1.1 Purpose for the Plan

Despite the fact that the catchment area is crucial to regional hydrology and sustains economic, pastoral, and agricultural activities, it faces numerous challenges such as:

- i. **Environmental degradation:** Deforestation, overgrazing, and agricultural expansion have led to soil erosion and biodiversity loss, while wetland encroachment threatens flood mitigation. Unregulated mining and poor waste disposal further contaminate soil and water.
- ii. **Reduced water flow:** Excessive water extraction, damming, and declining rainfall have diminished water availability and quality, while poor governance exacerbates regional conflicts.
- iii. **Climate Change Impacts:** Erratic rainfall and rising temperatures reduce water availability and agricultural productivity, while vegetation loss accelerates erosion and depletes soil fertility, threatening sustainable agriculture.
- iv. **Insecurity and Socio-economic Disruptions:** Insecurity in Borno State displaces communities, disrupting agriculture and livelihoods, while armed conflict hinders infrastructure development. The loss of traditional governance undermines community-based natural resource management.
- v. **Socio-economic pressure:** Rapid population growth is increasing competition for water, food, and land, straining resources. Poverty and unemployment lead to unsustainable practices, while weak coordination hinders conservation efforts.

1.2 Rationale for a Strategic Catchment Plan

The CMP provides a strategic framework for ecosystem restoration, water resource management, and sustainable development in the catchment as follows:

- i. **Enhancing water availability and quality:** The CMP promotes Integrated Water Resources Management to enhance water use efficiency and sustainability through small-scale reservoirs and dry-season water harvesting.
- ii. **Promoting Climate Resilience:** The CMP boosts climate resilience with early warning systems, improved flood management, climate-smart agriculture, and reforestation for carbon sequestration.

- iii. **Support Ecosystem Protection and Biodiversity Conservation:** The CMP focuses on restoring degraded ecosystems, protecting areas from deforestation, and promoting sustainable forestry, while monitoring biodiversity and habitat conditions.
- iv. **Facilitating Stakeholder Collaboration:** The CMP enhances collaboration through Catchment Management Committees for inclusive decision-making and strengthens partnerships for watershed protection and community resource management.
- v. **Encouraging Sustainable Land-use Practices:** The CMP promotes sustainable land use through balanced zoning, soil conservation techniques, sustainable grazing, and alternative livelihoods like eco-tourism and fisheries.

1.3 Expected Outcomes

The Strategic Catchment Management Plan for the Misau-Komadugu Gana Catchment is expected to produce the following outcomes:

- i. Coordinated water, land, and resource management for sustainability.
- ii. Water and soil conserving techniques to boost productivity.
- iii. Habitat restoration to sustain biodiversity and ecosystems.
- iv. Measures to reduce erosion and flood risks.
- v. Sustainable activities to improve livelihoods and resource use.
- vi. Strengthening institutions and stakeholder engagement.
- vii. Adaptive systems to track progress and guide decisions.

1.4 Sustainable Catchment Management Roles

The Strategic catchment management plan (SCMP) helps for Misau-Komadugu Gana catchment will ensure the sustainable management of the catchments natural resources. Some of the key roles are as follows:

1.5 Environmental Roles

The environmental roles include:

- **Watershed Conservation & Restoration:** Implement afforestation, wetland restoration, and soil erosion control to enhance biodiversity and ecosystem resilience.

- Sustainable Water Resource Management: Promote Integrated Water Resources Management (IWRM) to balance surface and groundwater use while reducing pollution and siltation.
- Climate Adaptation & Mitigation: Strengthen flood and drought resilience through early warning systems, reforestation, and sustainable agricultural practices.

1.6 Socio-Economic Roles

The socio-economic roles are:

- Livelihood Diversification: Develop alternative income-generating activities such as eco-tourism, sustainable fisheries, and agroforestry to reduce pressure on natural resources.
- Water Security & Agricultural Sustainability: Improve irrigation infrastructure, rainwater harvesting, and access to clean water for domestic and agricultural use.
- Community Engagement & Capacity Building: Empower local communities through training, cooperatives, and participatory natural resource management programs.

1.7 Governance and Institutional Roles

The governance and institutional roles will include:

- Strengthening Policy & Regulation Enforcement: Ensure strict enforcement of land use, water allocation, and pollution control laws to prevent resource overexploitation.
- Institutional Coordination & Stakeholder Collaboration: Establish strong partnerships between government agencies, private sectors, and local communities for integrated catchment governance.
- Public-Private Partnerships (PPPs) & Investment: Mobilize financial and technical resources for sustainable water infrastructure, conservation projects, and climate adaptation initiatives.

1.8 Catchment Policies

For harmonious relationship and engagement of stakeholders regarding equitable utilization of inter-state resources including water, the following treaties, policies, and laws need to be recognized, and ratified treaties further domesticated.

1. Treaties: the key treaties considered includes:

- Vienna Convention on the Law of Treaties on principle of binding nature of treaty once signed, ratified, and enforce (*pacta sunt servanda*),
- UN Watercourses Convention on non-navigational use of shared watercourses, application to surface water and connected groundwater,
- UNECE Water Convention on relevance to both surface and ground water as well as application to all uses of the shared watercourse,
- Niger Basin Water Charter as principal treaty of the Niger River Basin,
- Lake Chad Water Charter as principal treaty of the Lake Chad Basin.

2. International Policies That Affect Water Resources: the international policies considered are:

- Stockholm Declaration on Human Environment (1971)
- Dublin principles on water and sustainable Development (1992)
- Rio Declaration on Environment and Development and Agenda 21 (1992)
- ECOWAS Water Resources Policy (2008)
- Draft Articles on the Law of Transboundary Aquifer

3. National Laws and Policies:

- Constitution of Federal Republic of Nigeria (1999)
- National Water Resources Act (1993)
- National Water Resources Policy (2016)
- National Policy on Environment (2016)
- National Climate Change Policy for Nigeria (2021-2030)
- National Agricultural Policy (2016)
- Nigeria's Agricultural Transformation Agenda (ATA)
- Nigeria's National Forest Policy (2006)

The Strategic Catchment Management Plan can integrate with existing regional and national policies in Nigeria by aligning with their stated objectives. For instance, the SCMP can do so with the policy objectives of the National Water Resources Policy (2016) which is to ensure

sustainable water resources management and protecting the environment. Another policy is that of the National Environmental Policy (1999) which the SCMP can integrate with to promote conservation, protection, and restoration of the environment. For the National Agricultural Policy (2016), the SCMP can align with the policy's objectives, such as promoting sustainable agricultural practices and improving food security.

On a regional scale, the SCMP can be integrated with the Niger Basin Authority's (NBA) Water Charter: which aims to promote sustainable water resources management in the Niger Basin. It can also integrate with the Economic Community of West African States (ECOWAS) Water Resources Policy objectives, such as promoting regional cooperation and sustainable water resources management. There are sectoral policies such as the Nigeria's Agricultural Transformation Agenda (ATA) and the Nigeria's National Forest Policy (2006). The SCMP can integrate with these two policies by promoting sustainable agricultural practices and improving food security for the former while promoting sustainable forest management and conservation for the latter.

Some Key Integration Mechanisms Considered are:

- i. **Establish a coordination committee:** Set up a committee comprising representatives from relevant government agencies, regional organizations, and stakeholders to ensure coordination and integration.
- ii. **Conduct policy gap analysis:** Identify gaps and inconsistencies between the Strategic Catchment Management Plan and existing policies and develop strategies to address them.
- iii. **Develop a monitoring and evaluation framework:** Establish a framework to track progress, identify challenges, and make adjustments to ensure the plans align with national and regional policies.
- iv. **Engage stakeholders:** Involve stakeholders, including government agencies, regional organizations, and local communities, in the planning and implementation process to ensure ownership and buy-in.

The catchment area is well-acquainted with various development and intervention initiatives, including the Multisectoral Crisis Recovery Projects (MCRP) aimed at rehabilitating and enhancing critical infrastructure such as roads, bridges, hospitals, and water resources. The North East Development Commission (NEDC) oversees several initiatives, including Newmap

projects, initiatives from the Lake Chad Commission, the Upper Benue River Basin Development Authority, the Hadeija-Jamare River Basin Authority along with its Trust Fund, and the Rural Access and Mobility Project, FMWR-TRIMING project among others.

However, the Strategic Catchment Management Plan is anticipated to integrate the essential components of the catchment as outlined in this report, facilitating a comprehensive development approach for the region. This integration is crucial considering the interconnectedness of these components, thereby ensuring that the interventions are strategically planned with regard to the spatial relationships of these factors. The plan's development in this integrated fashion is expected to foster cohesive growth across the entire region, as opposed to conducting interventions in isolation.

Several noteworthy examples of successful strategic catchment management plans include South Africa's National Water Act, the Mpanga Catchment Conservation Project, and the River Rwizi Catchment Management Plan, all located in Uganda. Additionally, the Tana Catchment Area Management Plan, the Ngarelan Springs Catchment Area Management Plan, and the Dik Catchment Management Plan are prominent initiatives in Kenya.

CHAPTER 2 : CHARACTERISTICS OF THE CATCHMENT

2.1 Location

2.1.1 Location and Boundary

The Misau-Komadugu-Gana Catchment in northeastern Nigeria covers around 23,419 Km² (2,341,900 hectares). Bordered by Ngada (West Chad) to the east, Gongola to the south, and Hadeija Jama'are to the west, its diverse landscape supports pastoralism and agriculture, making it essential for regional economic integration and cultural exchange.

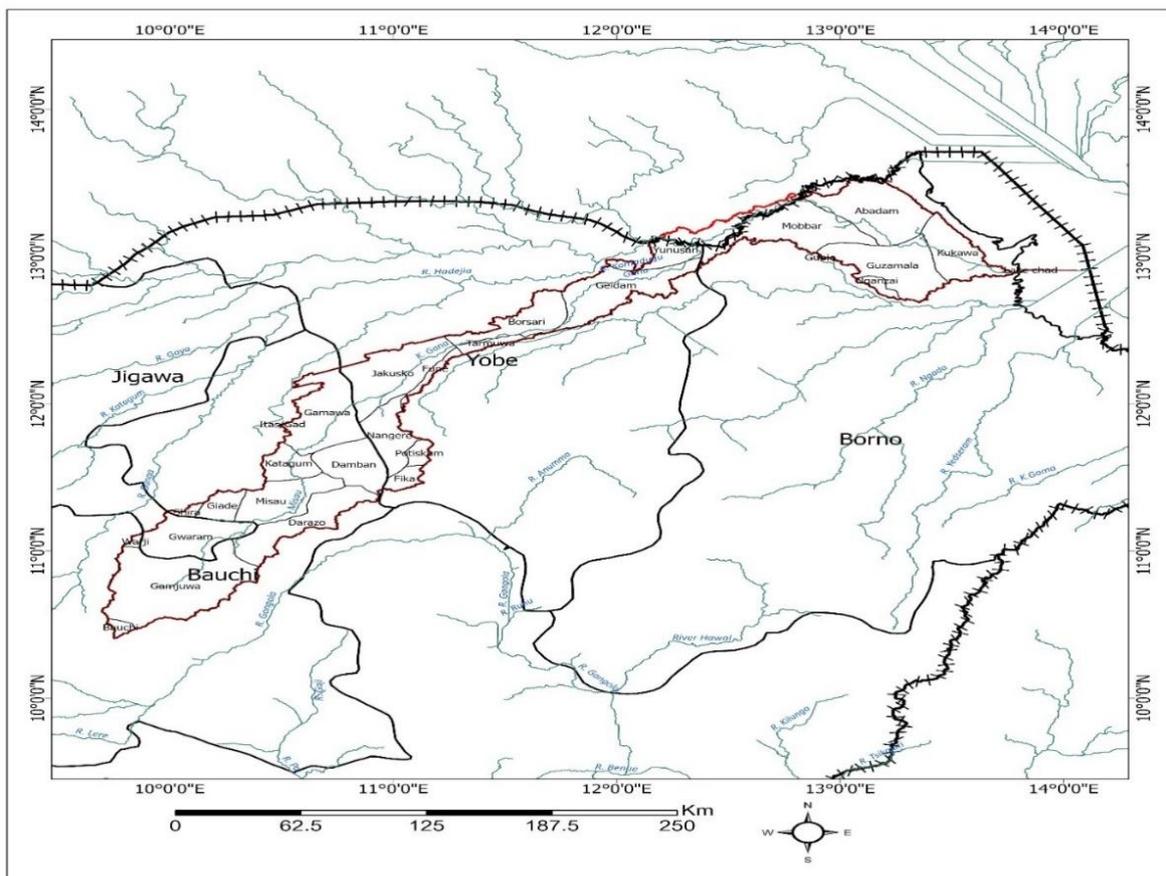


Figure 2.1: Misau-Komadugu-Gana Catchment showing the LGAs (MSL, 2024)

The Strategic Catchment Management Plan is created from a comprehensive technical, knowledge-driven scientific report, which comprises data gathered, obtained, and analyzed utilizing contemporary methods from multiple sources, including online resources, on-site observations, focus group discussions, interviews, secondary literature, and discussions with stakeholders.

2.2 Precipitation, Temperature, Sunshine, and Relative Humidity

2.2.1 Precipitation

The rainfall pattern in the Misau-Komadugu-Gana Catchment shows distinct interannual variability, which is a defining feature of the Sudano-Sahelian ecological zone. While the long-term trend suggests a modest decline in average annual rainfall, there are notable periods of above-average precipitation, such as in 2003, 2006, and 2020, and drier years like 2011 and 2013. Figure 2.2

This variation reflects:

- The influence of climatic cycles such as the Intertropical Convergence Zone (ITCZ) and Atlantic Ocean SST anomalies.
- Increasing unpredictability of rainy season onset and cessation, posing risks for agriculture and water resource planning.

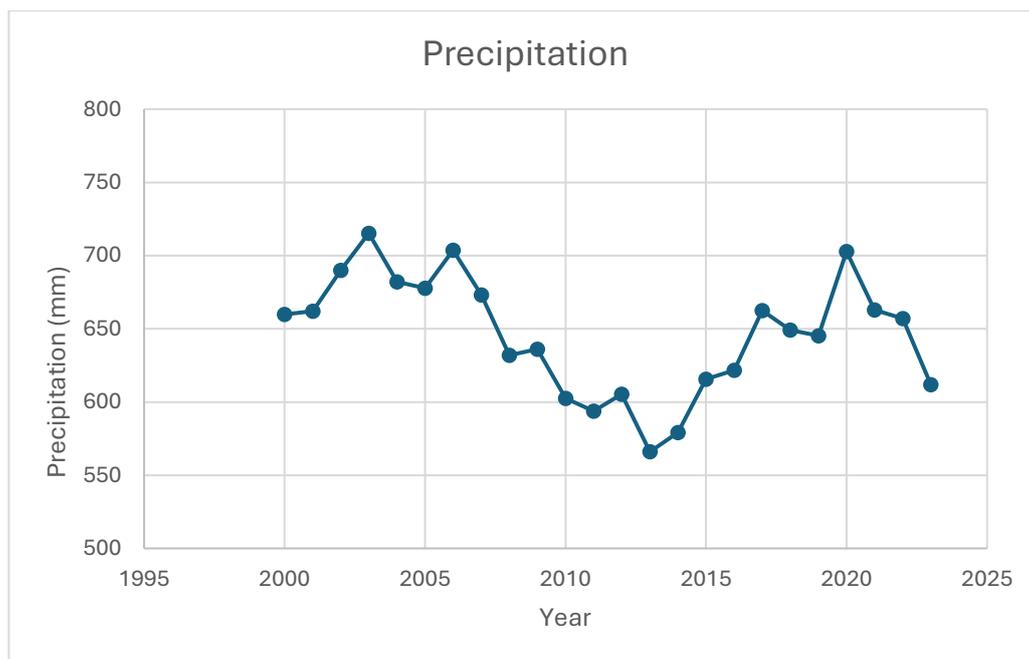


Figure 2.2: Annual Average Precipitation for Misau-Komadugu-Gana Strategic Catchment (Source: MSL, 2024)

2.2.2 Temperature

The Misau-Komadugu-Gana Catchment, situated in the semi-arid to sub-humid transition zone of northeastern Nigeria, exhibits a hot tropical climate characterized by high annual temperatures and pronounced seasonal fluctuations. The catchment experiences consistently

high temperatures throughout the year, with peak values occurring during the dry season, particularly between March and May.

Over the period from 2000 to 2023, a gradual warming trend has been observed in the catchment. Synthetic estimates suggest that the average annual temperature increased from approximately 34.8°C in 2000 to about 38.4°C by 2023. This implies an approximate rise of 0.15°C per year, which, although based on modelled data, aligns with broader climatic patterns observed across the Sudano-Sahelian region of West Africa. (Figure 2.3)

The annual temperature range is relatively narrow, with minimum temperatures occurring between December and January (during the Harmattan season) and maximum temperatures recorded in the late dry season, just before the onset of the rains. Daytime temperatures during the hottest months often exceed 40°C, especially in the northern portions of the catchment.

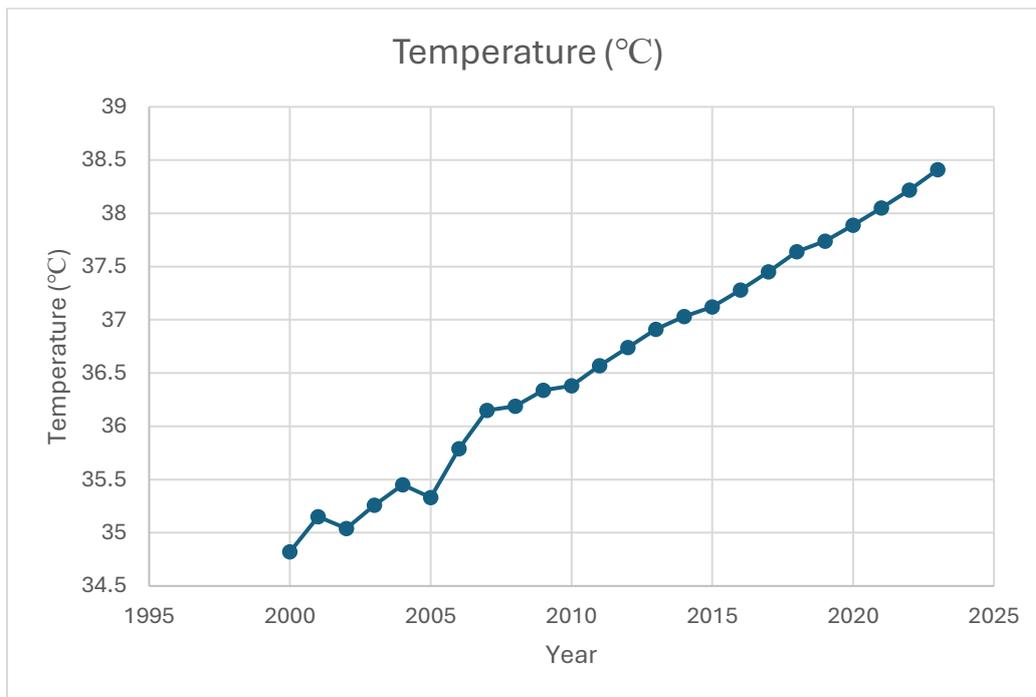


Figure 2.3: Average Annual Temperatures from 2000 to 2023 for the Misau K-Gana catchment (Source: MSL, 2024)

2.2.3 Sunshine Duration

The Catchment enjoys abundant sunshine year-round, a typical feature of Nigeria’s northern ecological zones. Annual sunshine duration generally exceeds 2,900 hours/year, with peak values recorded in recent years (e.g., 3300 hours in 2023). (Figure 2.4)

Key observations include:

- Higher sunshine duration in drier years, corresponding with less cloud cover (e.g., 2005–2007, 2022–2023).
- Slight upward trend over the 24-year period, likely influenced by increased aridity and climate-driven reductions in rainfall.
- Seasonal and interannual variations, shaped by monsoonal cloud cover during the wet season and clear skies during the Harmattan and dry season.

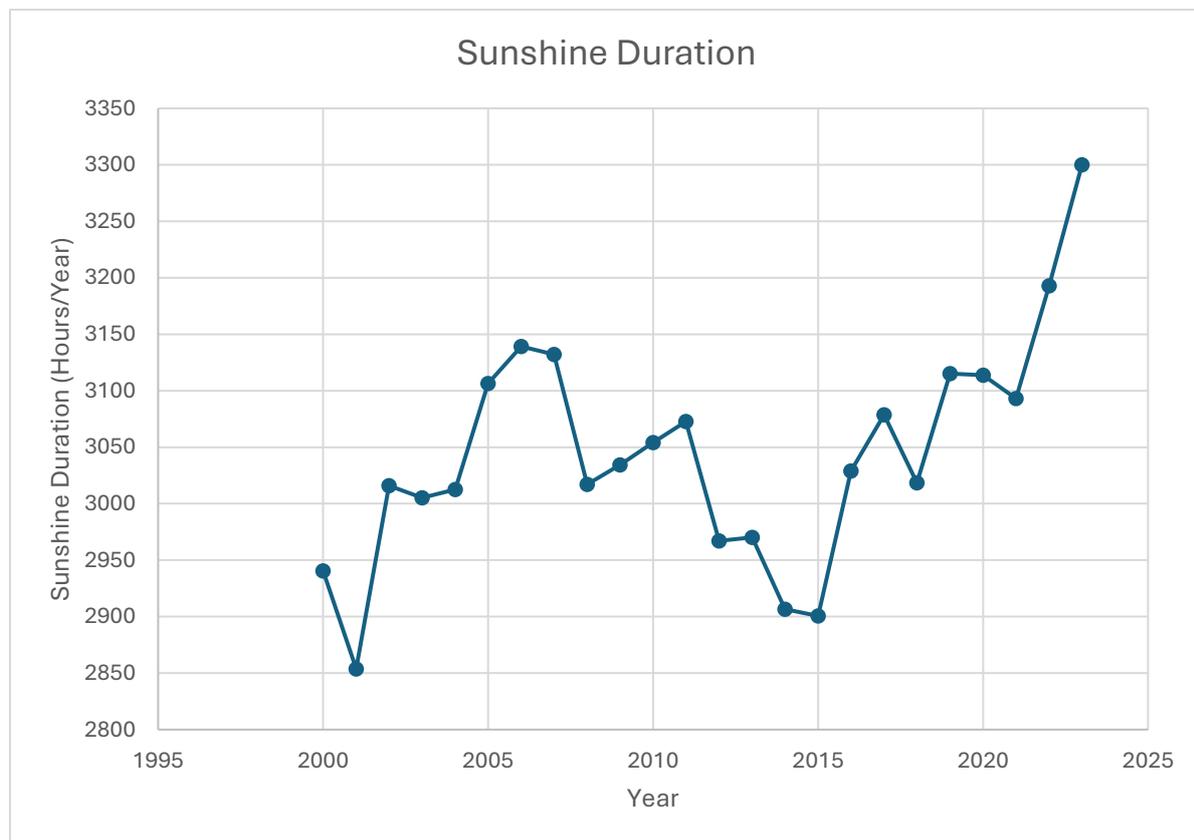


Figure 2.4: Annual Sunshine Duration (2000 – 2023) (MSL, 2024)

2.2.4 Relative Humidity

Relative humidity in the Catchment shows notable interannual variability, with values ranging from 39% to 61% over the 24-year period. These fluctuations largely correspond with annual rainfall variability, rising in wetter years (e.g., 2003, 2007) and dipping during drier periods (e.g., 2011, 2013). (Figure 2.5)

While there is no strong long-term decline, the data hints at a slight downward pressure on relative humidity over time—likely influenced by:

- Rising temperatures, which increase the atmosphere’s moisture-holding capacity.
- Reduced vegetation cover, leading to lower evapotranspiration.
- Irregular rainfall patterns, affecting soil and atmospheric moisture.

This pattern reflects broader climate dynamics in Nigeria’s semi-arid and dry sub-humid zones.

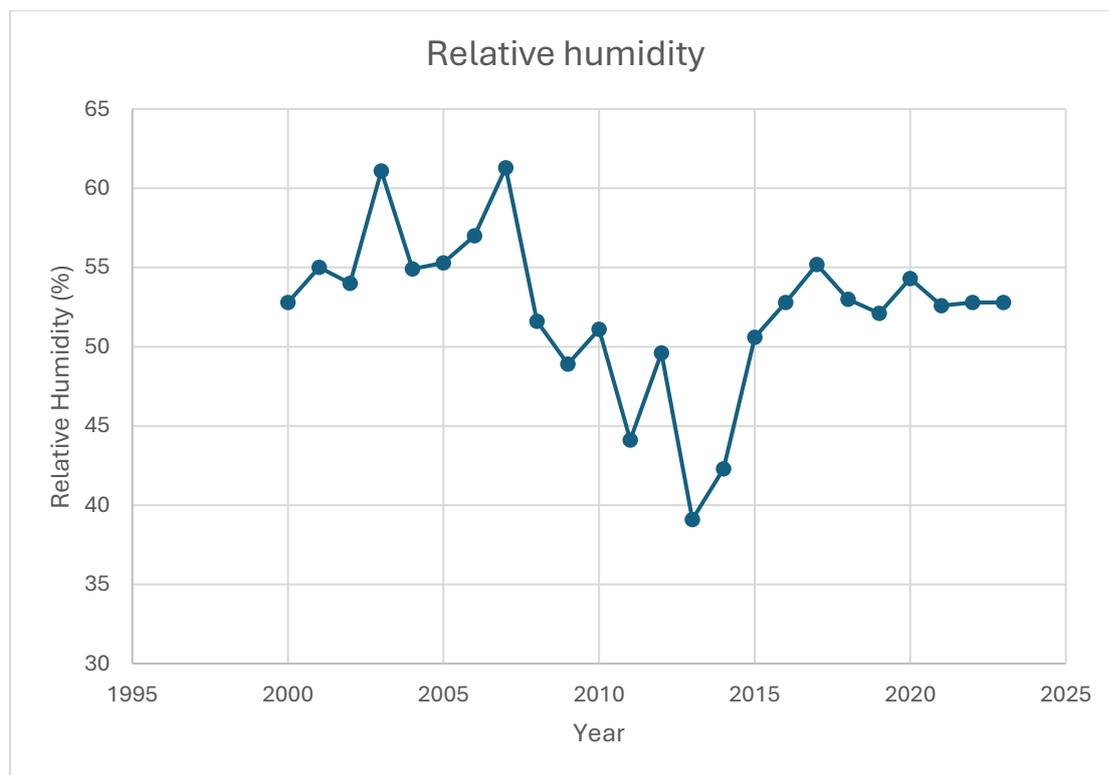


Figure 2.5: Annual Average Humidity for Misau K-Gana Catchment (Source: MSL, 2024)

2.3 Topography, Drainage, Geology and Soil Types

2.3.1 Topography

Geographically, the catchment is characterized by Plains and Lowlands, highlands, and Plateau, interspersed with seasonal rivers and floodplains that support wet-season agriculture. The southern is characterized by highland while the eastern part is characterized by lowlands. Figure 2.6 shows the digital elevation model of the catchment area. A highlight of the topography within the states that constitutes the catchment is given below.

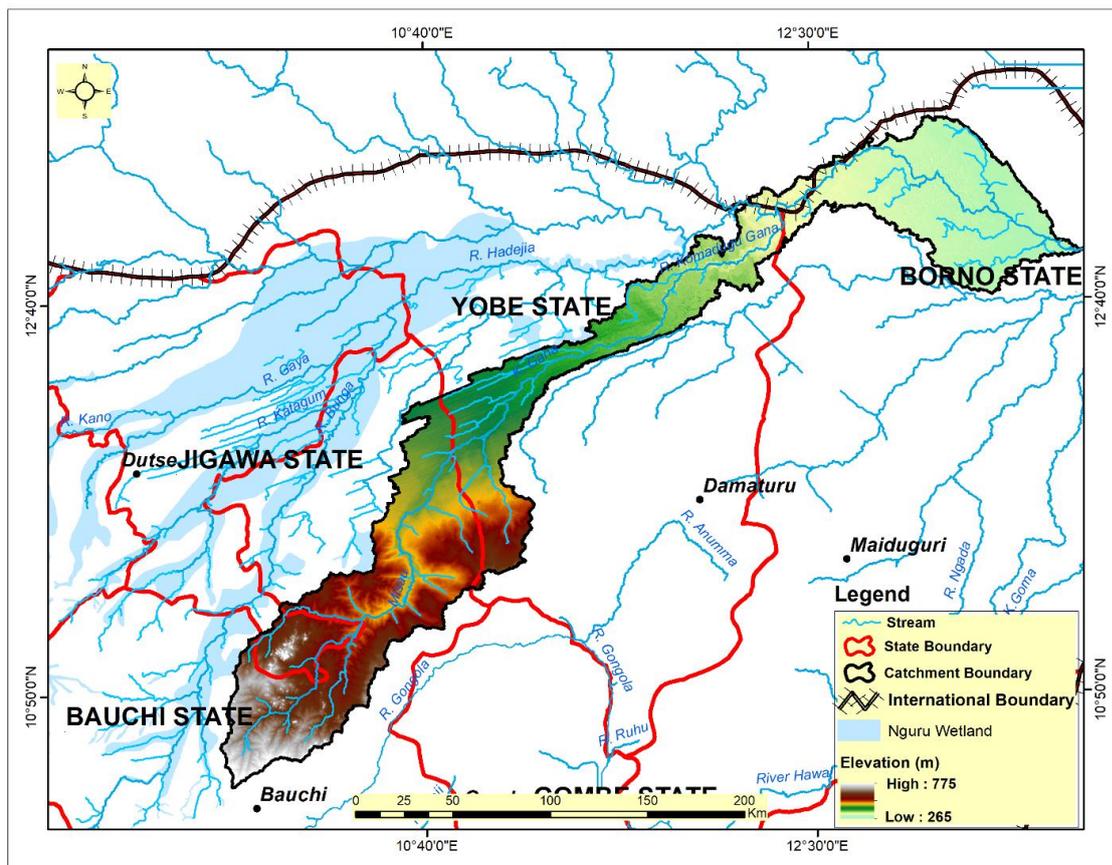


Figure 2.6: Digital Elevation Model of the Catchment (Source: MSL, 2024)

2.3.2 Drainage

The drainage system of the catchment is complex and influenced by its varied topography and geological features. The catchment's rivers and streams are essential for agriculture, water supply, and sustaining the natural environment. Figure 2.7 shows the drainage Map and morphometric analysis of Misau-Komadugu-Gana Catchment.

STATES OF INFLUENCE

1. Bauchi
2. Borno
3. Jigawa
4. Yobe

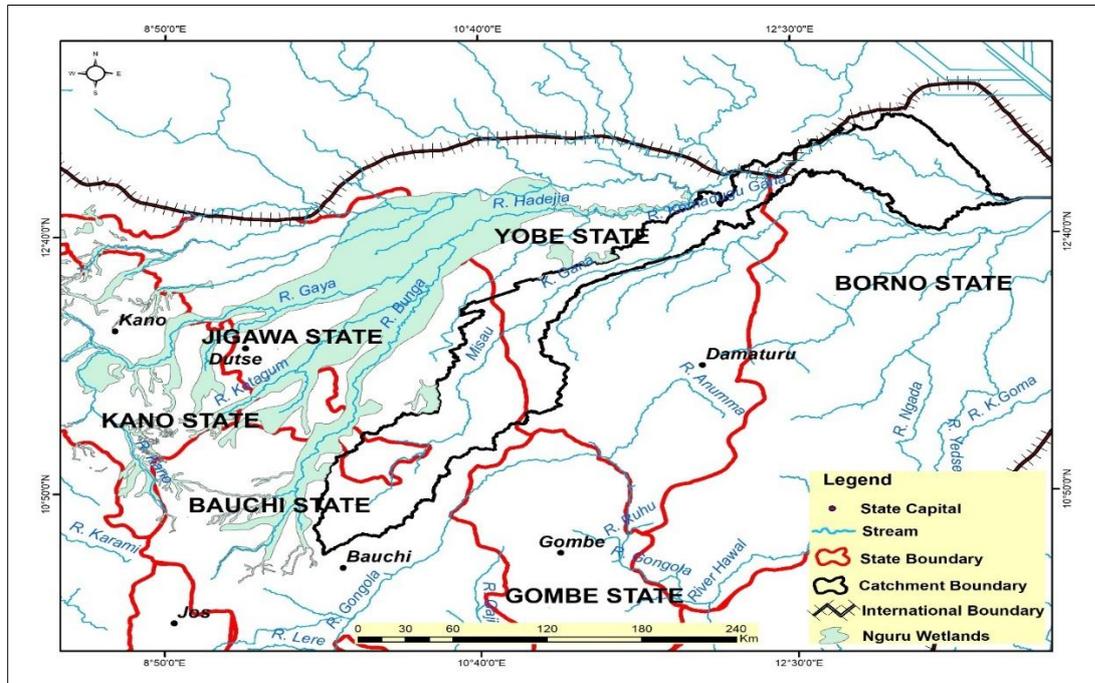


Figure 2.7: Drainage Map of Misau-Komadugu-Gana Catchment (Source: MSL, 2024)

- The Gongola River is the main river in Bauchi State, originating from the Jos Plateau and flowing into the Benue River.
- Yobe State is drained by the Komadugu Yobe River Basin, including the Yobe and Komadugu Gana Rivers, essential for water supply and agriculture, with the Yobe River draining into Lake Chad.
- In Borno, the Yedseram and Ngada Rivers flow into Lake Chad during the rainy season.
- Jigawa State’s drainage system includes the Hadejia River, a major Yobe tributary, and the Hadejia-Nguru Wetlands, vital for biodiversity and agriculture.

