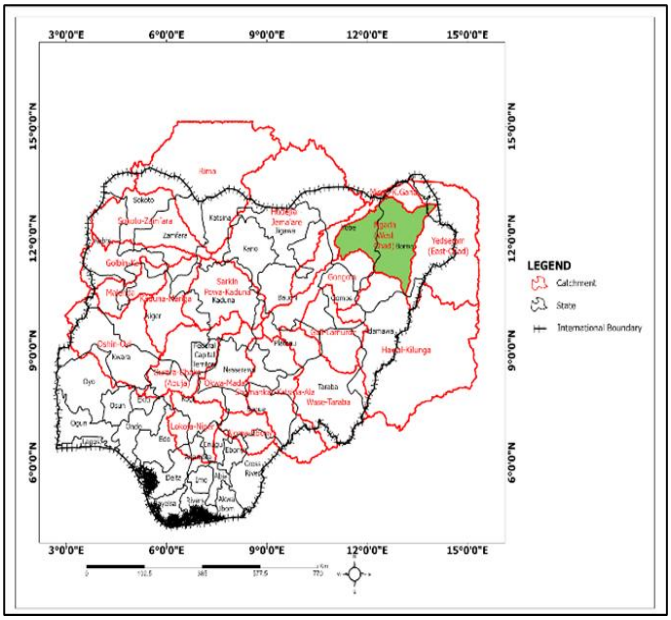
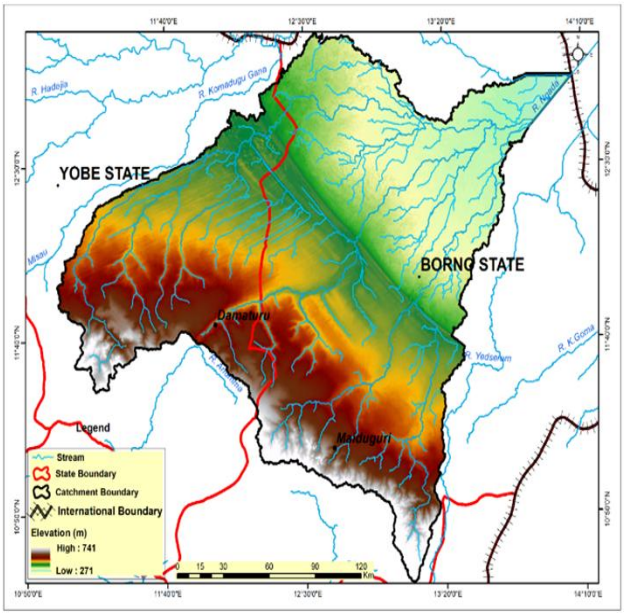
ACReSAL
Agro-Climatic Resilience in Semi-Arid Landscapes

THE WORLD BANK

NGADA-WEST-CHAD STRATEGIC CATCHMENT

MANAGEMENT PLAN





MARCH, 2025

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ABBREVIATIONS AND ACRONYMS

Abbreviation/ Acronym	**Description**
Symbols	**Description**
°C	Degree Celsius
°F	- Fahrenheit
ACReSAL	Agro Climatic Resilience in Semi-Arid Landscapes
ADP	Agriculture Development Program
AfDB	African Development Bank
AFOLU	Agriculture, Forestry, and Other Land Use
AI	Artificial Intelligence
AMSL	Above Mean Sea Level
ATA	Agricultural Transformation Agenda
AWF	African Water Facility
BCM	Billion Cubic Metre
BOSEMA	Borno State Emergency Management Agency.
BOSEPA	Borno State Environmental Protection Agency.
BSPHCDA	Borno State Primary Healthcare Development Agency.
BSWB	Borno State Water Board
CBDA	Chad Basin Development Authority
CBNRM	Community-Based Natural Resource Management
CBOs	Community-Based Organizations

CCAFS	Climate Change, Agriculture and Food Security
CCMA	Canadian Centre for Climate Modelling and Analysis
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station.
CIS	Catchment Information System
CJTF	Civilian Joint Task Force
CMCs	Catchment Management Committees.
CN	Curve Number
CNRM	Centre National de Recherches Météorologiques
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CSR	Corporate Social Responsibility
DEM	Digital Elevation Model
EA	Executing Agency
EC	Electrical Conductivity
ECOWAS	Economic Community of West African States
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union
FAO	Food and Agriculture Organization of United Nations
FDC	Flow Duration Curve
FEPA	Federal Environment Protection Agency
FGD	Focus Group Discussion
FMAFS	Federal Ministry of Agriculture and Food Security

FMEnv	Federal Ministry of Environment
FMWR	Federal Ministry of Water Resources
GBV	Gender-based violence
GESI	Mainstreaming Gender Equality and Social Inclusion
GCM	Global Climate Model
GCF	Green Climate Fund
GEFC	Global Environmental Flow Calculator
GHG	Greenhouse Gas
GIS	Geographic Information System
GIZ	German Agency for International Cooperation
GPS	Global Positioning System
GRDB	Global Runoff Data Base
GRDC	Global Runoff Data Centre
Ha	Hectares
HJKYB	Hadejia Jama'are Komadugu Yobe Basin
HJKYB-TF	Hadejia Jama'are Komadugu Yobe Basin - Trust Fund
HJRDBA	Hadejia-Jama'are River Basin Development Authority
HNW	Hadejia-Nguru Wetlands
HNWCP	Hadejia Nguru Wetlands Conservation Project
HVDP	Hadejia Valley Development Project
HVIP	Hadejia Valley Irrigation Project
HVIS	Hadejia Valley Irrigation Scheme

IAR	Institute Agricultural Research
ICM	Integrated Catchment Management
ICRC	International Committee of the Red Cross.
IDPs	Internal Displace Person's
INM	National Institute of Meteorology
IP	Irrigation Project
IPCC	Intergovernmental Panel on Climate Change
IoT	Internet of Things
ITCZ	Inter-Tropical Convergence Zone
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
IWRMD	Integrated Water Resources Management and Development
IWRMP	Integrated Water Resources Management and Planning
JICA	Japan International Cooperation Agency
KII	Key Informant Interview
KPIs	Key Performance Indicators
KYB	Komadugu Yobe Basin
LCBC	Lake Chad Basin Commission
LGAs	Local Government Areas
LGP	Length of Growing Period
LUA	Land Use Act
LULC	Land Use Land Cover

M	Metres
M&E	Monitoring & Evaluation
Masl	Metres above sea level
MCM	Million Cubic Metre
MDG	Millennium Development Goal
MSF	And Médecins Sans Frontières
MSL	Mecon Services Limited
NCAR	National Center for Atmospheric Research
NCWR	National Council on Water Resources
NDVI	Normalized Different Vegetation Index
NEAZDP	North East Arid Zone Development Programme
NESREA	the Nigerian Environmental Standards and Regulations Enforcement Agency.
NFDP	National Fadama Development Program
NGO	Non-Governmental Organization
NGSA	Nigerian Geological Survey Agency
NIHSA	Nigeria Hydrological Services Agency
NIMET	Nigerian Meteorological Agency
NIP	National Implementation Plan
NIWRMC	Nigeria Integrated Water Resources Management Commission
NNWRMP	Nigeria National Water Resources Master Plan
NNJC	Nigeria-Niger Joint Commission

NRCS	Natural Resources Conservation Service
NRW	Non-Revenue Water
NSE	Nash-Sutcliffe Efficiency
NW	North West
NWRMP	National Water Resource Master Plan
OSGOF	Office of Surveyor General
PES	Payments for Ecosystem Services
PET	Potential Evapotranspiration
PIM	Participatory Irrigation Management
PMT	Project Management Team
PPT	Precipitation
PPPs	public-private partnerships
PSC	Project Steering Committee
PWD	Projected Water Demand
RBDA	River Basin Development Authority
RRR	Ministry of Reconstruction, Rehabilitation, and Resettlement
RUWASA	Rural Water Supply and Sanitation Agency
SAP	Strategic Action Plan
SAPDWR	Strategic Action Plan for the Development of Water Resources
SCIP	South Chad Irrigation Project
SCMP	Strategic Catchment Management Plan
SCS	Soil Conservation Service

SESA	Strategic Environmental and Social Assessment
SGS	Streamflow Gauging Station
SHA	Sub Hydrologic Area
SMA	State Ministry of Agriculture
SME	Small Medium Enterprise
SMM	Soil Moisture Method
SNC	Nigeria's Second National Communication
SMWR	State Ministry of Water Resources
SSEA	Strategic Social and Environmental Assessment
SUBEB	Small Medium Enterprise
SWA	State Water Agencies
TAP	Technical Advisory Panel
TDS	Total Dissolved Salts
TOR	Terms of Reference
TRIMING	Transforming Irrigation Management in Nigeria
UBE	Universal Basic Education
UN	United Nations
UNECE	United Nations Economic Commission for Europe
UNESCO	United Nations Educational Scientific & Cultural Organization
UNFCCC	United Nations Framework Convention on Climate Change
UNICEF	United Nations Children's Fund
USAID	United States Agency for International Development

UTM	Universal Traverse Mercator
VAPP	Violence against Persons Prohibition
WASH	Water, Sanitation, and Hygiene
WBG	World Bank Group
WEAP	Water Evaluation and Planning
WHO	World Health Organisation
WMO	World Meteorological Organization
WRA	Water Resources Act
WRM	Water Resources Management
WSS	Water Supply and Sanitation
WSSSRP	Water Supply and Sanitation Sector Reform Programme

EXECUTIVE SUMMARY

The Ngada West Chad Catchment, spanning 4.4 million hectares in Borno and Yobe States, Nigeria, is a vital hydrological area within the Chad Basin. It is characterized by arid and semi-arid conditions, heavy reliance on both surface and groundwater resources, and a rapidly growing population projected to reach 11 million by 2050. The Ngada River, a key water source, experiences seasonal fluctuations, causing water scarcity during dry months and necessitating the use of boreholes and reservoirs, which remain insufficient for rising demand.

The climatic conditions of the catchment are semi-arid, with rainfall (400–800mm annually) concentrated from June to September, and temperatures ranging from 15°C to 40°C. The Ngada River, the Jere bowl and Alau Dam are primary water sources, but limited storage capacity and over-extraction of groundwater exacerbate shortages. Pollution from agricultural runoff, poor wastewater management, and overuse has led to increasing nitrate and coliform contamination, posing significant public health risks.

Notable socio-Economic and infrastructural Challenges includes:

- High to very high poverty rates (above 50%) across most LGAs, worsened by conflict, food insecurity, and economic downturns.
- Outdated infrastructure, reliance on boreholes and manual wells, and poor wastewater management contribute to disease outbreaks like cholera and typhoid.
- The Boko Haram insurgency has disrupted infrastructure development and displaced millions, leading to deteriorating living conditions in IDP camps.
- Dominated by rain-fed farming of millet, sorghum, maize, and groundnuts, but threatened by soil degradation, deforestation, and climate variability.

A shared vision among stakeholders including government agencies, NGOs, and local communities is critical for addressing these interconnected challenges. Priority interventions include:

- Expanding water storage through additional dams along the Ngada and Yedseram Rivers.
- Strengthening water governance to improve quality monitoring and sustainable extraction.
- Investing in climate resilience, including reforestation, shelterbelts, and drought-resistant crops.

- Enhancing sanitation infrastructure, particularly in urban areas and IDP camps, to curb waterborne diseases.
- Developing alternative livelihoods to reduce dependency on subsistence agriculture and promote economic diversification.

The Ngada West Chad Catchment faces significant environmental, socio-economic, and infrastructural challenges, yet presents opportunities for sustainable development through strategic water resource management, improved governance, and community-driven resilience initiatives. Addressing water security, climate adaptation, and poverty reduction will be essential in ensuring the region's long-term sustainability and ecological integrity.

This strategy organizes a variety of activities and initiatives aimed at improving climate resilience, fostering socio-economic development, and safeguarding natural resources within the Ngada-West Chad strategic catchment for its socio-economic and environmental advancement. The objective of this watershed plan is to assist decision-makers and practitioners at local, basin, state, and national levels in understanding the current situation, challenges, issues, risks, and opportunities within the Ngada-West Catchment, as well as to attract investments for enhancing watershed management over the short, medium, and long term. The approach used to formulate this plan will also be applicable to other watersheds in the areas covered by the ACReSAL Project in northern Nigeria. The effective execution of such a plan at the watershed level can further aid in the integrated management of larger river basins in the country.

Table ES 1 below shows Past and Ongoing Initiatives by Governments and Development Partners in Ngada West Chad Catchment

Table ES 1: Past and Ongoing Initiatives by Governments and Development Partners in Ngada West Chad Catchment

S/No.	LOCATION	PAST INITIATIVE	ONGOING INITIATIVE
1	Maiduguri	**Project**: Borno State Water Supply Project **Agency**- Borno State Water Board & World Bank. **Focus:** Water Supply Improvement and Institutional Capacity Building & Sanitation Studies.	
2	Borno	**Project**: Borno Rural Water Supply (BRWS) Scheme **Agency**- Borno State Government & Borno Rural Water Supply (BRWS). **Focus:** Deep Water Well Drilling & Rural Water Access and Infrastructure Development & Sustainable Water Management.	
3	Borno	**Project**: Borno Rural Water Supply (BRWS) Scheme. Deep Water Well Drilling. **Agency**- Borno State Water Corporation (BSWC) & World Bank. **Focus:** Urban Water Supply Infrastructure and Institutional Strengthening and Financial Sustainability.	
4	Komadugu Yobe	**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	**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
5	Within the entire catchment	**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.	
6	Damaturu (Yobe State)	**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 Challawa Gorge dams, urban water supply, agriculture water management, aquaculture, rangeland management, and ecosystem restoration	
7	Yobe, Jigawa, kano and Borno states		**Project***:* Hadejia-Jama'are Komadugu-Yobe Basin Trust Fund (HJKYBTF) ***Agencies***: Nigerian government and international partners. ***Focus***: Promoting integrated water resource management in the Komadugu-Yobe Basin, including Hadejia-Jama'are
8	Chad Basin Development Authority: Kano, Jigawa, Yobe, Borno, Bauchi, Plateau, Adamawa Hadejia-jama'are River basn Development Authority: kano, Jigawa, Yobe, Borno, Bauchi, Plateau, Adamawa		**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

9	Gwange 1, 2, 3, Maiduguri Metropolitan Council (MMC), Borno State	**Project**: Borehole Drilling Project for Improved Water Access **Agency**: Borno State Government, Borno State Rural Water Supply and Sanitation Agency (RUWASSA) **Focus**: Providing safe and adequate water supply through new boreholes, benefiting local communities and IDPs, as part of a statewide water project.	
10	Buni Gari, Buni Yadi, and Damaturu, Yobe State	**Project:** Buni Gari Water Treatment Plant & Buni Yadi/Damaturu Flood and Erosion Control Project **Agency:** Yobe State Government **Focus:** Providing safe drinking water, mitigating flood and erosion impacts, supporting agriculture through irrigation, and ensuring water quality monitoring with a new Water Quality Laboratory.	
11	Gashua, Zango, and Sabon Garin Lamido, Yobe State	**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.	
	Yobe		**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
	Potiskum, Yobe State	**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.	

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 Socio-economic Challenges

Assessment of the biophysical and socio-economic challenges of the Ngada-West-Chad Catchment indicates that the catchment is confronted with the following significant biophysical and socioeconomic challenges outlined below:

1. Biophysical Challenges

a. Climate Variability and Change

- Erratic rainfall patterns leading to unpredictable water availability.
- Increased frequency of extreme weather events (droughts, floods).
- Temperature rise exacerbating evapotranspiration and desertification risks.

b. Land Degradation

- Soil erosion reducing agricultural productivity.
- Deforestation due to over-reliance on wood for fuel and construction.