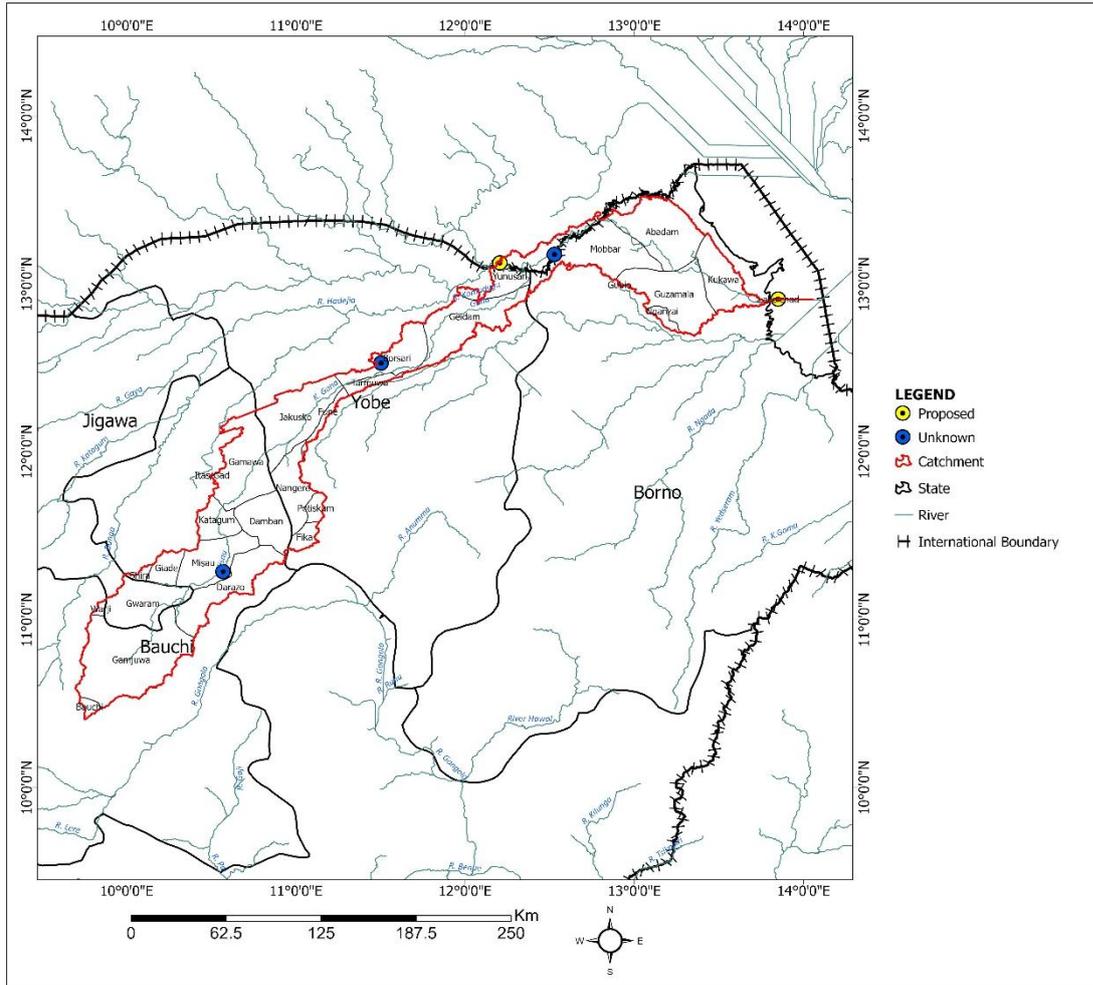


Figure 2.8: Map showing the Gauging Stations within the catchment (Source: MSL, 2024)

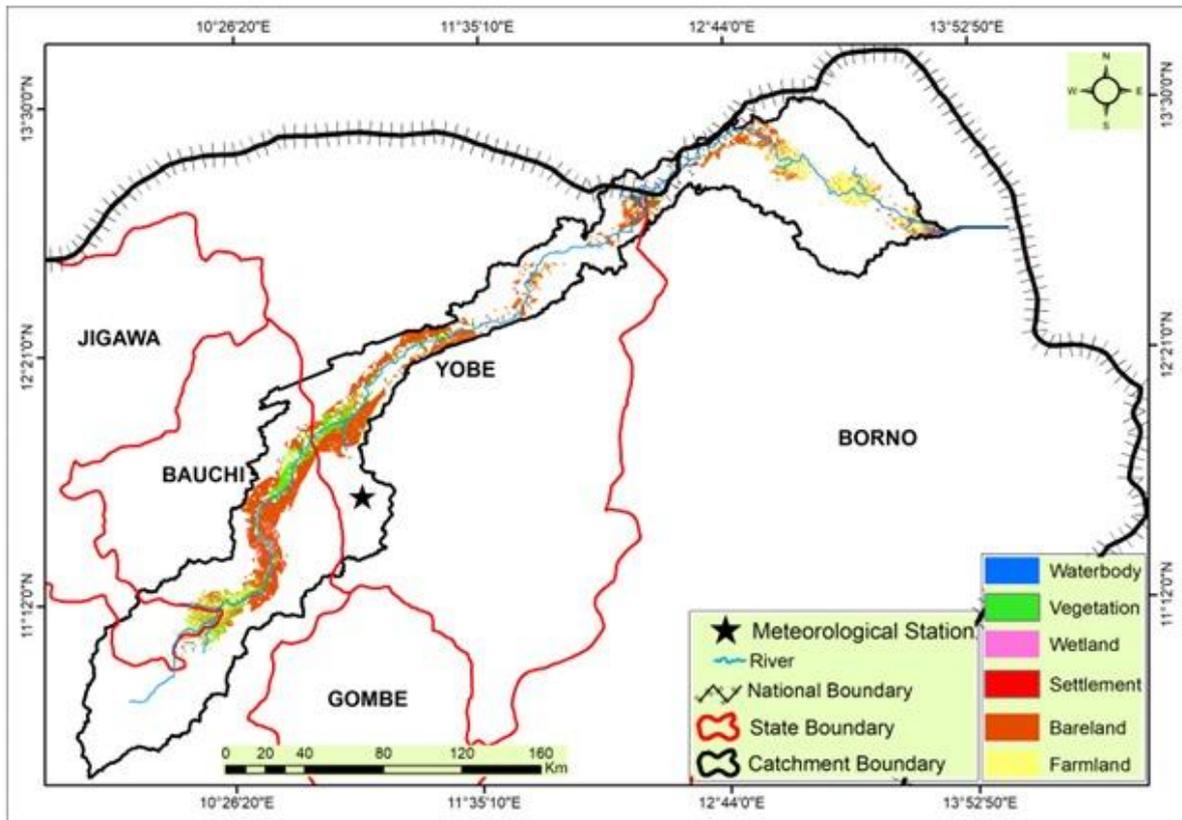


Figure 2.9: Map of Meteorological stations (Source: MSL, 2024)

The World Meteorological Organization (WMO) recommends 384 hydrological stations in Nigeria, but only 237 are recorded. For weather stations, WMO recommends 970, yet only 291 are recorded, with data received from just 54 (NIMET).

2.3.3 Geology and Soil Types

2.3.3.1 Geology

The Misau-Komadugu Gana Catchment's geology shown in Figure 2.10 influences water availability, drainage, and soil properties within the catchment. The main features of the catchment geology base on locations are:

- The western and southern parts are dominated by the Precambrian Basement Complex in Bauchi, with resistant metamorphic and igneous rocks like granite, gneiss, and schist.
- The north-eastern and central regions feature sedimentary formations from the Upper Benue Trough and Chad Basin, including sandstone, siltstone, and shale.
- Yobe's dominant Chad Formation consists of lacustrine and fluvial deposits, while the Kerri-Kerri Formation lies over basement rocks.
- Borno's geology includes Chad Basin sedimentary rocks in the north and older basement complex rocks near the Mandara Mountains.
- Jigawa lies within the Nigerian Basement Complex, featuring ancient crystalline rocks such as granite, gneiss, and schist, resistant to weathering.

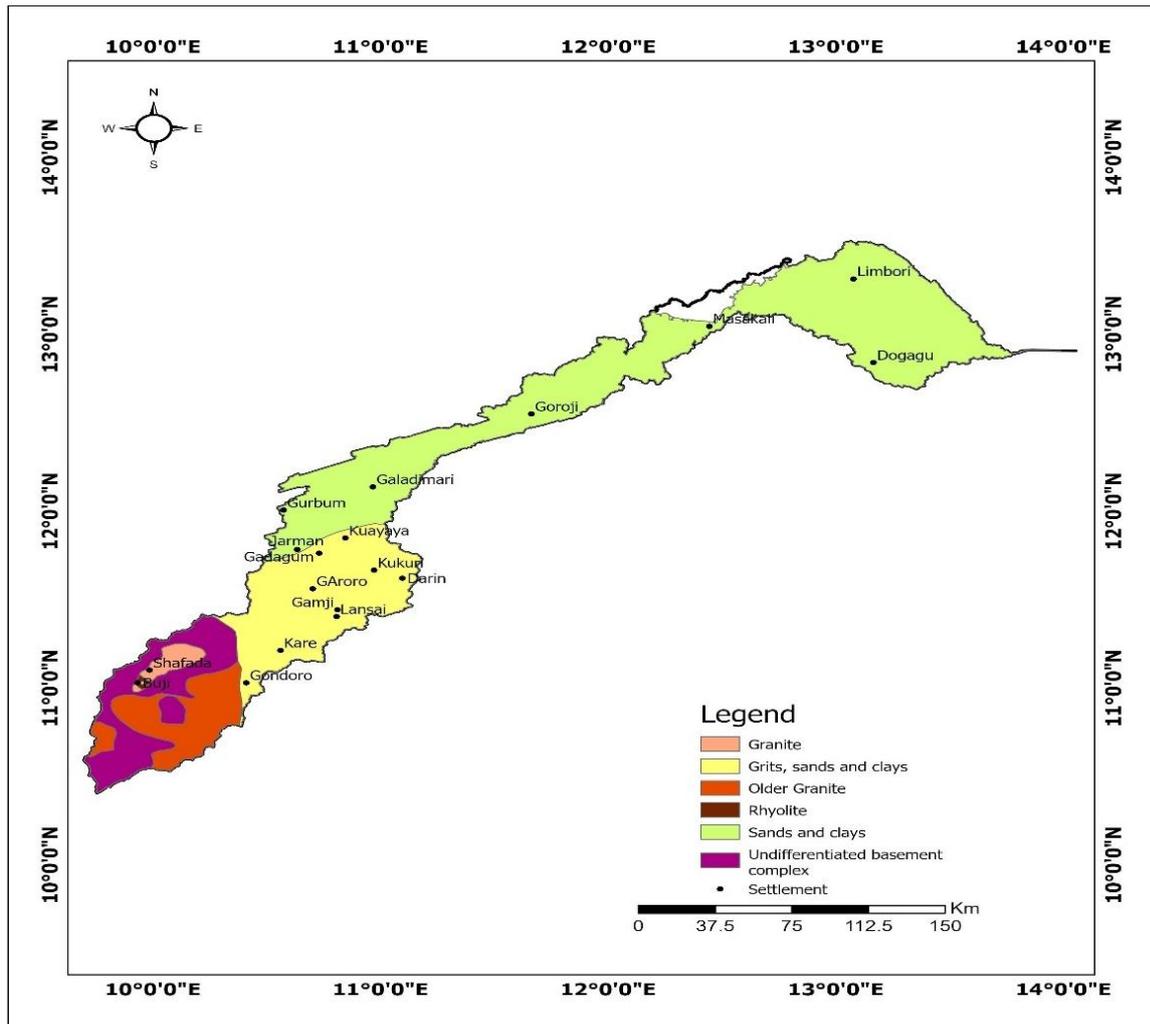


Figure 2.10: Geologic map of the catchment area (Source: MSL, 2024)

2.3.3.2 Soil Types

Soil types in the catchment area shown in Figure 2.11 vary depending on location and are primarily influenced by various factors such as geology, climate, and topography. The major soil types are outlined below according to the different state.

- **Ferralsols:** Found in Bauchi and Borno State, these soils are highly weathered, red to yellowish soils rich in iron and aluminium but low in nutrients.
- **Vertisols:** Clay-rich, fertile soils found in floodplains, prone to cracking and poor drainage. They are mostly found in Bauchi and Yobe State.
- **Arenosols:** Sandy, well-drained soils with low fertility, requiring careful management. They are highly permeable soils common in arid northern regions of Bauchi and Borno State.

- **Fluvisols:** Young, fertile alluvial soils ideal for wetland agriculture but susceptible to flooding found in Bauchi State.
- **Sandy Soils:** Found in the north most especially Yobe State, well-drained but low in fertility, supporting drought-resistant crops.
- **Loamy Soils:** A balanced mix of sand, silt, and clay, offering moderate fertility. Also found in Yobe State.
- **Clayey Soils:** Found in Yobe State, it is a moisture-retaining soil type but prone to waterlogging, suitable for rice farming.
- **Alluvial Soils:** Fertile river-deposited soils supporting intensive agriculture found in Yobe and Jigawa States.
- **Gleysols:** Waterlogged, nutrient-rich soils requiring careful management. Found in most parts of Borno State.
- **Luvisols:** Clay-rich and nutrient-dense, supporting intensive agriculture in most regions of Borno State.
- **Acrisols:** Clayey, acidic soils suited for sorghum and millet cultivation in most parts of Jigawa State.
- **Ferruginous Soils:** Iron-rich, well-drained soils found in the northern part of Jigawa State.

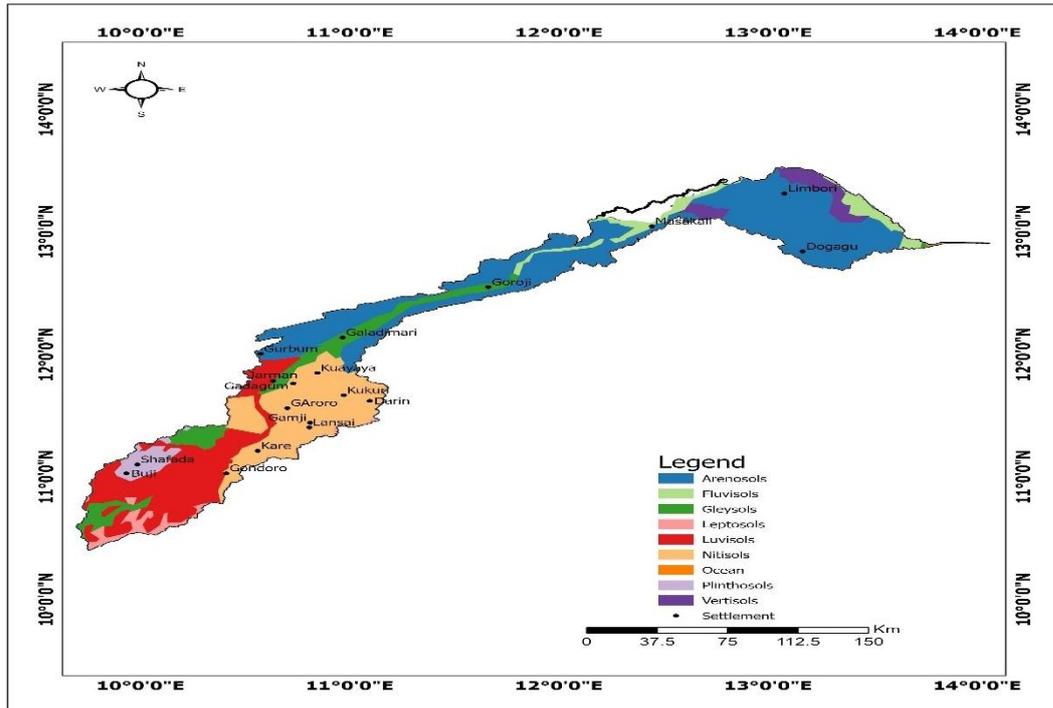


Figure 2.11: Soil Map of the catchment area (Source: MSL, 2024)

2.4 Land Use and Land Cover

The Misau-Komadugu Gana Catchment features diverse land use types influenced by geology, climate, topography, soil conditions, and human activities. Key components such as agricultural land, grazing areas, forests, urban settlements, wetlands, and water bodies are vital for hydrological balance, ecosystem stability, and local livelihoods.

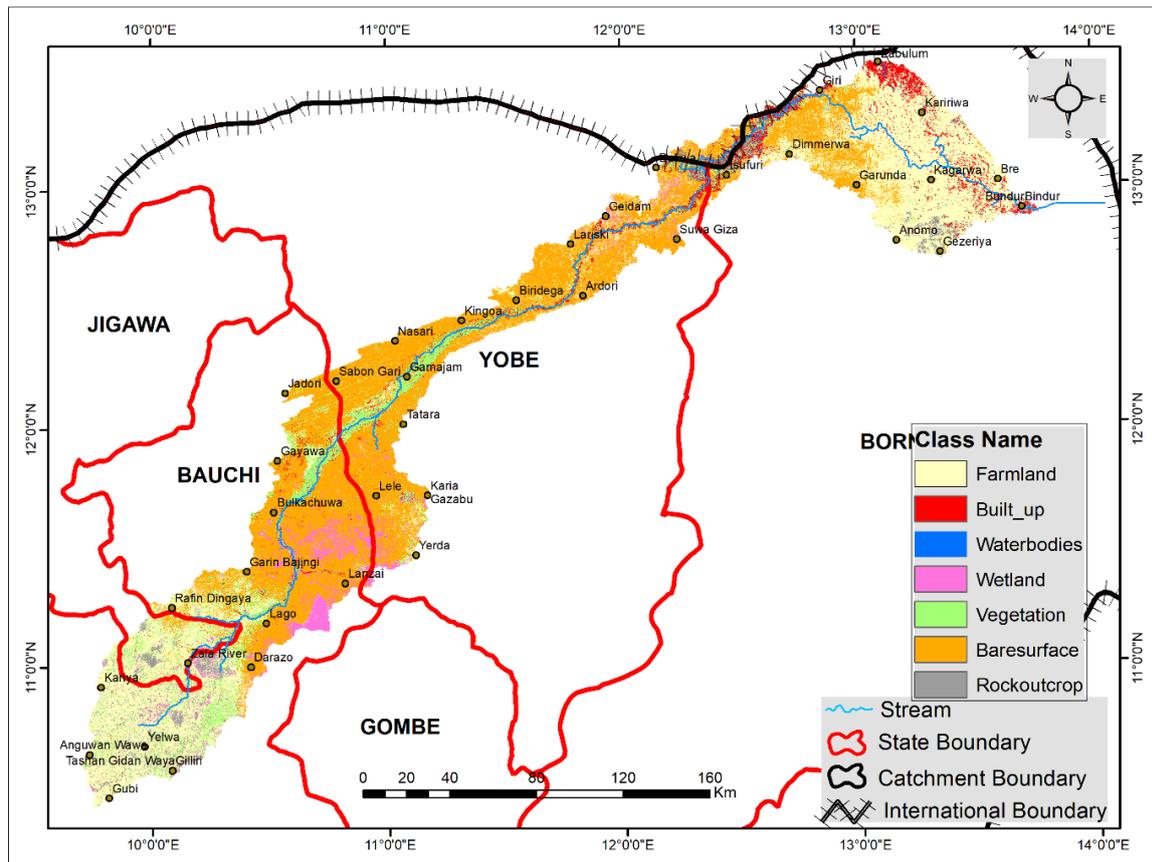


Figure 2.12: Land use/Land cover map of the catchment (Source: MSL, 2024)

2.4.1 Agricultural Land Use

Agricultural land use within the catchment area can basically be group into:

- Rainfed Agriculture: Predominantly rainfed farming occurs in Bauchi, Yobe, Jigawa and northern Borno State with millet, sorghum, maize, cowpeas, and groundnuts as key crops [Garba et al., 2019; Food and Agriculture Organization, 2023].
- Irrigated Agriculture: Irrigation farming is mostly practiced in river valleys and near reservoirs for rice and vegetable cultivation in states such as Bauchi, Jigawa State (Hadeija River and Hadeija-Nguru Wetlands) and southern Borno State. Some irrigation farming supports millet, sorghum, maize, and groundnuts. Irrigation farming is also known to boost dry season farming within the catchment area.
- Shifting Cultivation: Some shifting cultivation occurs in Bauchi and Yobe States, where farmers rotate farmlands to restore soil fertility. In semi-arid areas such as southern Borno, shifting cultivation is practiced alongside mixed farming systems.

2.4.2 Pastoralism

The second most important LULC activity in the Misau-Komadugu Gana catchment area is pastoralism. This basically involve:

- **Extensive livestock farming:** this involved the rearing of cattle, sheep, goats, and camels, often through transhumant systems in most regions of Yobe, Jigawa, central and northern parts of Borno State [Yahaya & Mohammed, 2018].
- **The movement of livestock:** this often follows seasonal patterns based on the availability of forage and water [World Bank Climate Data, 2023].

2.4.3 Forest and Woodlands

The Misau-Komadugu Gana catchment has forested areas, especially in the southern highlands, with species like *Isoberlinia doka* and *Daniellia oliveri*. Some key features are:

- Yobe's southern regions has savanna woodlands and grasslands.
- Borno faces limited forestry due to harsh conditions.
- Jigawa has sparse woodlands and forest reserves supporting fuelwood and biodiversity.

Efforts for reforestation and afforestation aim to combat deforestation and desertification.

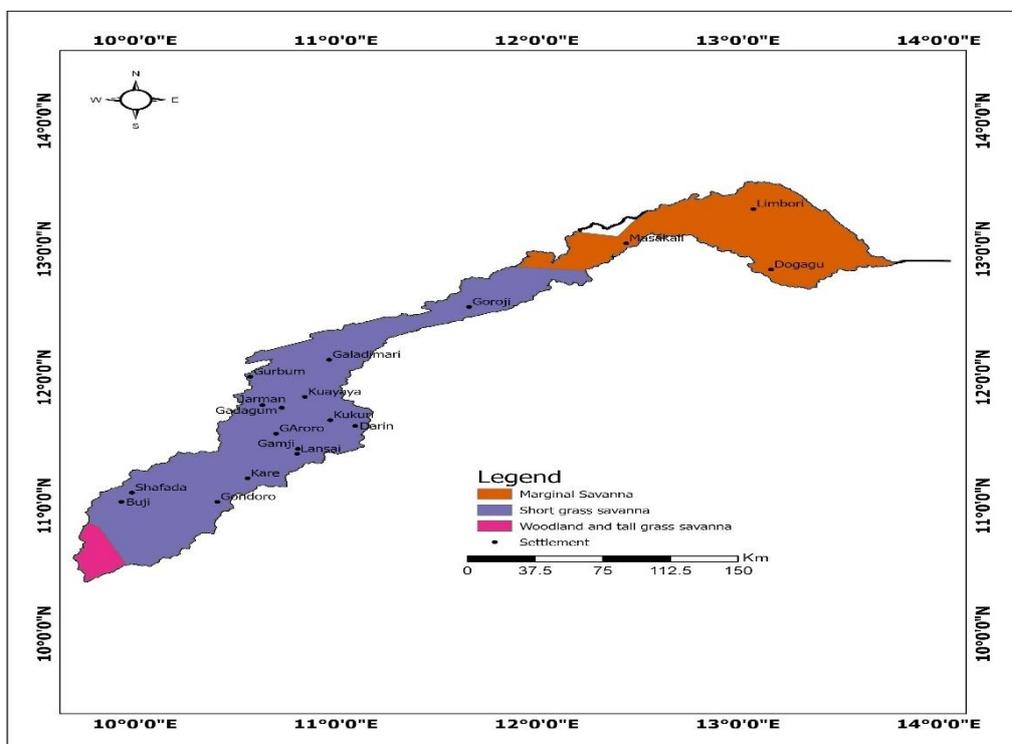


Figure 2.13: Map showing the vegetation cover in the catchment area (Source: MSL, 2024)

2.4.4 Urban and Built-Areas

Human settlements in the Misau-Komadugu Gana Catchment are shaped by topography, water availability, and economic activities.

- Bauchi State has rapidly growing urban areas, with Bauchi city as the largest city.
- Yobe State has a mix of pastoral lands and urban hubs like Damaturu and Potiskum.
- In Borno state, Maiduguri, Bama, and Damboa are concentrated near water sources and fertile land.
- Jigawa's urban growth is focused in Dutse, Hadeija, and Kazaure, supporting local administration and economy [National Space Research and Development Agency, 2023].

2.4.5 Wetlands and Waterbodies

Water bodies in the Misau-Komadugu Gana Catchment are vital for agriculture, domestic use, and industry.

- Bauchi State features important water bodies and wetlands, particularly along the Gongola River, which support wildlife and maintain the region's hydrological balance [Adamu & Garba, 2018].
- Jigawa State also has significant water resources, including the Hadeija River and seasonal streams, which impact agriculture and provide essential water for ecological and human needs [UNEP, 2023].

2.4.6 Desertification and Land Degradation

Deforestation, overgrazing, and climate change have led to barren land in parts of Jigawa State, with desertification resulting in minimal vegetation. Human activities, like deforestation, exacerbate this issue. Similarly, Yobe State experiences significant land degradation due to overgrazing and deforestation, particularly near populated areas.

2.4.7 Mineral Extraction

One of the main drivers of the catchment economy is the exploitation and extraction of minerals. In Jigawa State, for example, there are mining operations that concentrate on the extraction of minerals like granite and limestone. These activities support the state's economy and are mostly local in nature [Geological Survey of Nigeria, 2023].

2.4.8 Biodiversity and Ecosystem Summary

Table 2.1: Summary table of the Biodiversity of the Catchment

State	Ecosystems / Habitats	Flora	Fauna	Ecosystem Services	Notable Protected Areas / Sites
Bauchi	Sudan/Sahel savanna, rivers (Gongola), wetlands, Wikki Warm Springs	Acacia spp., Baobab (<i>Adansonia digitata</i>), Neem (<i>Azadirachta indica</i>), grasses, herbs	Elephants, antelopes, monkeys, baboons, birds (herons, storks), amphibians, fish	Fuelwood, medicinal plants, fisheries, ecotourism, nutrient cycling, habitat provisioning, water regulation	Yankari National Park, Sumu Wildlife Park, Gongola River
Yobe	Savanna grasslands, woodlands, Nguru Wetlands, Yobe River	Acacia, grasses, wetland vegetation (Typha, reeds)	Migratory birds (waders, ducks), amphibians, small mammals, fish (Tilapia, Catfish)	Food, fishing, flood regulation, groundwater recharge, carbon sequestration, habitat conservation	Nguru Wetlands, Dagona Bird Sanctuary, Gujba Forest Reserve
Borno	Sahel savanna, Lake Chad floodplains, Komadugu-Yobe River, seasonal wetlands	Papyrus, water lilies, tamarinds, Acacia spp., shea tree (<i>Vitellaria paradoxa</i>)	Elephants, antelopes, African jacana, Nile perch, frogs, storks, migratory birds, toads, turtles	Fisheries, water regulation, soil fertility, habitat for migratory birds, biodiversity hotspots, traditional flood-recession farming	Chad Basin National Park, Sambisa Forest, Lake Chad Basin

Jigawa	Floodplains, Sahelian grassland, rivers (Hadejia), ponds, reservoirs	Baobab, shea tree, grass species, riparian vegetation	Roan antelope, warthog, African grey hornbill, Secretary bird, Nile crocodile, catfish, tilapia	Irrigation, fisheries, habitat for endangered birds, flood mitigation, seasonal farming	
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2.5 Hydrology and Water Resources

2.5.1 Hydrology

The Misau-Komadugu Gana Catchment is an important hydrological system that supports agriculture, water supply, and biodiversity. The hydrology of the catchment is characterized by a network of rivers, seasonal flooding, and groundwater resources.

1. River System

The diverse topography and geology of the Misau-Komadugu Gana Catchment have an impact on its drainage system. These are the catchment's principal rivers:

- ***Gongola River (Bauchi State)***: Originates from the Jos Plateau and flows north-eastward before joining the Benue River. It is crucial for irrigation and floodplain agriculture.
- ***Yobe River (Yobe State)***: A significant watercourse that eventually drains into Lake Chad, playing a vital role in the region's hydrology.
- ***Komadugu Gana River (Yobe State)***: A major tributary of the Yobe River, essential for local water supply and agriculture.
- ***Hadejia River (Jigawa State)***: Supports the Hadejia-Nguru Wetlands and contributes to the region's agricultural activities.

2. Flooding and Wetlands

The catchment experiences seasonal flooding, which is largely caused by excessive rainfall and river overflow. Key flood-prone areas include:

- ***Hadejia-Nguru Wetlands (Jigawa and Yobe States)***: This globally renowned Ramsar wetland supports agriculture and fishing, regulates floods naturally, and is essential for biodiversity.
- ***Nguru Floodplain (Yobe State)***: Provides seasonal water retention and supports agriculture and grazing during wet periods.

3. Groundwater Resources

Groundwater is an important source of water, particularly in drier parts of the catchment area where surface water availability is limited. The groundwater system comprises:

- **Shallow Aquifers:** Found in floodplains and wetland areas, shallow aquifers are recharged by seasonal rainfall and river infiltration.
- **Deeper Aquifers:** More prominent in Borno and Yobe States, where boreholes provide water for domestic and agricultural use.

2.5.2 Hydrograph/Water Budget of the Catchment

2.5.2.1 The Misau-Komadugu Gana Strategic Catchment

Figures 2.14 - 2.18 present the hydrographs and water budget graph of the Misau-K-Gana strategic catchment. The Misau-K-Gana catchment experiences a seasonal runoff pattern typical of Nigeria's semi-arid northern regions, with peak flows occurring between September during the rainy season. Runoff is highly variable, influenced by intense but erratic rainfall, sparse vegetation cover, and relatively impermeable soils that promote rapid overland flow. Dry season flows are minimal, often reduced to isolated pools sustained by limited groundwater discharge. Flash floods occasionally occur following heavy downpours, but water scarcity prevails for much of the year, constraining agricultural and domestic water use in this predominantly rural catchment.

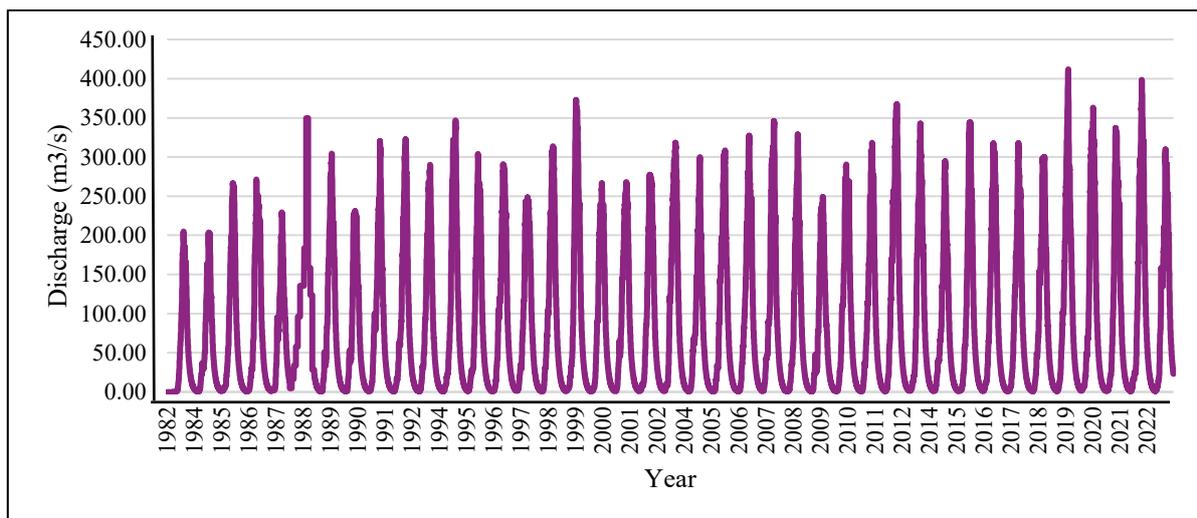


Figure 2.14: Hydrograph of Misau Strategic Catchment Based on HEC-HMS modelling for Strategic Catchment. (Source: MSL 2024)

The water budget of Misau-K-Gana catchment reflects its semi-arid climate, where potential evapotranspiration frequently exceeds annual rainfall ranging between 600 - 900mm. The excess evapotranspiration brings the water to 93.75mm. This water deficit creates significant challenges for water-dependent activities, requiring careful management of seasonal floodwaters and exploration of alternative water sources to meet community needs throughout the year. The monthly actual evapotranspiration distribution for Misau-K-Gana strategic catchment is shown in Figure 2.18, and a summary table is in Table 2.2.

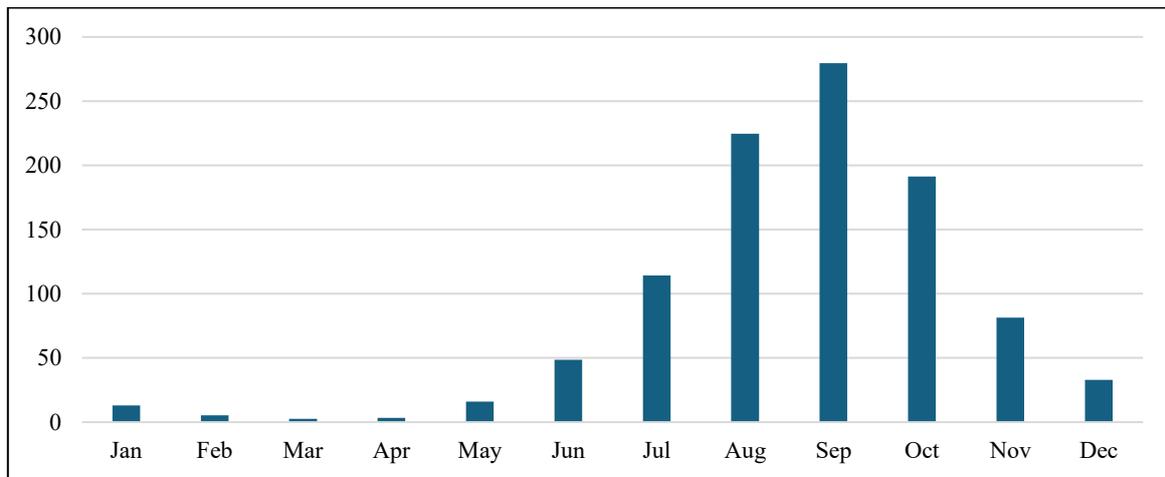


Figure 2.15: 40 Years Summary Hydrograph of Misau Strategic Catchment (Source: MSL, 2024)

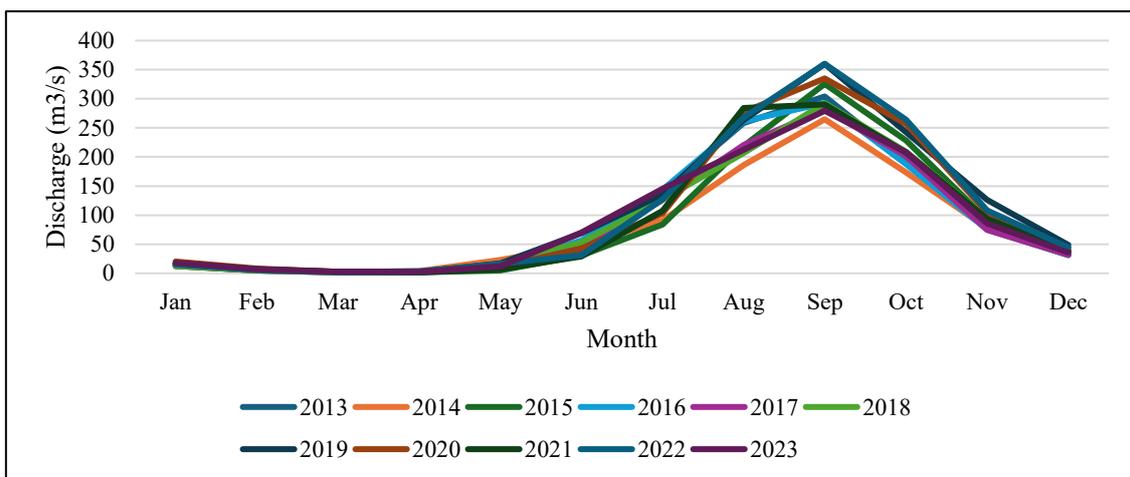


Figure 2.16: Hydrograph of Misau Strategic Catchment for Specific Year (Source: MSL, 2024)

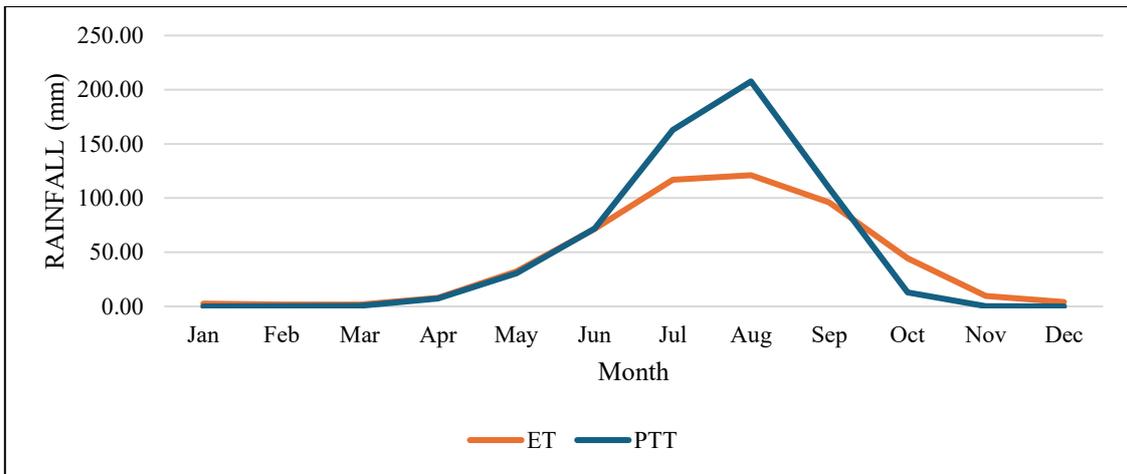


Figure 2.17: Water Budget for Misau Strategic Catchment (Source, MSL, 2024)

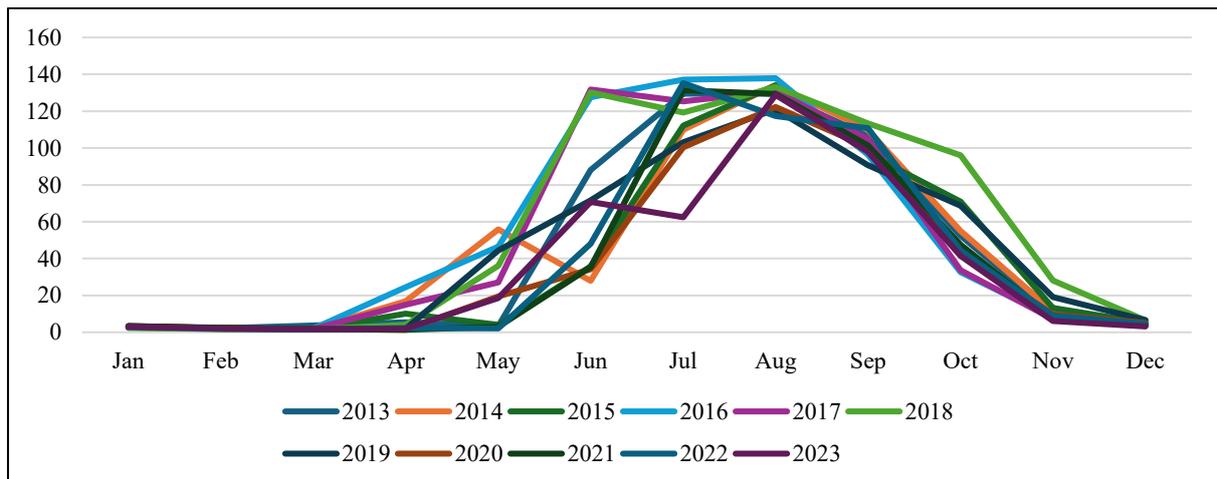


Figure 2.18: Monthly Actual Evapotranspiration Distribution for the Misau Catchment

Source: TerraClimate, MSL, 2024

Table 2.2: Summary of Discharge, Rainfall and Evapotranspiration Data for Misau Strategic catchment

MONTH	PPT	ET	Synthetic Peak Runoff (m³/s)
Jan	0.02	2.49	12.97
Feb	0.10	1.77	5.42
Mar	0.62	1.85	2.55
Apr	7.46	8.05	3.37
May	30.69	32.29	15.99
Jun	71.79	71.44	48.62
Jul	162.99	117.01	114.22
Aug	207.68	121.09	224.68
Sep	109.13	95.92	279.49
Oct	13.02	44.32	191.26
Nov	0.19	9.68	81.54
Dec	0.02	4.07	32.88

2.5.2.2 Prospects

Key prospects include:

- **Surface Water Reservoirs:** Capture peak flows (June–September) to store surplus water for use during dry months (January–April, November–December). This would mitigate water stress and reduce reliance on baseflow.
- **Floodwater Harvesting:** Utilize seasonal flooding (rising limb from May to August) for groundwater recharge or direct storage, reducing flood risks while enhancing water availability.
- **Agricultural Efficiency:** Promote drip irrigation, drought-resistant crops, and rainwater harvesting to reduce reliance on surface/groundwater during deficits.
- **Hydrological Modeling:** Use hydrograph and water budget data to optimize storage/release schedules for reservoirs and MAR systems.

2.5.3 Water Resources Assessment Concept in the Catchment

Water resources assessment is vital for managing availability, agricultural productivity, and environmental health.

- In northeastern Nigeria's catchment, understanding stream flow and discharge is essential because of its semi-arid climate and variable precipitation.
- This report summarizes current conditions, challenges, and management recommendations related to stream flow and discharge in the area.

2.5.3.1 Stream Flow and Discharge

Stream flow refers to the volume of water moving through a river or stream per unit of time. It is a critical parameter for assessing water availability, managing water resources, and planning for agricultural and domestic use. Some key significance are:

- *Hydrological Significance:* Stream flow data helps in understanding the hydrological cycle and predicting water availability during different seasons.

- *Water Resource Management:* Reliable stream flow measurements are essential for managing water resources, especially in semi-arid regions where water is a scarce resource.

In the catchment, stream flow varies significantly due to seasonal and annual variations in rainfall; the Misau river experiences fluctuating flow rates:

- *Seasonal Variability:* Stream flow in the catchment generally increases during the rainy season (June to September) and decreases significantly during the dry season (October to May). This seasonal variability affects water availability for various uses.
- *Annual Variability:* Year-to-year variations in rainfall, influenced by climate change and regional weather patterns, impact stream flow. Droughts and reduced rainfall can lead to lower stream flow and water shortages.

2.5.3.2 Discharge

Discharge refers to the quantity of water flowing through a river or stream at a given time and is a direct measure of stream flow. It is crucial for:

- *Water Allocation:* Discharge data informs decisions regarding water allocation for agriculture, drinking water, and industrial use.
- *Flood Management:* Accurate discharge measurements are essential for predicting and managing flood risks, particularly during the rainy season.

Discharge levels in the catchment are influenced by:

- *Rainfall Patterns:* High discharge rates typically occur during the peak of the rainy season, while low discharge rates are observed during the dry season.
- *Land Use Changes:* Deforestation, urbanization, and agricultural expansion can impact discharge by altering runoff patterns and increasing sediment loads.

2.5.3.3 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

- Groundwater storage is critical in the catchment, especially where surface water resources are insufficient.
- Catchment aquifers store a significant volume of water, accessed through boreholes and wells.
- Over-extraction and inadequate recharge raise concerns about groundwater sustainability.

The continuous decline in groundwater storage in some areas suggests that current extraction rates may not be sustainable in the long term (Musa et al., 2020).

2.5.4.1 Groundwater Recharge

Groundwater recharge in the catchment area is influenced by a number of factors.

- Groundwater recharge is declining due to climate change, with variations by region.
- Areas with lower recharge rates are mostly more significantly affected than those with higher rates, even with the same absolute reduction.
- Groundwater levels near rivers tend to remain stable, while more distant areas, especially inland regions on plateaus, will face greater declines. Therefore, addressing climate change requires consideration of these regional differences.

Balance of Demand and Supply of Groundwater

The balance between groundwater recharge and demand is shown in Table 2.3. Ratio of water groundwater demand/recharge is 6% in national average.

- However, it is 1-72% 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. 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 2.3: Groundwater Recharge and Groundwater Demand (2030)

S/No	State	Groundwater recharge (MCM/year)	Groundwater demand (2030) (MCM/year)					Groundwater demand/ recharge
			Water supply	Private irrigation	Livestock	aquaculture	Total	
1	Bauchi	3,833	205	69	12	3	289	8%
2	Borno	747	197	47	23	2	270	36%
3	Yobe	680	118	51	12	1	183	27%

Source: National Water Resources Master Plan (JICA)

The balance of groundwater recharge and demand shows a national average ratio of 8% for groundwater demand/recharge, up from 6% without climate change. However, this varies significantly by state, ranging from 1% to 94%, indicating that climate change will exacerbate water balance differences among states.

Table 2.4. 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	Livestock	aquaculture	total	
1	Bauchi	2,792	205	78	12	3	298	11%
2	Borno	407	197	53	23	2	275	68%
3	Yobe	414	118	57	12	1	189	46%

2.6 Water Demand for Misau-Komadugu Catchment

2.6.1 Water Availability by Sub-basin

Table 2.5 below is a summary of the cumulative annual flow volume (million cubic meters, or MCM) for various sub-basins under natural conditions.

Table 2.5: Cumulative annual flow volume (million cubic meters, or MCM) for Misau-Komadugu Catchment sub-basins

Sub-Basin	2018 (MCM)	2020 (MCM)	2030 (MCM)	2040 (MCM)	2050 (MCM)
Komadugu Gana	669	615	592	593	594
Yobe Inlet	2,517	2,313	2,229	2,231	2,233
Yobe Outlet	378	347	335	335	335

2.6.2 Rainfall Data for Misau-Komadugu Catchment

The Misau-Kamadugu-Gana catchment has a tropical savanna climate with distinct wet and dry seasons, influenced by factors like topography and proximity to the Sahara Desert.

- Most rainfall occurs from April to October, supporting crop growth and water resources.
- Yobe State has a hot, semi-arid climate with unimodal rainfall.
- Borno State is predominantly hot and dry, with a rainy season from June to September.
- Jigawa State experiences a semi-arid climate, and the Nguru Wetlands are essential for local biodiversity and agriculture.

Table 2.6: Rainfall Data for Misau-Komadugu Strategic Catchment

	DINGAIYA	NGELZARMA	YOBE	AVERG
Jan	0.03	0.00	0.00	0.02
Feb	0.15	0.01	0.00	0.11
Mar	0.87	0.10	0.09	0.67
Apr	9.76	5.22	5.47	8.57
May	43.67	12.26	8.82	35.31
Jun	92.73	59.05	47.00	83.61
Jul	195.12	146.60	129.36	181.98
Aug	246.17	178.30	171.17	228.11
Sep	132.62	97.17	92.90	123.18
Oct	18.71	9.88	9.08	16.36
Nov	0.38	0.10	0.07	0.31
Dec	0.03	0.00	0.00	0.02
Grand Total	740.25	508.69	463.95	678.24

2.6.3 Water Use and Demands

The water needs for the present and future were assessed for the Misau K.Gana Catchment area illustrated in the provided image using the approach utilized in the NWRMP (JICA, 2014 and SAP 2019 of SMEC). The data related to demand was gathered at the State level. The States considered include regions of Bauchi, Yobe, and Borno.

The water demand for the Misau-Komadugu Catchment is divided into the following categories:

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

- Aquaculture water demand.

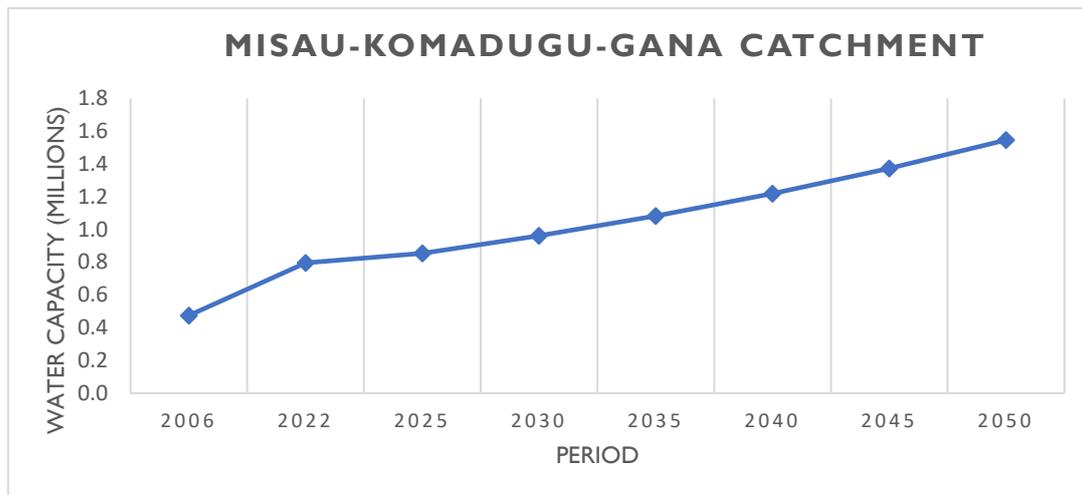


Figure 2.20: Misau Komadugu-Gana Catchment chart (Source: MSL, 2024)

2.6.4 Municipal Water Demand

Municipal water demand is mostly met by groundwater throughout the basin. Table 2.7 shows the water demand in the catchment.

Table 2.7. Water supply use by 2017 in the catchment

No.	SHAs	SHA No	Catchment Area (km ²)	Public Water supply use (MCM)
	Northern basin Joining Yobe River at Geidam	80804	6124	5.90
	Yobe River between Geidam and Damasak	80803	1497	1.50
	Northern basin Joining Yobe River at Geidam	80804	6124	5.90
	Yobe River between Gashua and Geidam	80805	9528	21.6
	Komadugu Gana River Basin	80802	30,170	64.3
			53,443	99.2

Source: SAP 2019 of SMEC

2.6.5 Livestock Water Demand

The characteristics of livestock water demand in the catchment are:

- Higher Livestock Population in the North: Due to frequent droughts, northern inhabitants rely more on livestock than crop farming.
- Limited Surface Water: Low annual precipitation leads to scarce surface water, especially in dry seasons.
- Dependence on Well Water: Livestock often rely on well water as a last resort.
- Water Needs of Livestock: Water consumption depends on temperature, live weight, and grazing availability.
- Grass as a Water Source: 80% of grazing grass is water; consuming 20 kg of grass provides 16 liters of water.
- Impact of Drought: In extreme drought (≤ 400 mm rainfall), cattle graze only 5 kg/day, requiring 11 liters of additional drinking water.
- Movement Increases Water Demand: Walking cattle need twice as much water as stationary ones.
- Daily Water Requirement: Adult cattle require 25–35 liters/day depending on weight and activity.
- Similar Needs for Other Ruminants: Goats and sheep follow similar water consumption patterns.

The following table shows the standard of livestock water requirement in the tropical zone shown in one of livestock guidebooks published by FAO in 1960s.

2.6.5.1 Inland Fishery

The characteristic of water demands for inland fishery are:

- Annual Water Supply Calculation: 0.03 MCM per hectare per year, replacing 50 cm of water every two months.
- Water Sources: 75–85% from shallow wells, the rest from surface runoff, lakes, or stagnant water.
- Water Quality Requirements: Must be free from detergents and chemicals, have neutral pH, and contain dissolved oxygen above 4 ppm.
- Preference for Groundwater: Cooler water holds more oxygen, making groundwater ideal for replacement.

2.6.6 Irrigation water demand

2.6.6.1 Irrigation Water Use

The various use of water for irrigation in the catchment includes.

- The Various Small-Scale Irrigation Systems: Both formal and informal systems exist in the catchment.
- Fadama Irrigation: Locally developed, using surface water diverted by gravity or small diesel pumps.
- Public Irrigation: Primarily relies on surface water.
- Private & Fadama Irrigation: Uses groundwater, especially after flood recession.
- Irrigation Outside Floodplains: Mostly depends on groundwater.

The irrigation water demand was extracted from the Irrigation Thematic Report (SMEC 2017) and Nigeria National Water Resources Master Plan (NNWRMP 2013).

2.6.6.2 Irrigation Water Demand Projection

The irrigation water demand is projected based on:

- Irrigation Water Demand Calculation: Product of gross irrigation requirement and cropped area.
- Irrigation Efficiency Assumption: 50% efficiency applied across the basin.
- Water Return to Surface: With drainage systems, 50% of abstracted water re-enters surface water.

2.6.7 Water Demand Vs Total Available Water

Total available water is projected to vary from approximately 1,302 MCM/yr in 2018 to 1,036 MCM/yr in 2050. The variation is related to the effects of climate change as shown in

Table 2.8.8.

Table 2.8: Water Balance for Komadugu Catchment

Demand / Availability	Water Volume (MCM)				
	2018	2020	2030	2040	2050
Climate Change					
Total demand	834	838	858	881	904.0
Total available	1,302	1,210	1,111	1,036	961.0
Balance	468	372	253	155	57.0
Demands as % of available	64%	69%	77%	85%	90%

Source: JICA 2014 MP Projected to 2050

A comparison of the sub-basin water demand and available water shows that neither surface water nor groundwater resources can meet the water demand alone, hence conjunctive water use will be required. Table 2.9 shows the total demand as a percentage of the available resources. The data shows water demand for Komadugu-Gana sub-basin will be 64% to 85% of the total available resources.

Table 2.9: Total water allocated Vs. Water available per resource – Komadugu Catchment

Allocation / availability	Source	Volume of Water (MCM/yr)				
		2018	2020	2030	2040	2050
Climate Change						
Allocated water demand	Surface	355	417	428	341	254
	Groundwater	381	318	324	450	576
	Total	736	734	752	791	830
Available water resources	Surface	669	615	592	593	594
	Groundwater	606	573	444	335	226
	Total	1,275	1,188	1,036	928	820
Balance available	Surface	314	198	164	252	340
	Groundwater	225	256	120	0	-120

	Total	539	454	283	252	221
Water allocated as	Surface	53%	68%	72%	57%	40%
% of available	Groundwater	63%	55%	73%	100%	100%

Source: JICA 2014 MP Projected to 2050

There is therefore a potential for the development of other economic activities to utilise the available resource in the Basin. The water surplus does not, however, imply there will be no water shortage in the entire sub-basin. Water shortages are rampant in the eastern part of the sub-basin due to low rainfall and poor aquifers; hence areas in the east will have perennial droughts and water shortages.

Future exhaustive evaluation will be required to evaluate the limited potential of additional water utilization in the sub-basin.

2.6.8 Total Water Demand

The total water demand in the Misau-Komadugu Catchment is generated by several sectors, including irrigation, municipal water supply, livestock, fisheries, and environmental demands. Table 2.10 shows the demand has been projected for different years based on available data.

Table 2.10: Total water demand in the Misau-Komadugu Catchment

Sector	2018	2020	2030	2040	2050
Irrigation (Fadama & Surface Water)	526.8	526.8	526.8	526.8	526.8
Yobe Sub-basin Irrigation	701.0	747.4	762.8	855.5	932.7
Municipal Water Supply	99.2	130.1	161.0	238.2	315.4
Livestock Demand	94.0	108.6	127.4	151.8	180.8
Fisheries & Aquaculture	1.7	1.8	1.9	2.0	2.0
Environmental & Other Demands	235.5	235.5	235.5	235.5	235.5
Total Water Demand	1,658.2	1,749.2	1,815.4	2,009.8	2,193.2

Sources: JICA 2014 MP and SAP 2019 of SMEC.

Table 2.11: Water Balance of the Catchment

WATER BALANCE ANALYSIS FOR MISAU-K.GANA CATCHMENT			
WATER DEMAND (CUBIC METER)		2025	2050
MUNICIPAL		239,856,368	433,960,468
LIVESTOCK		60,083,097	85,675,933.01
AQUACULTURE		1,789,670	2,012,100
IRRIGATION		36,600,000	113,200,000
TOTAL		338,329,135	634,848,501
AVAILABLE WATER RESOURCES (CUBIC METER)		909,963,500	909,963,500
WATER BALANCE (CUBIC METER)		571,634,365	275,114,999

2.6.9 Infrastructure and Assets

Table 2.12 below shows catchment infrastructure and assets.

Table 2.12: Catchment Infrastructure and Assets

S/No.	Infrastructure	State	Infrastructure, Project /Location	Importance	Risk Factors
1	Dams and Reservoirs Hydro power station	Bauchi	Gubi Dam Kafin Zaki Dam	Source of portable drinking water, provide supplementary irrigation water, mitigate seasonal floods, support aquatic ecosystems, fishing, hydro-energy production and contribute to groundwater recharge.	Sedimentation, structural aging, drought impaction Schemes, contamination from heavy metals such as Arsenic, Copper, and Nickel. Rising temperature and decreasing rainfall trends may reduce dam inflow, increasing reliance on groundwater.
		Yobe	Damaturu Water Treatment Plant (Damaturu)	Source of potable water for urban populations, reduces the spread of waterborne diseases, ensures water availability for commercial activities, including small-scale industries and businesses, and enhances agricultural	Inadequate maintenance and aging, frequent breakdowns and equipment failures disrupt water treatment processes, decreasing groundwater recharge and variable rainfall patterns, heavy metal contamination, inadequate funding for plant

				productivity by providing water for irrigation.	operation and expansion affects water production capacity and weak regulatory enforcement in water quality monitoring.
		Borno	Maiduguri Water Treatment Plant (Maiduguri)	main supplier of potable water for Maiduguri, supports domestic, commercial, and institutional water demands, and prevent outbreaks of waterborne diseases.	The plant operates below its designed capacity, making it inadequate for the city's growing population, infrastructure deterioration, limited maintenance and lack of spare parts, frequent power outages severely disrupt the plant's operations, insufficient supply of treatment chemicals, risk of bacterial and chemical contamination, seasonal drying of surface water sources and security and conflict-related challenges
		Jigawa	Dutse water treatment plant (Dutse)	Processes raw water from selected sources, provides safe drinking water to households, businesses, and institutions, removes contaminants,	The plant's current capacity is insufficient to meet the growing water demand, aging infrastructure & maintenance challenges, power

				sediments, and microbial pathogens, reduces waterborne diseases such as cholera, typhoid, and diarrhoea, and supports agriculture and food processing.	supply disruptions, inadequate government funding hampers expansion and modernization, poor enforcement of water quality standards increases the risk of contamination and declining groundwater recharge, and seasonal variability of surface water pose challenges to sustainable water sourcing
2		Bauchi	Gubi Dam Hydropower	Renewable energy generation, rural electrification, supplement local power needs, reducing dependence on fossil fuel-based electricity sources, enhancing food security and economic stability for local farmers, regulates seasonal water flow, helping mitigate downstream flooding risks and supports aquatic ecosystems and biodiversity, maintaining ecological balance.	Insufficient water flow, infrastructure degradation, high turbidity levels during the rainy season affect treatment efficiency, climate change-induced rainfall variability could further reduce inflows and affect reservoir storage, soil erosion from upstream areas leads to sediment buildup in the reservoir, reducing storage capacity, aging dam structures and inadequate maintenance can lead

					to structural vulnerabilities, limited hydropower capacity due to insufficient turbine infrastructure and seasonal water shortages and weak policy enforcement on water resource management affects sustainability.
		Yobe	Tiga Hydropower Station	Provides hydroelectric power to Yobe and neighbouring states, supports economic activities by ensuring a stable power supply for industries, businesses, and households, a critical component of the Kano River Irrigation Project, supplying water for large-scale irrigation in Yobe and Kano States, supports year-round farming, increasing crop yields and food security, regulates seasonal flooding of the Komadugu-Yobe River, preventing crop damage and displacement of communities, improves groundwater recharge, benefiting local aquifers and	Declining river flow due to climate change and reduced rainfall affects power generation capacity, water diversion for irrigation in upstream areas reduces availability for downstream users, leading to tensions between agricultural and energy sectors, downstream communities in Yobe and Borno face water shortages, affecting local livelihoods, soil erosion from deforested areas upstream increases sediment deposition in the reservoir, requires frequent dredging and maintenance, increasing operational costs, seasonal

				reducing water shortages, and provides employment for workers in the energy, agriculture, and water management sectors.	flooding changes disrupt aquatic habitats, leading to fish population decline, inadequate funding and poor maintenance threaten long-term sustainability and lack of integrated water resource management between states limits efficiency in water distribution.
		Borno	Lake Chad Basin Irrigation & Energy Scheme	Contributes to electricity supply in rural communities and reduce reliance on fossil fuels, supports industrial development, creating job opportunities in energy and agriculture, mitigate the effects of desertification and droughts by ensuring sustainable water flow, contributes to food security by expanding irrigated farmlands in Borno and neighbouring states, Boosts local fishing industries by increasing water availability and improving aquatic biodiversity, Strengthens cross-	Lake Chad has shrunk by over 90% in the past five decades due to climate change and over-extraction, reduced rainfall and increased evaporation rates threaten the sustainability of irrigation projects, upstream water diversions for agriculture and energy production could reduce downstream availability, affecting communities in Yobe, Niger, and Chad, potential for regional disputes over water rights, especially with increasing demand for irrigation, Aging dams, canals, and

				border cooperation with Chad, Niger, and Cameroon through transboundary water-sharing agreements	pumping stations require frequent repairs, leading to high operational costs, soil salinization risks from over-irrigation, reducing land fertility, insurgency in Borno State has disrupted water projects and threatened infrastructure security, and displacement of farming communities due to conflicts limits the full potential of the irrigation scheme.
		Jigawa	Hadejia Barrage (Proposed)	Helps regulate seasonal floods from the Hadejia River, preventing damage to farmlands, settlements, and infrastructure, Improves water storage and distribution for agricultural and domestic use, Enhances rice and wheat farming in the Hadejia Valley, improving food security, Aids in recharging groundwater levels Aids in recharging groundwater levels, supports the Hadejia-Nguru Wetlands,	Interference with natural river flow could impact downstream water users and ecosystem health, could reduce water availability in the Komadugu-Yobe Basin and Lake Chad, potential to disrupt seasonal flooding, May reduce fisheries productivity, affecting local livelihoods, upstream soil erosion could lead to sediment buildup, reducing storage capacity, requires regular dredging and

				<p>a critical ecosystem recognized under the Ramsar Convention for Wetlands, increases employment opportunities in farming, fishing, and water management and reduces water scarcity issues for communities dependent on the Hadejia River.</p>	<p>maintenance, increasing operational costs, competition between irrigation, domestic, and environmental needs could lead to disputes between farmers, fishermen, and local communities, downstream states (Yobe and Borno) could face water shortages, escalating interstate conflicts, and higher temperatures increase evaporation, lowering reservoir levels.</p>
3	Electricity Grid/Rural Electrification	Bauchi	National Grid (via Transmission Company of Nigeria - TCN)	<p>Supports economic activities and essential services, reduces reliance on self-generated power, enables mechanized farming and irrigation systems, boosting food production, supports manufacturing, small businesses, and commercial activities, driving economic expansion, provides stable electricity for water treatment plants, hospitals, and schools, and</p>	<p>Voltage fluctuations & frequent outages disrupt industries and essential services, Overloaded substations and aging transformers reduce efficiency, theft and sabotage of transmission lines lead to prolonged power failures, Weak security measures around substations make infrastructure vulnerable, Inadequate funding for grid</p>

				reduces reliance on fossil fuels, cutting emissions and ensuring energy security	expansion and maintenance leads to system failures, Delayed investments in grid modernization affect power quality, extreme weather events (storms, flooding) damage power infrastructure, and high temperatures & dust accumulation reduce the efficiency of transformers and lines.
		Yobe	Rural Electrification Projects (solar mini-grids in Damaturu & remote areas)	Provides stable electricity to off-grid communities that previously relied on kerosene and diesel generators, supports small businesses, schools, and healthcare facilities, improving living standards, enables irrigation and water pumping systems, boosting agriculture and food production, enhances small-scale enterprises such as welding, tailoring, and food processing, reduces reliance on fossil fuels, lowering carbon emissions and promoting clean energy, lessens deforestation, as	Insurgent attacks and theft threaten solar power installations, Lack of security for solar equipment increases the risk of damage and system failure, high initial costs of installation limit expansion to more villages, inadequate technical expertise affects maintenance, leading to frequent breakdowns, seasonal variations impact battery storage and power availability, limited government funding slows project expansion and

				households shift from wood and charcoal to solar power, and provides electricity for hospitals and schools, improving healthcare delivery and education.	inconsistent regulatory support affects long-term sustainability.
		Borno	Maiduguri Solar Power Initiative & National Grid (TCN)	Maiduguri Solar Power Initiative enhances electricity reliability, especially in rural and conflict-affected areas, National Grid (TCN) supports industrial activities and large-scale energy users, Powers the Maiduguri Water Treatment Plant, ensuring a steady water supply for residents, supports healthcare facilities, schools, and emergency services, improving public welfare, enables businesses and industries to operate efficiently, reducing dependence on costly diesel generators, expands job opportunities in renewable energy, construction, and maintenance, solar power reduces	Insurgent attacks on power infrastructure have repeatedly damaged grid transmission lines, frequent sabotage of substations and power lines results in prolonged outages, frequent power fluctuations and outages affect industrial and residential users, overloaded transmission infrastructure struggles to meet demand, solar power generation is weather-dependent, causing variability in supply, solar panels require regular maintenance due to dust and extreme heat and national Grid expansion requires

				reliance on fossil fuels, cutting emissions, and increases energy security, making Maiduguri less vulnerable to grid disruptions caused by insecurity	significant investment in repairs and security.
	Jigawa	Kano Electricity Distribution Company (KEDCO) & Mini-Grid Projects	Supplies electricity to kano, katsina, and jigawa states, powering industries, businesses, and residential areas, provides power to off-grid communities that lack access to the national grid, supports small businesses, schools, and healthcare centers in rural areas, enhances productivity for agro-processing industries, textiles, and smes, expands employment in renewable energy installation, maintenance, and distribution sectors, mini-grid projects reduce reliance on diesel generators, lowering carbon emissions, and promotes sustainable energy	Frequent power outages and voltage fluctuations impact industries and businesses, overloaded substations and aging transmission lines reduce grid efficiency, high costs of mini-grid installation and maintenance limit expansion, inconsistent government policies and lack of investment slow infrastructure upgrades, high operational costs make mini-grid projects financially challenging, theft of transformers and power cables disrupts supply and weak security measures increase risks to mini-grid installations	

				development, especially for rural communities.	
4	Grain Storage Facilities	Bauchi	Bauchi City, Misau, Toro, Ningi, Katagum	<ul style="list-style-type: none"> • Extends the shelf life of grains and ensures food availability during lean seasons. • Reduces post-harvest losses, which can account for 20-30% of grain losses due to inadequate storage. • Prevents price volatility by allowing grains to be stored and sold when demand is higher. • Ensures fair pricing for farmers, improving income stability. • Facilitates large-scale agro-processing industries, such as rice mills and flour production, • Supports export markets, increasing revenue from agricultural trade • Provides a buffer stock during droughts, floods, or conflicts, • Enhances national food security strategies. • Ensures resilience to climate-induced crop failures. 	<ul style="list-style-type: none"> • Many storage facilities lack modern temperature and humidity control. • Leading to spoilage, limited storage capacity results in grain overflow and wastage. • Poor storage management leads to infestations by weevils, rodents, and fungi. • Aflatoxin contamination in maize and groundnuts poses a major health risk. • High humidity and extreme temperatures cause grain deterioration. • Flooding and leaks in poorly maintained silos result in massive grain losses, poor road networks delay grain transportation, increasing spoilage risks. • High fuel costs and insecurity (banditry, insurgency) disrupt logistics. • Weak government policies on food storage & distribution lead to inefficiencies. • Limited private-sector investment in modern storage technology slows progress.



		Yobe	Damaturu, Gashua, Nguru, Potiskum		
		Borno	Maiduguri, Biu, Bama, Monguno, Gwoza		
		Jigawa	Dutse, Hadejia, Gumel, Kafin Hausa		
5	Research Institutes	Bauchi	Abubakar Tafawa Balewa University (ATBU) Research Centers	Conducts advanced hydrological modelling and climate change impact assessments, develops innovative water conservation and irrigation technologies, research on drought-resistant crops and precision agriculture to boost food security, studies land degradation, desertification control, and soil fertility management, conducts groundwater recharge studies to enhance water availability, develops strategies for flood control, river basin monitoring,	Insufficient research funding limits access to modern equipment and facilities, aging laboratories and inadequate research infrastructure affect scientific output, flooding and drought conditions disrupt long-term research projects, soil erosion and land degradation impact field research sites, limited partnerships with government agencies and private sector organizations, lack of open-access data platforms restricts research impact, risk of vandalism

				and pollution reduction, trains water resource managers, engineers, and environmental specialists and supports government agencies with policy recommendations for sustainable development	and theft of research equipment in remote field stations and limited security measures to protect researchers working in rural areas
		Yobe	Yobe State University (YSU) Research Institute	Conducts hydrological modelling and water management studies, improving catchment planning, monitors groundwater and surface water interactions to support sustainable water allocation, develops climate-resilient crop varieties for drought-prone areas, advances in renewable energy solutions for rural electrification, trains water resource professionals, improving institutional capacity and provides data-driven recommendations for water governance policies.	Limited research funding affects laboratory modernization, aging facilities hinder cutting-edge research , banditry and communal conflicts in rural areas restrict field research and data collection, weak partnerships between government agencies and the university slow research adoption and limited private-sector involvement in funding applied research.

		Borno	University of Maiduguri (UNIMAID) Water & Environmental Research Institute	Monitors Komadugu-Yobe basin hydrology for sustainable water allocation, provides data for water conservation and flood mitigation plans, supports lake Chad basin restoration efforts, and assesses climate vulnerability and recovery strategies for conflict-affected communities.	Research projects halted due to Boko Haram insurgency, Low funding from global climate research programs and limited real-time monitoring systems for water pollution and soil erosion.
		Jigawa	Jigawa Research Institute for Agricultural & Environmental Studies	Research on high-yield crops, improved irrigation techniques, and soil fertility enhancement, promotes efficient water use in dryland farming, studies on drought-resistant crops and adaptation measures and provides scientific data to guide agricultural policies and land use planning.	Lack of modern laboratories and research stations, Low funding for expansion and new research initiatives, Frequent droughts and desert encroachment affect long-term experiments and Farmers have limited access to innovations due to weak extension services.
6	Local Markets and Abattoirs	Bauchi	Maiduguri Cattle Market (Misau LGA) and Katagum Market (Katagum LGA)	<ul style="list-style-type: none"> Markets serve as trade hubs, boosting local economies and attracting investment. 	<ul style="list-style-type: none"> Insurgent attacks and banditry in Borno and Yobe threaten market operations. Cross-border trade faces restrictions due to security concerns

		Yobe	Nguru International Market (Nguru LGA) and Gashua Market (Bade LGA)	<ul style="list-style-type: none"> • Livestock trade in abattoirs provides jobs for butchers, traders, and transporters. • Ensures food availability by linking farmers and consumers. • Supports agricultural value chains, including grain and meat processing. • Nguru and Maigatari International Markets facilitate trade with Niger and Chad. • Gamboru Ngala Market supports transnational livestock exchange. • Tax revenue from market activities funds local infrastructure. • Exports from livestock and crops bring foreign exchange earnings 	<ul style="list-style-type: none"> • Lack of modern storage facilities causes post-harvest losses in grain markets. • Inadequate waste disposal in abattoirs leads to public health hazards. • Seasonal price volatility affects farmers and traders. • Transport disruptions (bad roads, fuel shortages) impact supply chains. • Unregulated meat processing in abattoirs increases the risk of disease transmission. • Poor waste management causes water and air pollution
		Borno	Maiduguri Monday Market (Maiduguri LGA) and Gamboru Ngala International Cattle Market (Ngala LGA)		
		Jigawa	Maigatari International Market (Maigatari LGA) and Hadejia Market (Hadejia LGA)		

2.7 Water Quality

2.7.1 The Misau-K.Gana Catchment

Sewage collection and wastewater treatment in the urban areas of the Misau-K.Gana Catchment area are not well organized. These include Nguru (Hadejia River), Gashua, Geidam, Damasak and Diffa (Yobe River). The towns along the Komadugu-Gana and Jama'are Rivers are relatively small.

- At the downstream of the Hadejia River System, Doody (2000) conducted a surface water quality survey at Marma Channel and Nguru Lake during the dry season (May/June). Electrical conductivity ranged from 100 to 210 $\mu\text{S}/\text{cm}$.
- Nitrate ($<2.5 \text{ mg/l}$) and phosphate ($<1 \text{ mg/l}$) levels were low at all sites, while arsenic (mean 0.018 mg/l , max 0.03 mg/l) exceeded the WHO limit (0.01 mg/l), likely due to pesticide use.
- The study indicated the waters were generally unpolluted, but agrochemicals posed a potential threat to wetland water quality (IUCN 2011).