- Desertification advancing due to unsustainable land-use practices.

c. Water Resource Constraints

- Declining groundwater levels due to over-extraction and low recharge rates.
- Surface water scarcity affecting irrigation, domestic, and industrial uses.
- Water quality degradation from pollution and sedimentation.

d. Biodiversity Loss

- Habitat destruction reducing wildlife populations.
- Overfishing and poaching leading to species decline.
- Loss of indigenous plant species due to agricultural expansion.

2. Socioeconomic Challenges

a. Population Pressures

- Rapid population growth increasing demand for land and water.
- Uncontrolled urban expansion causing encroachment on fragile ecosystems.
- High dependency ratios placing stress on local economies.

b. Economic Activities and Livelihood Pressures

- Agriculture under stress due to land degradation and water scarcity.
- Over-reliance on rain-fed farming making communities vulnerable to climate shifts.
- Limited alternative livelihood options increasing poverty and food insecurity.

c. Governance and Institutional Challenges

- Weak enforcement of environmental regulations exacerbating land and water mismanagement.
- Limited cross-border cooperation affecting transboundary water resources management.
- Insufficient financial and technical resources hindering climate adaptation initiatives.

d. Social and Cultural Pressures

- Conflicts over land and water use between farmers, herders, and industries.

- Migration and displacement driven by environmental and economic factors.
- Traditional land tenure systems sometimes hindering sustainable land management practices.

Figure ES below shows the ongoing interventions in the catchment

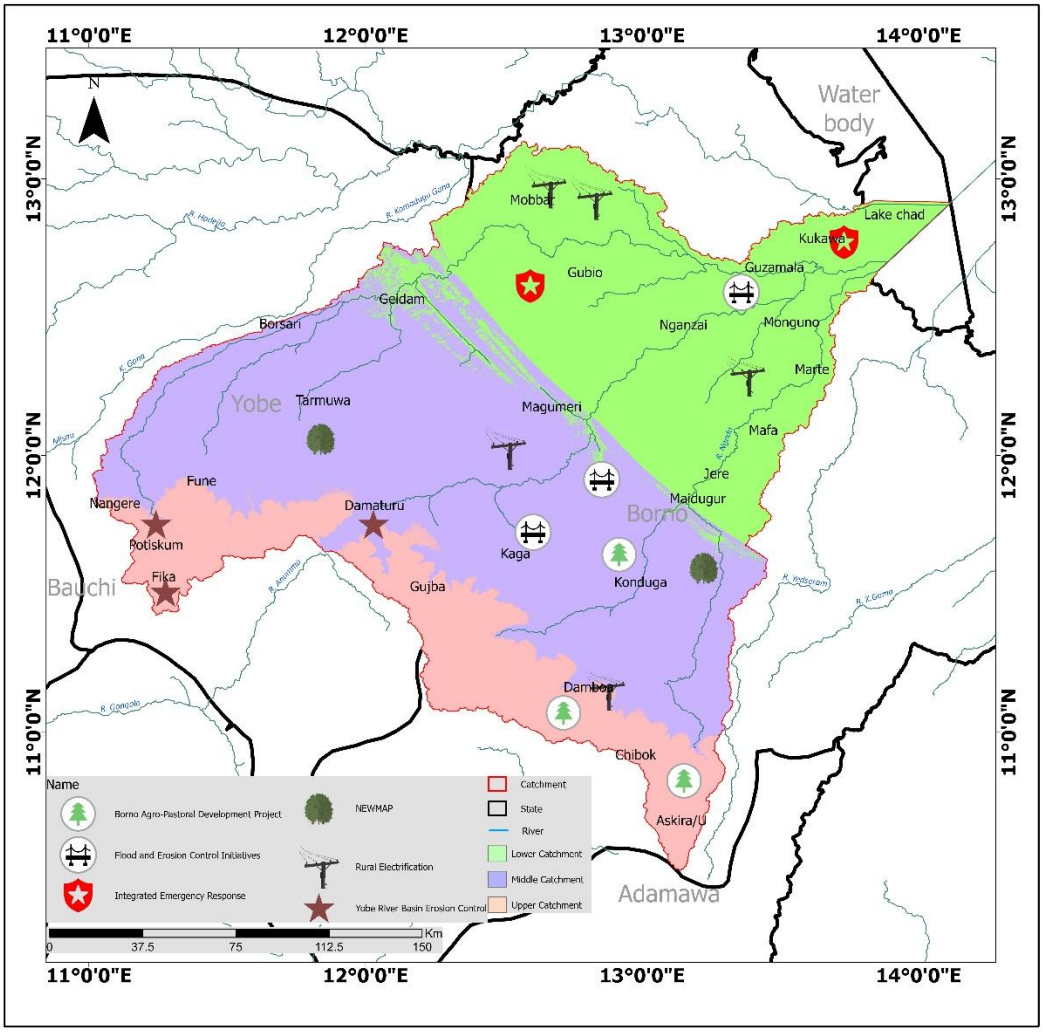

Figure ES 1: Ngada-West Chad Catchment Showing Past Interventions (Source: MSL, 2024)

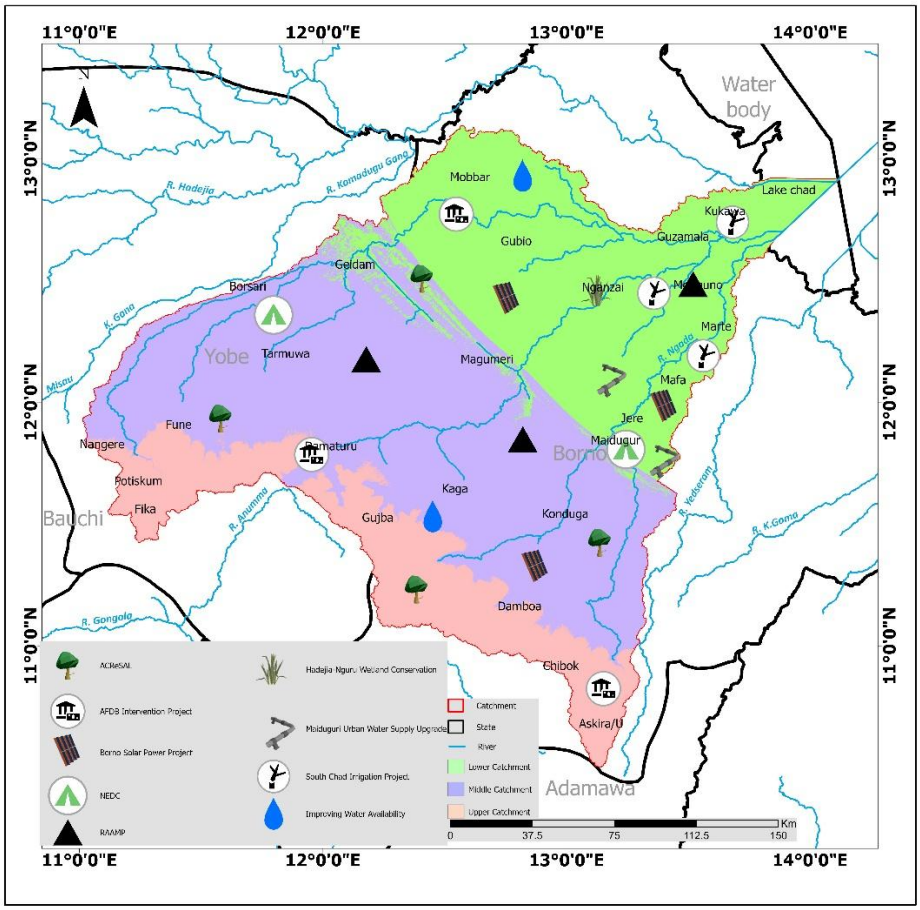

Figure ES 2: Ngada-West Chad Catchment Showing Ongoing Interventions (Source: MSL, 2024)

Elements of the Catchment Management Plan

The comprehensive roadmap developed by the Ngada-West-Chad Strategic Catchment Plan in addressing water security, environmental sustainability, and community resilience are captured through the lenses of the strategic vision and objectives outlined below:

Strategic Vision

The strategic vision of the Catchment Plan is to establish a sustainable, resilient, and community-driven catchment management system that balances environmental protection with socioeconomic progress.

Strategic Objectives

The outlined strategic objectives of the Ngada-West Chad Catchment Management Plan establish a comprehensive approach to balancing water sustainability, environmental conservation, and socioeconomic development. The strategic objectives include the following:

i. **Strengthening Water Governance and Management** to develop integrated policies for equitable water use, enhance institutional coordination and stakeholder engagement, and enforce water laws and promote public-private partnerships (PPPs).
ii. **Expanding Water Infrastructure and Sustainable Use** to construct and rehabilitate reservoirs, dams, and boreholes, promote rainwater harvesting and improve irrigation efficiency and introduce water pricing, conservation incentives, and reuse strategies.
iii. **Enhancing Environmental Conservation and Climate Resilience** to implement afforestation, reforestation, and wetland restoration programs, strengthen pollution control and sustainable land-use practices and develop early warning systems and nature-based climate adaptation solutions.
iv. **Ensuring Groundwater Protection and Sustainable Extraction** to implement policies to prevent over-extraction and contamination, monitor groundwater levels and establish buffer zones and promote artificial recharge methods to replenish reserves.
v. **Promoting Sustainable Agriculture and Economic Diversification** to support climate-smart agriculture and resilient farming techniques, encourage alternative livelihoods such as ecotourism, fisheries, and microfinance and provide training and cooperative support for sustainable income generation.
vi. **Strengthening Community Participation and Regional Cooperation** to establish community water user associations and inclusive decision-making mechanisms, foster gender-equitable governance and leadership training and develop cross-border cooperation with Chad for shared resource management.

This strategic vision and objectives establish a framework for the management of the Ngada-West Chad catchment's natural resources, support ecosystem services, and enhance livelihoods while preserving ecological integrity. They serve as the guiding principles for identifying the subsequent strategic interventions or elements of the Catchment Plan.

Catchment Policies

The Ngada-West-Chad Strategic Catchment Policies provide a framework for sustainable water resource management, environmental conservation, climate resilience, and socioeconomic development. These policies aim to enhance governance structures, improve resource sustainability, and promote equitable access to water and environmental benefits.

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

Component 1: Sustainable Preservation, Oversight, and Use of Water Resources: Integrated Water Resource Management (IWRM) aims for ecological sustainability, socioeconomic development, and fair water distribution. Key initiatives include improving storage, promoting rainwater harvesting, and enhancing efficiency through water reuse. Public-private collaboration can boost investment in water technologies. However, challenges like financial limitations and regulatory enforcement need addressing for sustainable water security.

Component 2: Conservation and Rehabilitation of Essential Ecosystems for Sustainable Land Management: Safeguarding ecosystems is essential for biodiversity and land productivity, emphasizing afforestation to combat deforestation and improve carbon absorption. Sustainable agriculture practices like agroforestry and organic farming enhance soil health and food security. Community-driven conservation, supported by funding, empowers local efforts. Challenges such as land-use conflicts require integrated governance and collaboration for effective management.

Component 3: Enhanced Livelihood Diversification for Socioeconomic Well-Being: The promotion of sustainable, climate-resilient livelihoods aims to enhance economic stability by advancing climate-smart agriculture and sustainable fisheries. Supporting alternative activities like ecotourism and artisanal crafts, along with microfinance and vocational training, fosters financial inclusion and self-sufficiency, especially for youth and women. However, challenges such as limited access to financial resources and infrastructure deficits remain, necessitating targeted policy support and partnerships for inclusive growth.

Component 4: Adapting to climate change, managing disaster risks, and building resilient infrastructure. Enhancing climate resilience and disaster preparedness involves early warning systems, nature-based solutions, and climate-adaptive infrastructure. Key actions include developing early warning systems, promoting natural defenses, and building resilient infrastructure. Integrating climate adaptation into development frameworks is crucial for securing funding and resources. Addressing challenges like high costs and limited capacity requires scalable financing and collaboration for long-term resilience.

Component 5: Enhancing Institutional Capacity and Mechanisms for Project Coordination. Enhancing institutional capacity and governance is essential for effective water resource management and environmental sustainability. A centralized coordinating body is

needed to oversee policies and foster transboundary cooperation with Chad and neighboring states. Empowering local governance structures and implementing capacity-building programs will improve decision-making and resource allocation. Addressing bureaucratic inefficiencies and promoting multi-stakeholder engagement are crucial for a cohesive governance framework.

Component 6: Mainstreaming Gender Equality and Social Inclusion (GESI) in Resource Governance: Integrating gender equity and social inclusion (GESI) principles into water resource management enhances women's participation in decision-making and resource governance. This requires gender-sensitive policies, targeted interventions, and inclusive development programs for marginalized groups. Capacity-building for women and vulnerable communities fosters resilience and sustainability. However, challenges like cultural barriers and weak institutional enforcement must be addressed through advocacy and reforms..

Component 7: Advancing Research, Innovation, and Knowledge-Sharing for Sustainability. Strengthening research institutions is crucial for developing innovative water conservation, land-use management, and climate adaptation strategies. Key initiatives include fostering technological advancements, establishing knowledge-sharing platforms, and encouraging multi-sectoral collaboration. Public-private partnerships and international research grants will enhance resource mobilization for climate resilience. Addressing challenges like limited funding and data infrastructure is essential for sustainable development.

Component 8: Establishing a Comprehensive Monitoring, Evaluation, and Reporting System: The development of standardized frameworks for assessing water resource management, environmental conservation, and climate resilience is essential. Implementing real-time data collection to monitor indicators like water quality and ecosystem health is a priority. This ensures effective policy implementation through stakeholder engagement and adaptive management. Additionally, leveraging digital tools and addressing challenges like inconsistent data collection will enhance these efforts.

Table ES shows a Summary of Components and Activities of the Ngada-West-Chad Catchment Plan.