2.7.2 Surface Water Quality

2.7.2.1 Physical Parameters

Bauchi

Temperature

- Water Temperature Impact: A key factor in water quality in Bauchi State.
- Surface Water Variability: Can exceed 30°C in the dry season, especially in shallow bodies [Adewumi et al., 2017].
- Stable Groundwater: Generally, ranges between 25°C and 28°C but varies with depth and ambient temperature [Muhammad et al., 2018].

pH Storage

- Surface Water pH: Ranges from 6.5 to 8.5, with rainfall sometimes lowering pH due to dilution and organic acids [Garba & Abubakar, 2019].
- Groundwater pH: Typically, between 6.8 and 7.5 but can be more alkaline in areas with mineral deposits.

- Mineral Influence: Boreholes in limestone-rich regions may have pH above 8.0.
- Importance of pH Balance: Essential for aquatic ecosystems and safe drinking water [Adewumi et al., 2017].

Turbidity

- Higher Turbidity in Wet Season: Rainfall and runoff increase suspended sediments in surface water.
- Impact on Aquatic Life: High turbidity reduces light penetration, affecting photosynthesis and oxygen levels water [Garba & Abubakar, 2019].
- Lower Turbidity in Groundwater: Generally clearer but can be an issue in poorly constructed wells.
- Health Concerns: High turbidity can harbor pathogens and reduce disinfection effectiveness [Muhammad et al., 2018].

Yobe

Temperature

- Temperature & Gas Solubility: Affects oxygen levels and aquatic metabolism.
- Yobe State Water Temperature: Ranges from 25°C to 35°C due to the hot, semi-arid climate.
- Impact on Oxygen Levels: Higher temperatures reduce dissolved oxygen, affecting aquatic life.
- Water Quality Concerns: Elevated temperatures can degrade overall water quality (Musa, 2020).

pH

- pH as a Water Quality Indicator: Essential for human health and the environment.
- Variability in Yobe State: pH levels differ across water sources.
- Typical pH Range: Groundwater and surface water are usually slightly acidic to neutral.
- Influencing Factors: Natural minerals and soil-water interactions affect pH levels.

Turbidity

- **Turbidity Definition:** Measures water cloudiness from suspended solids like silt and organic matter.
- **Turbidity Levels in Yobe:** Ranges from 5 to 50+ NTU, increasing during the rainy season.
- **Health Risks:** High turbidity may indicate pathogens in water.
- **Disinfection Challenge:** Reduces the effectiveness of water treatment processes.

Borno

Temperature

- **Role of Water Temperature:** Affects aquatic health and water treatment efficiency.
- **High Temperatures in Borno:** Promote microorganism growth and impact water quality.
- **Chemical Reactions & Treatment:** Speeds pollutant breakdown but reduces dissolved oxygen.
- **Need for Monitoring:** Seasonal changes require regular checks for effective water management.

pH

- **Typical pH Range:** 6.5 to 8.5, within WHO standards for drinking water.
- **Factors Affecting pH:** Agricultural activities and natural processes can cause deviations.
- **Importance of pH:** Influences chemical and biological properties of water.
- **Need for Monitoring:** Regular testing ensures safe drinking water and ecological balance.

Turbidity

- **Turbidity Definition:** Measures water cloudiness from suspended particles, impacting quality.
- **High Turbidity in Borno:** Exceeds safe levels due to erosion, runoff, and poor treatment facilities.
- **Environmental Impact:** Reduces light penetration, affecting aquatic plants and ecosystems.
- **Management Solutions:** Improve water treatment and control erosion through better land use.

Jigawa

Temperature

- Temperature Range: 25°C to 30°C, influenced by Jigawa's semi-arid climate.
- Seasonal Variation: Higher in the dry season (Oct–Apr), lower in the rainy season (May–Sep).
- Impact on Water Quality: Higher temperatures reduce oxygen levels, affecting aquatic life.
- Risk of Algal Blooms: Warmer water increases the likelihood of harmful algae growth (NiMet, 2024).

pH

- pH Importance: Influences chemical solubility, biological processes, and aquatic health.
- Typical pH Range in Jigawa: 6.5 to 8.5, common for freshwater in semi-arid regions.
- Seasonal Variations: Affected by water flow and land runoff changes.
- Extreme pH Risks: Can harm aquatic life, alter nutrient availability, and affect water treatment (FME, 2022).

Turbidity

- Turbidity Range in Jigawa: Varies from 5 to 50 NTU, influenced by rainfall, erosion, and human activities.
- Seasonal Increase: Higher turbidity during the rainy season due to runoff and sediment load.
- Impact on Water Quality: Reduces light penetration, affects aquatic life, and carries pollutants [Water Quality in Northern Nigeria". Report by the Nigerian Environmental Study/Action Team (NEST) (2023)].

2.7.2.2 Chemical Parameters

Bauchi

Nutrients

- Key Nutrients: Nitrogen and phosphorus are essential but can cause eutrophication if excessive.

- Sources of Pollution: Agricultural runoff (fertilizers) and domestic wastewater contribute to nutrient buildup [Aliyu et al., 2020].
- Seasonal Impact: Elevated nitrate and phosphate levels in surface water during the wet season.
- Water Quality Risks: Algal blooms increase turbidity, alter pH, and deplete oxygen, affecting aquatic life [Garba & Abubakar, 2019].

Heavy Metals

- Heavy Metal Contamination: A major concern in Bauchi, especially near mining and industrial areas.
- Toxic Metals: Lead, mercury, cadmium, and arsenic pose serious health risks even at low levels.
- Sources of Pollution: Enter water through runoff, atmospheric deposition, and soil leaching.
- Environmental & Health Impact: Harmful to both humans and aquatic life (Aliyu et al., 2020).

Total Dissolved Solids (TDS)

- Surface Water TDS: Lower during the wet season due to rainfall dilution but increases in the dry season.
- Groundwater TDS: Higher in deeper aquifers due to mineral dissolution from soil and rock layers.
- Seasonal Impact: Evaporation and reduced flow raise TDS levels in the dry season [Garba & Abubakar, 2019].
- Health & Irrigation Risks: High TDS in mineral-rich areas can exceed safe limits for drinking and farming [Muhammad et al., 2018].

Yobe

Heavy metals

- **Heavy Metal Risks:** Lead, arsenic, and cadmium can cause neurological and cardiovascular issues.
- **Contamination Sources:** Linked to mining activities and natural geological formations.
- **Yobe State Concern:** Studies highlight the presence of heavy metals in local water sources [Ahmed and Usman, 2019].

Total Dissolved Solids (TDS)

- **TDS Levels in Yobe:** Ranges from 300 to 1200 mg/L, higher in groundwater sources.
- **Impact of High TDS:** Can affect taste and pose health risks if exceeding recommended limits [Usman and Ibrahim, 2018].
- **Water Colour Factors:** Influenced by organic matter, minerals, and algae, measured in TCU.
- **Colour Levels in Yobe:** Ranges from 10 to 70 TCU, indicating organic pollution and mineral presence [Garba et al., 2019].

Borno

Nutrient Storage

- **Nutrient Importance:** Nitrogen and phosphorus are essential for plant growth and water quality.
- **Eutrophication Risk:** Excess nutrients from runoff and wastewater cause algal blooms, depleting oxygen.
- **Forms of Nitrogen & Phosphorus:** Nitrate (NO_3^-), nitrite (NO_2^-), ammonium (NH_4^+), and phosphate (PO_4^{3-}).
- **Mitigation Measures:** Regular water monitoring and best agricultural practices help reduce nutrient runoff.

Heavy Metals

- Heavy Metal Risks: Lead (Pb), mercury (Hg), cadmium (Cd), and arsenic (As) pose severe health hazards.
- Health Effects: Lead affects child development, mercury harms kidneys/nervous system, cadmium damages kidneys/bones, and arsenic is linked to cancer.
- Sources of Contamination: Industrial discharges, mining, and improper waste disposal.
- Mitigation Measures: Regular monitoring, pollution reduction, and improved waste management are crucial.

Total Dissolved Solids (TDS)

- TDS Levels: Borno State's TDS ranges from 100 to 1200 mg/L, with some areas exceeding WHO's 500 mg/L limit.
- Contamination Risks: High TDS near industrial zones may indicate pollution affecting health and ecosystems.
- Health & Environmental Impact: Elevated TDS can degrade water quality and harm aquatic life.
- Mitigation Measures: Regular monitoring and pollution control are essential for safe water quality.

Jigawa

Nutrients

- Nutrient Impact: Excess nitrogen and phosphorus can cause eutrophication, degrading water quality.
- Nitrogen Levels: Nitrate (0.5–5 mg/L) and ammonium (0.1–2 mg/L) vary with agriculture and wastewater sources.
- Phosphorus Levels: Orthophosphate ranges from 0.1–1.5 mg/L, contributing to algal blooms.
- Environmental Risks: Excess nutrients reduce oxygen storage, harming aquatic ecosystems.

Heavy metals:

- Heavy Metal Sources: Enter water through industrial discharge, mining, and agriculture.
- Lead (Pb): Causes neurological damage; levels range from 0.01–0.2 mg/L.
- Cadmium (Cd) & Mercury (Hg): Highly toxic; Cd (0.001–0.05 mg/L), Hg (<0.01 mg/L, higher near industries).
- Arsenic (As): Carcinogenic; levels range from 0.01–0.1 mg/L, impacting human health and aquatic life.

2.7.2.3 Biological Parameters

Bacterial Contamination

- Bacterial Contamination: Common in Bauchi State, especially in surface water.
- Key Pathogens: *E. coli*, *Salmonella*, and *Vibrio cholerae* indicate faecal contamination.
- Sources: Untreated sewage, agricultural runoff, and open defecation [*Aliyu et al., 2020*].
- Health Risks: Can cause cholera and typhoid; groundwater is also vulnerable if poorly protected [*Garba & Abubakar, 2019*].

Algal Growth

- Algal Growth: Naturally present but can become excessive, leading to harmful algal blooms.
- Causes: High nutrient levels (nitrogen & phosphorus), warm temperatures, and light exposure [*Aliyu et al., 2020*].
- Impacts: Produces toxins harmful to humans and aquatic life, affecting water taste and quality.
- Occurrence in Bauchi: Common in wet season due to agricultural runoff, notably in the Gongola River.

Other Microorganisms

- Microbial Contaminants: Protozoa, viruses, and parasites can cause diseases like giardiasis and viral gastroenteritis.
- Sources: Contamination linked to sewage discharge, agricultural runoff, and poor sanitation [*Garba & Abubakar, 2019*].
- High-Risk Areas: Surface water is most vulnerable, especially during the rainy season.
- Groundwater Risks: Poorly sealed wells in areas with pit latrines or high-water tables are also at risk [*Aliyu et al., 2020*].

Yobe

- Total Coliform Bacteria: Indicators of possible contamination, with counts ranging from 0 to 500 CFU/100 mL. High levels suggest risks of waterborne diseases like diarrhea and typhoid [*Musa and Hamidu, 2017*].
- Escherichia coli (E. coli): A strong indicator of fecal contamination, with counts from 0 to 100 CFU/100 mL, posing serious health risks [*Usman and Abubakar, 2017*].
- Fecal Streptococci: Found in human and animal intestines, counts range from 10 to 300 CFU/100 mL, confirming faecal pollution and pathogen presence [*Garba and Mallo, 2017*].
- Helminth Eggs: Parasitic worm eggs found in stagnant waters, with counts between 0 to 50 eggs/L, posing infection risks [*Musa and Hamidu, 2017*].
- Protozoan Cysts: Dormant forms of parasites like Giardia and Cryptosporidium, resistant to chlorine, often found in untreated water [*Garba and Abubakar, 2019*].
- Biochemical Oxygen Demand (BOD): Measures organic pollution, with levels between 2 to 20 mg/L. High values indicate oxygen depletion, affecting aquatic life [*Yakubu & Abdullahi, 2017*].

Borno

- Bacterial Contamination: Presence of coliform bacteria, especially *E. coli*, indicates faecal contamination due to poor sanitation, increasing the risk of waterborne diseases.
- Algal Blooms: Caused by nutrient enrichment from agricultural runoff, leading to oxygen depletion, aquatic life loss, and reduced water quality.
- Parasitic Infections: Waterborne parasites, including schistosomiasis, pose health risks, particularly in communities relying on untreated water.
- Macroinvertebrate Diversity: Reduced diversity in polluted water bodies signals poor water quality and highlights contamination effects on ecosystems.

Jigawa

- Algal Growth: Affects water quality by altering nutrient levels and oxygen content; cyanobacteria (blue-green algae) can produce harmful toxins.
- Phytoplankton Biomass: Measured as chlorophyll-a concentration (1–10 $\mu\text{g/L}$ in Jigawa), with higher levels during the rainy season and in nutrient-rich areas.
- Cyanobacterial Density: Ranges from 10^4 to 10^6 cells/L, contributing to harmful algal blooms, oxygen depletion, and potential toxin production.

2.7.3 Groundwater Quality

Groundwater quality has a significant influence on groundwater availability potential. Groundwater qualities were analysed in the context of its availability by considering following chemical characteristics.

- i. Groundwater Electrical conductivity (EC)
- ii. Heavy metals
- iii. Fluoride
- iv. Nitrates

i. Groundwater Electrical Conductivity

- Electrical Conductivity (EC) indicates the concentration of soluble salts in water, reflecting total dissolved solids (TDS).
- EC Levels: Fresh drinking water typically has $<100 \mu\text{S/cm}$, while seawater reaches $\sim 54,000 \mu\text{S/cm}$.
- High EC Areas: Groundwater in basement aquifers and large settlements can exceed $1,000 \mu\text{S/cm}$.
- Impact: Elevated EC suggests potential salinity issues, affecting water quality and usability.

ii. Fluoride Distribution

- Fluoride Mapping helps identify high-risk areas and develop treatment measures to prevent fluorosis.
- Safe Limits: WHO and Nigerian standards set 1.5 mg/L as the maximum permissible fluoride concentration.

- Groundwater Impact: Shallow aquifers are generally safe, but deeper aquifers may have high fluoride levels.

iii. Nitrates Distribution

- Nitrate Sources: Found in groundwater due to fertilisers, septic tanks, livestock, and pit latrines.
- Safe Limits: NIS and WHO set a maximum nitrate concentration of 50 mg/L for drinking water.
- Groundwater Impact: High nitrate levels can limit groundwater availability, especially around Kano.
- Prevention: Reducing contamination requires improved sanitation and better waste management.

iv. Heavy Metals and other metals

- Source: Heavy metals enter groundwater from industrial processes.
- Common Metals: Includes lead, chromium, zinc, copper, nickel, cadmium, arsenic, and mercury.
- Health Risk: Even in microgram concentrations, prolonged exposure can cause serious health issues.

Maximum allowable limits and health implications of continuous ingestion of high quantities of heavy metals are presented in table 2.13:

Table 2.13: Health risks of heavy metals in groundwater

Heavy metal	Recommended Limits (mg/l)	Impacts on Humans (Long-term exposure)
Arsenic	0.01	Cancer of the bladder, lungs, skin, kidney, liver and more. Death
Cadmium	0.003	Renaldys function, lung disease and lung cancer, bone defects and high blood pressure

Chromium	0.05	Skin irritation, ulceration, liver and kidney damage. Damage to circulatory and nervous tissue
Lead	0.01	Problems in the synthesis of haemoglobin, effects on the kidneys, gastrointestinal tract, joints and reproductive system, and acute or chronic damage to the nervous system.
Mercury	0.002	Kidney damage Permanent nervous system damage
Nickel	0.02	Decreased body weight, heart and liver damage, and skin irritation

Source: JICA 2014 MP

- Most of the laboratory analysis that involved determination of heavy metals in groundwater was done for metropolis centres with high groundwater exploitation. These were: Gashua, Karasuwa, Nguru, Borsari LGAs and other centres in Yobe state.
- Laboratory analysis results show contamination by heavy metals with concentration above allowable limits in all these centres. Table 2.13 show pollution from industrial activities within the urban areas.
- Concentrations of aluminium in the catchment are all below the maximum allowable limit, and therefore not threat. Concentrations of iron above limit are prevalent in the basin and iron can be a limitation to available groundwater resources. Manganese and Zinc are within allowable limits.
- Groundwater pollution threatens groundwater availability potential in the following areas: River valleys and flood plains where contaminants are readily recharge into the groundwater system from rivers due to high infiltration. The most affected rivers are those draining urban centres of, Bauchi, Gashua and Karasuwa.

Table 2.14: Preliminary Conclusion of Water Quality Status of Some Rivers within the Catchment

S/No.	State	River Name	Code	Wet Season	Dry Season	NFA
1		River Gaidan Maiwa at the Bridge	SW/001	Good	To be confirmed	As ,Pb, Cd
2	Bauchi	Wikki spring at Yankari Game Reserve	SW/001	Poor	Moderate	Fe, As
3		Gubi Damat intake to Bauchi WTP	SW/003	Good	Moderate	As, Cu, Ni
4	Yobe	River Komadugu- Gana at Gashua	SW/002	Moderate	Poor	Ni, As

Source: JICA 2014 MP

Note: The number of samplings of water quality is only two times (one in wet season and another in dry season). Table 2.14 shows only preliminary evaluation based on the results of these limited samples.

Criteria:

 Good quality: $BOD = < 3$ and $6 \leq DO$ (based on Nigeria Standard Values for surface water- recreation & fisheries)

 Moderate: $3 < BOD \leq 6$ and $4 \leq DO < 6$ (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.

2.8 Climate Change Impact on Water and Land Resources

Misau-Kamadugu-Gana catchment has a tropical savanna climate with distinct wet and dry seasons.

- i. Rainfall Patterns: Most rainfall occurs from April to October, influenced by the Intertropical Convergence Zone (ICZ) and the Sahara Desert.
- ii. Regional Variations:
 - Yobe State: Hot, semi-arid climate with a unimodal rainfall pattern.
 - Borno State: Hot, dry climate with a short rainy season (June–September).
 - Jigawa State: Semi-arid climate; Nguru Wetlands support biodiversity and agriculture

2.8.1 Historical and Future Climatic Trend

- i. Climate Classification: Tropical savanna (Köppen classification) with distinct wet and dry seasons.
- ii. Influencing Factors: Topography, altitude, ITCZ, and proximity to the Sahara Desert.
- iii. Climate Projections: Temperature and rainfall trends forecasted for 2023–2050 using historical data (1981–2022).
- iv. Projection Method: Growth rate schema formula performed in Excel using the formula:
$$\text{Growth Rate} = (\text{Ending Value} - \text{Beginning Value}) / \text{Beginning Value} \times 100.$$

Table 2.15 presents a comparison of historical and projected mean monthly temperatures for Misau K-Gana, with data spanning from 1981-2022 and projections for 2023-2050. Figure 2.21 shows a slight but consistent increase in temperatures for most months, reflecting an overall warming trend in the region.

Table 2.15: Mean Monthly Temperature for the Misau K-Gana Catchment for 1981-2022 and 2023-2050.

Month	Mean monthly Temperature	Mean monthly Temperature
January	22.65	22.87
February	25.50	26.42
March	29.29	30.47
April	31.71	32.74
May	31.15	32.34
June	28.98	29.59
July	26.51	27.12
August	25.14	25.14
September	25.52	25.51
October	26.16	26.63
November	24.86	25.67
December	22.93	22.95
Mean	26.70	27.29
Maximum	31.71	32.74
Minimum	22.65	22.87

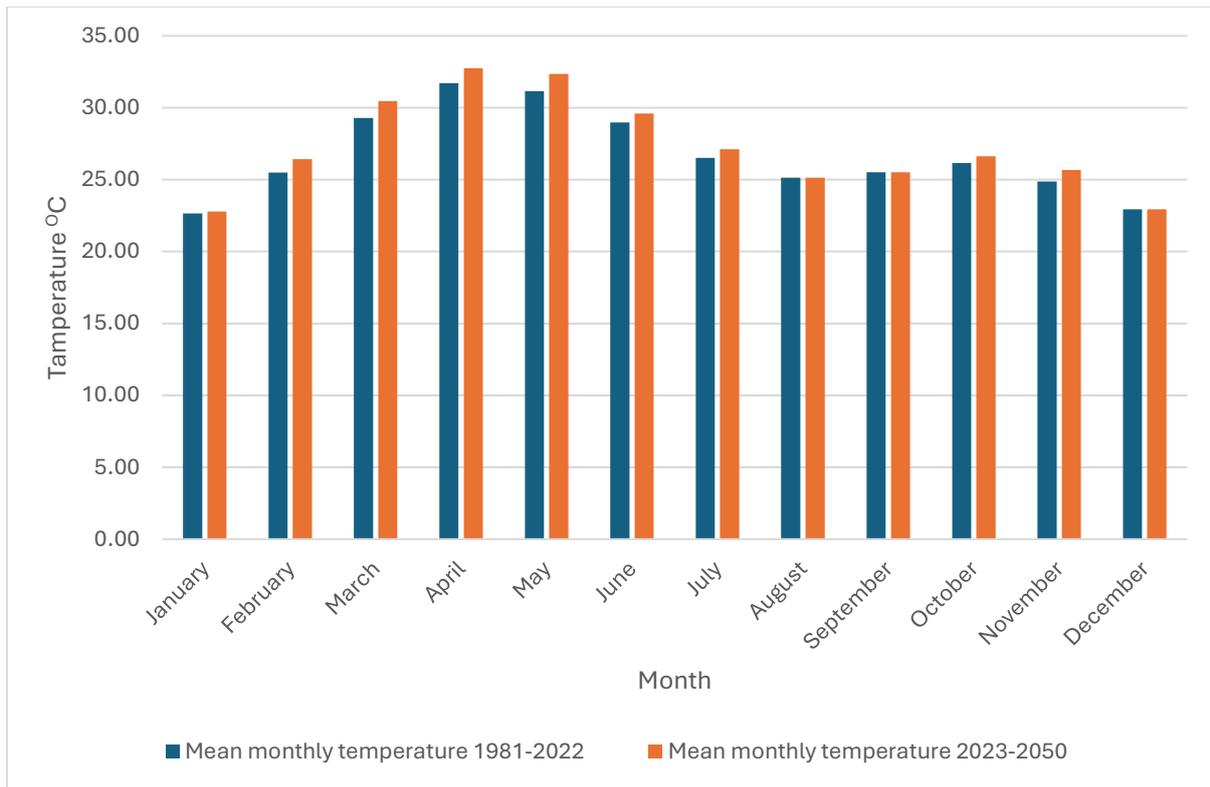


Figure 2.21: Mean monthly temperatures from 1981 to 2022 and 2023 to 2050 for the Misau K-Gana catchment

2.8.1.1 Effects of climate change on annual rainfall

- i. Rainfall Aggregation: Bias-corrected daily rainfall was aggregated into monthly and annual values from 2018 to 2040 for all sub-hydrologic areas (SHAs).
- ii. Baseline Comparison: Average annual rainfall (1950–2015) was used to assess changes over the planning period.
- iii. Rainfall Trends: On average, 15 out of 24 sub-catchments show a decline in annual rainfall, while the rest indicate an increase.
- iv. Regional Variations:
 - Largest Decrease: K808075 (Hadejia), with declines ranging from 3% to 64%.
 - Largest Increase: K80802 (Komadugu), with increases between 4.8% and 33%, notably in Wudil, Hadejia, and Gashua.

2.8.1.2 Effect of Climate change on PET

- i. Temperature Aggregation: Bias-corrected daily maximum and minimum temperatures were averaged into monthly and annual values from 2017 to 2040 for all sub-hydrologic areas (SHAs).
- ii. PET Calculation: Potential evapotranspiration (PET) was computed using the Hargreaves formula.
- iii. Baseline Comparison: The average annual PET (1950–2015) was used as a reference to assess changes over the planning period.

2.8.2 Projected Annual Rainfall for The Misau K-Gana Catchment

Rainfall Variability: Historical data (1981–2022) in Figure 2.22 shows:

- i. Significant year-to-year fluctuations with multiple peaks and troughs.
- ii. Declining Trend: A gradual decrease in rainfall is observed, with an annual decline of 4.2 mm, as indicated by the trend equation $y = -4.2029x + 788.8$.
- iii. Moderate Correlation: The R^2 value of 0.3279 suggests that 32.8% of the trend is explained by the declining rainfall, with short-term climate factors contributing to variability.
- iv. Future Projections (2023–2050): Rainfall is expected to continue decreasing by 4.2 mm per year, potentially leading to water scarcity and agricultural challenges.
- v. Adaptation Strategies: Urgent measures are needed to mitigate water shortages, support agriculture, and ensure ecosystem sustainability.

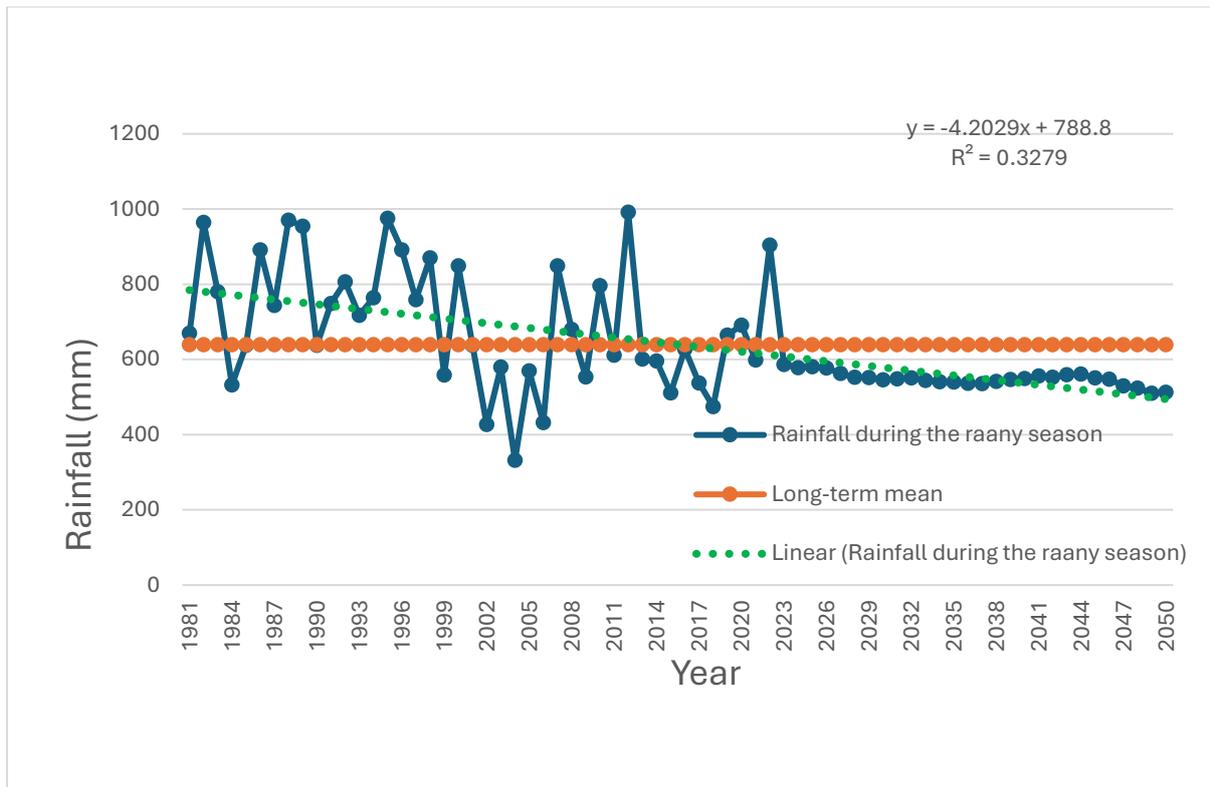


Figure 2.22: Projected Annual Trend (1981-2050) for the Misau K-Gana catchment (Source: MSL, 2024)

2.8.3 Projected Mean Annual Temperature for The Misau K-Gana Catchment

Figure 2.23 shows the mean annual temperature trend for a Misau K-Gana catchment from 1981 to 2050, with historical data from 1981 to 2022 and projected data from 2023 onwards.

Key observations from Figure 2.23 shows:

- i. Temperature Variability: Historical data shows fluctuations with both warm and cooler years.
- ii. Warming Trend: Mean annual temperature from 1981 to 2050 shows a gradual increase, with an estimated rise of 0.0209°C per year.
- iii. Moderate Fit: The R^2 value of 0.4716 suggests that the trend explains about 47.16% of temperature variations.
- iv. Future Projections: From 2023 to 2050, temperatures are expected to continue rising, impacting agriculture, water resources, and climate conditions.

- v. Climate Adaptation: The trend aligns with global climate change patterns, emphasizing the need for adaptation strategies.

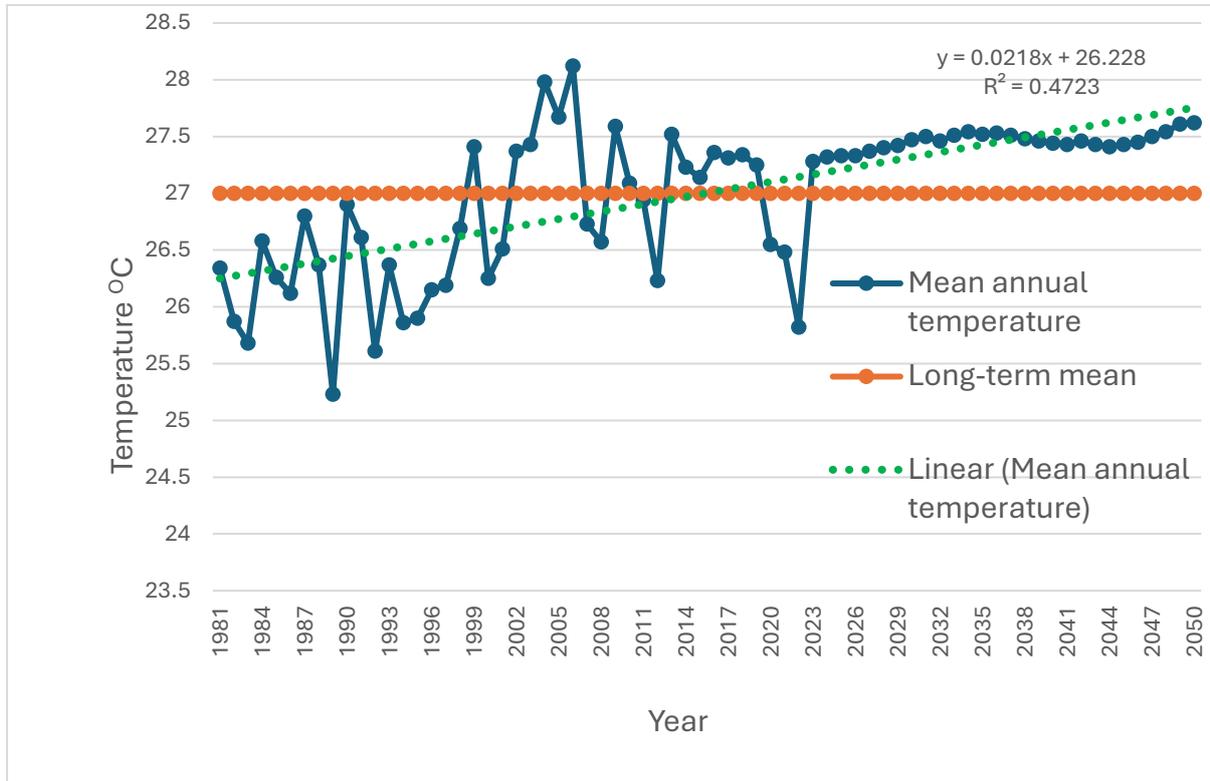


Figure 2.23: Projected Mean Annual Temperature Trend (1981-2050) for the Misau K-Gana catchment (Source: MSL, 2024)

2.8.4 Analysis of Downscaled Output of GCMs

The SMEC Hydrologist have completed calibration of the water resources model based on SMM hydrologic WEAP model. The climate data series were downscaled, and the bias were corrected by CCFAS for RCP 4.5 and SRES A2. The selected GCM scenarios are shown in Table 2.16.

Table 2.16: Available coupled GCMs SRES runs deployed

Centre	Acronym	Model	SRES Scenario Run
Australia’s Commonwealth Scientific and Industrial Research Organisation	CSIRO	CSIRO_aces_1_0	A2
National Centre for Atmospheric Research	NCAR	NCAR_CCSM4	A2
Geophysical Fluid Dynamics Laboratory	GFDL	GFDL-CM3	A2
Canadian Centre for Climate Modelling and Analysis	CCCma	CCCma_canesm2	A2
National Centre for Meteorological Centre	CNRM	CNRM_CM5	A2
Russian Institute of Russian Mathematics	INM	INM_CM4	A2
Bjerknes Centre for Climate Research	BCCM	BCCM_1_1	A2

Source: JICA 2014 MP

The monthly data series for each GCM scenario were fed into the calibrated WEAP model. The estimated annual natural runoffs at the outlet of incremental areas for each of the four sub-basins were computed then the water balance and allocation were carried out with the predicted flows based on the climate data from each GCM. The result of the water balances is expected to vary from one GCM scenario to another, but it shows a trend where the streamflow’s for all sub-basins are generally decreasing over the SAP planning period. The results for each sub-basin are discussed in the following sections.

2.8.5 Projected Annual Evapotranspiration for The Misau K-Gana Catchment

Figure 2.24 illustrates the trend in evapotranspiration (ET) for the Misau K-Gana Catchment from 1990 to 2050, showing historical data (1990–2023) and projected values (2024–2050).

The following annual evaporation patterns are observed:

- **Increasing Evapotranspiration (ET):** Historical data (1990–2023) shows yearly fluctuations but an overall positive trend ($y = 2.914x + 7.1447$, $R^2 = 0.7482$), indicating a strong correlation between years and rising ET values.
- **Future Projections (2024–2050):** ET is expected to increase consistently, surpassing historical values by 2050, posing major challenges for water resource management and agriculture.
- **Impact on Agriculture:** Higher ET will increase water demand for crops, stressing rainfed and irrigated farming, reducing productivity, and exacerbating farmer-herder conflicts due to land degradation.
- **Water Scarcity Risks:** Rising ET will accelerate evaporation from water bodies, deplete groundwater reserves, and reduce long-term water availability in the catchment.
- **Adaptation Strategies:** Urgent measures are needed, including drought-resistant crops, soil moisture conservation, optimized irrigation, and water-efficient technologies, to sustain agriculture and water resources.

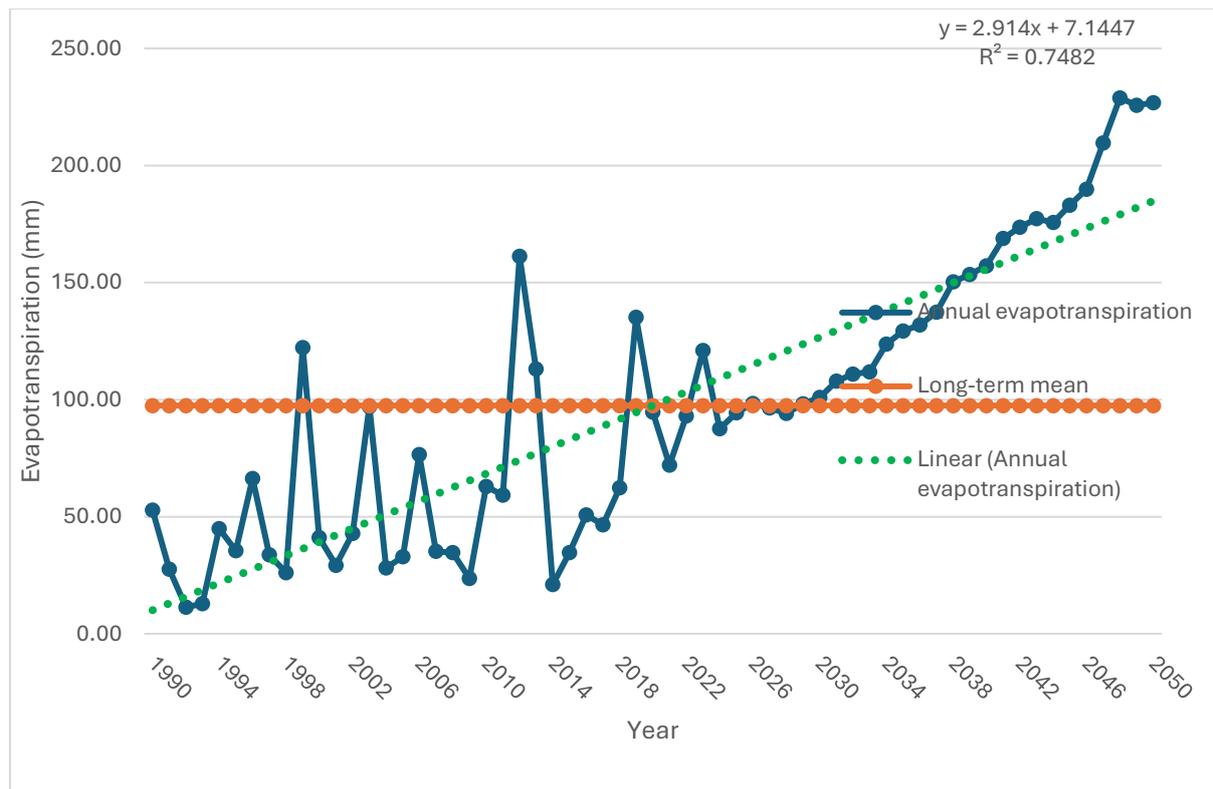


Figure 2.24: Trend in Evapotranspiration for Misau K-Gana Catchment.