Table ES 2: Summary of Components and Activities of the Ngada-West-Chad Catchment Plan

S/No	Component	Activities	Key Indicators	Responsibilities/Partners
1	**Sustainable Preservation, Oversight, and Use of Water Resources:**	- Implement Integrated Water Resource Management (IWRM) strategies - Expand water storage infrastructure (reservoirs, irrigation, rainwater harvesting) - Enforce water-use efficiency policies (pricing, reuse, conservation) - Strengthen governance for equitable access	- Increase in water storage capacity - % reduction in water losses - Adoption of water-efficient practices	- National Water Authorities - Local Governments - Private Sector (PPPs) - Development Partners
2	**Conservation and Rehabilitation of Essential Ecosystems for Sustainable Land Management:**	- Implement afforestation and reforestation programs - Restore wetlands and degraded ecosystems - Promote sustainable agriculture and livestock practices - Develop land-use planning policies to prevent degradation	- % increase in forest cover - Number of restored wetlands -% reduction in land degradation	- Environmental Agencies - Agricultural Departments - Conservation NGOs - Local Communities
3	**Enhanced Livelihood Diversification for Socioeconomic Well-Being:**	- Promote climate-smart agriculture and sustainable fisheries	- % increase in alternative livelihoods - Number of small businesses supported	- Ministries of Agriculture & Trade - Financial Institutions - Community Cooperatives

		- Develop alternative income-generating activities (ecotourism, handicrafts, small industries) - Provide microfinance and cooperative support - Implement vocational training programs Implement vocational training programs	- Household income improvement	- Development Agencies
4	**Adapting to climate change, managing disaster risks, and building resilient infrastructure.**	- Establish early warning systems for climate hazards - Develop nature-based solutions (green infrastructure, riparian buffers) - Build climate-resilient infrastructure (flood barriers, irrigation) - Integrate climate adaptation into policies	- Functionality of early warning systems - % reduction in climate-related damages - Increase in climate-resilient infrastructure	- Meteorological Agencies - Disaster Management Authorities - International Climate Funds - Local Governments
5	**Enhancing Institutional Capacity and Mechanisms for Project Coordination.**	- Establish a centralized government body for water and environmental management - Strengthen transboundary cooperation with Chad - Build local governance capacity - Enhance knowledge-sharing between institutions	- Establishment of coordination bodies - Number of regional cooperation agreements - Increase in institutional capacity-building programs	- National and Regional Governments - River Basin Organizations - Research Institutions - International Partners

6	**Mainstreaming Gender Equality and Social Inclusion (GESI) in Resource Governance:**	- Promote women's participation in water and environmental governance - Implement gender-sensitive policies in agriculture, water access, and disaster risk management - Support marginalized groups through inclusive programs - Provide capacity-building for women and youth	- % increase in women in leadership roles - Number of gender-sensitive policies implemented - Inclusion of marginalized groups in decision-making	- Ministries of Gender & Social Welfare - Women's Organizations - Local Governments - International Donors
7	**Advancing Research, Innovation, and Knowledge-Sharing for Sustainability.**	- Strengthen research institutions to develop innovative conservation strategies - Promote smart water technologies (irrigation sensors, digital monitoring) - Establish knowledge-sharing platforms for stakeholders - Foster collaboration between research institutions and policymakers	- Number of research studies conducted - Adoption rate of smart water technologies - Participation in knowledge-sharing initiatives	- Universities & Research Institutions - Government Agencies - Private Sector - International Scientific Networks
8	**Establishing a Comprehensive Monitoring, Evaluation, and Reporting System:**	- Implement standardized monitoring frameworks - Establish real-time data collection for water and ecosystem health	- Functionality of data monitoring systems - % improvement in reporting accuracy	- National Statistical Offices - Environmental Monitoring Agencies

		- Develop performance indicators for resilience, biodiversity, and socioeconomic progress - Conduct regular stakeholder engagement for transparency	- Stakeholder participation in monitoring	- Development Organizations - Local Communities

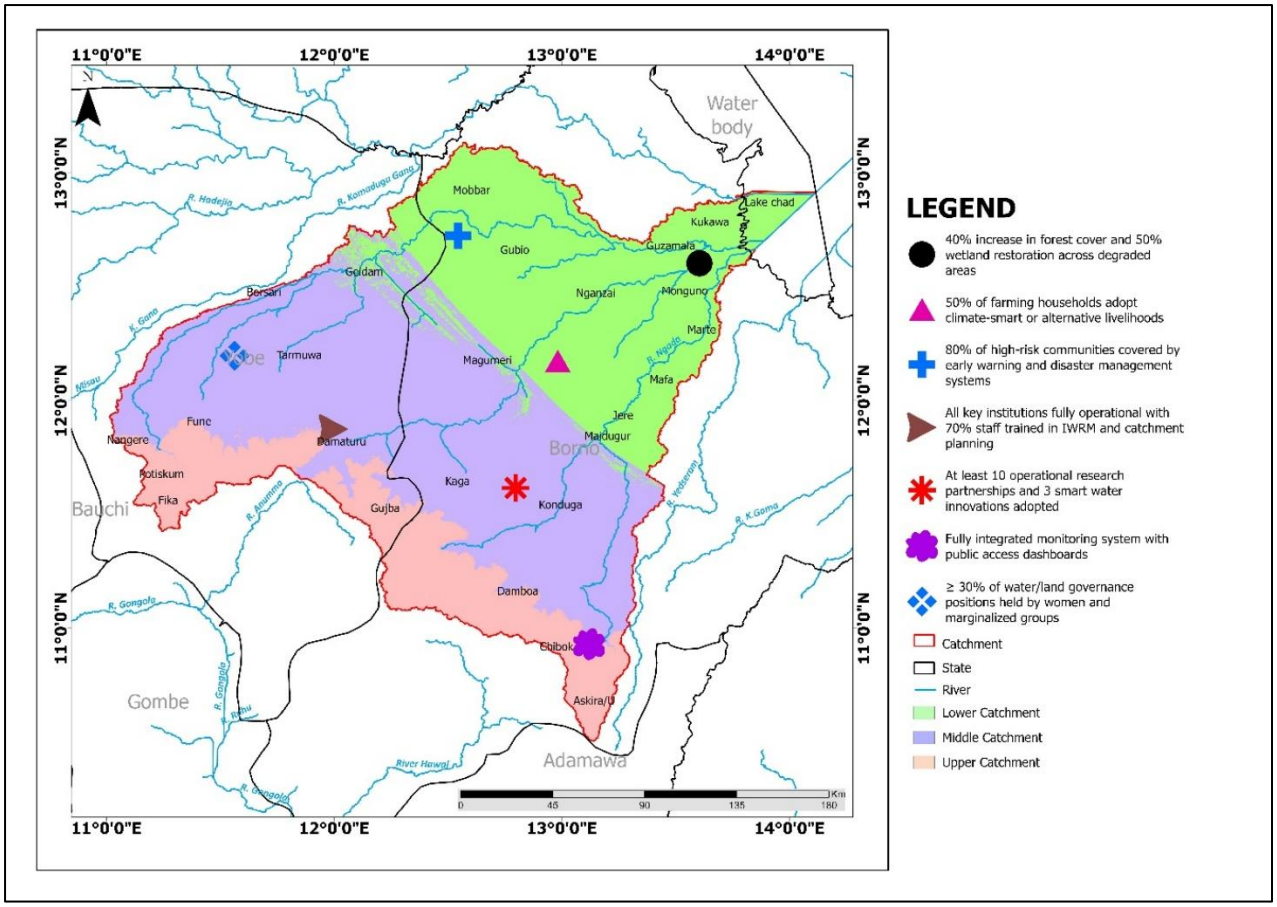

Figure E.S.3: Ngada-West Chad Catchment Showing the Recommended Interventions (Source: MSL, 2024)

Table E.S.3: Upper Catchment of the Ngada-West Chad Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Town	Identified Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Upper Catchment	**Askira**	Gully erosion and farmland loss on hilly slopes	Construction of check dams and reforestation	Drone-based erosion mapping, DEMs GIS slope analysis Interviews, CBO tracking	Borno State Ministry of Environment, ACReSAL, FMEnv, (NIWRMC)	Reduced erosion and improved soil productivity
	Chibok	Environmental degradation due to displaced populations and tree loss	Assisted natural regeneration (ANR), clean cooking programs	Remote sensing, community tree nurseries Biodiversity Conservation	UNDP, FMEnv, NEMA, ACReSAL. FMEnv, Ministry of Tourism	Restored landscapes and improved energy access
	Damboa	Conflict-related infrastructure damage and poor access roads	Rural road rehabilitation and stabilization	Road condition surveys, terrain analysis	NEDC, FERMA, Borno State Ministry of Works	Improved mobility and regional recovery
	Gujba	Seasonal landslides in upland settlements	Slope stabilization through terracing and geogrid installation Construct embarkment	NDVI satellite imagery, urban planning GIS	Yobe State Ministry of Works, Geological Survey Agency. FMEnv,	Safer settlements and reduced disaster risk

		Flash flooding	and improve drainage system in high-risk area	Terracing, gully control structures, check dams	(NIWRMC) NIHSA, ACReSAL, FMWR	
	Fika	Lack of clean water in upland villages	construction of elevated reservoirs Gravity-fed piped water systems from springs	Hydrogeological mapping, solar pump tech	RUWASSA, UNICEF, FMWR, NIHSA, ACReSAL, FMWR (NIWRMC	Reliable potable water access
	Potiskum	Youth unemployment and pressure on land resources	Agro-processing and value-chain-based youth training	e-Extension platforms, cooperative networks	SMEDAN, NDE, FMAFS	Youth employment and reduced rural drift
	Nangere	Poor rural market connectivity due to degraded roads	Construction of all-weather rural access roads	GIS road network planning tools	Yobe State Ministry of Transport, FERMA, FMW, NIWRMC	Increased market access and economic activity

Table E.S.4: Middle Catchment of the Ngada-West Chad Strategic Catchment – Spatial Challenges and Intervention Matrix

Middle catchment	LGA/Towns	Specific Challenge	Proposed Intervention	Appropriate Tools for Sustained Monitoring and Evaluation	Responsible Agencies	Expected Outcome
	Tarmuwa, Geidam, Borsari	Water scarcity and over-extraction of groundwater	- Aquifer recharge ponds - Community water budgeting awareness	Hydrogeological mapping, groundwater sensors,	RUWASSA, UNICEF, UNDP, NIHSA, ACReSAL, FMWR NIWRMC, Ministry of Water Resources	Sustainable water supply, recharged aquifers, improved access
	Magumeri, Borsari	Desertification, sand encroachment, and wind erosion	- Sand dune stabilization with vetiver grass - Tree planting campaigns and shelterbelts	Wind erosion maps, satellite imagery, buffer strip design	FMEnv, UNCCD, Borno State Forestry Department	Reduced land loss, protected farm areas, improved microclimate
	Fune, Borsari	Poor post-harvest management and market access for farmers	- Cold storage and hermetic grain storage solutions - Rural logistics	Value chain analysis tools, agri-logistics planning platforms	FMAFS, SMEDAN, IFAD-VCDP, Yobe ADP	Reduced losses, increased farmer income, better market linkage

			and value chain support			
	Damaturu, Konduga	Urban waste mismanagement & sanitation gaps (conflict-exacerbated)	- Solid waste management & recycling facilities - WASH infrastructure in public areas	GIS urban sanitation maps, waste flow tracking tools	Ministry of Environment, NEDC, UNICEF, UN-Habitat	Cleaner urban centers, improved public health
	Kaga, Magumeri	Land degradation due to poor farming practices & biodiversity loss	- Conservation agriculture (no-till, cover crops) - Community-led biodiversity conservation	Remote sensing, soil fertility maps, biodiversity surveys	FMAFS, Borno ADP, IITA, FMEnv	Rejuvenated soil, enhanced biodiversity, sustainable farming
	Konduga, Kaga	Post-conflict infrastructure damage and youth unemployment	- Cash-for-work schemes for facility repair - Vocational training for displaced youth	Conflict impact assessments, skills gap mapping tools	NEDC, NEMA, Ministry of Humanitarian Affairs	Stable returnee communities, improved youth employment
	Damaturu, Tarmuwa	Rapid urbanization leading to pressure on water and health services	- Expansion of urban planning and basic services (water, WASH) - Urban greening	Urban GIS mapping, climate vulnerability indices	Damaturu Urban Planning Board, FMEnv, UNDP	Resilient urban infrastructure, improved service delivery

			and climate adaptation plans			

Table E.S.5: Lower Catchment of the Ngada-West Chad Strategic Catchment – Spatial Challenges and Intervention Matrix

Lower catchment	**LGA/Town**	**Identified Challenges**	**Proposed Interventions**	**Appropriate Tools for Sustained Monitoring and Evaluation**	**Responsible Agencies**	**Expected Outcomes**
	Mobbar	Flooding and waterlogging of farmland during the rainy season	- Construction of flood retention basins - Raised-bed farming	Flood hazard maps, topographic surveys	HJRBDA, Yobe State Emergency Agency, FMAFS CBDA NIHSA, ACReSAL, FMWR (NIWRMC	- Reduced crop loss - Improved agricultural productivity
	Gubio	Insecurity and displacement due to insurgency	- Resettlement support for returnees - Community policing & infrastructure rehabilitation	Post-conflict community mapping, needs assessment tools	NEDC, NEMA, UNHCR, Borno State Govt	- Resettled population - Improved safety and basic services

	Lake Chad	Shrinking water body and disrupted fisheries livelihoods	- Restocking of native fish species - Sustainable aquaculture systems	Satellite-based lake monitoring, aquatic biodiversity tools	LCBC, NIFFR, FMEnv NIHSA, ACReSAL, FMWR NIWRMC	- Revived livelihoods - Ecological balance restored
	Kukawa	Desert encroachment and livelihood collapse	- Shelterbelt development - Livelihood diversification (beekeeping, crafts)	NDVI satellite tools, livelihood assessment GIS	FMEnv, UNDP, Borno State Forestry Dept, CBDA, ACReSAL	- Reduced desert advance - Strengthened household resilience
	Guzamala	Inaccessibility due to poor roads and frequent insecurity	- Road rehabilitation with security patrol integration - Mobile humanitarian services	GIS road network planning, humanitarian access maps	FERMA, NEDC, ICRC, Ministry of Works	- Enhanced mobility - Improved humanitarian access
	Monguno	Overpopulation in IDP camps and sanitation crisis	- Expansion of sanitation facilities - Public health education & hygiene kits	WASH vulnerability mapping, outbreak early warning systems	UNICEF, MSF, Ministry of Health	- Reduced disease spread - Improved hygiene standards
	Marte	Dry season farming challenges due to	- Rehabilitation of small-scale irrigation canals	Remote sensing of irrigation needs,	HJRBDA, FMAFS, FAO	- Increased dry season yields - Improved

		irrigation infrastructure collapse	- Farmer field schools on water-efficient farming	soil moisture sensors		water efficiency
	Nganzai	Animal-human conflict in pastoral zones	- Designated grazing corridors - Veterinary outreach programs	GPS tracking of livestock, rangeland mapping	NLTP, Ministry of Livestock, FAO	- Reduced conflict - Healthier livestock
	Mafa	Youth unemployment and lack of vocational opportunities	- TVET centers for youth (tailoring, mechanics, ICT) - Business incubation hubs	Digital skills training tools, youth employment databases CBO Tracking	SMEDAN, NDE, UNDP	- Empowered youth - Reduced economic migration
	Jere	Poor drainage and recurring urban flash floods	- Urban drainage master plan implementation - Solid waste management	Flood modeling software, GIS for urban runoff	Jere LGA, Borno State Urban Dev. Board, ACReSAL, FMW, FMEnv, NIWRMC	- Reduced flood risk - Cleaner, healthier environment
	Maiduguri	Overburdened public infrastructure (schools, water, health) due to IDP influx	- Expansion of urban infrastructure - Inclusive city planning for displaced populations	Urban growth modeling, infrastructure stress analysis	UN-Habitat, NEDC, Borno State Government	- Improved service delivery - Social cohesion in host communities

Expected Outcomes

The effective execution of the interventions in the Ngada-West Chad Strategic Catchment Management Plan will promote long-term sustainability by enhancing environmental resilience, expanding economic opportunities, and strengthening governance frameworks. The expected outcome of the intervention is outlined as follows:

- Sustainable Water Resource Management
- Ecosystem Restoration & Biodiversity Conservation
- Climate Resilience & Disaster Risk Reduction
- Enhanced Livelihoods & Economic Diversification
- Improved Community Well-Being & Social Inclusion
- Strengthened Policy & Regulatory Frameworks
- Improved Institutional Capacity & Project Coordination

CHAPTER 1 INTRODUCTION

1.1 Purpose for the Plan

The Ngada West Chad Strategic Catchment in Borno and Yobe states is crucial for sustainable water and land management, aiming to enhance water security and climate resilience. It confronts challenges that threaten its sustainability and community resilience. These challenges include:

i. **Climate Change and Hydrological Variability**: Erratic rainfall and rising evapotranspiration are leading to unpredictable water availability, with prolonged droughts followed by intense floods, increasing water scarcity and disaster risks.

ii. **Flooding and Droughts**: Severe floods in September 2024 displaced over 1 million people and damaged infrastructure from dam failures. Seasonal droughts exacerbate water scarcity, threatening agriculture and domestic supply, making effective water management essential.

iii. **Deforestation, Soil Erosion, and Desertification**: Unsustainable land use and deforestation lead to soil degradation and desertification, reducing agricultural productivity and increasing vulnerability to climate extremes. This exacerbates food and water insecurity.

iv. **Water Resource Depletion and Poor Management**: Excessive water withdrawals for agriculture and urban use are depleting groundwater in the Lake Chad Basin, while inadequate storage worsens seasonal shortages.

v. **Pollution and Poor Sanitation**: Poor wastewater management and agricultural runoff contaminate water sources, increasing health risks from waterborne diseases like cholera due to open defecation and improper waste disposal.

vi. **Infrastructure Deficits**: Poor roads and drainage exacerbate flood impacts and hinder emergency response. Limited access to clean water, healthcare, and education deepens poverty, making climate adaptation harder.

vii. **Socio-Economic and Governance Challenges**: Conflict and insurgency have displaced communities, limiting access to farmland and water, while weak governance exacerbates resource scarcity and instability.

1.2 Rationale for a Strategic Catchment Plan

A Strategic Catchment Management Plan (SCMP) is essential for sustainable water resource management and long-term socio-economic stability, the key issues necessitate the following:

a. **Enhance Water Security**: Integrated management will regulate supply, prevent over-extraction, and ensure fair distribution. Developing reservoirs and improving irrigation will boost storage capacity, securing water for agriculture and communities.
b. **Mitigate Climate Change Impacts**: SCMP measures like afforestation, erosion control, and sustainable land use will combat climate challenges. Drought-resistant crops and water conservation techniques will strengthen agricultural resilience.
c. **Promote flood and Drought Risk Management**: Improved drainage systems and floodplain zoning will reduce flood impacts. Early warning systems and disaster preparedness programs will enhance community resilience.
d. **Improve Water Quality and Sanitation**: Implementation of stricter pollution controls and wastewater treatment facilities will reduce contamination and public health risks. Community-based water management initiatives will ensure sustainable sanitation practices.
e. **Biodiversity and Ecosystem Restoration**: Conservation efforts, including wetland restoration and riparian buffer zones, will improve ecological balance and water retention. Protecting forests and promoting reforestation will curb desertification.
f. **Strengthening Governance and Policy Enforcement**: Institutional reforms and capacity-building programs will improve governance in water resource management. Establishing local catchment management committees will enhance community participation and accountability.
g. **Boosting Socio-Economic Development**: Improved access to water will support livelihoods, agriculture, and small-scale industries. Investment in infrastructure and education will reduce poverty and enhance long-term sustainability.

1.3 Expected Outcomes

By achieving the following outlined outcomes below, the SCMP will ensure sustainable water management, climate resilience, environmental protection, and socio-economic stability in the Ngada West Chad Catchment. These include:

These include:

i. **Sustainable Water Resource Management**: Integrated management will regulate supply, balance demand, and enhance sustainability. Increased storage through reservoirs and better irrigation will boost availability, while recharge initiatives will prevent groundwater depletion.

ii. **Climate Resilience and Disaster Risk reduction**: Improved drainage, floodplain zoning, and early warning systems will mitigate floods and droughts. Sustainable land use, afforestation, and erosion control will combat desertification, while climate-adaptive farming ensures agricultural stability.

iii. **Improved Institutional Capacity and Project Coordination**: Stricter controls on runoff and wastewater treatment will reduce pollution. Improved waste disposal and sewage systems will prevent waterborne diseases, while regular monitoring will ensure safe water quality.

iv. **Ecosystem Restoration and Biodiversity Conservation**: Reforestation and soil conservation will restore degraded areas. Protecting wetlands and riparian zones will enhance biodiversity, while controlled deforestation and grazing will prevent habitat destruction.

v. **Strengthened Policy and Regulatory Framework**: Stronger policies and compliance monitoring will improve enforcement. Community involvement will enhance accountability, while capacity building will equip institutions and stakeholders with effective catchment management skills.

vi. **Enhanced Livelihoods and Economic Diversification**: Sustainable water management and irrigation will boost agriculture. Infrastructure projects and conservation efforts will create jobs, while improved water access will enhance living standards for communities and
industries.

vii. **Improved Community wellbeing and social inclusion**: Empowering individuals within the catchment to thrive, fostering a sense of belonging and connection, by promoting equal access to resources and opportunities, breaking down social barriers, especially against vulnerable groups so as to build more resilient communities.

The different roles outlined in the Ngada West Chad Strategic SCMP are essential for improving water security, climate resilience, and socio-economic stability in the catchment. These roles include the following:

1.4 Environmental Roles

- **Water Resource Protection & Sustainable Use**: Implement measures to regulate water use, control over-extraction, and promote groundwater recharge initiatives.
- **Ecosystem and Biodiversity Conservation**: Restore degraded areas through afforestation and soil conservation. Protect wetlands and riparian zones to maintain ecological balance.
- **Climate Adaptation Measures**: Implement erosion control, floodplain zoning, and sustainable land-use planning to mitigate climate change impacts.
- Pollution Control & Waste Management: Enforce stricter regulations on wastewater treatment, agricultural runoff, and industrial pollution to improve water quality.

1.5 Socio-Economic Roles

- Water Security & Agricultural Development: Enhance irrigation infrastructure, promote efficient water use, and introduce climate-resilient agricultural practices.
- Livelihood Support & Poverty Reduction: Create job opportunities in conservation, eco-friendly industries, and water infrastructure projects.
- Disaster Risk Reduction: Establish early warning systems, emergency response mechanisms, and resilient infrastructure to mitigate flood and drought risks.
- Health & Sanitation Improvement: Promote access to clean water, improve sanitation facilities, and implement hygiene education programs to prevent waterborne diseases.

1.6 Governance and Institutional Roles

- Policy Implementation & Compliance: Strengthen enforcement of environmental regulations and water management policies.
- Community Engagement & Stakeholder Participation: Involve local communities in decision-making to enhance ownership and sustainability.
- Institutional Capacity Building: Train local authorities, farmers, and water resource managers on best practices in catchment management.
- Inter-Governmental Coordination: Enhance collaboration among federal, state, and local agencies to ensure integrated water resource governance.

1.7 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.

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,
- Lake Chad Water Charter as principal treaty of the Lake Chad Basin.

International Policies That Affect Water Resources

- 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

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 promotes 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.

Integration Mechanisms

- Establish a coordination committee: Set up a committee comprising representatives from relevant government agencies, regional organizations, and stakeholders to ensure coordination and integration.
- Conduct policy gap analysis: Identify gaps and inconsistencies between the Strategic Catchment Management Plan and existing policies, and develop strategies to address them.
- Develop a monitoring and evaluation framework: Establish a framework to track progress, identify challenges, and make adjustments to ensure the plan's alignment with national and regional policies.
- 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 Eastern 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 Dik Catchment Management Plan are prominent initiatives in Kenya.

CHAPTER 2 : CHARACTERISTICS OF THE CATCHMENTS

2.1 Location

2.1.1 Location and Boundary

The Ngada West Chad Catchment shown in Figure 2.1 below, spanning 4,430,330 ha across Borno and Yobe states, lies between latitudes 10° 30′ 10’’N - 13° 05′ 15’’N and longitudes 11° 03′ 30’’E - 14° 11′ 45’’E. It borders Lake Chad to the north, Yedseram Catchment to the east, and extends to northern Borno and Nigeria-Cameroon border, where transboundary water management is crucial for Lake Chad's sustainability (Nwilo and Badejo, 2017).

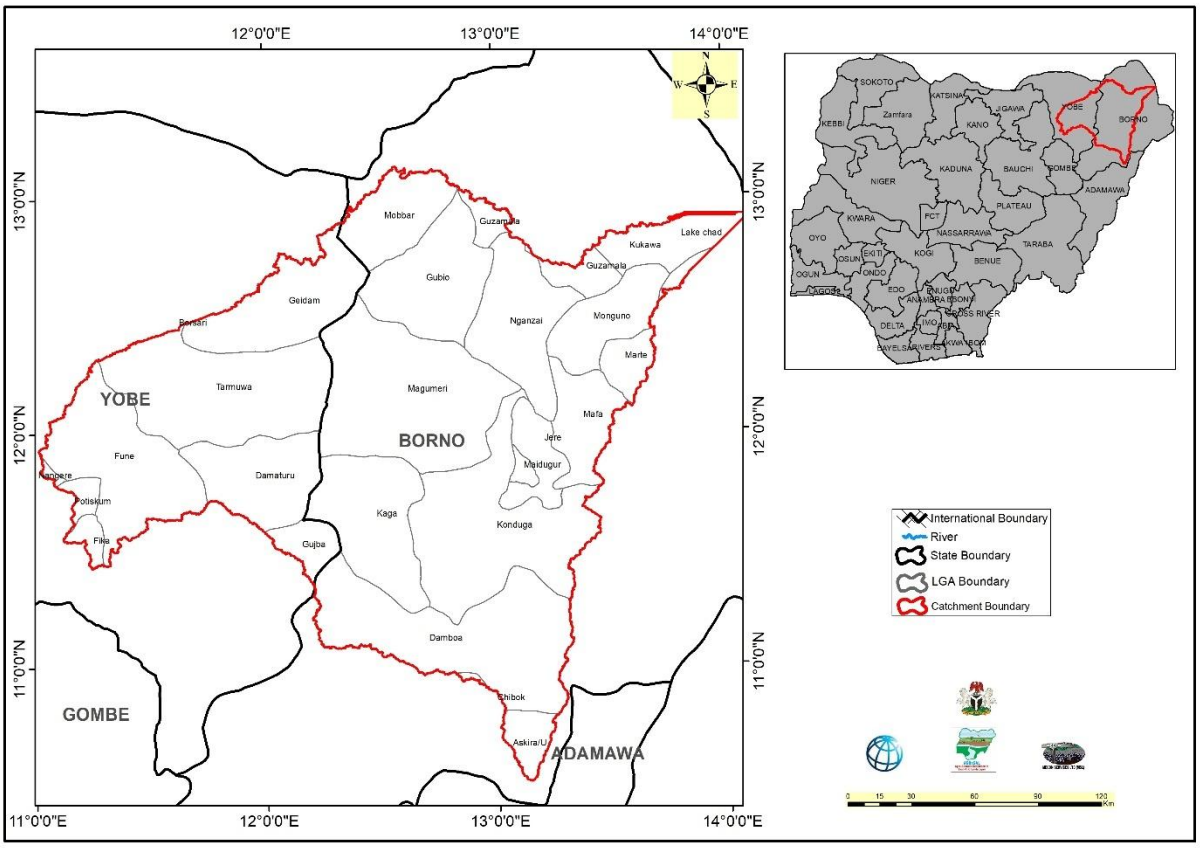

Figure 2.1: Ngada West-Chad Catchment showing the LGA's (Source: MSL, 2024)

This strategic catchment plan is based on a detailed scientific report that utilized data collected from various sources, including online research, fieldwork, focus group discussions, interviews, secondary literature and stakeholder engagement.

2.2 Precipitation, Temperature, Sunshine and Relative Humidity

2.2.1 Precipitation

The Ngada catchment experiences a unimodal rainfall pattern, with the rainy season extending from June to September. Annual precipitation averages between 200 to 700 millimeters, with variability across different areas of the catchment. The peak rainfall months are July and August, during which the region receives the majority of its annual rainfall. This seasonal rainfall is crucial for replenishing water resources and supporting agricultural activities.

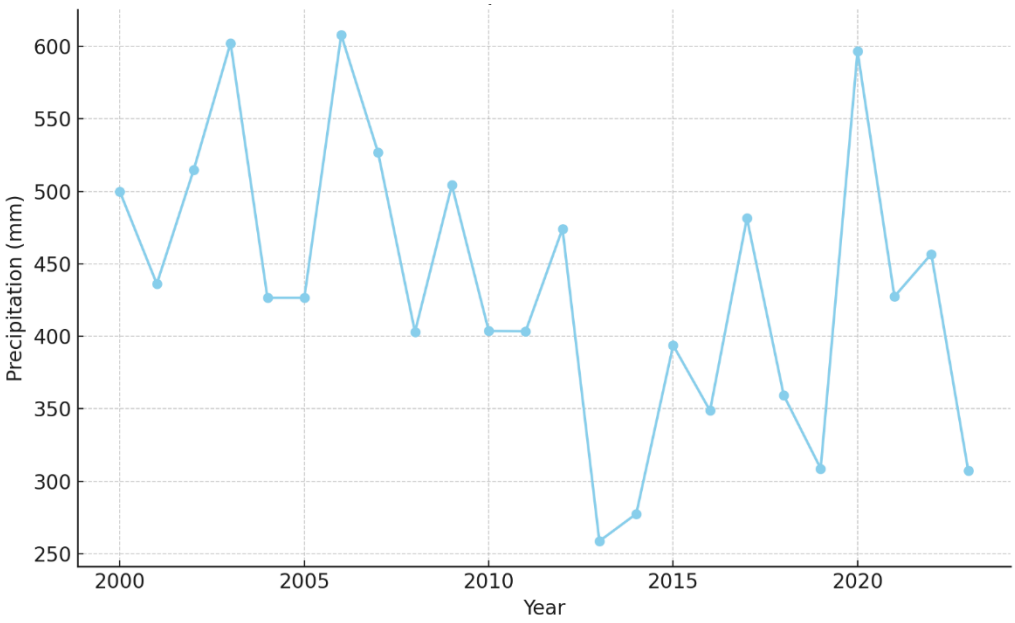

Figure 2.2: Annual Precipitation of the Catchment (Source: MSL, 2024)

2.2.2 Temperature

Temperatures in the catchment are characteristically high throughout the year. The hottest period occurs between March and May, with average maximum temperatures ranging from 40°C to 42°C. During the cooler months, particularly December and January, average maximum temperatures range between 32°C and 35°C, while average minimum temperatures can drop to approximately 15°C to 18°C. This temperature variation influences evaporation rates and water availability in the region.

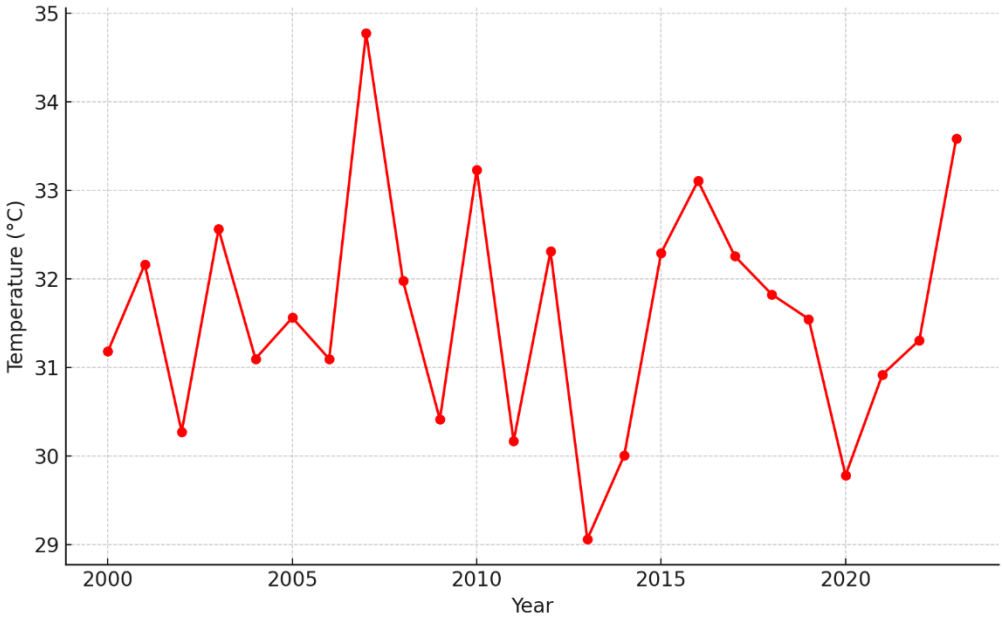

Figure 2.3: Annual Average Temperature of the Catchment (Source: MSL, 2024)

2.2.3 Sunshine Duration

The catchment enjoys substantial sunshine throughout the year, averaging approximately 3,200 hours annually. During the dry season (November to May), sunshine duration is at its peak, with monthly averages between 9 to 10 hours per day. In contrast, the rainy season (June to September) sees reduced sunshine hours, averaging around 6 to 7 hours per day, due to increased cloud cover. This high solar exposure has implications for evaporation rates and potential solar energy utilization.