2.8.6 Major Impacts of Climate Change

The Misau-Komadugu Gana Catchment is being significantly impacted by climate change (see Table 2.17), especially in terms of temperature rise, changed precipitation patterns, extreme weather, availability of water resources, and ecosystem changes. These changes pose serious challenges to agriculture, biodiversity, and local livelihoods.

Table 2.17: Key Impacts of Climate Change

S/No.	Impacts	Details
1	Water Resources	Surface water levels are dropping because of anticipated decreases in groundwater recharge and runoff.
2	Agriculture and Food Security	Higher temperatures and less water availability will result in lower crop yields, especially for staple crops like rice, sorghum, and millet. Due to increased evapotranspiration and unpredictable rainfall, farmers will need to switch to irrigation-based farming and drought-resistant crops.

		As desertification causes pastures to deteriorate, grazing livestock will become more challenging.
3	Ecosystem and Biodiversity Loss	Decreasing water availability in the Hadejia-Nguru Wetlands threatens migratory bird species and aquatic biodiversity. Deforestation and land degradation will increase habitat loss, impacting wildlife and natural vegetation.
4	Socio-Economic Vulnerabilities	Large investments in water infrastructure will be necessary as urban areas like Damaturu and Azare experience increased water scarcity. Increasing competition for land and water could make disputes between farmers and pastoralists more intense.

2.8.7 National and International Climate Change Frameworks/Agreements

- **Rising Temperatures:** Over the past 50 years, air temperature in Nigeria has increased linearly, with most parts of the country experiencing a long-term warming trend.
- **Declining Rainfall:** Rainfall has shown a linear decreasing trend, with an annual decline of 2 to 8mm/year in many regions, though decadal variations are more pronounced.
- **Future Projections (JICA, 2014):** Over the next 35 years, annual rainfall is expected to remain stable, but temperatures are projected to increase by 2.6°C, highlighting ongoing climate change challenges.

2.8.7.1 Climate Change Scenarios

- **Temperature Projections:** The A1B scenario from the Fourth IPCC Report (2007) predicts a 3–5°C rise in air temperature in West Africa by 2100, which is 1–5 times higher than the global average.
- **Uncertain Precipitation Trends:** Forecasts for precipitation changes vary significantly across General Circulation Models (GCMs), making it difficult to determine a consistent trend for future rainfall patterns.

2.8.7.2 Nigeria's First National Communication on Climate Change

In the Nigeria's First National Communication (2003), 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.

2.8.7.3 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

2.8.7.4 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

2.8.7.5 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.”

2.9 Flood and Drought Vulnerability

Flood vulnerability was assessed using GIS analysis and the weighted overlay process, which ranks locations based on various criteria rather than giving a simple vulnerable/not vulnerable result. This approach allows for a more nuanced understanding of vulnerability by breaking the problem down into smaller sub-models.

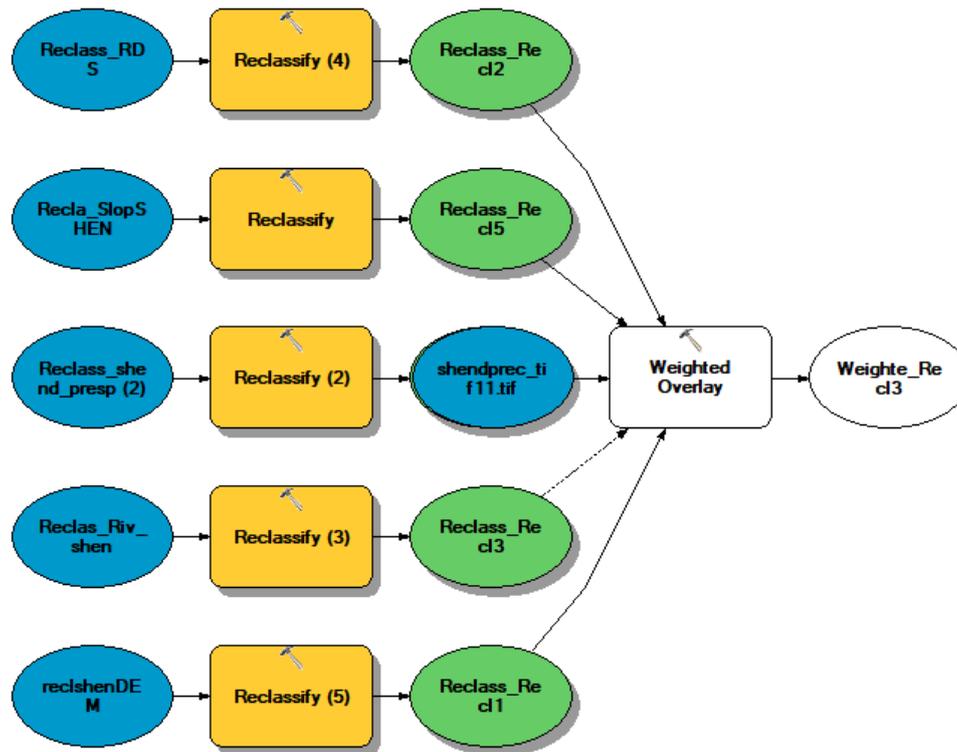


Figure 2.25: The flow chart of the methodology

- We identify key factors determining vulnerable areas using datasets on slope, elevation, proximity to rivers, land use/land cover, and rainfall. Each layer is standardized through reclassification to a common scale (e.g., 1 to 5, 1 to 9), as shown in Figure 2.25.
- We assign weights to each layer, combine them in a weighted overlay, and analyze the results. Figure 2.25 illustrates the flood vulnerability model used in this study.

2.9.1 The Digital Elevation Map (DEM)

- Elevation Variations: The Misau-Komadugu-Gana Catchment has distinct elevation changes as shown in Figure 2.26 with higher elevations (792m) in southern Bauchi and Yobe States and lower elevations (192m) elsewhere.

- Topographic Features: The area exhibits steep slopes and significant elevation disparities, particularly around river sources and drainage systems.
- Predominantly Flat Terrain: Most of the catchment consists of flat terrain, extending across a large portion of the region.

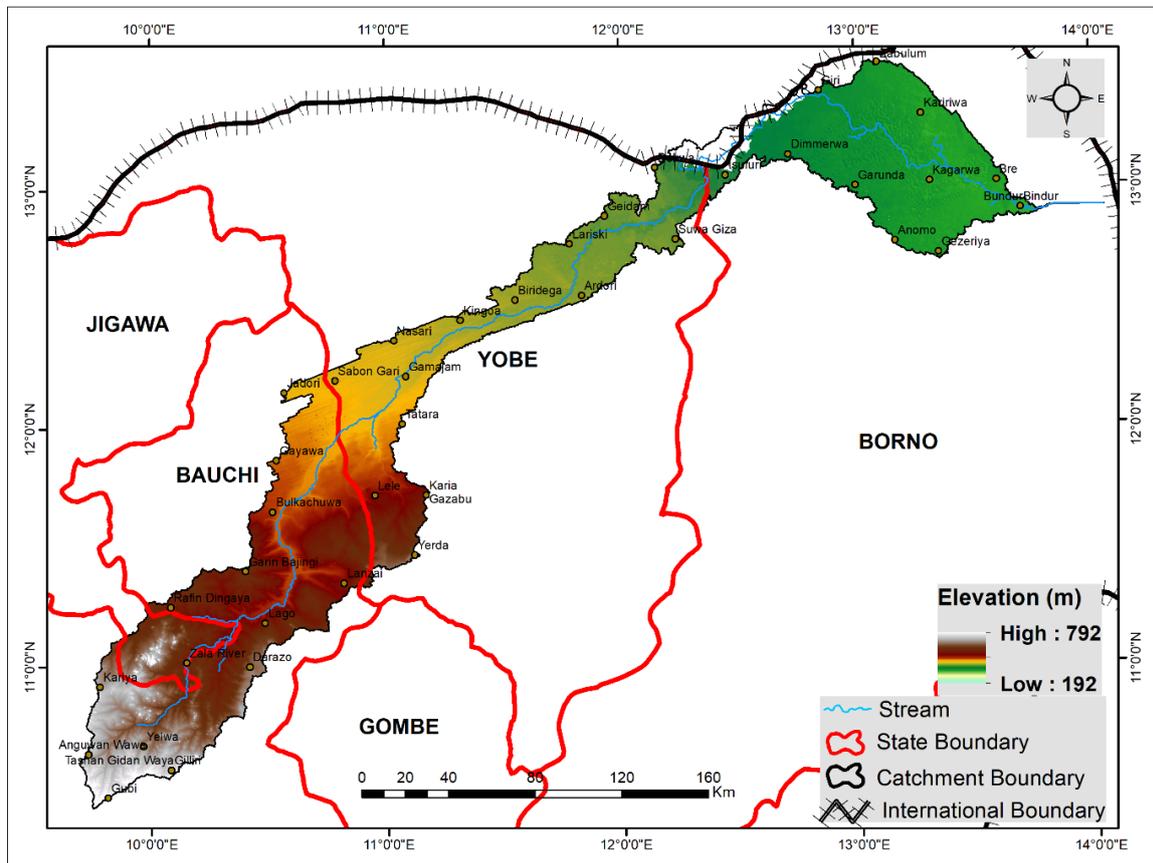


Figure 2.26: Digital Elevation Model (Source: MSL, 2024)

2.9.2 Slope map

- Slope Classification: The catchment has varying slopes (refer to Figure 2.27: Slope map of the catchment), influencing water flow and erosion risks.
- Flat to Gentle Slopes (0–6°): Found in most areas, increasing water pooling and flood risks during heavy rainfall.
- Moderate Slopes (7–13°): Encourage faster runoff, reducing water retention but increasing soil erosion risk.
- Steep Slopes (14–22°): Prone to rapid runoff and erosion, accelerating sediment displacement.

- Very Steep Slopes (25–65°): Found in southern Adamawa, causing maximum runoff velocity and impacting floodplains downstream.

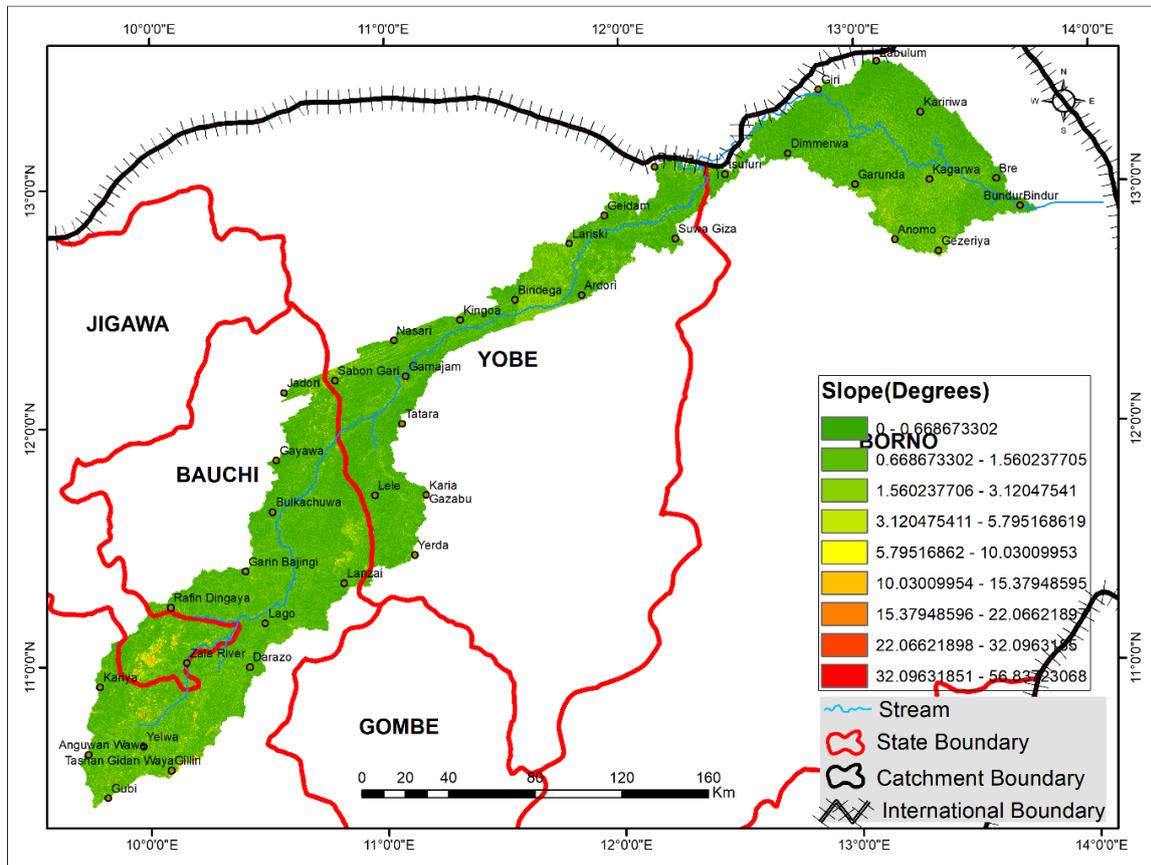


Figure 2.27: Slope map of the catchment

2.9.3 Rainfall map

- Rainfall Distribution: Varies significantly, from 689mm in Adamawa mountains to 216mm in 85% of the catchment (see Figure 2.28).
- Flooding Risk: High rainfall variability makes precipitation a key driver of flooding in the region.
- Flash Floods: Intense, localized storms can overwhelm drainage systems, especially in urban areas.
- Data Limitations: The rural nature of the catchment means annual averages may not fully capture localized rainfall variations.

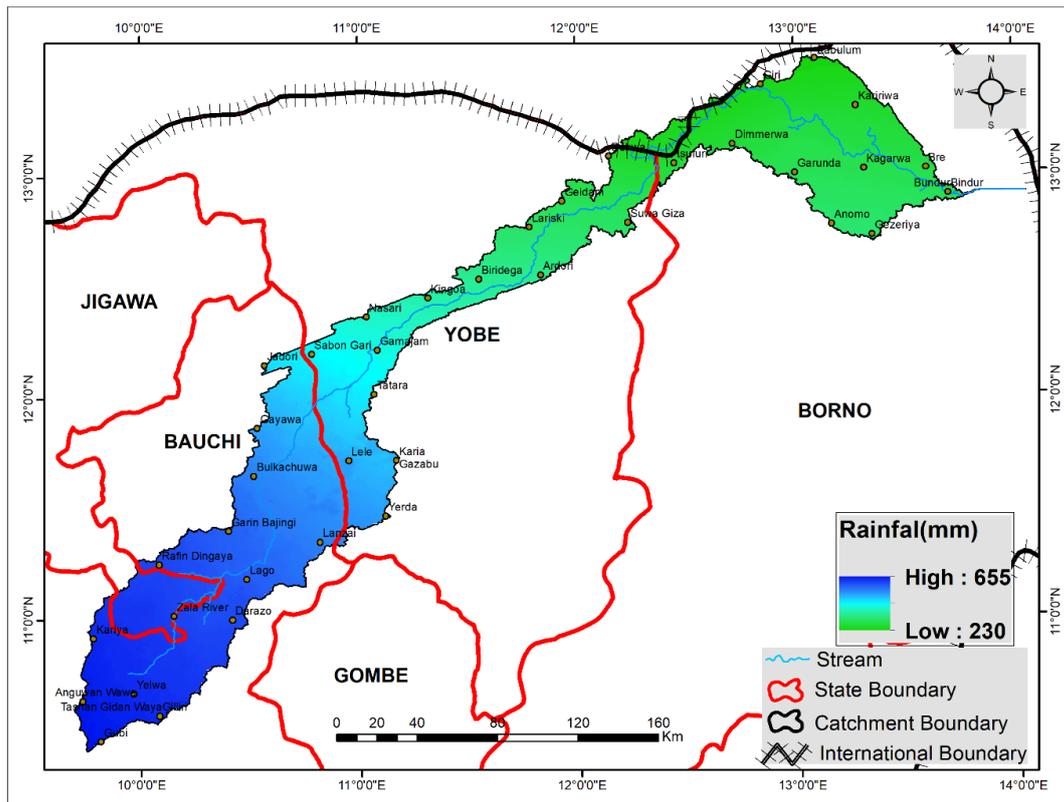


Figure 2.28: Rainfall map of the Catchment (Source: MSL, 2024)

2.9.4 Proximity to water sources

- Proximity to Streams & Flood Risk: Areas 0-15km from rivers are most vulnerable; 95-111km away are least at risk as shown in Figure 2.29.
- Water Bodies & Wetlands: Extremely vulnerable to flooding due to direct water involvement and overflow risks.
- Settlement/Built-up Areas: High vulnerability (rating: 4) due to impermeable surfaces increasing runoff.
- Cropland & Bare Surface: Moderate vulnerability (rating: 3) as they retain some water but can cause runoff.
- Shrubland: Low vulnerability (rating: 2), with some vegetation reducing runoff.
- Forests: Least vulnerable (rating: 1) due to dense vegetation aiding water absorption.

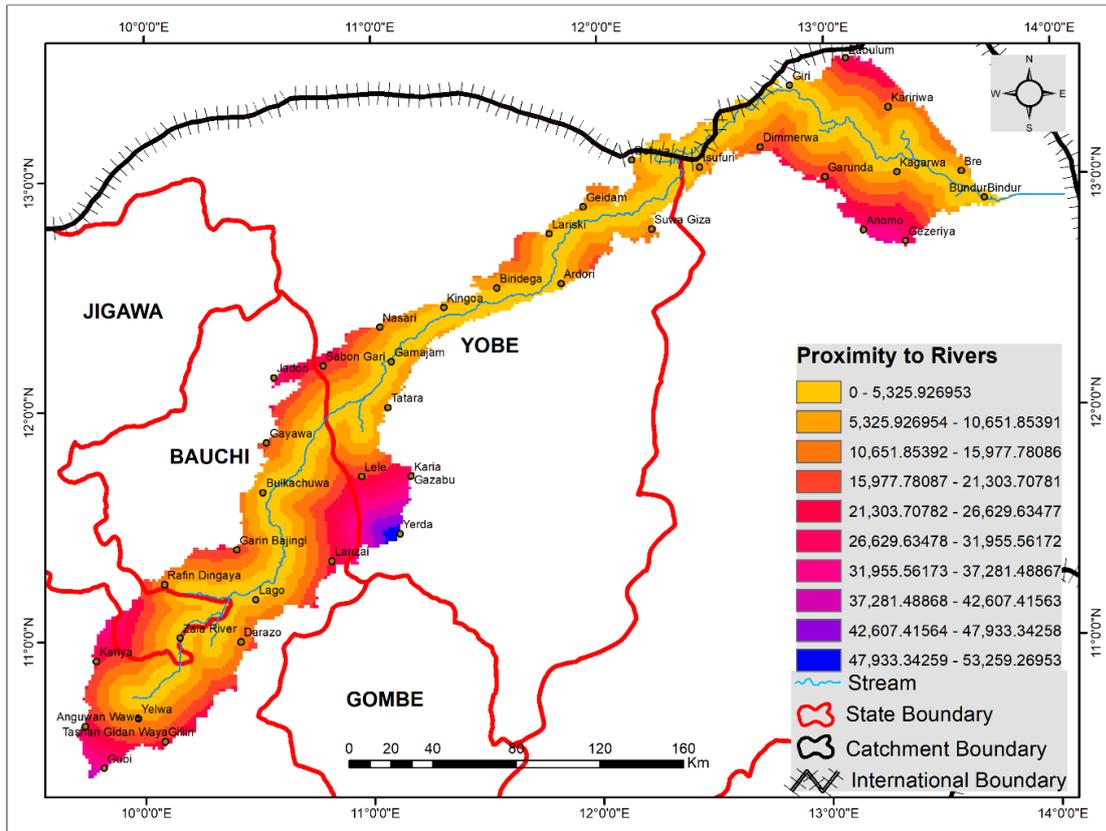


Figure 2.29: Distance to River Map (Source: MSL, 2024)

2.9.5 LULC

- Diverse Land Use and Land Cover: Reflects ecological zones, socio-economic activities, and environmental pressures (refer to Figure 2.30).
- Climate Influence: The catchment spans semi-arid and sub-humid zones, affecting LULC patterns.
- Human Impact: Deforestation, grazing, urban expansion, and agriculture shape land use.
- Population Growth: Increasing settlements and land transformation due to human activities.

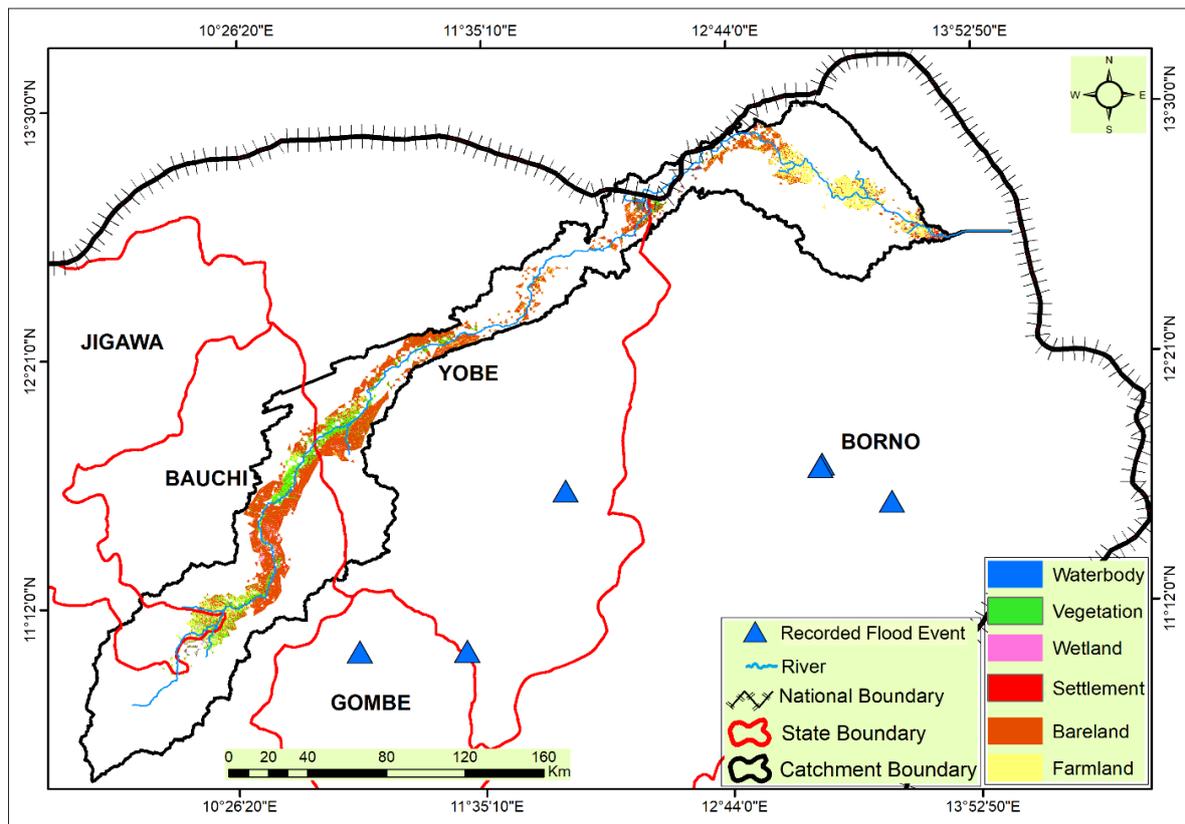


Figure 2.30: LULC Map of the Catchment (Source: MSL, 2024)

2.9.6 Flood Risk

The flood risk assessment within the catchment was based on:

- i. Flood Vulnerability Assessment: Conducted using weighted overlay analysis incorporating DEM, proximity to rivers, precipitation, slope, and land use/land cover.
- ii. Weighting & Risk Classification: Proximity to rivers had the highest weight, followed by elevation, precipitation, slope, and land use; risk levels categorized into Highly Not Vulnerable, Not Vulnerable, Moderate, Vulnerable, and Highly Vulnerable (Table 2.18).

Key observations from the findings in Figure 2.31 shows that:

- i. Low-Risk Areas: Found in high-elevation regions and around Lake Chad, where topography and low rainfall reduce flood risk.
- ii. Moderate-Risk Zones: Located around Adamawa highlands, with potential for flooding during heavy rainfall events.

- iii. High & Very High Flood Risk: Concentrated in low-elevation areas near highlands, facing greater flooding threats.
- iv. Overall Flooding Trends: Region experiences less flooding due to sedimentary geology enhancing infiltration and reducing runoff.
- v. Flood Risk to Land Use (Figure 2.31 and **Error! Reference source not found.**):
 - a. Farmland: 928.27 Ha (25.3%) at high risk.
 - b. Bare surface: 1,745.1 Ha (47.6%), largely farmland, at significant risk.
 - c. Built-up areas: 226.2 Ha (6.43%) at risk.
- vi. No Severe Flood Events Recorded: Misau-K Gana historically has not experienced major flooding, though vulnerability analysis highlights potential risks.

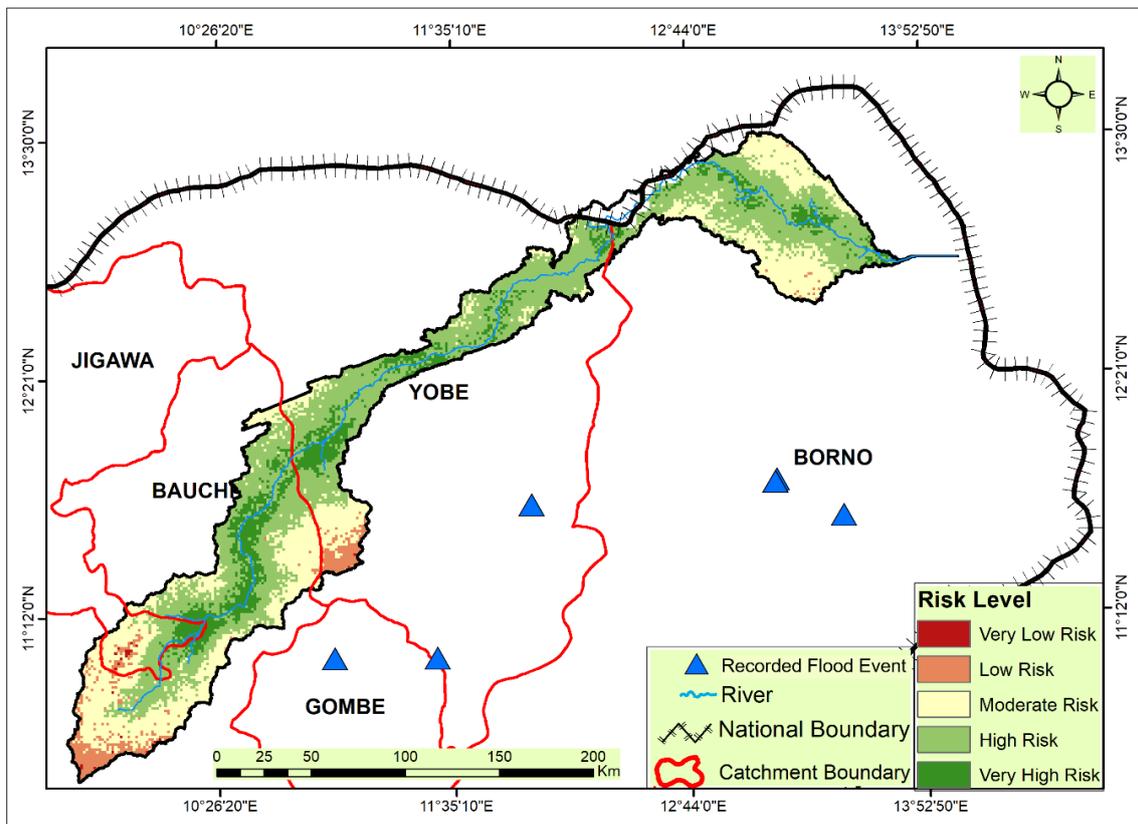


Figure 2.31: Risk Level map of the Catchment

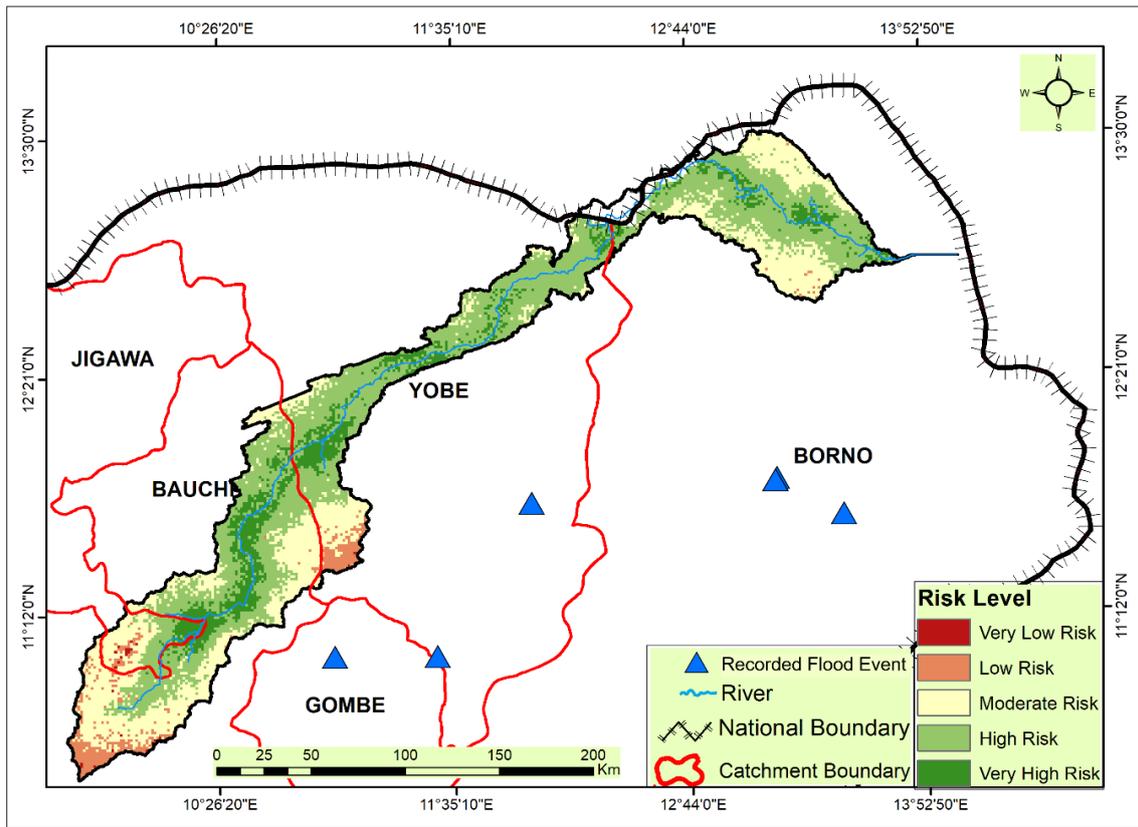


Figure 2.32: Flood Vulnerability Map of the Catchment (Source: MSL, 2024)

Table 2.18: Flood Risk Analysis of the Catchment

Class Name	Ha	%
Farmland	928.272	25.27527
Built_up	236.2119	6.431648
Waterbodies	22.79594	0.620695
Wetland	124.8408	3.399201
Vegetation	552.4245	15.04158
Baresurface	1745.071	47.51532
Rockoutcrop	63.03334	1.716291

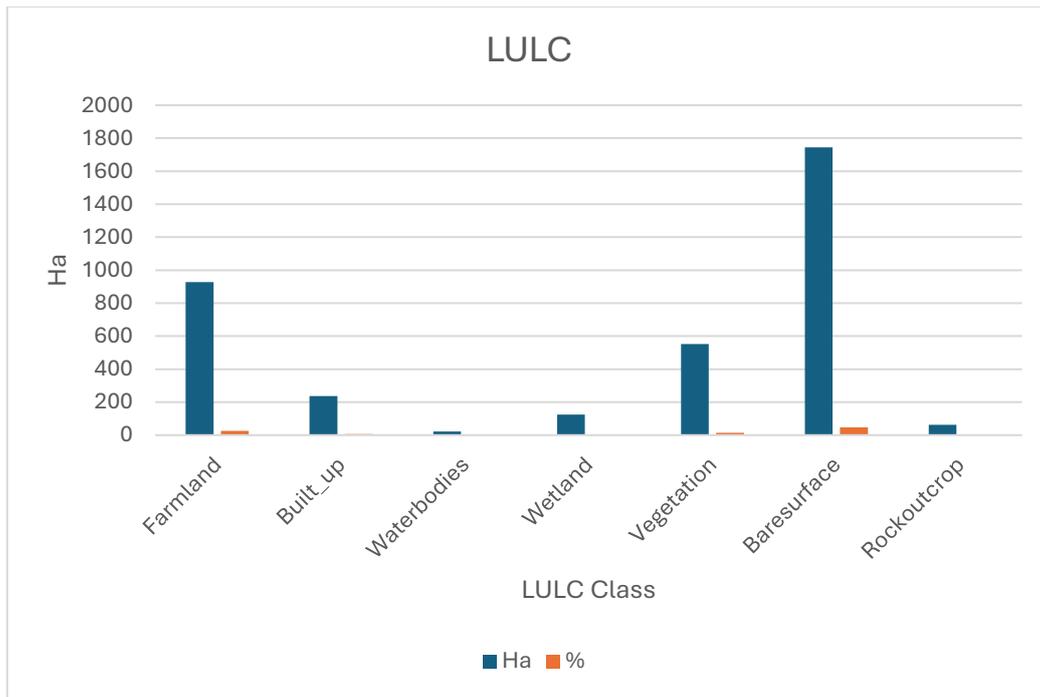


Figure 2.33: LULC bar chart (Source MSL 2024)

2.10 Socio-Economic Dynamics

2.10.1 Population Distribution and Growth

Bauchi State

- **Uneven Population Distribution:** Higher concentration in urban areas like Bauchi city, while rural areas are less populated.
- **Influencing Factors:** Population distribution is shaped by availability of infrastructure, economic opportunities, and social services.
- **Population Growth Rate:** Estimated at 2.8% per annum (Figure 2.34).

Yobe State

The population of Yobe state is predominantly rural, with a youthful demographic profile. The state's population growth rate is estimated at around 2.6% per annum (refer to Figure 2.34).