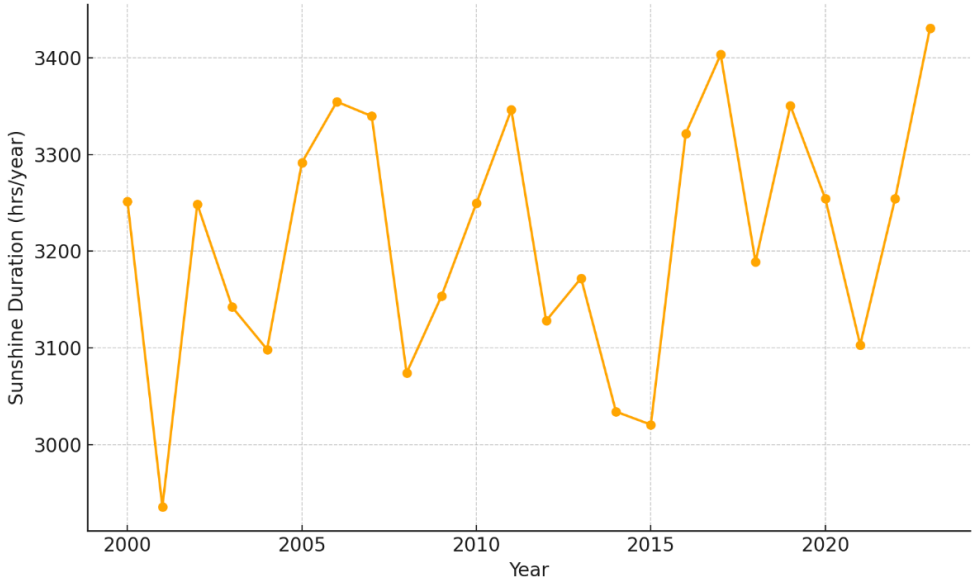

Figure 2.4: Annual average Sunshine Duration chart of the Catchment (Source: MSL, 2024)

2.2.4 Relative Humidity

Relative humidity in the catchment varies seasonally. During the dry season, humidity levels are low, often ranging between 10% and 25%, contributing to arid conditions and high evaporation rates. In the rainy season, humidity increases significantly, ranging from 25% to 75%, which can influence precipitation patterns and agricultural productivity.

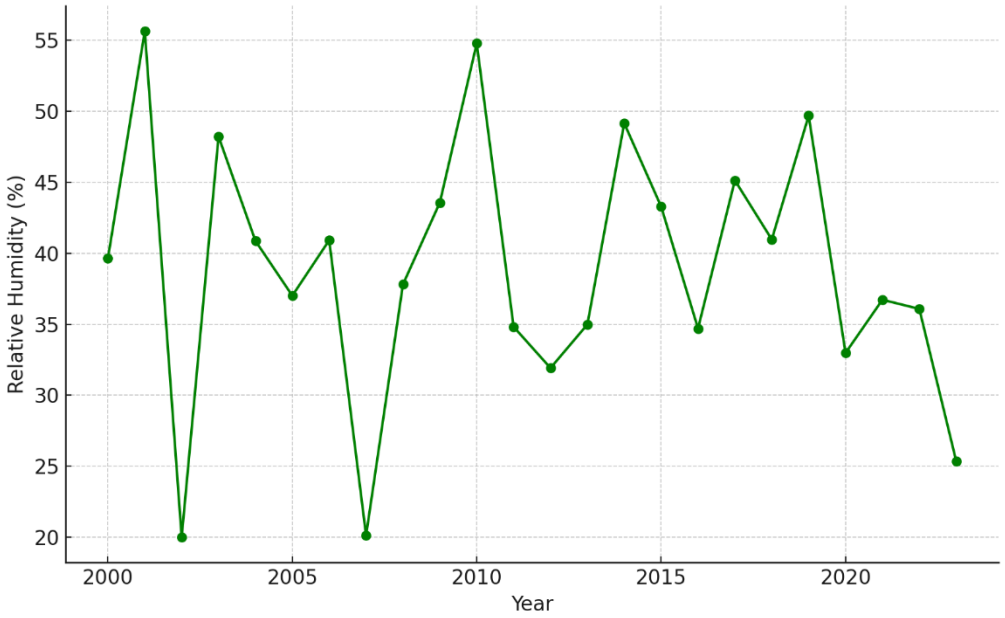

Figure 2.5: Annual Average Relative Humidity of the Catchment (Source: MSL, 2024)

2.3 Topography, Drainage, Geology and Soil Types

2.3.1 Topography

The Ngada west catchment topography is diverse, in both Borno and Yobe states, reflecting its geographical and climatic variations.

- The catchment is predominantly flat terrain features with vast plains and low-lying areas, with altitudes ranging from about 200 meters above sea level in the southwest to approximately 500 meters near the northeastern border with Chad.
- While in Yobe state, the elevation ranges from 200 meters in the north to over 600 meters in the south, where the terrain becomes more undulating (refer to Figure 2.6).
- The landscape slopes gently towards the northeast, facilitating surface water flow towards the Yobe River (Magaji et al., 2020).

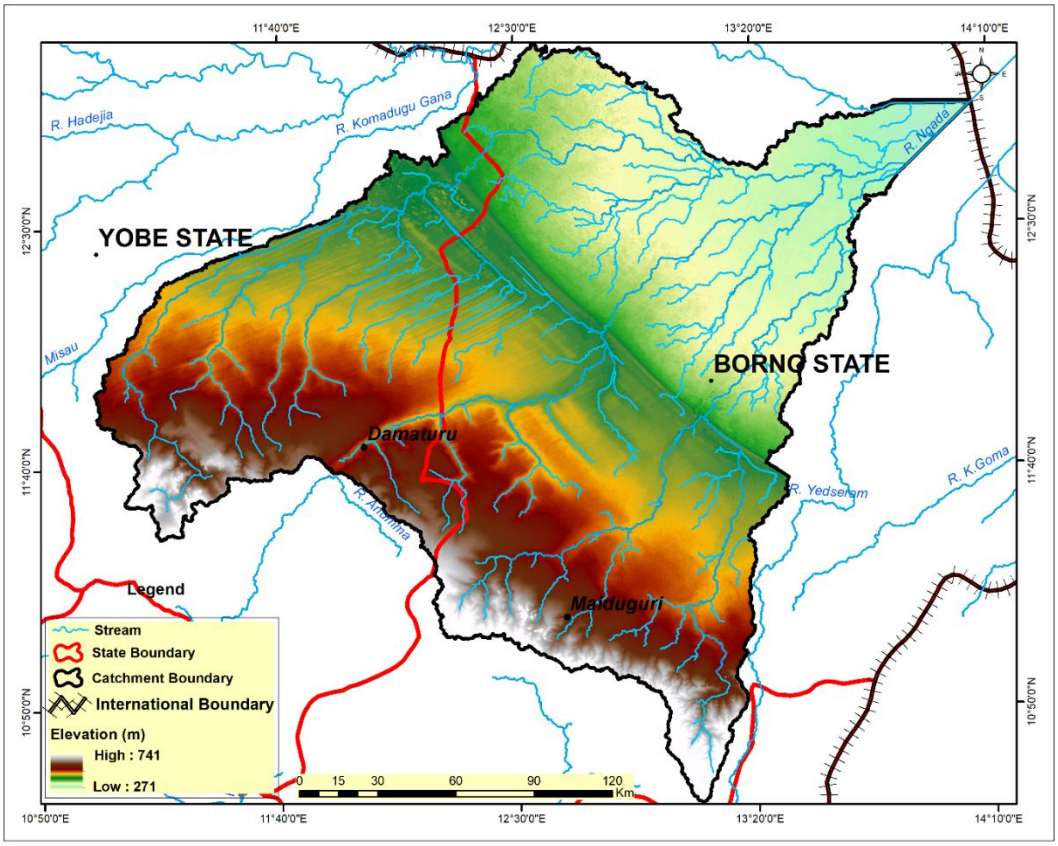

Figure 2.6: Digital Elevation Model (DEM) of the Catchment (Source MSL, 2024)

2.3.2 Drainage

The Ngada catchment exhibits a dendritic drainage pattern where several tributaries join the main river at various locations creating a convergence towards a single channel.

- The Ngada catchment drainage system is influenced by its topography and climate as shown in 2.7.
- The catchment is within the larger Chad Basin, with an endorheic basin that drains into Lake Chad rather than any ocean or sea. Lake Chad, located in northeastern Nigeria, is a shallow freshwater lake that fluctuates in size with seasonal rainfall and inflows from surrounding rivers.
- Its size has significantly decreased in recent decades due to climate change and human activities, raising concerns about water availability and environmental sustainability (Okonkwo and Onuoha, 2016).

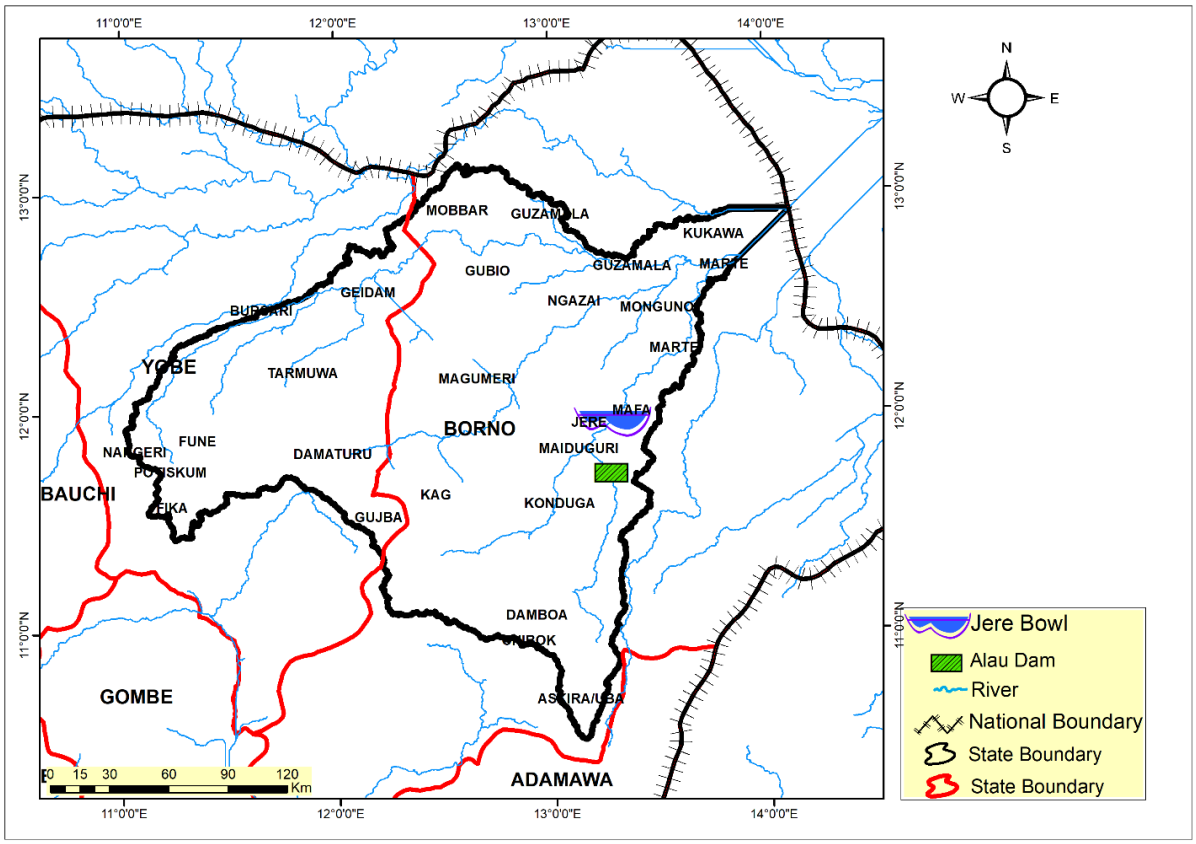

Figure 2.7: Drainage Map of Ngada West Chad Catchment Area, showing the recorded water infrastructure (Source: MSL, 2024)

STATE OF INFLUENCE

1. Borno State

2. Yobe State

Figure 2.8 and Figure 2.9 below shows a Map of The Recorded Gauging Stations and Meteorological stations within the Ngada-West-Chad Catchment.

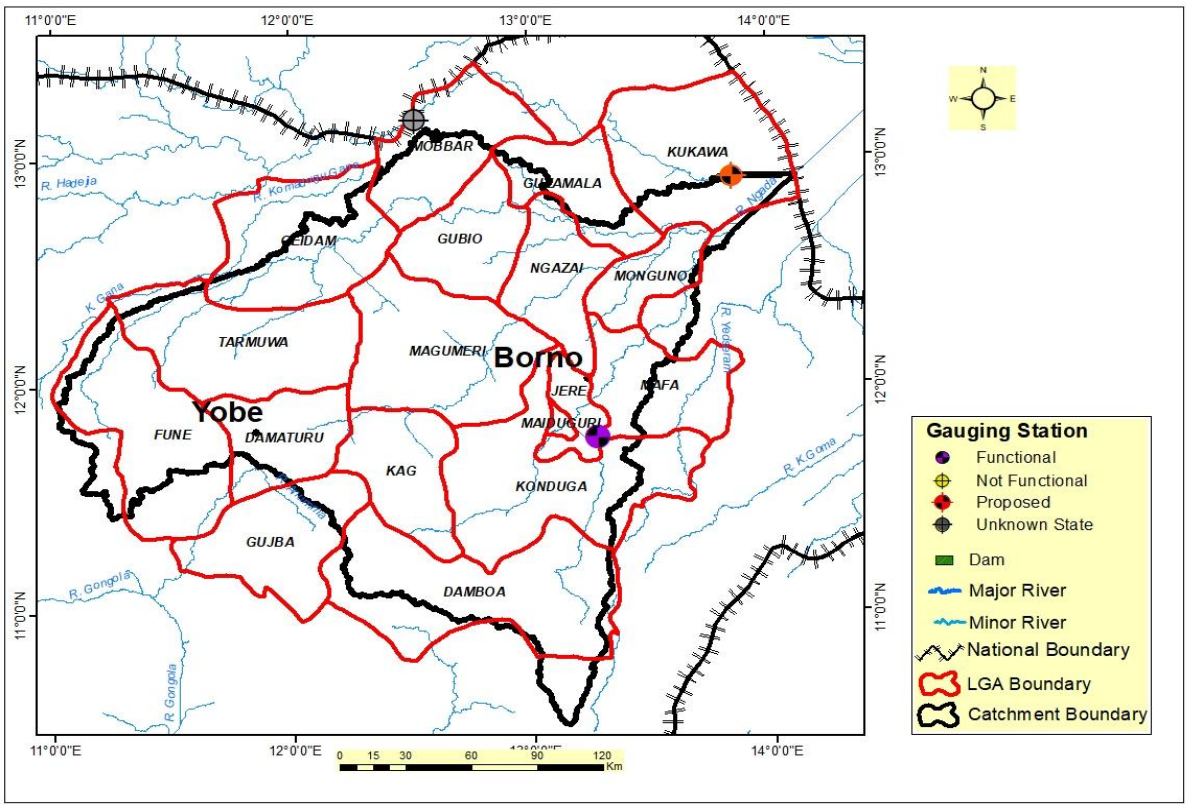

Figure 2.8: Map of The Recorded Gauging Stations (Source: MSL, 2024)

World Meteorological Organization (WMO) recommends 384 hydrological stations, but only 237 are recorded in Nigeria.

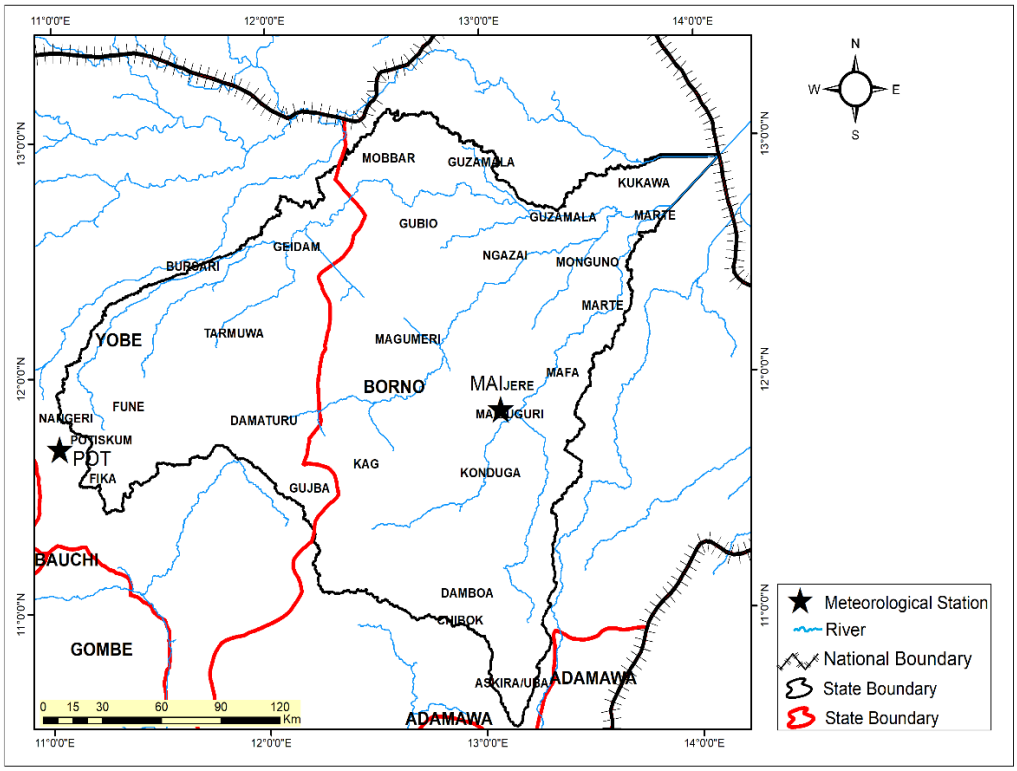

Figure 2.9: Map of Meteorological stations (Source: Mecon Services, 2024)

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

2.3.3 Geology and Soil Types

2.3.3.1 Geology

The geology of the Ngada West-Chad catchment is diverse, with distinct variations across its regions. In the northern section, the Chad Basin is dominated by sedimentary rocks, including alluvial deposits, sandstones, and clays, contributing to the formation of sandy soils.

- Moving southward, towards the Mandara Mountains, the landscape shifts to older basement complex rocks, comprised mainly of granites and gneisses.
- This basement complex includes both metamorphic and igneous formations such as granite, gneiss, and schist. In the northeastern region, sedimentary deposits primarily consist of sandstone, siltstone, and shale (Okosun, 1995).
- Key geological features within the Ngada catchment (refer to Figure 2.10Figure 2.10) include the Gongola Basin, a sedimentary basin extending into Borno, and the Bima Sandstone, which occasionally appears in the Yobe region of the catchment.

- Surrounding Maiduguri, the state capital, lies the Maiduguri Plain, characterized by younger sedimentary deposits overlying ancient basement rocks.
- Additionally, the Precambrian Basement Complex, composed of granites, schists, gneisses, and migmatites, forms the underlying foundation beneath the sedimentary layers in the Yobe area (Obaje, 2009).

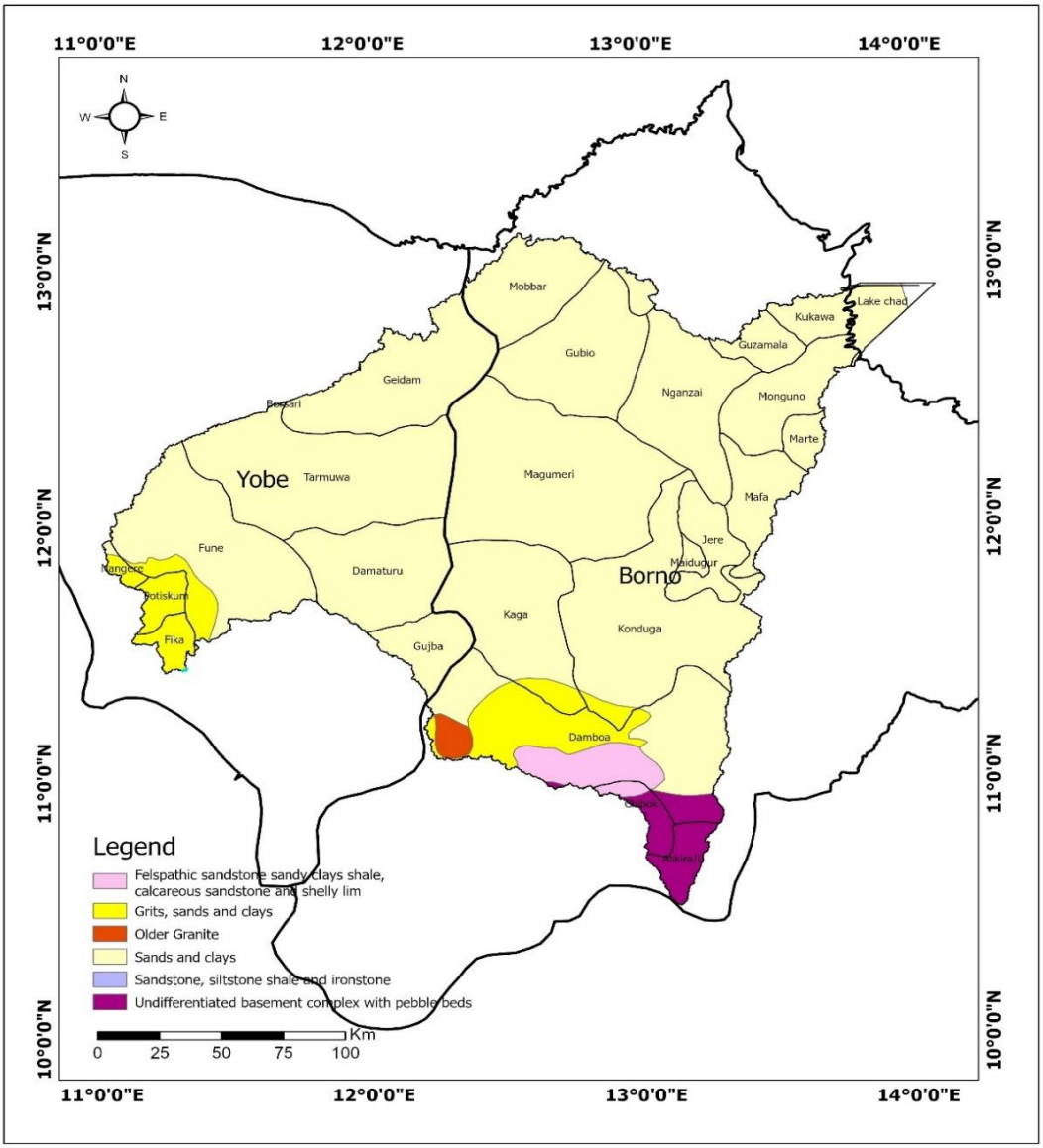

Figure 2.10: Geological Map of The Catchment (Source: MSL, 2024)

2.3.3.2 Soil Types

Soil types in the catchment vary with topography and geology. The different soil types identified in the catchment as shown in Figure 2.11 are as follows:

- Ferralsols: Dominant in tropical areas, highly weathered, and nutrient-poor.

- Arenosols: Found in arid regions like northern Borno, sandy with low fertility.
- Gleysols: Present in poorly drained areas, nutrient-rich but require careful management.
- Luvisols: Located in the south, clay-rich and highly suitable for agriculture.
- Soil Texture Variation: Sandy soils dominate the north, transitioning to clayey soils in the south, influencing water retention and fertility.
- Yobe Region: Northern plains have sandy, low-fertility soils, while the southern areas contain more fertile loamy and clayey soils.
- Alluvial Soils: Found along rivers, highly fertile and suitable for intensive agriculture.
- Vertisols: Challenging to manage but can be productive with appropriate agricultural practices.

(FAO, 2006).

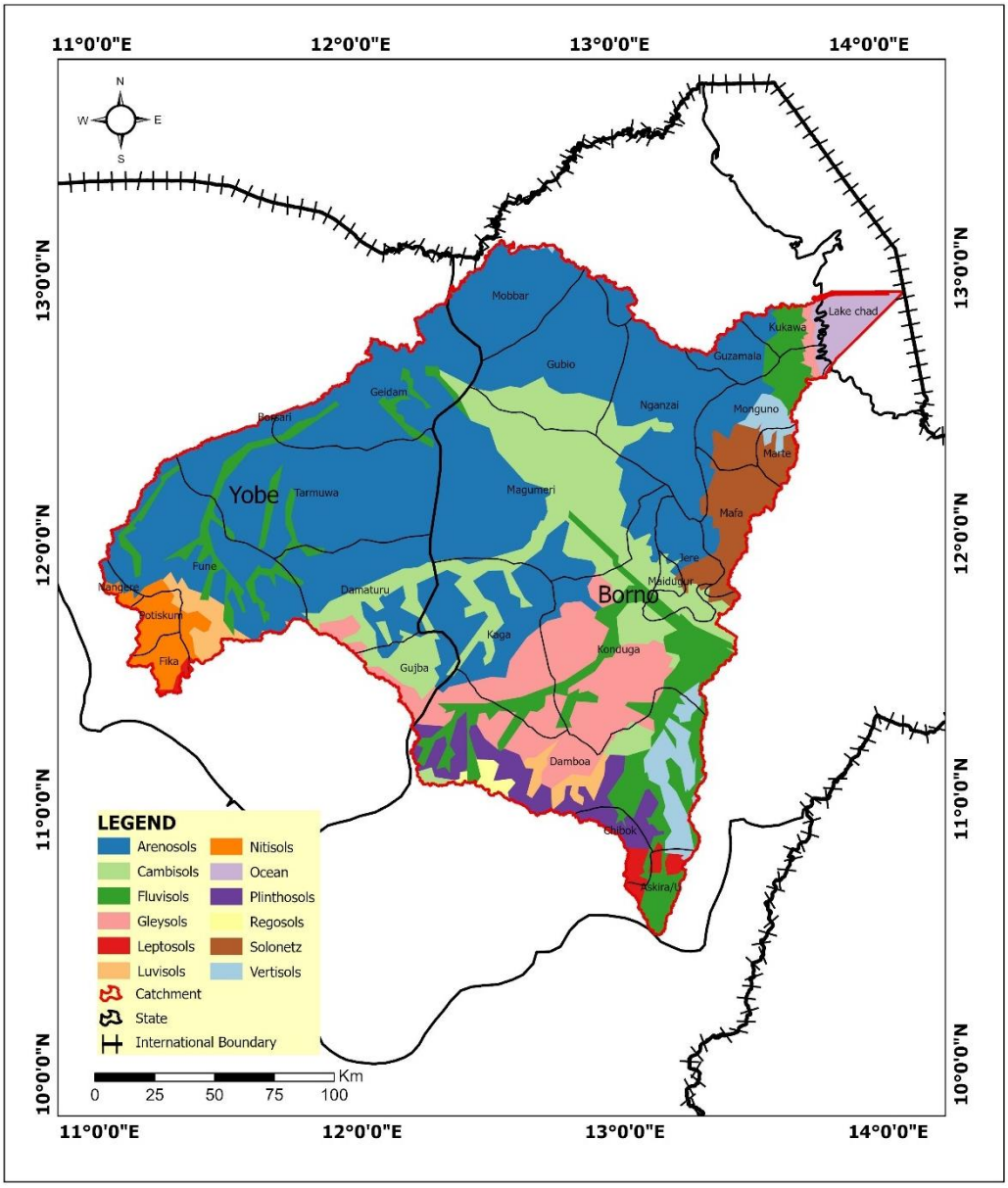

Figure 2.11: Soil Map of The Catchment (Source: MSL, 2024)

2.4 Land Use and Land Cover

- The Ngada West Chad Catchment, part of hydrological area 8 in northeastern Nigeria, contributes to the Chad Basin's water system.
- Land use and cover are influenced by natural and human activities, impacting agriculture and urbanization. Savannahs feature drought-resistant trees, while riparian zones thrive near rivers. However, deforestation and habitat loss from agriculture and overgrazing are significant concerns.
- Subsistence farming and irrigated agriculture near water bodies drive soil degradation and desertification.
- Rapid urbanization, conflict-driven displacement, and informal settlements are converting agricultural land into urban infrastructure. Water bodies, wetlands, and groundwater are crucial for agriculture and livestock, but over-extraction threatens long-term sustainability (Akiyode and Akanmu, 2015).