Borno State

- **Large Land Mass & Population:** Borno is one of Nigeria's largest states in both area and population.
- **Low Population Density:** About 60 people per km², lower than more densely populated regions.
- **Uneven Distribution:** Higher concentrations in urban areas like Maiduguri, with lower densities in rural and conflict-affected areas.

Jigawa State

- **Population Growth:** Jigawa State has a 3.2% annual growth rate over the past decade (refer to Figure 2.34).
- **Rural Dominance:** 80% of the population resides in rural areas, with urban areas growing moderately.
- **Urbanization Trends:** Gradual increase in urban population (see Table 2.18), especially in Dutse (state capital).
- **Growth Factors:** Driven by natural population increase and migration patterns.

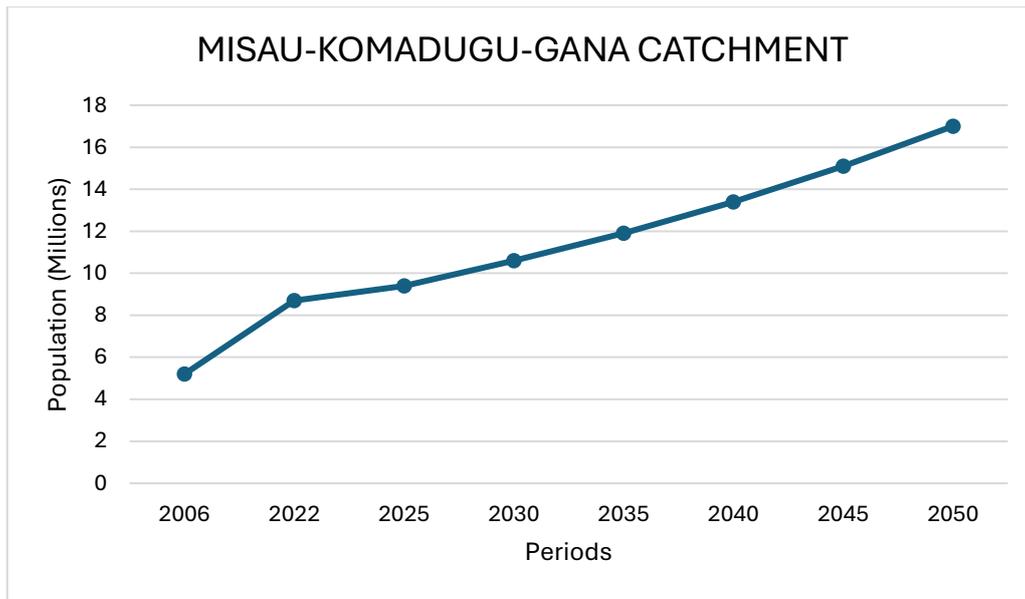


Figure 2.34: Population projection Graph of the Catchment (Source: MSL, 2024)

Table 2.19. Summary of Misau-Komadugu-Gana Catchment

NAME	STATES	POPULATION	GEOGRAPHY	GEOLOGY	HYDROGEOLOGY	VEGETATION	SOCIAL ECONOMICS
Misau-Katagum-Komadugu-Gana Catchment	Jigawa, Bauchi, Yobe	Estimated 1-3 million people	Covers parts of Bauchi, Yobe, Borno, Jigawa and Bauchi states. Primarily plains with some low hills.	Primarily sedimentary rocks	Katagum River feeds into Lake Chad. Groundwater resources are essential, but face pressure and potential salinization	Sudanian savanna with desertification threats	livestock rearing, and domestic use. Poverty, water scarcity (seasonal), environmental degradation, and limited infrastructure development are common challenges

2.10.2 Demographics and Poverty

The Misau-Komadugu Gana catchment area stretches across Bauchi, Yobe, Borno and Jigawa states, each with unique population dynamics, socio-economic conditions, poverty levels, and access to basic services. Table 2.20 below gives a description of each state's demography and poverty.

Table 2.20. Catchment Demographics and Poverty

S/No.	State	Demographic and Poverty
1	Bauchi	<p>Population of over 3.5 million people as of 2022 (National Population Commission, 2023)</p> <p>The state's population density is moderate, with Bauchi City having a high concentration of urban residents.</p> <p>According to the National Population Commission, the state has a growth rate of 2.8%.</p> <p>According to the National Bureau of Statistics (2022), the state has a higher fertility rate of 5.8 children per woman and a higher male and female ratio.</p> <p>The state has a moderate rate of in-migration because of job opportunities and urbanization.</p> <p>Bauchi's population is expected to continue to increase in the coming decades. By 2050, the population is expected to reach around 10.7 million if the current growth rate continues (United Nations, 2022).</p> <p>Bauchi is a viable agricultural hub. Mining, fishing, and livestock are additional potential industries to draw in investment. The state's two main markets are Katagun and Maiduguri Cattle Markets.</p> <p>In comparison to other states in Northern Nigeria, the education rate in Bauchi State is moderate. With a literacy rate of roughly 50%, the state's urban areas offer more educational opportunities than rural ones.</p> <p>Bauchi's population is predominantly Muslim. Most families are extended, which affects land use and economic cooperation. large family sizes and a higher ratio of reliance on natural resources due to the high rate of polygamy.</p> <p>In urban areas, the state's access to sanitation services is low (about 30%) and its access to clean water is moderate (about 60%). Rural areas, on the other hand, have only limited access to the basic services mentioned above.</p>

2	Borno	<p>Population of over 3.53 million people as of 2022 (National Population Commission, 2023).</p> <p>Borno state has an unevenly distributed population density of about 60 people per km².</p> <p>The projected population growth is estimated at 2.5% (National Population Commission, 2023).</p> <p>According to the National Bureau of Statistics (2022), Borno state has a declining fertility rate due to conflict-driven displacement.</p> <p>The state has a high displacement due to insurgency, leading to refugee settlements.</p> <p>Despite ongoing insurgency in the state, Borno's population is projected to continue to increase in the coming decades. By 2050, the population is expected to reach around 9.7 million (United Nations, 2022).</p> <p>Cross-border trade, agriculture, livestock, and fishing are Borno State's main economic activities. The two main markets in the state are Maiduguri Monday Market and Gamboru Ngala Market.</p> <p>Educational activities are disrupted by protracted conflicts, which is why there are many children living in Borno State who do not attend school.</p> <p>Most people in Borno State are Muslims. Most families are extended, which has an impact on land use and economic cooperation.</p> <p>Large families and a higher proportion of dependence on natural resources due to the high polygamy rate.</p> <p>Access to clean water is very low (~35 percent) and sanitation services are very poor (~15 percent) in urban areas. Access to healthcare had been destroyed by conflicts. The situation is worse in most rural communities.</p>
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3	Jigawa	<p>Jigawa State has a population of 2.79 million people as of 2022 (National Population Commission, 2023). The state has a population density that is not evenly distributed, with about 80% of people living in rural areas. The projected population growth rate is estimated at 3.2%. Jigawa State is expected to have a population of over 6.3 million people by 2050 (National Population Commission, 2023). The National Bureau of Statistics (2022) reports that Jigawa State has one of the highest fertility rates in the area, with about 6.5 children per woman. The state experiences both seasonal migration for trade and out-migration to urban areas. Irrigation farming, livestock, trade, and craft are Jigawa State's main economic activities. The two main markets in the state are Maigatari International Market and Hadejia Market.</p> <p>Jigawa State's educational system has gradually improved over time. Nonetheless, the state's female school enrollment rate remains low. Jigawa State's population is predominantly Muslim. Most families are extended, which affects economic cooperation and land use. Due to the high rate of polygamy, there are larger families and a greater percentage of reliance on natural resources. Sanitation services and access to clean water are moderate in urban areas (~55% and 40%, respectively). Urban areas have better coverage, access to healthcare and other basic services than rural communities.</p>
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4	Yobe	<p>Yobe state has the lowest population in the catchment area compared to other states with 1.83 million people as of 2022 (National Population Commission, 2023).</p> <p>Yobe state has a low and predominantly rural population density.</p> <p>The projected population growth in the state is estimated at 2.6% (National Population Commission, 2023).</p> <p>The National Bureau of Statistics (2022) reports that Yobe state has experienced rapid natural growth and a high fertility rate (~6.2 children per woman).</p> <p>The state has low migration with seasonal movements for agriculture.</p> <p>An estimated 2.6 percent is the projected rate of population growth. According to the National Population Commission (2023), Yobe State is predicted to have a population of over 5.5 million by 2050.</p> <p>Dryland farming, livestock, trade and fishing are Yobe State's main economic activities. The two main markets in the state are Nguru International Market, and Gashua Market.</p> <p>The state has a high dropout rate and a low literacy rate, particularly among women (~30 %).</p> <p>Yobe State's population is predominantly Muslim. Since most families are extended, land use and economic cooperation are affected.</p> <p>Because polygamy is so common, there are larger families and a greater percentage of reliance on natural resources.</p> <p>Access to clean water is low (~ 40%) and sanitation in urban areas is poor (~ 15%). Access to healthcare is also very low with widespread malnutrition.</p>
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2.10.2.1 Unsustainable Livelihoods

Various unsustainable livelihoods threaten the ecological balance and long-term profitability of these activities in the catchment area. Some of these unsustainable practices include.

1. Overgrazing

- Large-scale livestock grazing leads to land degradation, soil erosion, and desertification.
- Pastoralist activities in Jigawa and Yobe cause soil compaction and reduced vegetation cover, limiting water infiltration.

2. Deforestation

- Wood harvesting for fuel and land clearing for agriculture accelerate soil erosion and biodiversity loss.
- Bauchi and Borno states face severe deforestation, while illegal logging and bush burning in Jigawa contribute to gully erosion and soil fertility loss.

3. Unsustainable Farming Practices

- Slash-and-burn techniques, overcultivation, and chemical fertilizers degrade soil health.
- Hadejia-Nguru Wetlands suffer from irrigation mismanagement, reducing water flow and causing sedimentation.
- Monocropping in Yobe and Borno depletes soil nutrients, weakening food security.

4. Excessive Groundwater Extraction

- Urban centres like Damaturu experience 1.5-meter drops in water tables per decade.
- Overuse of boreholes and inefficient irrigation accelerate groundwater depletion.

5. Pollution

- Mining activities introduce heavy metal contamination in rivers and aquifers.
- Poor waste management in Maiduguri and Dutse leads to untreated sewage polluting water bodies.

6. Land Degradation

- Desertification is expanding in northern Borno and Yobe due to vegetation loss.
- Soil erosion is worsened by deforestation, overgrazing, and poor agricultural practices, reducing land productivity.

2.10.3 Gender Issues

2.10.3.1 Challenges

Gender-Related Challenges in the Misau-Komadugu Gana Catchment include but not limited to the following:

- i. **Water Scarcity & Access:** Women, primarily responsible for water collection, face long travel distances, safety risks, and water scarcity.
- ii. **Land Ownership & Economic Participation:** Cultural norms and inheritance laws restrict women's land ownership, limiting their role in commercial agriculture.
- iii. **Limited Involvement in Governance:** Women and marginalized groups have little participation in land-use planning and water governance.
- iv. **Climate Change Impacts:** Droughts, floods, and climate change disproportionately affect women, especially those in subsistence farming, worsening food insecurity.
- v. **Gender-Based Violence (GBV):** High prevalence of GBV, particularly in conflict-affected areas, impacts women's safety, economic participation, and mobility.

2.10.3.2 Opportunities for Gender Inclusivity

Opportunities to Enhance Gender Parity in the Catchment include the following:

- i. **Policy Interventions:** The Borno State Gender and Social Inclusion Policy (2018) promotes gender equity and inclusion in governance and economic activities.
- ii. **Capacity-Building & Empowerment:** Skill acquisition centres, women's development programs, and microcredit schemes can enhance women's financial independence.
- iii. **Community Engagement in Water Resource Management:** Strengthening women's participation in Integrated Water Resources Management (IWRM) can improve equitable water access.

- iv. Climate-Smart Agriculture & Alternative Livelihoods: Promoting climate-adaptive farming, renewable energy initiatives, and cooperative farming can enhance women's resilience and economic opportunities.

2.10.3.3 Impacts of Gender Disparities

The impacts of gender disparities within the catchment area includes:

- i. **Reduced Community Resilience:** Exclusion of women from governance and resource management limits community adaptability to climate and environmental changes.
- ii. **Food and Water Insecurity:** Gender imbalances in land access and agricultural support reduce productivity, affecting household nutrition and livelihoods.
- iii. **Weak Water Governance:** Lack of gender representation in decision-making hinders sustainable water allocation and conservation efforts.

2.10.3.4 Recommendations

To address these challenges and leverage opportunities, the following strategies should be implemented:

- i. ***Strengthening Policy and Institutional Frameworks:*** Implement and enforce gender-sensitive policies, ensuring women's participation in governance and resource management.
- ii. ***Enhancing Access to Land and Water:*** Reform land tenure policies to promote women's land ownership and equitable water distribution.
- iii. ***Promoting Sustainable Livelihoods:*** Support women's involvement in climate-smart agriculture, entrepreneurship, and alternative income-generating activities.
- iv. ***Investing in Community-Based Solutions:*** Develop gender-responsive IWRM programs, participatory decision-making, and capacity-building initiatives.
- v. ***Addressing Gender-Based Violence and Social Barriers:*** Strengthen legal frameworks, awareness campaigns, and support services for women affected by GBV.

CHAPTER 3 : STAKEHOLDER ENGAGEMENT AND GOVERNANCE

3.1 Methodology

The catchment composed of complex socio-political dynamics, environmental challenges, and economic activities. Various stakeholders, ranging from government agencies to international organizations, local communities, and private sector actors, have vested interests in the development and stability of the state. Understanding these stakeholders and their interests is crucial for effective governance, conflict resolution, and sustainable development in the region. For the purpose of this study, the stakeholder engagement concepts that have been employed are as follows:

3.2 Key Stakeholders Engaged

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

- i. Natural Resources (Land, water, vegetation, wildlife, minerals etc.)
- ii. Threats and Challenges
- iii. Socioeconomics
- iv. Policies

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

Stakeholders

The stakeholders comprise of government and public sector stakeholders, such as Federal and State Governments and Local Government Authorities.

Federal Government Agencies/Ministries

- Federal Ministry for Water Resources
- Water Resources Regulatory Commission
- National Council of Water Resources
- Nigerian Hydrological Services Agency (NIHSA)
- Catchment Management Offices and Committees (CMO)
- River Basin Development Authorities (RBDAs) of Nigeria

- National Water Resources Institute (NWRI)
- National Environmental Standard and Regulations Enforcement Agency (NESREA)
- The Nigerian Meteorological Agency (NiMET)
- The National Inland Waterway Authority (NIWA) of Nigeria
- Nigeria Integrated Water Resources Management Commission (NIWRMC)

State Water Agencies

- Rural Water Supply and Sanitation Agencies (RUWASSA)
- United Nations Agencies: United Nations agencies, such as the United Nations High Commissioner for Refugees (UNHCR), United Nations Children’s Fund (UNICEF), and the World Food Programme (WFP).
- World Bank Water Projects in Nigeria

Non-Governmental Organizations (NGOs)

- Donor Agencies: Donor agencies, including the World Bank, the United States Agency for International Development (USAID), the European Union (EU), and the United Kingdom’s Department for International Development (DFID), African Development Bank (AfDB).
- Local communities and traditional institutions
- Local Communities: The residents of the catchment, including farmers, herders, traders, and IDPs, are primary stakeholders with diverse interests.
- Traditional Leaders and Religious Authorities: Traditional leaders and religious authorities hold significant influence in the catchment, particularly in rural areas.

Private Sector Stakeholders

The private sector stakeholders includes:

- Agricultural and Livestock Sectors: The agricultural and livestock sectors are vital components of the catchment’s economy, with stakeholders including farmers, herders, agro-businesses, and cooperatives.
- Small and Medium Enterprises (SMEs): SMEs in the catchment that are involved in various sectors, including retail, construction, and services.

Security Agencies

Nigerian Military and Police: The Nigerian military and police are key stakeholders in the catchment, with the primary interest of restoring and maintaining security.

Civilian Joint Task Force (CJTF) and local vigilante groups.

3.3 Major Topics for Stakeholder Discussions

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

Stakeholders were engaged in group settings in each State to discuss key issues affecting development of catchment and opportunities for addressing these issues. The FPMU team first presented the results of the catchment analysis, focusing on the biophysical and socio-economic aspects. The meetings then tried to develop a consensus around a long-term vision, strategic goals for catchment development, and finally, priority actions.

The discussions covered issues and potential best practices around:

- Water management
- Land-Use
- Environmental protection/biodiversity conservation
- Community benefits
- Economic development
- Climate change resilience
- Monitoring and evaluation alignment of policies governing the catchment
- Insecurity Issues

More specific topics included:

- Water supply
- Agriculture
- Industrial use
- Making rivers more navigable
- Implementing the water charter of the Basin

- Creating and maintaining a decision support system/databank for the catchment.
- Need for a Dam within the catchment.
- River training.
- Flow proportioning structures.
- Restoration and expansion of the hydromet monitoring network.

3.4 Key Points of Stakeholder Engagement

As part of the engagement of Misau-Komadugu Gana Catchment stakeholders, strategic issues and opportunities related to water management, land use, environmental protection and governance were discussed. The following are some of the important issues raised during stakeholder engagement:

1. Water Management and Access

- Improve surface and groundwater monitoring systems.
- Address water pollution from household waste and agricultural runoff.
- Implement Integrated Water Resources Management (IWRM) for better regulation.
- Promote water conservation and efficient irrigation systems.

2. Land Use and Degradation

- Revise land use laws to address environmental conservation and urbanization.
- Tackle bush burning, illegal logging, soil erosion, desert encroachment, and overgrazing.
- Promote sustainable land use planning and reforestation initiatives.

3. Environmental Protection

- Strengthen climate adaptation, biodiversity conservation, and habitat restoration.
- Promote renewable energy to mitigate climate change.
- Establish controlled grazing zones and community tree nurseries.

4. Community and Livelihoods

- Address water and land degradation affecting food security.

- Empower smallholder farmers and pastoralists with microcredit programs and post-harvest facilities.
- Ensure gender-inclusive development in economic opportunities.

5. Institutional Gaps and Policy Alignment

- Strengthen enforcement of environmental laws and reduce overlapping regulatory roles.
- Improve policy alignment with catchment management objectives.
- Propose institutional reforms for better governance.

6. Strengthening Coordination Mechanisms

- Address lack of coordination between communities, NGOs, government, and private sector.
- Establish multi-stakeholder forums to resolve disputes over land and water use.
- Form Catchment Management Committees for improved collaboration.

7. Promoting Sustainable Practices

- Support community-led sustainable agriculture and irrigation methods.
- Promote climate-smart agriculture and drought-resistant crops.
- Provide training programs for farmers and herders on modern techniques.

8. Enhancing Data and Monitoring Systems

- Improve data collection on pollution, water levels, and climate trends.
- Implement a result-based monitoring & evaluation (M&E) system.
- Increase funding for GIS mapping, remote sensing, and hydrological stations.

9. Engaging Communities

- Encourage community ownership of conservation efforts.
- Support riverbank protection and tree planting initiatives.
- Raise public awareness on environmental sustainability.

3.5 Coordination Mechanisms

The Misau-Komadugu Gana CMP involves a number of federal, state, and local stakeholders, including research institutions, private sector players, community-based organizations, and foreign organizations. The roles of the different stakeholders in the CMP and their implementation are as follows:

Federal Stakeholders

1. Federal Ministry of Water Resources (FMWR): oversees the implementation of national water policy, provides technical support and financing for water resource projects and develops integrated water resource management frameworks.
2. Water Resources Regulatory Commission: ensures compliance with water use regulations and licensing and providing guidance on sustainable water abstraction.
3. National Council of Water Resources (NCWR): sets policy guidelines for national and subnational water governance and makes it easier for agencies to coordinate and resolve conflicts.
4. Nigerian Hydrological Services Agency (NHISA): provides technical hydrological data to support water allocation planning, monitors flood risk, and performs hydrological assessments.
5. National Environmental Standards and Regulations Enforcement Agency (NESREA): ensures environmental compliance in water resource management, monitors pollution and enforces environmental impact assessments (EIAs).
6. National Inland Waterways Authority (NIWA): regulate the use of navigation and inland waterways and promote the development of infrastructure for sustainable waterway transport.

State Government Agencies

7. State Water Agencies & Rural Water Supply and Sanitation Agencies (RUWASSA): Execute water supply initiatives at the state level and offer local water user associations (WUAs) technical support.
8. State Ministries of Environment & Water Resources: develop state water policies aligned with national frameworks and oversee environmental protection initiatives within the catchment.

9. River Basin Development Authorities (RBDAs): manage regional water supply projects and support large-scale irrigation schemes.
10. State Environmental Protection Agencies (BASEPA, JISEPA, YOSEMA, BOSEPA): monitor environmental degradation and pollution and enforce state-level environmental laws.

Local Government & Community Stakeholders

11. Local Government Authorities (LGAs): implement local-level catchment management projects and work with communities on land and water conservation efforts.
12. Catchment Management Committees (CMCs): facilitate participatory water governance and engage communities in water conservation activities.
13. Water User Associations (WUAs): manage local water distribution and irrigation schemes and resolve conflicts over water use.

Community Orientation Stakeholders

Engage in local water governance via Catchment Management Committees (CMCs). Promote sustainable land and water practices, raise awareness for water rights and environmental protection, and advocate for equitable access. Assist in conflict resolution and ensure fair resource distribution among users. Share traditional knowledge for sustainable management.

14. Water User Associations (WUAs): Manage local water distribution and irrigation practices.
15. Community-Based Organizations (CBOs): Promote conservation and climate adaptation awareness.
16. Traditional & Religious Leaders: Act as mediators in water resource disputes and promote sustainable water practices.

Private Sector Stakeholders

17. Private Sector Invest in water infrastructure projects like irrigation, hydropower, and treatment facilities. Develop climate-smart agriculture with drought-resistant crops. Implement IoT water monitoring and GIS mapping. Fund research for sustainable catchment management and support CSR initiatives for local community development.

Research Institutions

18. Research Institutions: Develop climate change adaptation strategies, water protection techniques and solutions for environmental restoration. Support policy making by providing expert advice on sustainable river management. Provide scientific data on groundwater levels, river flows, and pollution levels.

International Stakeholders & Non-Governmental Organizations (NGOs)

19. United Nations Agencies (UNICEF, UNHCR, WFP, UNECE): Provide technical and financial support to water security projects. Support humanitarian interventions in the area of water supply in vulnerable communities.
20. Development Partners (USAID, EU, DFID, AfDB, GIZ, JICA): Fund capacity-building programs and infrastructure projects. Strengthen institutional frameworks for water governance.

CHAPTER 4 : STRATEGIC VISION AND GOALS

The strategic vision focuses on sustainable water management, land protection, community resilience, and government reform, based on biophysical assessments, socio-economic factors, and stakeholder engagement.

The strategic vision for the Misau-Komadugu Gana Catchment is:

"To establish a climate-resilient, inclusive, and sustainably managed catchment that ensures equitable access to land and water resources, supports livelihoods and ecosystems, and promotes long-term resilience through integrated planning and stakeholder partnerships."

The strategic goals

To operationalize this vision, five strategic goals have been defined. These goals are integrated, outcome-driven, and informed by technical analyses and community priorities.

1. **Sustainably manage land and water resources:** by improving water storage, promoting efficient use, and supporting nature-based solutions that restore degraded landscapes and ecosystems.
2. **Build climate resilience and disaster preparedness:** through flood and drought management systems, early warning mechanisms, and climate-smart agricultural practices.
3. **Enhance inclusive livelihoods and food security:** by supporting smallholder farmers, promoting equitable access to resources, and empowering women, youth, and vulnerable groups.
4. **Strengthen governance, coordination, and institutional capacity:** across local, state, and federal levels to ensure transparent, participatory, and accountable implementation.
5. **Leverage data, innovation, and financing** to support decision-making, improve monitoring, and mobilize public and private investment aligned with catchment priorities.

Table 4.1 below shows the consensus on the Misau-Komadugu Gana Catchment's strategic short- and long-term goals, anticipated results, and implementation challenges.

Table 4.1. Misau-Komadugu Gana Catchment's Strategic Goals and Objectives for Sustainable Catchment Development

Short-Term Strategic Goals (0-5 Years)	Key Performance Indicators (KPIs)	Long-Term Strategic Goals (5+ Years)	Key Performance Indicators (KPIs)	Expected Outcomes and Measurable Targets
<p>1. Water Management & Conservation: Implement Integrated Water Resources Management (IWRM): to ensure equitable water distribution, pollution control, and efficient irrigation. Establish monitoring stations for surface and groundwater to track resource availability and quality.</p> <p>2. Land Use and Environmental Protection: Review land use laws to address urbanization pressures, deforestation, overgrazing, and desert encroachment. Introducing community-driven reforestation and conservation programs.</p>	<ul style="list-style-type: none"> • Percentage reduction in water pollution (e.g BOD/COD levels) • Percentage of monitoring stations operational. • Percentage increase in irrigation efficiency (e.g water saved/acre). • Number of communities adopting IWRM practices. <ul style="list-style-type: none"> • Number of land use policies revised/enacted. • Hectares of land reforested annually. • Percentage reduction in illegal grazing/logging incidents. • Number of communities engaged in conservation programs. 	<p>1. Water Security and Infrastructure Development: Expand water storage facilities, such as dams and reservoirs, to mitigate seasonal water scarcity. Strengthen cross-border river basin management to prevent conflicts over water allocation.</p> <p>2. Economic Growth and Community Empowerment: Promote renewable energy adoption (solar irrigation, biogas) to reduce dependence on fossil fuels. Provide microcredit and skill development programs to support alternative livelihoods.</p>	<ul style="list-style-type: none"> • Percentage increase in water storage capacity. • Number of transboundary water agreements signed/enforced. • Reduction in water-related conflicts (annual incidents). • Percentage of population with year-round water access. <ul style="list-style-type: none"> • Percentage increase in renewable energy adoption. • Number of households using solar/biogas systems. • Number of microcredit loans disbursed (by sector). • Income diversification index (survey-based). 	<p>1. Environmental Outcomes: Improved water quality through pollution control measures. Increased vegetation covers due to reforestation and erosion control efforts. Reduced desertification and land degradation.</p> <p>2. Social and Economic Outcomes: Enhanced food security through improved irrigation and soil management.</p>

<p>3. Community and Livelihood Development: Expand sustainable agriculture initiatives through improved irrigation and climate-smart farming. Implement capacity-building programs for women, youth, and smallholder farmers.</p> <p>4. Policy Reforms and Governance: Strengthen catchment-based policy frameworks and stakeholder engagement in governance. Improve institutional coordination between government agencies, NGOs, and local communities.</p>	<ul style="list-style-type: none"> • Number of farmers trained in climate-smart techniques. • Percentage increase in crop yields (pilot projects) • Number of women/youth led agribusinesses launched. • Number of irrigation systems modernized. • Number of stakeholder consultations held. • Number of interagency MOUS signed. • Percentage increase in local budget allocated to IWRM. • Number of communities with resource management committees. 			<p>Greater economic resilience via diversified livelihood opportunities. Strengthened community participation in resource governance.</p> <p>3. Governance and Institutional Strengthening: Better policy alignment with national and international frameworks (IWRM, SDGs, Paris Agreement). Improved stakeholder engagement in decision-making.</p>
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CHAPTER 5 : STRATEGIC CHALLENGES AND PRIORITY INTERVENTIONS

Stakeholder engagement and biophysical assessments reveal the following critical and location-specific challenges across the Misau-Komadugu-Gana catchment. These challenges, drawn from the detailed diagnostics in chapter 2 and stakeholder insights in chapter 3, inform the strategic themes and interventions presented below.

5.1 Key Challenges

1. **Hydrological Stress and Water Scarcity:** Over-extraction and inefficient water use in agriculture and domestic consumption, particularly in water-deficit sub-catchments (notably northern Yobe and Borno), lead to severe seasonal water shortages.
2. **Flooding and Drought Cycles:** Flood-prone areas in downstream Bauchi and Jigawa contrast with drought-affected regions in northern Yobe, reflecting extreme hydro-climatic variability.
3. **Groundwater Depletion:** Over-dependence on boreholes for irrigation and domestic use, especially in dry zones, exceeds natural recharge capacity.
4. **Deforestation and Land Degradation:** Unregulated logging and unsustainable agricultural practices have led to soil erosion, desert encroachment, and declining soil fertility.
5. **Biodiversity Loss:** Wetlands and riverine ecosystems face threats from habitat encroachment and pollution, impacting fisheries and ecological services.
6. **Conflicts Over Resource Use:** Competition between farmers and herders over land and water has led to frequent conflicts and social instability.
7. **Limited Access to Sustainable Livelihoods:** Over-reliance on rain-fed agriculture makes communities vulnerable to climate shocks and food insecurity.
8. **Lack of Community Awareness:** Inadequate knowledge of climate adaptation, conservation techniques, and sustainable farming practices hampers local resilience.
9. **Weak Policy Implementation:** Despite existing water and environmental policies, enforcement is ineffective due to lack of coordination, funding, and technical capacity.
10. **Limited Stakeholder Engagement:** The absence of community participation in resource management has led to marginalization of local voices in decision-making.

5.2 Strategic Interventions

The following strategic interventions are directly informed by catchment diagnostics in Chapter 2 and the participatory insights from Chapter 3. They are tailored to sub-catchment conditions (e.g., flood-prone zones, groundwater deficit areas) and aligned with the five strategic goals in chapter 4:

5.2.1. Sustainable Conservation Management and use of Water Resources

This section will aid address key issues in water resources management and aid the achievement of goal one (Sustainably manage land and water resources). Key interventions will include:

- i. **Integrated Water Resources Management (IWRM):** Develop a spatially targeted water allocation framework based on hydrological zones. Prioritize irrigation efficiency upgrades in surplus areas (e.g., central Bauchi) and groundwater recharge in drylands (Yobe and northern Borno).
- ii. **Improved Water Infrastructure:** Develop rainwater harvesting systems, small-scale irrigation projects, and wastewater recycling initiatives to enhance water availability. Most especially in the catchment region receiving low amounts of rainfall (Borno and Yobe state region). And the provision of community-based water monitoring apps within the catchment. Also develop digital monitoring tools such as mobile apps for community water use monitoring and integrate with basin-level data platforms.

Figure 5.2 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.2. Preservation and Restoration of Critical Ecosystems and Services for Sustainable land-use

This section is also key in the achievement of goal one (Sustainably manage land and water resources) and goal two (Build climate resilience and disaster preparedness). Interventions recommends include:

- i. **Flood and Drought Early Warning Systems:** Deploy real-time monitoring tools and GIS-based models to predict and mitigate climate-related water risks.
- ii. **Sustainable Agriculture Practices:** Promote agroforestry, conservation tillage, and climate-smart farming techniques to restore soil health and increase productivity.

- iii. **Afforestation and Reforestation Programs:** Launch community-led tree planting projects and protected forest zones to combat desertification. And the creation of riparian buffer zones, agroforestry corridors
- iv. **Land-Use Planning and Policy Reforms:** Review and enforce regulations on grazing corridors, deforestation bans, and sustainable urban expansion.

Figure 5.3 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.3. Improved Diversification for Enhanced Sustainable Livelihoods and well Being

Interventions in this section will aim in the achievement of goal three (Enhance inclusive livelihoods and food security) by

- i. Supporting smallholder farmers, promoting equitable access to resources, and empowering women, youth, and vulnerable groups within the catchment.
- ii. **Alternative Livelihoods and Economic Diversification:** Develop microcredit schemes and vocational training programs to reduce dependence on unsustainable farming.
- iii. **Community Awareness and Capacity Building:** Organize educational campaigns on climate change adaptation and environmental conservation.

Figure 5.4 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.4. Climate Resilience, Disaster Risk management Framework and Climate Resilient infrastructure.

Interventions in this section are also geared towards the effective achievement of goal two (Build climate resilience and disaster preparedness) through:

- i. **Flood and drought management systems:** Deploy real-time monitoring tools and GIS-based models to predict and mitigate climate-related water risks.
- ii. The provision and installation of early warning mechanisms

- iii. **Climate-smart agricultural practices:** the use of renewable energy for water and agriculture (solar-powered boreholes, Biogas for irrigation).
- iv. **Climate resilient infrastructure:** the construction of climate resilience infrastructures such as roads, dams, and irrigation systems.
- v. **Catchment reforestation and erosion control:** This will aid restoring the ecosystem, preserving biodiversity and promoting sustainable land use. Basically, through reforestation, riparian restoration, terracing, contour planting, mulching, gully stabilization, rainwater harvesting, soil conservation tillage and bioengineering.
- vi. **Sustainable water management:** through Groundwater recharge, small-scale water harvesting, and irrigation modernization should be encouraged, most especially in catchment regions around Borno and Yobe state.

Figure 5.5 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.5. Strengthening Institutional Mechanisms and Project Coordination Mechanism

This section highlights basic interventions geared towards the strengthening institutional mechanisms and project coordination mechanism. This is vital for the achievement of goal four (Strengthen governance, coordination, and institutional capacity) and goal five (Leverage data, innovation, and financing). Key interventions should include:

- i. **Conflict Resolution Mechanisms:** Strengthen community-based conflict resolution frameworks and engage stakeholders in dialogue over shared resources.
- ii. **Strengthening Regulatory Frameworks:** Enhance policy enforcement mechanisms for water conservation, pollution control, and land management.
- iii. **Multi-Stakeholder Coordination:** Establish Catchment Management Committees to facilitate inclusive decision-making and improve governance.
- iv. **Sustainable Financing Strategies:** Secure long-term funding through public-private partnerships (PPPs) and climate finance mechanisms, for catchment infrastructure development, provision of tools and clean energy for irrigation.
- v. **Capacity Building:** enhancing technical training for water managers.

Figure 5.6 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.6. Mainstreaming Gender Equality and Social inclusion (GESI) Mechanism

This section highlights gender equality and social inclusion mechanisms interventions, which are geared towards the achievement of goal three (Enhance inclusive livelihoods and food security) goal one (Sustainably manage land and water resources). Key interventions should include:

- i. **Gender sensitive vulnerability assessment:** identifying and addressing the specific needs and concern of women, men, girls, and boys in the catchment area, such as access to land and water by women and girls.
- ii. **Inclusive decision-making processes:** ensuring that all stakeholders, including women, youth, and marginalized groups, participate in decision making processes related to catchment management and disaster risk reduction.
- iii. **Capacity building and Training:** providing training and capacity building programs for local communities, particularly women and other marginalized groups, on catchment management, disaster risk reduction, and climate change adaptation.
- iv. **Access to information and resources:** ensuring that all stakeholders have access to relevant information, resources, and services, such as early warning system, emergence respond plans, and climate resilient agriculture practices.
- v. **Promoting gender equitable distribution of benefits:** ensuring that disaster risk reduction interventions such as irrigation systems or flood protection infrastructure are equitably distributed among all stakeholders including women and marginalized groups.
- vi. **Addressing underlying social and economic inequalities:** addressing the underlying social and economic inequalities that exacerbate the impacts of flooding and drought on vulnerable populations, such as poverty, lack of access to education and healthcare, and social exclusion.

Figure 5.7 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective interventions.

5.2.7. Research and Extension Framework for Strategic Catchment Management Plan

This section highlights key intervention areas for research and extensions framework for strategic catchment management plan. Interventions in this section are vital towards the effective achievement of all the five goals of this catchment management plan. Key intervention areas are:

- i. Hydrological monitoring and modelling
- ii. Climate-resilient water allocation, ecosystem restoration (Wetland and forest)
- iii. Water governance reforms
- iv. Stakeholder engagement and participatory water management
- v. Climate-smart agriculture and livelihood resilience
- vi. Water conservation and demand management

Figure 5.8 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective intervention of this section.