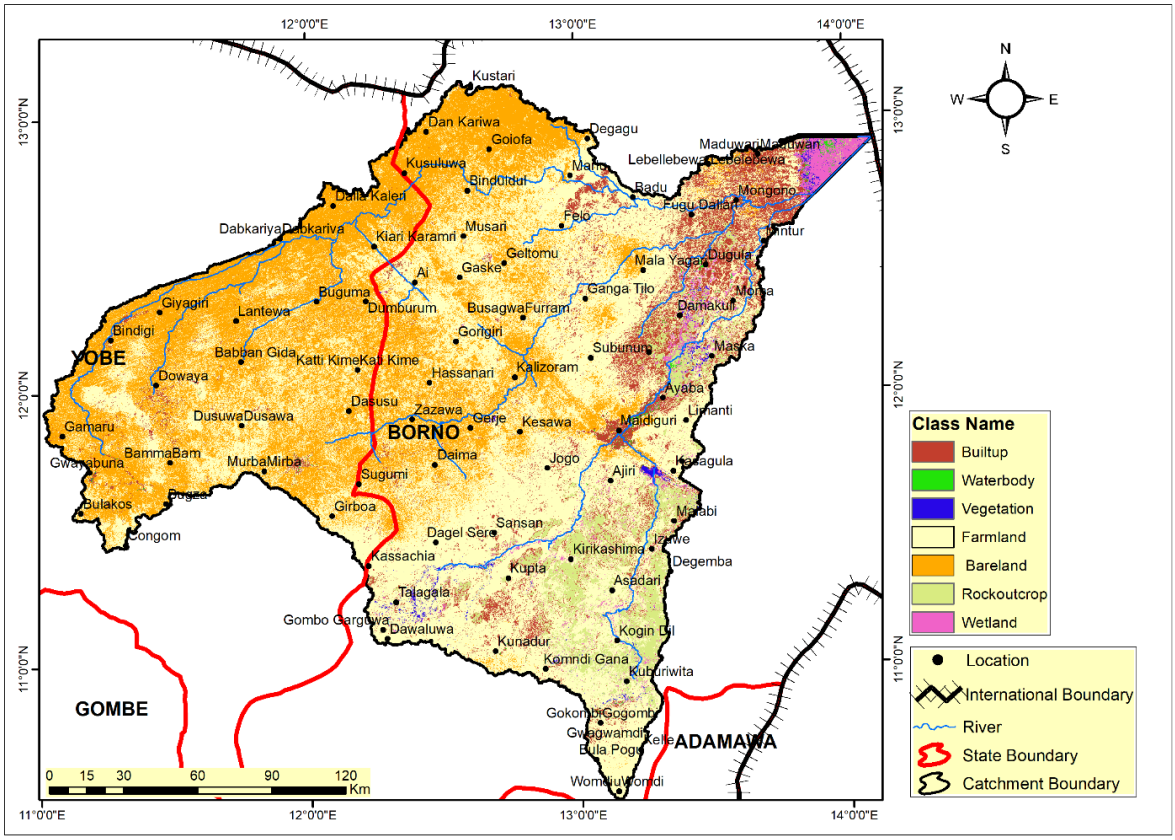

Figure 2.12: Land Use and Land Cover of the Catchment (Source: MSL, 2024)

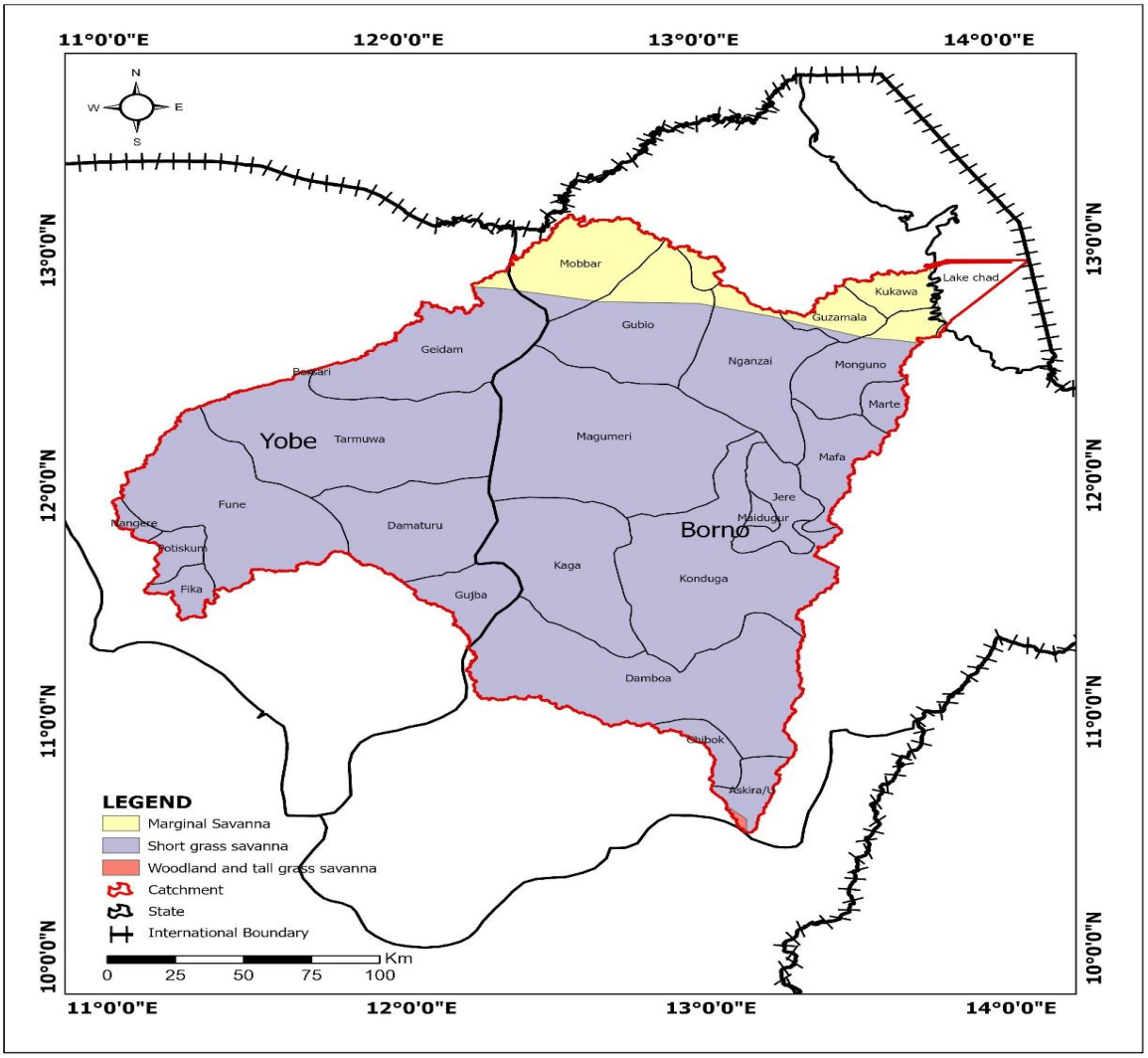

Figure 2.13: Vegetation Map of The Catchment (Source: MSL, 2024)

2.4.1 Agricultural Land Use

- Agriculture is a key land-use activity in the Ngada West Chad Catchment, supporting livelihoods, food security, and the economy.
- Millet, sorghum, maize, and cassava are staple crops, while groundnuts, soybeans, sesame, and cowpeas generate income. Though some areas practice irrigated farming, most rely on rain-fed agriculture, facing challenges from limited irrigation infrastructure, climate variability, and resource constraints.

2.4.2 Pastoralism

- Pastoralism is a key livelihood in the Ngada West Chad Catchment, supporting thousands of households through cattle, sheep, goats, and camels for meat, milk, hides, and trade.

- Both nomadic and semi-nomadic systems contribute to food security, local economies, and livestock markets, but sustainability is threatened by environmental and socio-economic challenges.

2.4.3 Forest and Woodlands

- Forests and woodlands in the Ngada West Chad Catchment support biodiversity, climate regulation, and local livelihoods, but face threats from deforestation and land degradation.
- Protected areas like Sambisa, Gombole, Kusur, and Shegali reserves act as carbon sinks, help regulate climate, and support watershed protection, preventing soil erosion and maintaining groundwater recharge.

2.4.4 Urban and Built-Areas

The Ngada West Chad Catchment is experiencing rapid urban expansion, especially in Maiduguri, Damaturu, Konduga, Jere, and Potiskum, due to population growth, conflict displacement, and economic development. This growth is putting pressure on land, water, and infrastructure, leading to the conversion of farmlands and ecosystems into residential, commercial, and industrial areas.

2.4.5 Wetlands and Waterbodies

The wetlands and waterbodies of the Ngada West Chad Catchment are crucial for water supply, agriculture, fisheries, and biodiversity. However, they face threats from climate change, overuse, and pollution. Lake Chad, vital for fishing and irrigation, is shrinking due to reduced inflows and excessive withdrawals, jeopardizing regional water security and ecosystems.

2.4.6 Desertification and Land Degradation

Desertification and land degradation in the Ngada West Chad Catchment threaten agriculture, water resources, and biodiversity, impacting local livelihoods. Issues such as over-cultivation, deforestation, and overgrazing deplete soil and accelerate erosion. Climate change, erratic rainfall, and urban expansion further worsen these challenges, escalating resource conflicts.

2.4.7 Mineral Extraction

Mineral extraction in the Ngada West Chad Catchment supports the local economy, infrastructure, and employment, but unsustainable mining leads to environmental degradation, water pollution, and land instability.

- Sand and Gravel are essential for construction, roads, and infrastructure, but extraction from riverbeds causes riverbank erosion and habitat destruction.
- Limestone is mostly used in cement production and industrial applications, but quarrying leads to dust pollution, deforestation, and hydrological disruptions.
- Clay supports pottery, brick-making, and ceramics, but unregulated extraction depletes topsoil, alters drainage patterns, and causes land degradation.

2.4.8 Biodiversity

Biodiversity Component	**Description**	**Ecosystem Services**	**Conservation Challenges**
Ecosystems	Semi-arid Sahelian and Sudan Savanna; includes seasonal rivers, wetlands (e.g., Dagona, Lake Alau), floodplains, and dry woodlands. Agroforestry systems are common.	- Water regulation - Soil fertility and retention - Groundwater recharge - Livelihoods (agriculture, grazing, fishing)	- Deforestation - Seasonal drying of wetlands - Land degradation
Flora	Dominant species include *Acacia spp.*, *Balanites aegyptiaca*, *Adansonia digitata* (Baobab), *Azadirachta indica* (Neem), *Cenchrus biflorus*, and *Sorghum spp.* Vegetation adapted to arid conditions and agroforestry.	- Fuelwood - Traditional medicine - Erosion control - Livestock fodder - Food and fibre	- Overharvesting - Charcoal production - Conversion to farmland
Fauna – Mammals	Includes *Dorcas gazelle*, *African hare*, *Warthogs*, and *Jackals*. These species are	- Trophic regulation - Ecotourism potential	- Habitat fragmentation - Overhunting

	adapted to drylands and open savanna.	- Cultural value	- Conflict and insecurity
Fauna – Birds	Located on the Sahelian flyway, supporting migratory birds such as *Abyssinian Ground Hornbill*, *Crested Lark*, and *Chestnut-bellied Sandgrouse*. Important breeding and stopover site.	- Seed dispersal - Pollination - Indicators of ecosystem health	- Habitat loss - Wetland degradation - Illegal bird trade
Reptiles & Amphibians	Includes *Desert Monitor Lizard*, snakes, and amphibians in seasonal wetlands. Amphibians appear during wet season.	- Pest control - Aquatic food web balance	- Seasonal habitat loss - Pollution of wetlands
Aquatic Biodiversity	Fish species such as *Clarias spp.* (catfish) and *Oreochromis niloticus* (tilapia) thrive in seasonal streams and wetlands. Supports amphibians and wetland birds.	- Local fisheries- Food security- Livelihoods	- Dry-season overfishing- Siltation- Reduced flow regimes
Human-Associated Biodiversity	Agroforestry (with millet, sorghum, maize + trees), pastoralism with cattle, sheep, goats, and camels. Contributes to landscape diversity.	- Mixed-use ecosystems - Food and fodder security - Cultural resilience	- Overgrazing - Agricultural encroachment - Weak tenure systems
Protected Areas & Reserves	Nearby or partially overlapping reserves include: Chad Basin National Park (Yobe Sector), Dagona Waterfowl Sanctuary, Sambisa Forest Reserve, and Lake Chad Basin wetlands.	- Biodiversity refugia- Wetland bird habitat- Water regulation	- Weak enforcement - Security challenges - Pressure from surrounding communities

2.4.8.1 Key Conservation Initiatives

Initiative	Description
Reforestation Programs	Community tree planting and soil conservation targeting degraded lands and desertification control.
Community-Based Resource Management	Involvement of local groups in sustainable resource use, agroforestry, and conflict resolution.
Wetland Conservation	Protection of the Dagona Sanctuary and Lake Chad wetlands for migratory birds and aquatic biodiversity.
Conflict Recovery	Ecosystem restoration in areas affected by insurgency (e.g., Sambisa Forest), integrating peacebuilding with biodiversity goals.

2.5 Hydrology and Water Resources

2.5.1 Hydrology

The hydrology of Ngada catchment is linked to its climate, characterized by seasonal rivers and streams that fluctuate with the rainy and dry seasons.

- Lake Chad, a key hydrological feature, has shrunk over decades due to reduced inflow, increased water extraction, and climate change.
- The catchment is vital for agriculture and biodiversity, the catchment is experiencing seasonal flooding that supports diverse ecosystems.
- Desertification, driven by overgrazing, deforestation, and unsustainable practices, affects the hydrological cycle, increasing water scarcity.
- Climate change exacerbates these challenges, leading to reduced river flows, lower groundwater levels, and more extreme weather events.

2.5.2 Hydrograph/Water Budget of the Catchment

The strategic catchments consist of multiple catchments, each with two or more sub-catchments.

- To generate a representative synthetic hydrograph using the SCS model and incorporating CHIRPS rainfall and evapotranspiration data, the analysis was conducted at the sub-catchment level.
- Synthetic hydrographs were created for each sub-catchment and then aggregated to represent the entire strategic catchment. This approach ensured that the hydrographs captured the dynamics of each area while accounting for variability.
- The resulting hydrographs and water budget graphs are valuable tools for understanding water availability, managing resources, and forecasting water supply and demand. They are presented as follows:

2.5.2.1 Ngada Strategic Catchment

The Ngada strategic catchment, consisting of Kogin Goya, Allagamo, and Gubio Rivers, shares homogeneous hydrographic characteristics. As shown in Figures 2.14, 2.15, 2.16, 2.17, and 2.18, a seasonal pattern is observed, with a sharp increase in discharge between May and June and a peak discharge in August. A gradual decline in discharge takes place in October as rains

subside, transitioning to dry-season baseflow sustained by groundwater. Discharge diminishes significantly (October–April), relying on groundwater and ephemeral streams. Baseflow may decline further toward April due to high evaporation and water extraction. The catchment has a brief four-month period of water surplus and a low average water budget of 105.81 mm, indicating limited water storage. Therefore, alternative water supply interventions should be prioritized for this catchment.