5.2.8. Robust Monitoring and Reporting System for the strategic catchment management Plan

This section highlights key intervention areas for robust monitoring and reporting system for the strategic catchment management Plan. Interventions in this section are vital towards the effective achievement of all the five goals of this catchment management plan. Key intervention areas are:

- i. **Real time hydrological climate data collection:** this is expected to improve forecast for flood and drought preparedness.
- ii. **Standardized reporting mechanisms:** improve transparency in water usage reporting.
- iii. **Geospatial and remote sensing data collection and integration:** Enhance tracking of water pollution and land degradation.
- iv. **Stakeholder driven governance:** engage local communities in participatory governance.
- v. **Adaptive water management strategies:** promotes climate resilience farming techniques

Figure 5.9 presents detail activities, timelines, key performance indicators, responsibilities, stakeholders views and recommendations geared towards effective intervention.

These strategic interventions (in components) are as outlined in figures 5.1 to 5.9

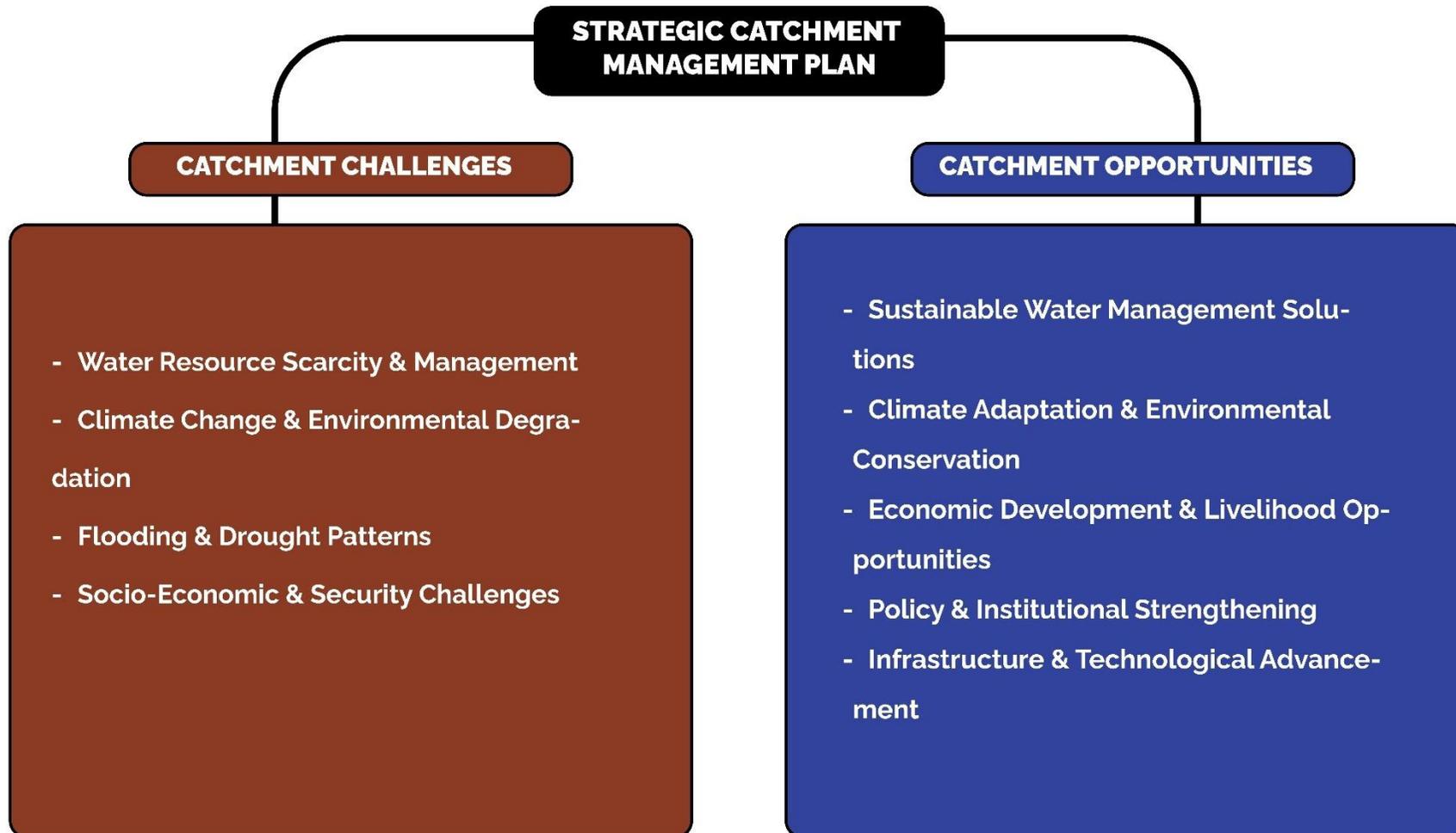


Figure 5.1: Strategic Catchment Management Plan

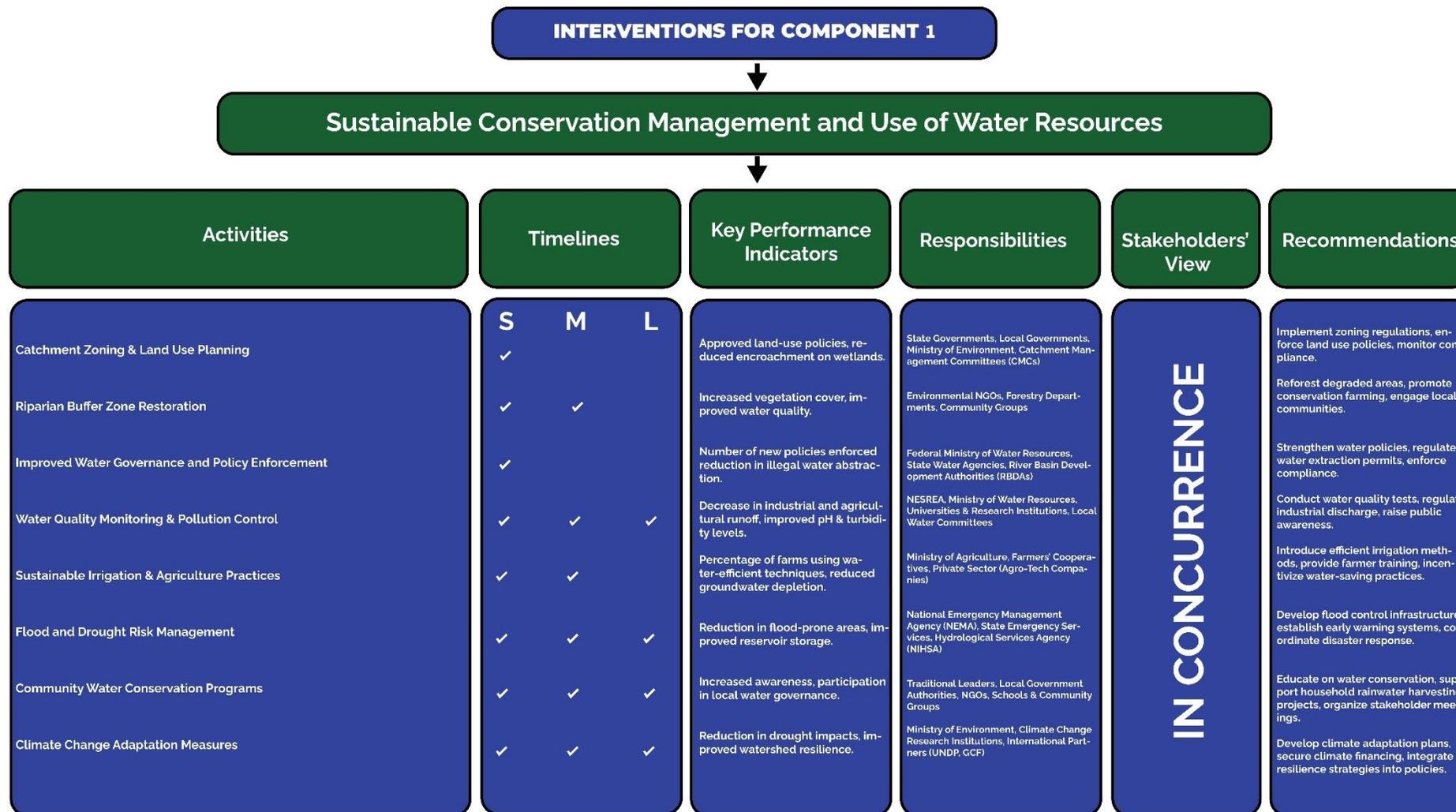


Figure 5.2: Component 1 (Sustainable Conservation Management and Use of Water Resources)

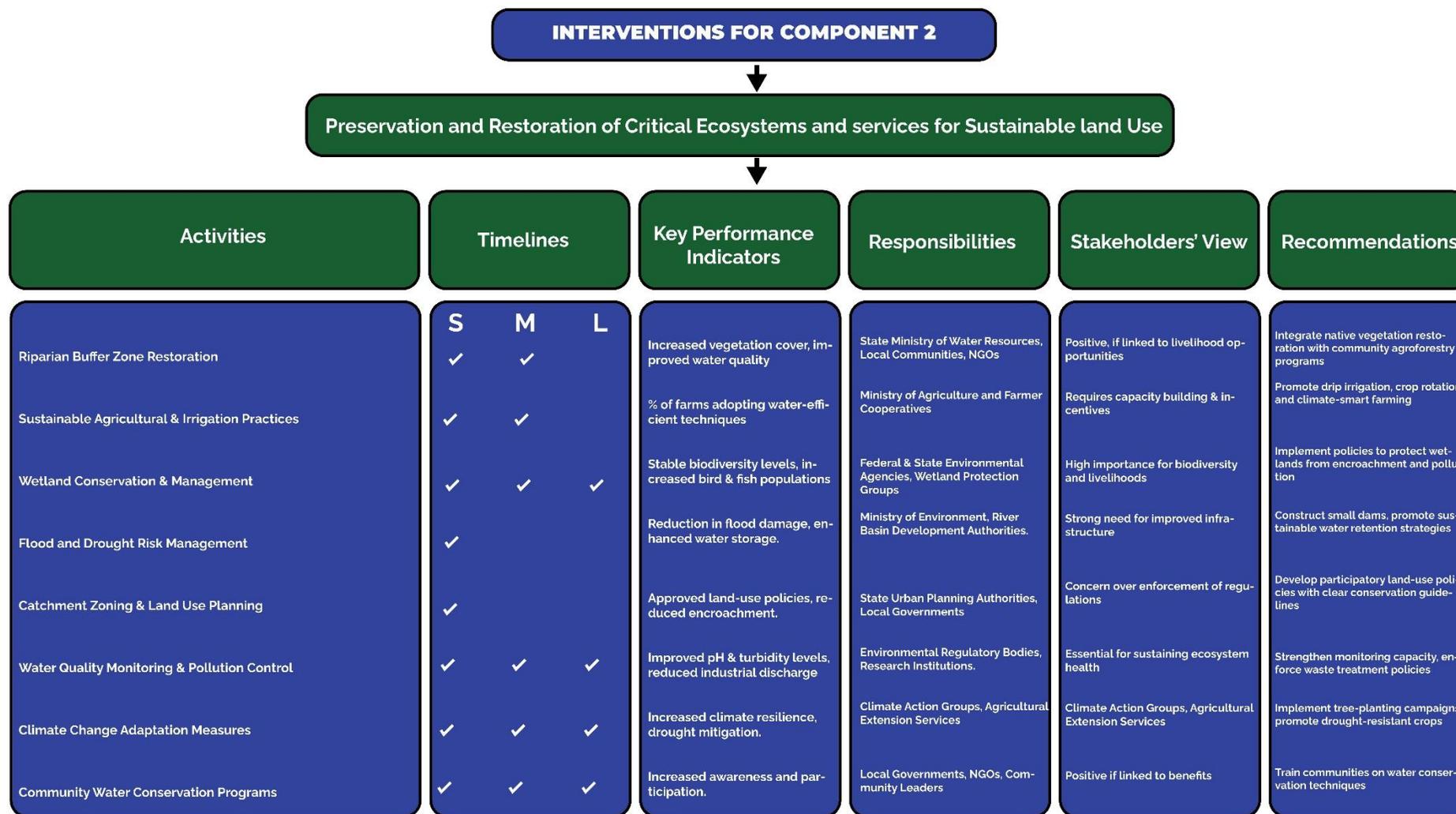


Figure 5.3: Component 2 (Preservation and Restoration of Critical Ecosystems and Services for Sustainable land Use)

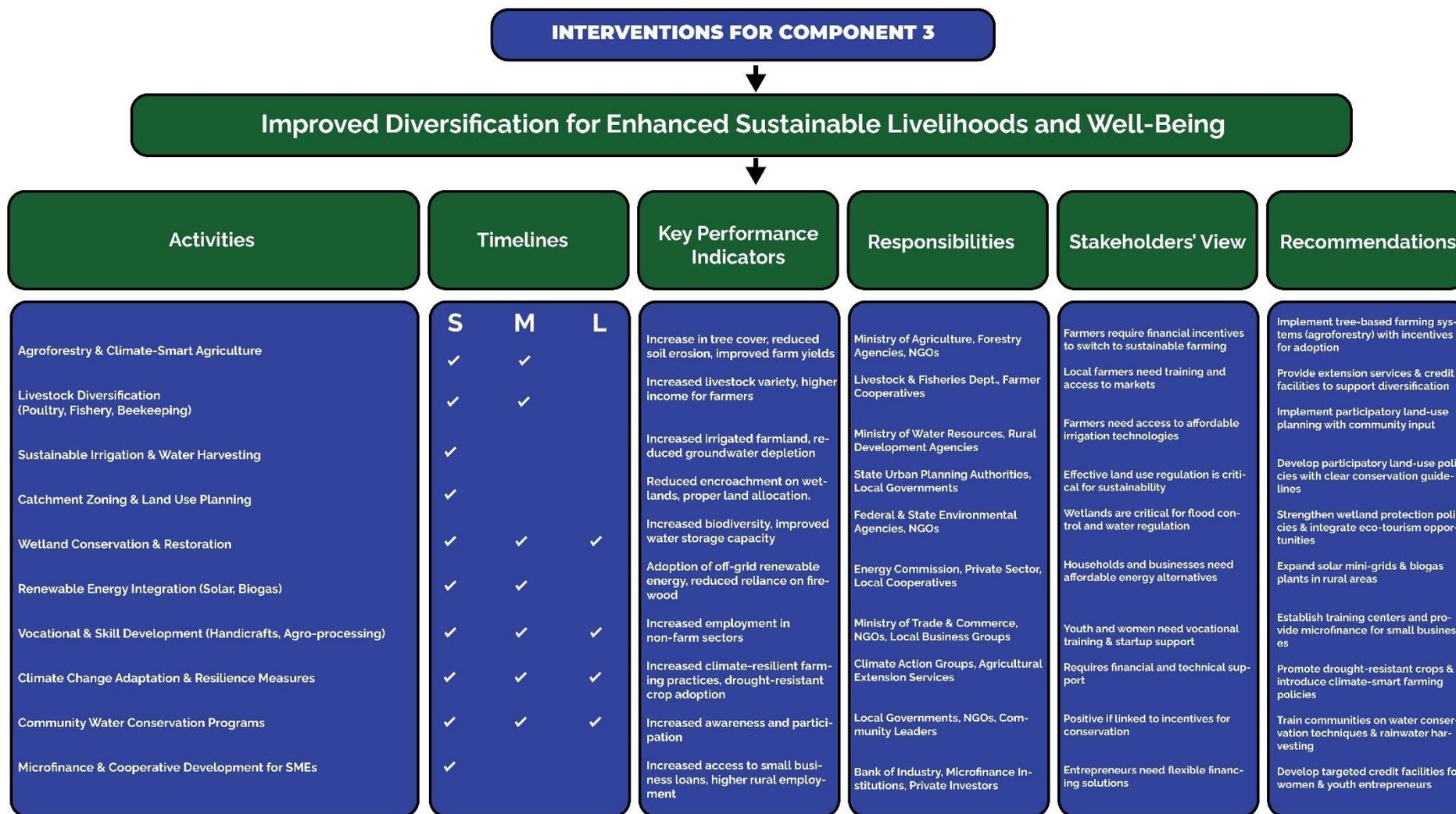


Figure 5.4: Component 3 (Improved Diversification for Enhanced Sustainable Livelihoods and Well-Being)

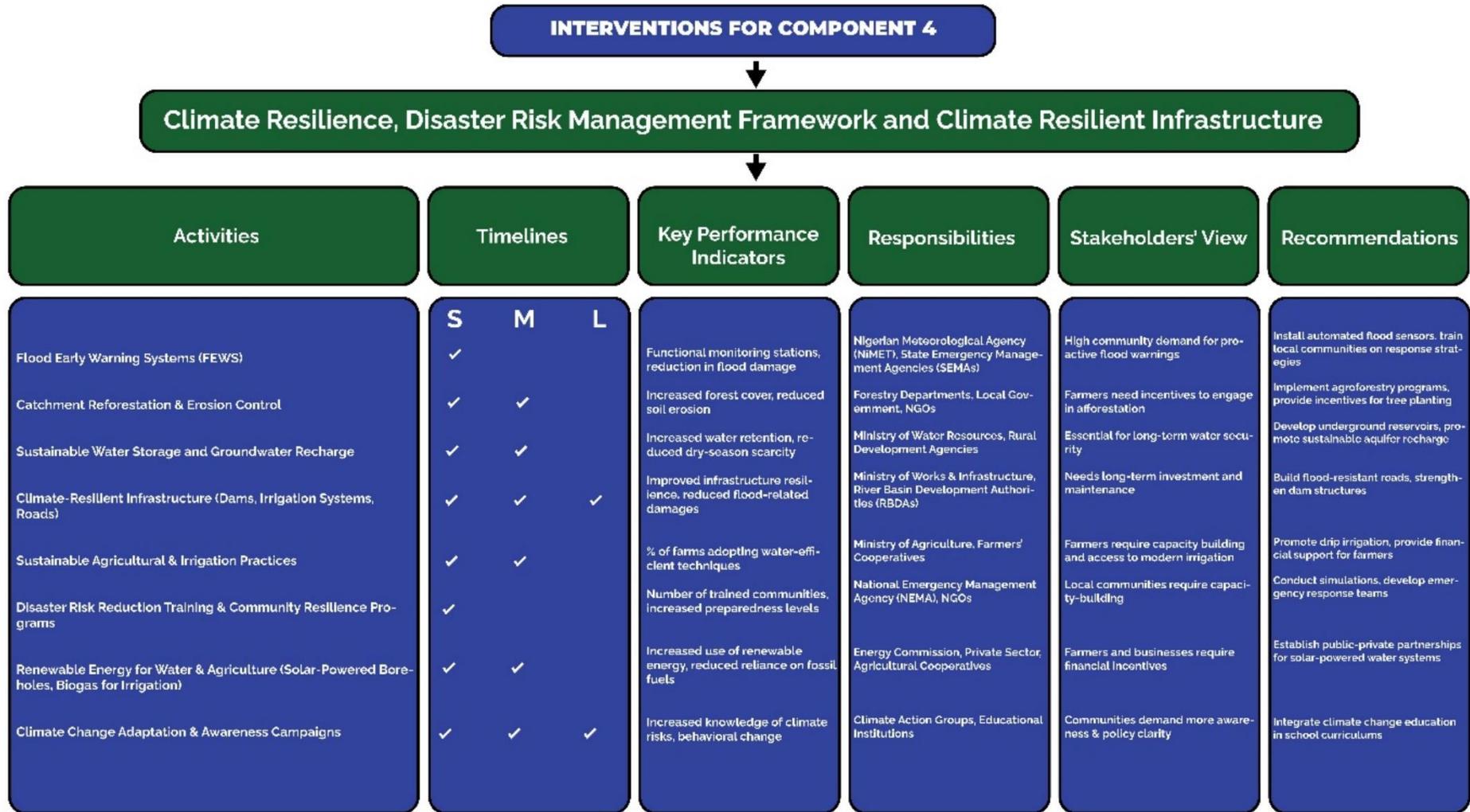


Figure 5.5: Component 4 (Climate Resilience, Disaster Risk Management Framework and Climate Resilient Infrastructure)

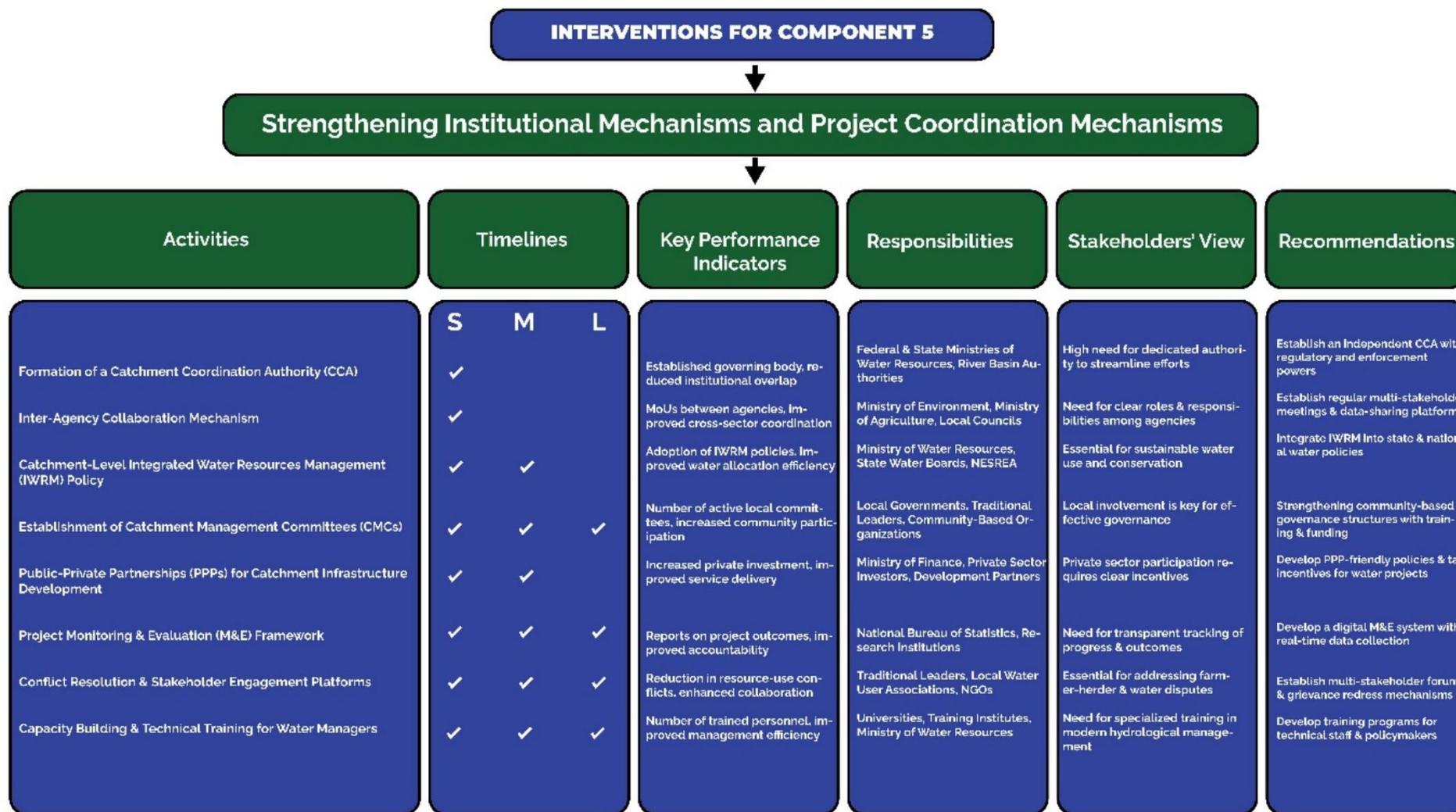


Figure 5.6: Component 5 (Strengthening Institutional Mechanisms and Project Coordination Mechanisms)

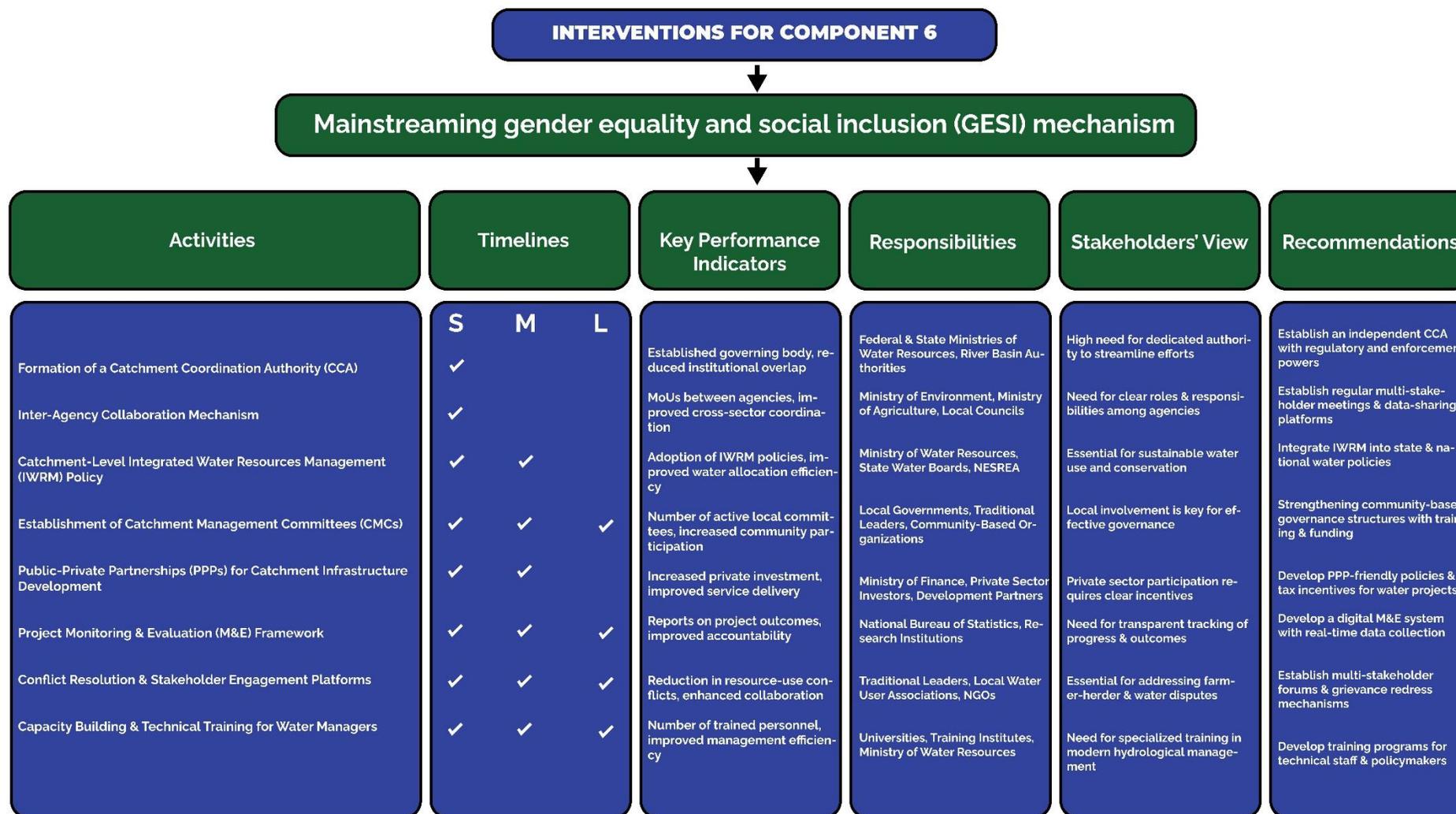


Figure 5.7: Component 6 (Mainstreaming Gender Equality and Social Inclusion (GESI) Mechanism)

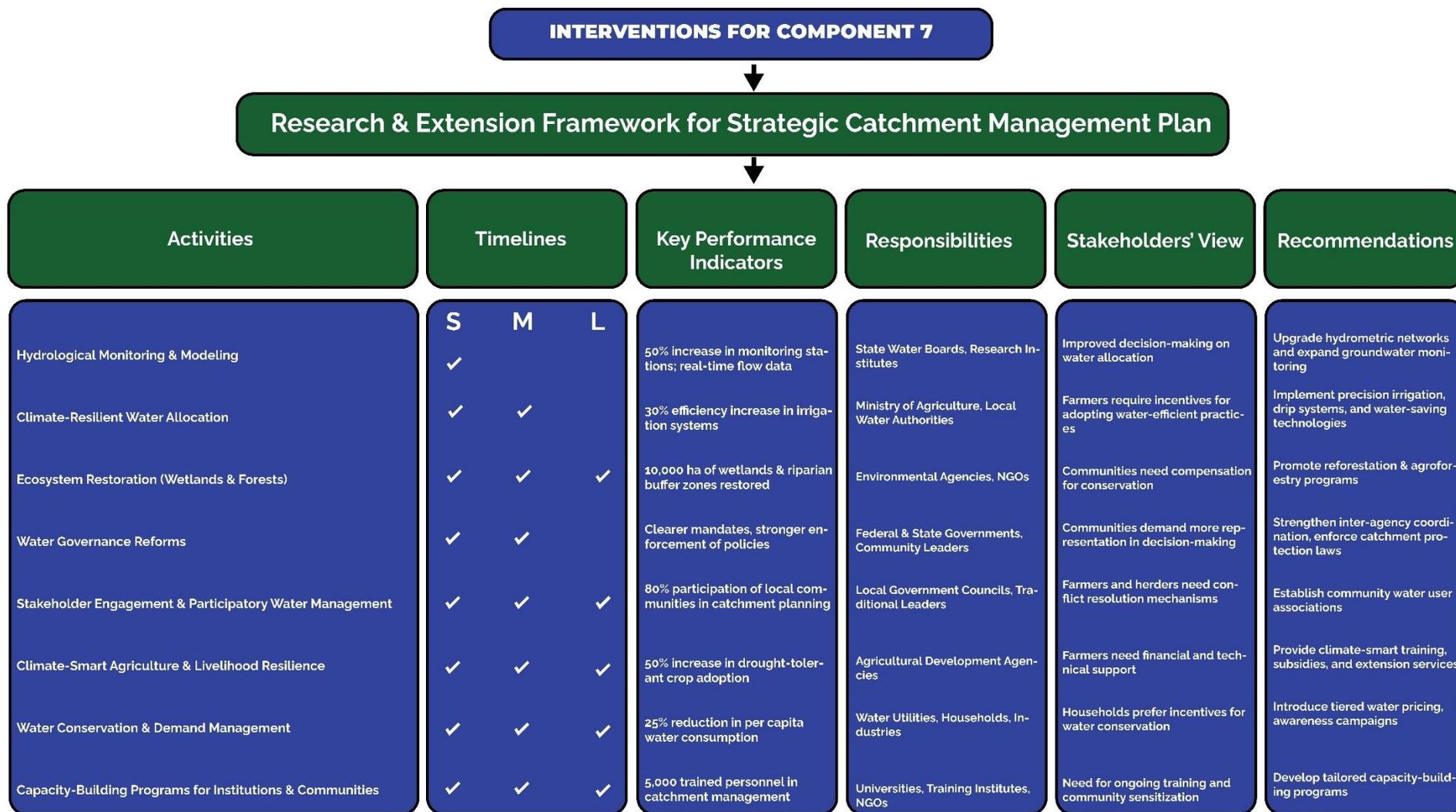


Figure 5.8: Component 7 (Research & Extension Framework For Strategic Catchment Management Plan)

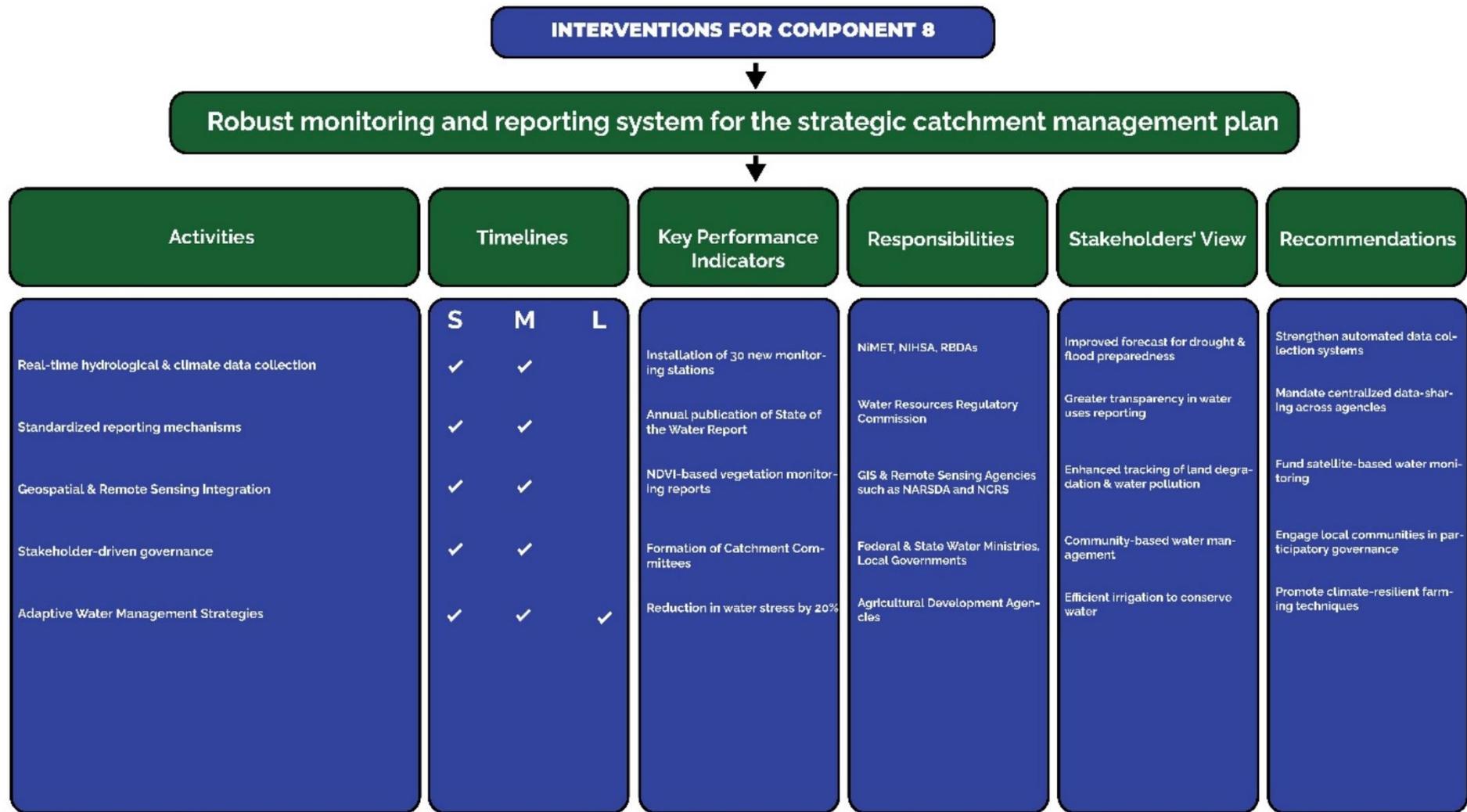


Figure 5.9: Component 8 (Robust Monitoring and Reporting System For The Strategic Catchment Management Plan)

5.3 Expected Outcomes and Feasibility of Implementation

This section groups the expected outcomes to be archive, if the strategic interventions highlighted in section 5.2 are properly implemented into short-term and long-term.

Short-Term (0–5 Years)

- i. Enhanced water security through improved access to safe and reliable water sources.
- ii. Reduction in land degradation via community-led afforestation and soil conservation projects.
- iii. Stronger institutional capacity for enforcing water and land-use policies.

Long-Term (5+ Years):

- i. Sustainable ecosystem recovery through reforestation, wetland restoration, and biodiversity conservation.
- ii. Climate-resilient communities with diversified income sources and improved agricultural practices.
- iii. Improved governance and stakeholder collaboration, leading to inclusive, participatory decision-making.

CHAPTER 6 : MONITORING, EVALUATION AND LEARNING

It is imperative to conduct ongoing monitoring and evaluation of strategic catchment plans to ensure their effectiveness and to implement necessary adjustments as required. It ensures that interventions are effectively implanted, tracked and adjusted based on evolving conditions and new insights. This chapter outlines a robust MEL framework that supports transparency, accountability, and adaptive management aligned with the five strategic goals in Chapter 4 and the thematic priority areas in Chapter 5. These reviews will encompass, but are not limited to, the following elements:

- Activities undertaken and milestones achieved.
 - Results from water quality monitoring.
 - Challenges faced and lessons learned.
 - Financial data.
 - Amendments to the governance structure, if applicable.
 - Significant modifications to the Implementation Plan.
- This document serves as a dynamic operational guide, with actions expected to change based on evolving priorities.
 - Amendments will be documented in the original management plan's appendix.
 - Appropriate indicators will be identified to assess the impacts of catchment management activities, including both biophysical and social dimensions.
 - These indicators may incorporate multimedia elements and will capture qualitative and quantitative data. The Monitoring and Evaluation Plan is detailed in Table 6.2.

6.1 Data Collection Methods

To ensure a comprehensive and responsive monitoring process, the MEL framework integrates various tools and approaches, each suited to specific intervention types:

- i. **Water Quality Monitoring:** Regular sampling of water quality parameters such as pH, turbidity, and nutrient levels at designated monitoring sites.
- ii. **Field Observations:** Regular field visits to monitor changes in vegetation cover, erosion, and other environmental indicators.

- iii. Remote Sensing: Use of satellite or aerial imagery to monitor changes in land use, vegetation cover, and water quality.
- iv. Stakeholder Surveys: Regular surveys of stakeholders, including landholders, community groups, and government agencies, to gather information on their perceptions, attitudes, and experiences related to catchment management.
- v. Community-Based Monitoring: Engagement of local communities in monitoring and reporting on environmental indicators, such as water quality and vegetation cover.
- vi. Automated Sensors: Installation of automated sensors to monitor water quality, flow, and other environmental parameters in real-time.

6.2 Feedback Mechanisms

Feedback channels are essential to ensuring responsiveness and legitimacy of the catchment plan:

- i. Regular Progress Reports: Preparation and dissemination of regular progress reports to stakeholders, highlighting achievements, challenges, and future directions.
- ii. Stakeholder Meetings: Regular meetings with stakeholders to provide updates, gather feedback, and discuss emerging issues.
- iii. Community Engagement Forums: Hosting of community engagement forums to provide information, gather feedback, and build support for catchment management initiatives.
- iv. Social Media: Utilization of social media platforms to share information, gather feedback, and engage with stakeholders.
- v. Online Feedback Mechanisms: Establishment of online feedback mechanisms, such as surveys or comment boxes, to gather feedback from stakeholders.
- vi. Independent Review Panels: Establishment of independent review panels to provide objective feedback and assessment of catchment management initiatives.

6.3 Data Management and Analysis

- i. Data Storage: Establishment of a secure and accessible data storage system to store and manage data.
- ii. Data Analysis: Regular analysis of data to identify trends, patterns, and insights that inform catchment management decisions.

- iii. Data Visualization: Use of data visualization tools to present complex data in a clear and concise manner.
- iv. Reporting and Dissemination: Preparation and dissemination of reports and other communication materials to stakeholders, highlighting key findings and insights.

6.4 Institutional Roles and Coordination

Table 6.1 outlines institutional responsibilities for different MEL tasks. Coordination will be overseen by the State Project Management Unit (SPMU), with technical support from consultants and specialized agencies.

Table 6.1: Institutional Responsibilities For MEL Tasks

S/N	Task	Lead Agency	Supporting Partners
1	Water Monitoring	Ministry of Water Resources	SPMU, RBDA, NGOs
2	Vegetation and Erosion Monitoring	Ministry of environment	NASRDA, NCRS, Consultants
3	Socio-economic surveys	SPMU	LGAs, NGOs, Community Groups
4	Data analysis	SPMU/Consultant	NASRDA, Academic Institutions
5	Community Feedback	SPMU/Consultant	FoNGOS, Community Leaders

6.5 Adaptive Management Process

The MEL system is not only a compliance tool but a learning engine. Key mechanisms for adaptive management include:

- Quarterly technical reviews: Analyze data, flag emerging risks, and recommend adjustments.
- Annual stakeholder summits: Reflect on overall progress, refine targets, and re-align actions.
- Dynamic plan updates: Amendments documented in the plan's appendix.

Table 6.2. Monitoring and Evaluation Plan for the Misau-Komadugu Gana catchment

S/No.	Monitoring Tools and Techniques	Target/Output	Monitoring	Evaluation	Responsibility
1	Geographical Information Systems	To analyze and visualize spatial data use, water quality, and hydrological data	Establish Key performance Indicators to track progress	Mid-Term and End Term: Conduct comprehensive evaluations at the midterm and end of implementations	WB/SPMU
2	Remote Sensing/Drone technology	Using remote sensing technology, such as satellite imagery to monitor land use and environmental changes	Stakeholder Feedback and Participation: Engaging Stakeholders within the local communities	Stakeholder Feedback and Participation: Engaging Stakeholders within the local communities.	Consultant, NASRDA, NCRS, SPMU, FoNGO, community.
3	Statistical Analysis.	To analyze new data and monitor trends, patterns, and corrections.	Hydrological Monitoring: monitor precipitation, stream flow and ground water	Cost -Benefit analysis: an assessment of the economic and social costs.	SPMU/Consultant

			levels to understand hydrological trends.		
4	Participatory Rural Appraisal (PRA)	Engage local communities in the evaluation of the process, E.g., FGD, surveys and stakeholder workshops	Land Use, Land cover monitoring to track changes.	Environmental impact assessment.	Consultant, NASRDA, NCRS
5	Ground truthing of intervention sites periodically	Entire catchment	Socio Economic Monitoring through data collection to assess the plans' impact on local communities	Institutional and governance assessment.	Consultant, SPMU, Ministry of Environment, FoNGO, community.
6	Video Documentary.	Entire catchment		A movie documentary on the socio-economic and biophysical impact of environmental issues. It will also capture the	Consultant, SPMU, Ministry of Environment, FoNGO, community.

				progress of the implementation of BMPs	
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6.6 Specific Indicators for Success and Potential Reporting Framework

A typical measurable success story that can be used to monitor and evaluate a strategic catchment management plan will be indicated in the following:

Environmental Indicators

- i. **Water Quality Index:** Measures the overall health of the waterway based on parameters such as pH, turbidity, and nutrient levels.
- ii. **Sediment Load Reduction:** Tracks the reduction in sediment loads entering the waterway.
- iii. **Vegetation Cover:** Monitors the increase in vegetation cover along the waterway and its tributaries.
- iv. **Biodiversity Index:** Measures the health and diversity of aquatic and terrestrial ecosystems.

Social Indicators

- i. **Community Engagement:** Tracks the number of community events, meetings, and activities related to catchment management.
- ii. **Stakeholder Satisfaction:** Measures the satisfaction of stakeholders, including landholders, community groups, and government agencies, with the catchment management plan.
- iii. **Education and Awareness:** Monitors the increase in knowledge and awareness of catchment management issues among the community.

Economic Indicators

- i. **Cost-Benefit Analysis:** Evaluates the economic benefits of catchment management activities, such as reduced sedimentation and improved water quality.
- ii. **Job Creation:** Tracks the number of jobs created in industries related to catchment management, such as conservation and restoration.
- iii. **Agricultural Productivity:** Monitors the impact of catchment management activities on agricultural productivity and profitability.

6.7 Annual Report Template

It is important that monitoring and evaluation is reported either quarterly or annually based on a framework. The reporting framework provides a structure for presenting progress against objectives, highlighting key achievements and challenges, and identifying areas for future improvement. This plan will report monitoring and evaluation in the following manner:

1 Executive Summary

- Brief overview of progress against objectives
- Key achievements and challenges

2 Environmental Performance

- Water Quality Index
- Sediment Load Reduction
- Vegetation Cover
- Biodiversity Index

3 Social Performance

- Community Engagement
- Stakeholder Satisfaction
- Education and Awareness

4 Economic Performance

- Cost-Benefit Analysis
- Job Creation
- Agricultural Productivity

5 Case Studies and Success Stories

- Examples of successful catchment management projects
- Lessons learned and best practices

6 Challenges and Future Directions

- Identification of challenges and areas for improvement
- Outline of future directions and strategies for addressing challenges

7 Conclusion

- Recap of progress and achievements
- Commitment to ongoing improvement and accountability.

The MEL framework outlined here offers a practical, inclusive, and adaptive approach to track the effectiveness of the catchment management plan. Its integration with strategic goals, emphasis on institutional roles, and mechanisms for feedback and learning will support successful implementation and long-term impact.

CHAPTER 7 : CONCLUSION AND MOVING FORWARD

The Catchment Management Plan for the Misau-Komadugu Gana Catchment provides a foundational roadmap to guide sustainable natural resource management, climate resilience, inclusive development, and institutional coordination across Bauchi, Borno, Yobe, and Jigawa states. It consolidates extensive data, stakeholder inputs, and policy analysis into a strategic action framework that aligns with national and regional priorities.

7.1 Summary of Strategic Issues and Priorities

The Misau-Komadugu Gana Catchment, is vital for agriculture, fisheries, and livestock production. It plays a key role in the region's socio-economic stability and food security but is under threat from environmental degradation, water scarcity, and climate change.

The Catchment Management Plan (CMP) adopts a comprehensive, data-driven approach to tackle multi-dimensional challenges, emphasizing sustainable water resource management, ecosystem restoration, and climate adaptation. It integrates Integrated Water Resources Management (IWRM) principles to prioritize water security, pollution control, and land conservation in regional development strategies.

The CMP aims to ensure long-term water availability for agriculture, industry, and domestic use through efficient allocation and conservation. It focuses on pollution control and water quality monitoring, promotes climate-smart agriculture for soil health and drought resilience, and strengthens economic resilience by supporting sustainable livelihoods and skills development in water-dependent sectors.

Achieving these objectives requires a strong institutional framework and sustainable financing, including increased federal and state budgets for water, agriculture, and environmental programs. Public-Private Partnerships (PPPs) should be explored for investment in water infrastructure and conservation technologies. Additionally, international support from agencies like AfDB, USAID, and the EU can enhance climate resilience, along with community-driven financing through cooperatives and local resource mobilization.

The CMP emphasizes multi-stakeholder coordination to ensure effective governance and on-the-ground implementation. This coordination includes the following:

- i. Federal-Level Coordination – Led by the Federal Ministry of Water Resources, River Basin Development Authorities (RBDAs), and environmental agencies, ensuring policy alignment and regulatory oversight.
- ii. Community Participation – Engaging Catchment Management Committees (CMCs) and Water User Associations (WUAs) to facilitate local ownership, equitable water access, and conflict resolution.
- iii. Private Sector Involvement – Encouraging investment in innovative water conservation, irrigation efficiency, and renewable energy solutions.

The CMP identified Key Stakeholders as the driving force to achieving the set aim and objectives of the plan. They include but not exclusive to the following:

- i. **Government Agencies:** Responsible for policy formulation, regulation, and implementation.
- ii. **Local Communities:** Primary beneficiaries and key actors in conservation and resource management.
- iii. **Research Institutions:** Providing scientific data, hydrological assessments, and sustainable management solutions.
- iv. **International Organizations & Development Partners:** Offering financial, technical, and capacity-building support.

Through strategic partnerships, evidence-based policy interventions, and stakeholder-driven governance, the Misau-Komadugu Gana Catchment Management Plan establishes a sustainable framework for water security, environmental restoration, and socio-economic development, ensuring long-term resilience for the region.

7.1.1 Key Priorities for 2025-2027

To bridge strategy with implementation, the following priority action areas have been identified. These are directly aligned with the strategic goals outlined in Chapter 4 and are intended to guide immediate-term efforts.

Table 7.1: Strategic Priorities for Implementation (2025-2027)

Priority Area	Description
Climate Resilience	Strengthen ecosystem buffers, climate-smart agriculture, flood management.
Sustainable Land & Water Use	Promote integrated watershed, soil, and water management practices.
Inclusive Livelihoods	Expand climate-resilient and alternative livelihoods, especially for women/youth.
Institutional Strengthening	Build capacity of catchment-level institutions and coordination platforms.
Data & Innovation Systems	Improve data collection, early warning systems, and digital platforms.
Monitoring & Learning (MEL)	Establish robust systems for tracking, evaluating, and adapting efforts.

7.2 Recommendations for Aligning with Broader National and Regional Programs

The Misau-Komadugu Gana catchment management plan should align with existing frameworks to enhance impact and sustainability. Key recommendations include:

7.2.1 Alignment with National Policies

Aligning with the national policies will involve:

1. Adopt Integrated Water Resource Management (IWRM)

- To guarantee pollution control, fair distribution, and water conservation, create catchment based IWRM committees.
- Implement water monitoring stations to track groundwater and surface water changes.

2. Enhance Climate Resilience Strategies

- Develop drought and flood early warning systems to mitigate extreme climate impacts.
- Promote climate-smart agriculture and introduce drought-resistant crops and efficient irrigation technologies.

7.2.2 Enhance Cross-Border Water Governance

3. Strengthening Regional Collaboration

- To ensure sustainable transboundary water sharing, Nigeria should work more closely with the Nigeria-Niger Joint Commission (NNJC) and the Lake Chad Basin Commission (LCBC).
- To track water availability, Nigeria and its neighbours should enhance data exchange and hydrological modelling.

4. Develop Joint Conservation Programs

- To safeguard the Hadejia-Nguru Wetlands and other shared ecosystems, implement cooperative biodiversity conservation programs.
- Promote regional reforestation projects to combat desert encroachment and land degradation.

5. Promote Regional Water Security Initiatives

- Strengthen collaborative infrastructure development for irrigation, flood control, and water storage.
- Advocate for regional climate change adaptation programs to address common vulnerabilities.

6. Enhancing Community-Driven Development

- Empowering local communities in catchment management
- Establishing community-led monitoring programs for water quality, deforestation, and soil erosion.

7.2.3 Educate local pastoralists and farmers on sustainable land-use techniques.

7. Support Livelihood Diversification

- Promoting eco-tourism, sustainable fishing, and agroforestry to generate alternative sources of income.
- Introduction of microcredit programs to support local entrepreneurs in green businesses.

8. Improve Public Awareness and Education

- Run public awareness campaigns about climate change adaptation and water conservation.
- Establish environmental education programs in schools to promote sustainability awareness.

7.3 Catchment Policy for Interstate River Systems

The policies for the catchment interstate river systems are:

- An essential part of the Komadugu-Yobe River system, the Misau-Komadugu Gana catchment spans portions of the northeastern Nigerian states of Bauchi, Borno, Jigawa, and Yobe. The Misau-Komadugu Gana catchment operates under Nigeria's National Water Resources Policy and the Water Resources Act (2004), which emphasize Integrated Water Resources
- The key policies for sustainable and equitable water distribution in catchments include the Water Resources Act, which mandates catchment-level management for coordinated use across state boundaries.
- Water governance involves federal and state agencies, local governments, river basin development authorities (RBDAs), and community stakeholders. Regulatory bodies like the National Environmental Standards and Regulations Enforcement Agency (NESREA) oversee sustainable water use and pollution control.
- The Nigeria Integrated Water Resources Management Commission (NIWRMC) promotes cooperation among states to prevent conflicts over water allocation.

The Misau-Komadugu Gana Catchment's interstate and transboundary river systems are primarily composed of the Komadugu Yobe river, Hadejia river, Jama'are river, Katagum river, Yedseram and Ngada rivers in Borno state. These water systems are essential for agriculture, fisheries, and sustaining biodiversity.

- The Lake Chad Basin Commission (LCBC) is the main international body that regulates transboundary water resources in the region. Nigeria, as a member, collaborates with Cameroon, Chad, Niger, the Central African Republic, and Libya to manage the Lake Chad Basin.
- The LCBC's Integrated Water Resources Management (IWRM) Strategy aligns with Nigeria's national policies to ensure sustainable water use and conflict resolution. The

Hadejia-Jama'are-Komadugu-Yobe Basin Trust Fund (HJKYB-TF) also plays a crucial role in regional water governance, promoting basin-wide coordination and conservation efforts.

Asides its membership to the Lake Chad Basin Commission (LCBC), Nigeria is also a signatory to the 1992 UNECE Water Convention, the 2008 Niger Basin Water Charter, the 2012 Lake Chad Basin Water Charter, and the 1997 UN Watercourses Convention. Nigeria is therefore bound by international law, specifically Article 26 of the Vienna Convention on the Law of Treaties, to abide by the terms of the treaties as a ratifying nation.

In addition to the tenets of international water law, other pertinent tools include the National Water Resources Act and environmental, climate change, and water resources policies. Additional policies are ECOWAS Water Resources Policy and international soft laws enacted under UN auspices.

Five Principles of International Water Law Enunciated in The Water Treaties

- Scope of application of the treaty: Does it address surface water, ground water or both?
Is it applicable to non-navigational uses only or for all purposes?
- Substantive principles
- Principle of equitable and reasonable utilization
- Obligation not to cause significant harm (no harm rule)
- Protection of the ecosystems
- Procedural principles
- Principle of cooperation
- Notification of any planned project
- Exchange of data and information
- Institutional Framework (river basin organization)
- Dispute Resolution Provisions

The Niger Basin Water Charter, Lake Chad Water Charter and UN water treaties reflect the five principles generously. Relevant treaties for transboundary watercourse management in Nigeria are:

- i. Vienna Convention on the Law of Treaties on principle of binding nature of treaty once signed, ratified and inforce (*pacta sunt servanda*),

- ii. UN Watercourses Convention on non-navigational use of shared watercourses, application to surface water and connected groundwater,
- iii. UNECE Water Convention on relevance to both surface and ground water as well as application to all uses of the shared watercourse,
- iv. Niger Basin Water Charter as principal treaty of the Niger River Basin,
- v. Lake Chad Water Charter as principal treaty of the Lake Chad Basin.

International Policies That Affect Shared Water Resources

They are soft laws not treaties, but they provide direction. However, they lack legal significance and not binding.

- i. 1971 Stockholm Declaration on Human Environment that states the principle of ‘no harm rule’ (Principle 21)
- ii. 1992 Dublin principles on water and sustainable Development, which heralded integrated water resources management.
- iii. 1992 Rio Declaration on Environment and Development, Agenda 21 that expounded on the Stockholm Declaration and also codifies other principles of sustainable environment, applicable to management of transboundary watercourse, which were absent in the Stockholm Declaration. They are Principle 15 (Precautionary Principle), Principle 16 (Polluter Pays Principle), Principle 17 (Environmental Impact Assessment) and Principles 18 and 19 (Principle of prior and timely notification of transboundary harm.)
- iv. 2008 ECOWAS Water Resources Policy is not a regional water treaty but policy statements to guide ECOWAS member states in managing their water resources. According to the Policy, a river basin organization is paramount for cooperation and equitable sharing of water resources that affects transboundary watercourses. Article 2.3 of the ECOWAS Water Policy reflects guiding principles of equitable sharing of water resources and other principles of shared watercourse protection such as precaution, prevention, and polluter-pays principles as well as principles exchange of information, subsidiarity, and cooperation. Other enunciated principles are user pays, notification or information, effective governance in water resources management, gender equality, solidarity, progressiveness, partnership, and hydrographic basins or aquifers systems management.

- v. Draft Articles on the Law of Transboundary Aquifer currently guides riparian states in negotiating groundwater treaties.

National Water Law and Policies on Water Resources

- i. **National Water Resources Policy:** The framework for managing Nigeria's water resources is provided by the National Water Resources Policy (2016). It places a strong emphasis on Integrated Water Resources Management (IWRM), a comprehensive strategy for maintaining sustainability while balancing water use across sectors. The policy promotes catchment-based planning for efficient resource management, stakeholder participation in water governance, and conservation and safeguarding of water sources against pollution and overuse.
- ii. **Water Resources Act (2004):** The legal foundation for water management across the country is provided by the Water Resources Act (2004). It controls the use and distribution of water resources, the preservation and protection of catchments, and the licensing of water abstraction to avoid over-extraction.
- iii. **Environmental Protection and Catchment Laws:** To supplement federal regulations, several states in the Misau-Komadugu Gana catchment have enacted laws and policies:
 - **Bauchi State:** Water supply, sanitation, and pollution control strategies are outlined in the Bauchi State Water Supply and Sanitation Policy.
 - **Yobe State:** Water use is governed by the Environmental Protection Law (2012) and the Water Corporation Law, which guarantee adherence to national regulations.
 - **Borno State:** The BOSEPA Law (2002) protects water quality by enforcing waste management and pollution control.

The plan aligns with several critical frameworks, including:

- National Water Resources Master Plan (NWRMP)
- Nigeria's National Adaptation Plan (NAP)
- ACREsAL Programme Objectives
- National Irrigation and Drainage Policy

- Regional frameworks, including ECOWAS Water Policy and Lake Chad Basin Commission (LCBC) instruments.

This alignment is vital for ensuring consistency, facilitating federal buy-in, and leveraging donor funding. The transboundary implications of water and environmental management in the catchment also necessitate compliance with international water laws and cooperation under shared basin agreements.

7.4 Catchment Management Policies and Framework

A systematic approach to managing river basins and catchments is offered by the National Guidelines on IWRM. This includes water-use permits to control industrial and agricultural consumption, water quality monitoring to control pollution, and restoration projects like afforestation and erosion control.

The Misau-Komadugu Gana catchment has state-specific catchment management plans that have been developed by each state. These plans place a high priority on community involvement in water governance, protecting wetlands and floodplains to lessen the effects of climate change, and sustainable land-use practices.

7.4.1 Institutional Leadership and Governance

Effective governance is crucial for cross-sectoral and multi-level coordination. The following institutional arrangement is proposed for oversight and implementation:

Table 7.2: Institutional Roles and Responsibilities

Institution/Platform	Role
Catchment Coordination Platform	Lead coordinating entity, composed of state and federal stakeholders.
State Project Management Units	Implementation leads within each state.
Federal Project Management Unit	Oversight, policy alignment, technical support, and donor coordination.
LGAs and Community Structures	Grassroots implementation and community mobilization.
RBDA (Hadejia-Jama'are Komadugu Yobe)	Technical execution, infrastructure, water resources monitoring.

Civil Society & Research Actors	Advocacy, knowledge generation, capacity building.
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A formalized Catchment Coordination Platform (CCP) is recommended to provide leadership, ensure coherence, and manage cross-state efforts.

7.5 High-Level Funding Strategies and Partnership Opportunities

To accomplish the strategic catchment goals specified in the plan, sustainable funding and strategic alliances are needed. To improve the Misau-Komadugu Gana catchment's financial sustainability, a number of funding mechanisms are suggested. These consist of, but are not restricted to, the following:

7.5.1 Government Budgetary Allocations and Climate Financing

Federal and State Budgetary Appropriations: While some states in the Misau-Komadugu Gana catchment (e.g., Yobe) have budget resources for climate change programs, others (e.g., Bauchi and Borno) lack clear funding allocations. It is necessary to push for state and federal budgets to include funds specifically for the development of water resources. Funding provisions for afforestation, solar-powered management projects, and erosion control should also be promoted.

7.5.2 National and International Climate Funds

The catchment management authorities should find ways to integrate climate action plans at the subnational level to secure funding for climate adaptation. In climate-vulnerable areas like the Misau-Komadugu Gana catchment, states and the federal government should try to access funding for water management projects through the Green Climate Fund (GCF) and Adaptation Fund. To increase funding for sustainable land use, water conservation, and catchment restoration projects, states can apply for international climate financing through programs like the Agro-Climate Resilience in Semi-Arid Landscapes (ACReSAL) project.

7.5.3 Public-Private Partnerships (PPP)

PPP models that allow private investors to construct infrastructure while government organizations oversee and regulate compliance should be established in order to promote cooperation between the public and private sectors. Collaboration with private sector actors on sustainable water infrastructure and adaptation to climate change by investing in innovative solutions such as drip irrigation, water reuse, and conservation techniques should also be

promoted. Opportunities for corporate social responsibility (CSR) initiatives from local water resources should be explored by catchment management authorities.

7.5.4 International Development Grants and Loans

Collaboration with international development partners for integrated water resource management (IWRM) projects, such as the World Bank, African Development Bank (AfDB), and United Nations agencies should be encouraged. River basin authorities should consider seeking potential grants from international donors for sustainable agriculture and water resources management. The opportunity to finance water-related projects in Nigeria through bilateral and multilateral aid programs with organizations such as USAID, JICA and GIZ should also be promoted.

7.5.5 Partnership Opportunities for Catchment Management

Cooperation between local communities, international organizations, and government agencies is necessary so that the water resources of the Misau-Komadugu Gana catchment can be effectively managed. Key partnership opportunities are:

7.5.5.1 Government Agencies

- **Federal and State Government Agencies:** State and federal ministries in charge of environmental protection, climate action, and water resources. Government agencies such as the Nigerian Integrated Water Resources Management Commission (NIWRMC), the Ministry of Water Resources, and the River Basin Development Authorities (RBDAs) are key stakeholders as they are involved in creating policies and implementing projects.
- **Local Governments and Community-Based Organizations (CBOs):** local councils should be actively involved in catchment protection programs such as afforestation and erosion control.

7.5.5.2 International and Development Partner Collaborations

- **Cooperation with United Nations agencies** (UNDP, UNICEF, FAO, UNEP) known to contribute to climate resilience and sustainable water development should be promoted. These organizations assist programs that promote water security, sanitation, and conservation in areas that are at risk such as Misau-Komadugu Gana catchment.

- **Lake Chad Basin Commission (LCBC):** given the transboundary nature of the catchment, cooperation with the LCBC ensures harmonized management of shared water resources.

7.5.5.3 Academic and Research Institutions

Cooperation with universities and research institutions concerned with climate adaptation and catchment management should be promoted to support hydrological studies, climate modelling and water conservation research.

7.5.5.4 Private Sector and NGOs

- Water-dependent sectors like agriculture and industry ought to be encouraged to make investments in water-saving technologies.
- Non-governmental organizations (NGOs) should be encouraged to support community-led initiatives for water protection and adaptation to climate change.
- Promoting water conservation and ecosystem restoration initiatives through corporate social responsibility (CSR).

To operationalize this CMP, a dedicated financing mechanism is proposed; The Catchment Development Fund (CDF)

Table 7.3: Conceptual Overview- Catchment Development Fund (CDF)

Element	Description
Funding Sources	Federal budget, ACRE SAL, donor grants (World Bank, AfDB, GCF), private sector, community contributions.
Disbursement Mechanism	Performance-based tranches through implementing agencies and approved proposals.
Governance	Managed by the Catchment Coordination Platform, with audit and transparency provisions.
Investment Areas	Afforestation, wetland restoration, small dams rehab, livelihoods, erosion control.

7.6 Moving Forward with the Catchment Plan

The Misau-Komadugu Gana Catchment Plan offers a comprehensive approach to sustainable water resource management. Its long-term success relies on adapting policies, ensuring financial sustainability, and engaging stakeholders. Strengthening governance and diversifying funding will be crucial for keeping the plan relevant for future generations.

The following tasks as tabulated in table 7.4 are required to ensure that the catchment plan remains adaptive and dynamic.

Table 7.4: Next steps and key actions points

Next Steps	Key Action Points	Responsibilities	Timeline
Review and Update Plan	Review progress against objectives	Catchment Management Committee	Quarterly
	Update plan to reflect changes in policy, legislation, or catchment condition	Catchment Management Committee	Annually
Monitor and Evaluate Progress	Establish monitoring and evaluation framework	Catchment Management Committee	Ongoing
	Collect and analyze data on key indicators	Catchment Management Committee	Quarterly
	Report on progress against objectives	Catchment Management Committee	Annually
Engage Stakeholders	Identify and engage key stakeholders	Stakeholder Engagement Team	Ongoing
	Develop stakeholder engagement strategy	Stakeholder Engagement Team	Quarterly
	Report on stakeholder engagement activities	Stakeholder Engagement Team	Annually
Build Capacity and Skills	Identify capacity and skills gaps	Capacity Building Team	Ongoing
	Develop capacity building plan	Capacity Building Team	Quarterly
	Report on capacity building activities	Capacity Building Team	Annually
Secure Funding and Resources	Identify funding and resource needs	Funding and Resources Team	Ongoing
	Develop funding and resource mobilization plan	Funding and Resources Team	Quarterly
	Report on funding and resource mobilization activities	Funding and Resources Team	Annually

The catchment management committee comprising representatives from key stakeholders, including government agencies, local communities, and NGOs. The plan further:

- encourages the preparation of annual monitoring reports through regular progress assessments, and the results should be incorporated into future revisions.
- promotes the development of climate resilience strategies, such as better management of flood areas and water protection technologies.
- promotes the establishment of a local water management authority through the establishment of Catchment Management Committees (CMCs) to oversee implementation and resolve disputes.
- identifies the policy framework, unification, and intergovernmental coordination between Bauchi, Yobe, Jigawa and Borno states as the catchment area stretches across these states.
- identifies water use regulations as being essential to ensuring legal enforcement through enhanced licensing, water permits, and compliance monitoring to prevent pollution and over-extraction.
- identifies frequent town hall meetings and workshops as a means of incorporating community input into policy decisions.
- identifies campaigns to increase awareness by teaching farmers, companies, and households about sustainable land use, pollution prevention, and water conservation.
- places a high priority on capacity building initiatives because they are crucial for educating local farmers, water managers, and legislators about efficient water use practices.
- plan promotes private sector investment in water infrastructure development through public-private partnerships (PPP).
- highlights cooperation between global grants and climate finance from institutions like the Green Climate Fund (GCF), African Development Bank (AfDB), and World Bank.
- promotes cost recovery models for industrial and agricultural water users to generate revenues.
- promotes the implementation of an IWRM approach that integrates land use planning, surface water and groundwater management.
- Ensuring cross-sectoral cooperation between agricultural, urban planning and environmental authorities is highly encouraged in the strategic plan.
- Hydrological Monitoring Stations should be incorporated into the plan through the installation of real-time water quality and quantity monitoring systems.

- advocates for the incorporation of remote sensing and geospatial analysis by utilizing satellite imagery to monitor vegetation loss, erosion trends, and changes in land use.
- promotes the use of a Centralized Catchment Information System (CIS) as a digital platform for the exchange of data regarding water resources and analysis.
- Through the promotion of groundwater recharge programs, small-scale reservoirs, and rainwater harvesting, the plan promotes the adaptation of drought mitigation measures.
- promotes flood risk management by advocating for the development of early warning systems, embankments, and wetland restoration projects to mitigate flood risks.
- encourages precision irrigation, soil conservation methods, and drought-resistant crops as ways to advance sustainable agricultural practices.
- Through cooperation with the UNDP, GEF, and regional water governance organizations, the strategic plan finds opportunities for international partnerships.
- By encouraging companies to invest in pollution prevention and water-efficient technologies, the plan aims to increase private sector involvement.
- The use of intelligent technologies by implementing IoT-based water monitoring systems and AI-based data analytics to improve management decisions is strongly recommended as part of the strategic plan.
- The strategy suggests enhancing policy coordination by harmonizing federal and state laws to guarantee a cohesive approach to water governance.

7.7 Risks and Adaptive Management

The plan acknowledges several risks that may affect implementation:

- Political changes that disrupt continuity
- Delays in financing or resource allocation
- Institutional fragmentation or weak capacity
- Climate variability impacting project outcomes

To mitigate these, an adaptive management approach is proposed:

- Annual implementation reviews
- Mid-term evaluations in 2027
- Phased or modular implementation

- Flexibility in financing and partnership models

This will ensure that the CMP remains relevant, responsive, and results-focused throughout its lifecycle.

Conclusion

The Misau-Komadugu Gana Catchment Management Plan is a framework for sustainable water resource management and climate resilience. Its success relies on financial sustainability, strong governance, adaptable management processes, and community involvement. By tackling challenges and leveraging opportunities, the plan can be refined to meet the evolving environmental and socio-economic conditions of the region.

To facilitate a smooth transition from planning to action, the following roadmap outlines key steps for the first three years.

Table 7.5: Roadmap for Implementation (2025-2027)

Timeframe	Key Actions
2025	Establish Catchment Coordination Platform (CCP), finalize financing mechanisms, conduct capacity-building.
2026	Expand MEL systems, roll out priority investments, conduct capacity-building.
2027	Conduct mid-term review, adjust interventions, prepare scale-up phase.

ANNEXES

ANNEX 1: DETAILED POPULATION STATISTICS FOR THE CATCHMENT

POPULATION PROJECTION FROM 2006 – 2050								
LGA	2006	2022	2025	2030	2035	2040	2045	2050
Bauchi	493,730	881,600	946611	1065789	1199972	1351048	1521145	1712657
Damban	150,212	268,200	287978	324234	365055	411015	462762	521024
Darazo	249,946	446,300	479211	539544	607472	683953	770062	867013
Gamawa	284,411	507,900	545353	614013	691318	778354	876349	986682
Gamjuwa	278,471	497,300	533972	601199	676890	762110	858060	966089
Giade	156,022	278,600	299144	336807	379211	426953	480707	541228
Itas/Gad	228,527	408,100	438194	493363	555477	625411	704151	792803
Katagum	293,020	523,200	561782	632510	712143	801802	902748	1016404
Misau	261,410	466,800	501223	564327	635375	715369	805434	906838
Shira	233,999	417,800	448609	505089	568680	640277	720887	811647
Warji	114,983	205,300	220439	248192	279440	314621	354232	398830
Abadam	100,065	146,600	157411	177229	199542	224664	252949	284795
Gubio	151,286	221,700	238049	268019	301762	339754	382529	430690
Guzamala	95,991	140,600	150968	169975	191375	215469	242596	273139
Kukawa	203,343	297,900	319868	360139	405480	456530	514008	578721
Mobbar	116,633	170,900	183502	206605	232617	261903	294877	332002
Nganzai	99,074	145,200	155907	175536	197636	222518	250533	282076
Gwaram	271,368	466,600	501008	564085	635103	715062	805089	906449
Borsari	109,692	172,500	185220	208540	234795	264355	297638	335110
Fika	136,736	215,000	230854	259919	292643	329487	370969	417674
Fune	301,954	474,700	509705	573877	646128	727476	819065	922185
Geidam	155,740	244,900	262959	296066	333341	375308	422559	475760
Jakusko	232,458	365,500	392453	441862	497493	560127	630647	710045
Nangere	87,517	137,600	147747	166348	187291	210871	237420	267311
Potiskum	204,866	322,100	345852	389395	438420	493617	555763	625734
Tarmuwa	77,667	122,100	131104	147610	166194	187118	210676	237200
Yunusari	125,940	198,000	212601	239367	269504	303434	341636	384648
	5,215,061	8,743,000	9,387,725	10,569,638	11,900,355	13,398,609	15,085,492	16,984,754

ANNEX 2: THREATS, CHALLENGES, SOCIO-ECONOMIC AND POLICIES LINKED TO WATER INFRASTRUCTURE IN THE CATCHMENT AS INDICATED BY THE STAKEHOLDERS

STAKEHOLDER ENGAGEMENT PHOTOGRAPHS



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	A remote sensing indicator used to assess vegetation health and density by measuring the difference between near-infrared (NIR)

Vegetation Index (NDVI)	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.

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