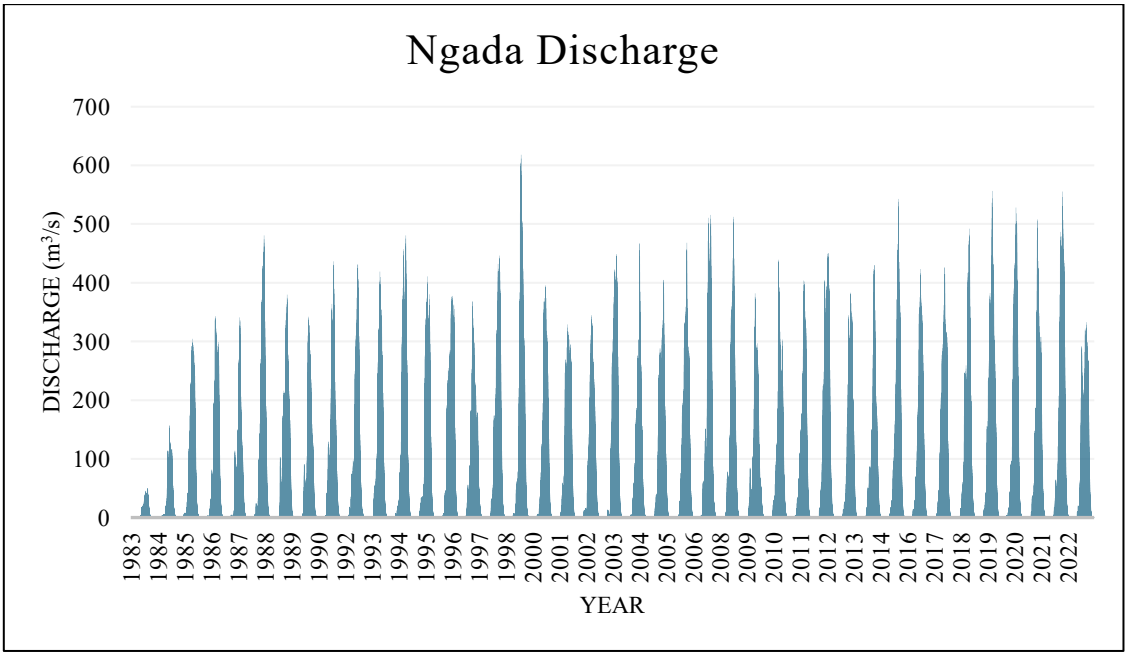

Figure 2.14: *Hydrograph of Ngada Strategic Catchment Based on HEC-HMS modelling for Strategic catchment.*

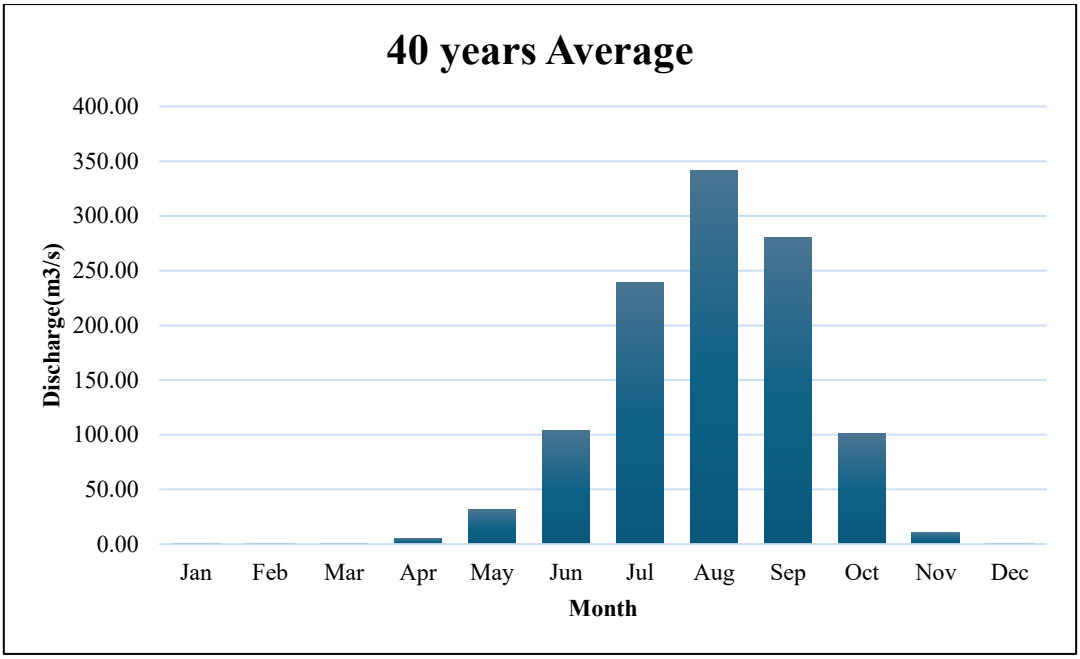

Figure 2.15: 40 - Year Summary Hydrograph of Ngada Strategic Catchment

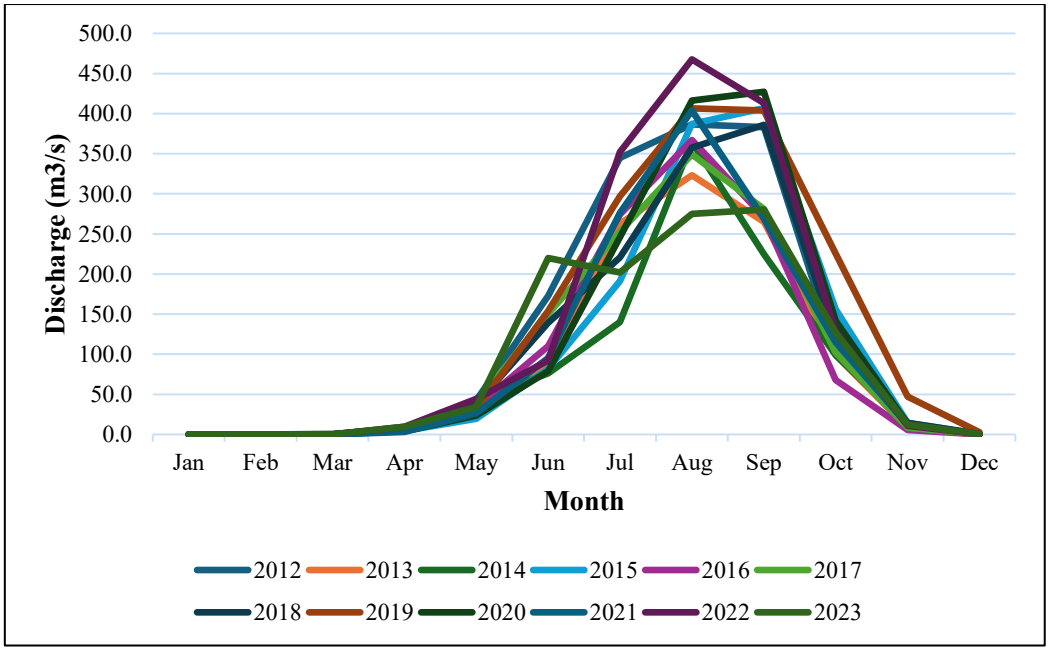

Figure 2.16: Hydrograph of Ngada Strategic Catchment for Specific Years

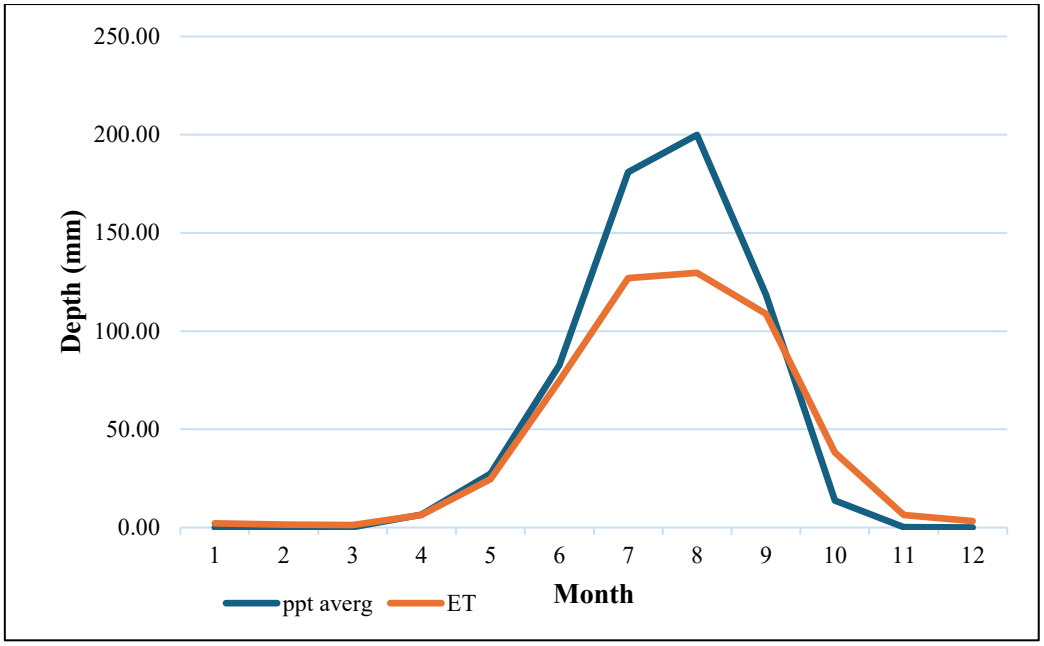

Figure 2.17: Water Budget for Ngada Strategic Catchment

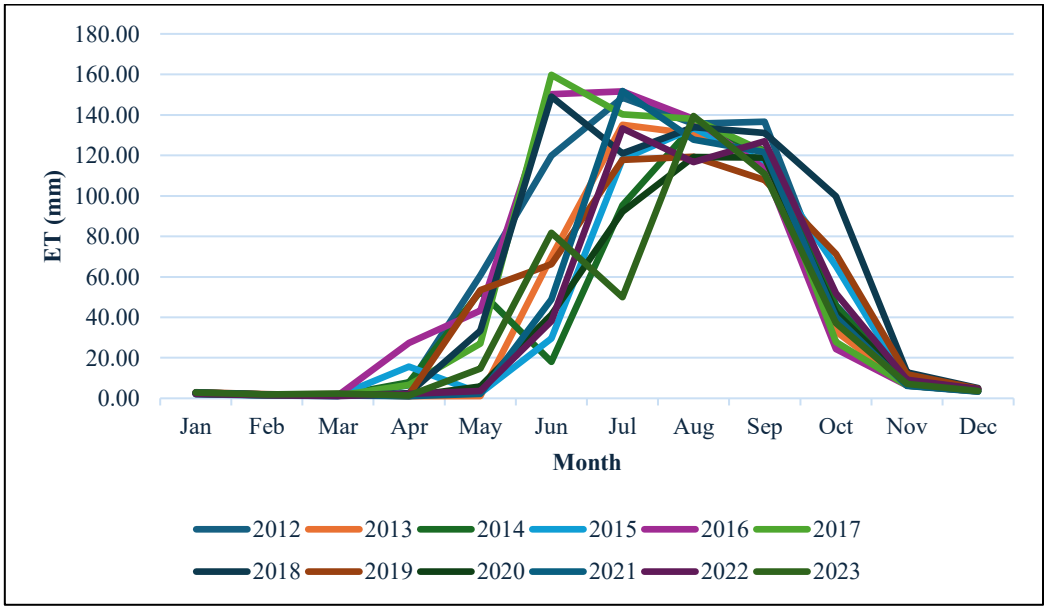

Figure 2.18: Monthly Actual Evapotranspiration Distribution for Ngada Strategic Catchment

Source: TerraClimate

Table 2.1: *Summary of Discharge, Rainfall and Evapotranspiration Data for Ngada Strategic catchment*

MONTH	PPT	ET	Synthetic Peak Runoff (m^3/s)
Jan	0	2.12	0
Feb	0	1.5	0
Mar	0.22	1.29	0.08
Apr	6.57	6.33	5.55
May	27.41	24.67	31.6
Jun	82.63	74.69	103.81
Jul	180.91	127.02	239.08
Aug	199.88	129.68	341.06
Sep	118.32	108.82	280.51
Oct	13.67	38.14	101.03
Nov	0.17	6.38	10.99
Dec	0	3.33	0.49

Prospects

- Peak Flow Harvesting: Construct small to medium-scale reservoirs or check dams on the Kogin Goya, Allagamo, and Gubio Rivers to capture peak flows during May–August. This stored water can offset dry-season shortages (October–April).
- Managed Aquifer Recharge (MAR): Use surplus flows (June–September) to recharge aquifers via infiltration basins, recharge wells, or floodplain spreading, bolstering baseflow for the dry season.
- Riparian Zone Protection: Restore vegetation along rivers to reduce evaporation, stabilize baseflow, and enhance infiltration.
- Real-Time Monitoring: Deploy sensors to track river discharge, groundwater levels, and soil moisture, enabling dynamic allocation during dry months.

2.5.3 Hydrogeological Disposition of the Catchment

The hydrogeological disposition of the catchment and its hydrogeological units and aquiferous layers make up part of the water resources of the catchment, as seen and explained in Figure 2.19

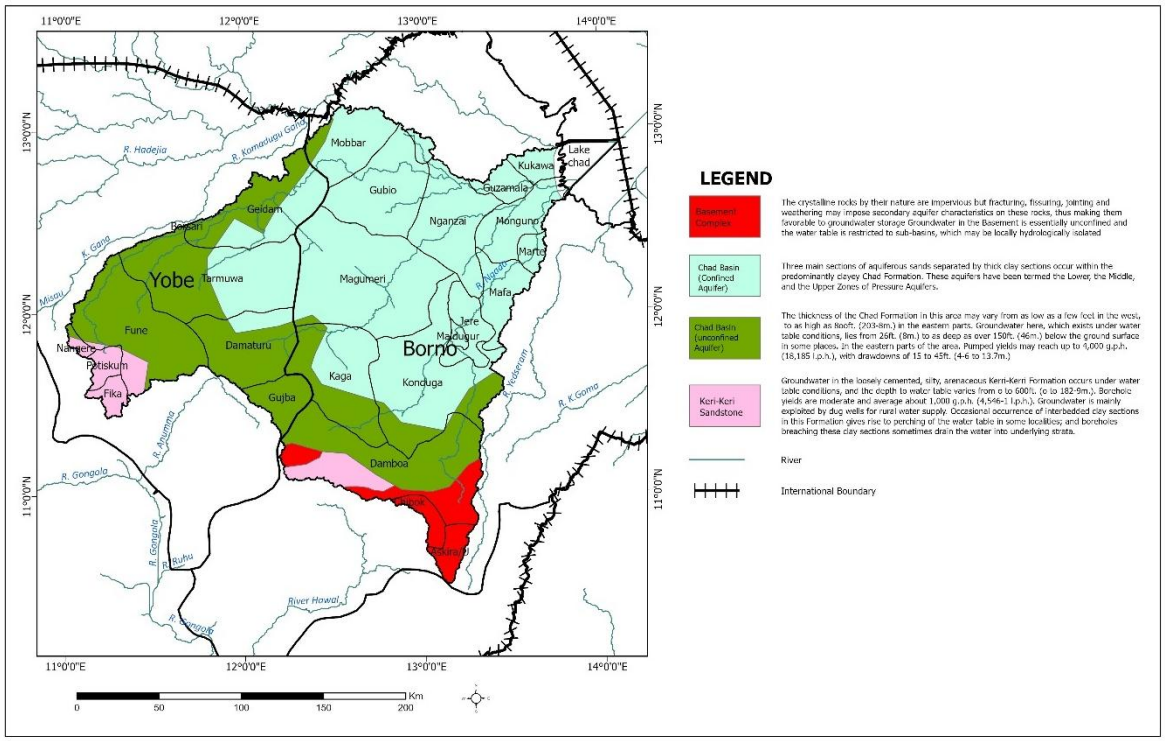

Figure 2.19: Hydrogeological province Map of the Catchment (Source: MSL, 2024)

2.5.3.1 Groundwater Recharge

Groundwater storage is critical in the catchment, particularly in areas where surface water resources are insufficient.

- The state's aquifers store a significant volume of water, which is accessed through boreholes and wells. However, over-extraction and inadequate recharge have led to concerns about the sustainability of groundwater resources.
- The continuous decline in groundwater levels in some areas suggests that current extraction rates may not be sustainable in the long term (Musa et al., 2020).
- The decline in groundwater levels due to reduced recharge will be less pronounced near rivers, as groundwater levels tend to remain relatively stable at riverbeds. Conversely, areas situated far from rivers are likely to experience a more substantial decrease in

groundwater levels. Consequently, inland regions on plateaus that are distanced from river systems will be more adversely affected by the decline in groundwater recharge. As such, countermeasures to address climate change must take these regional variations into account.

2.6 Water Demand for Ngada West Chad Catchment

The water demand is divided into the following categories:

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

Irrigation water demand.

Livestock water demand.

Aquaculture water demand.

Municipal Water Demand

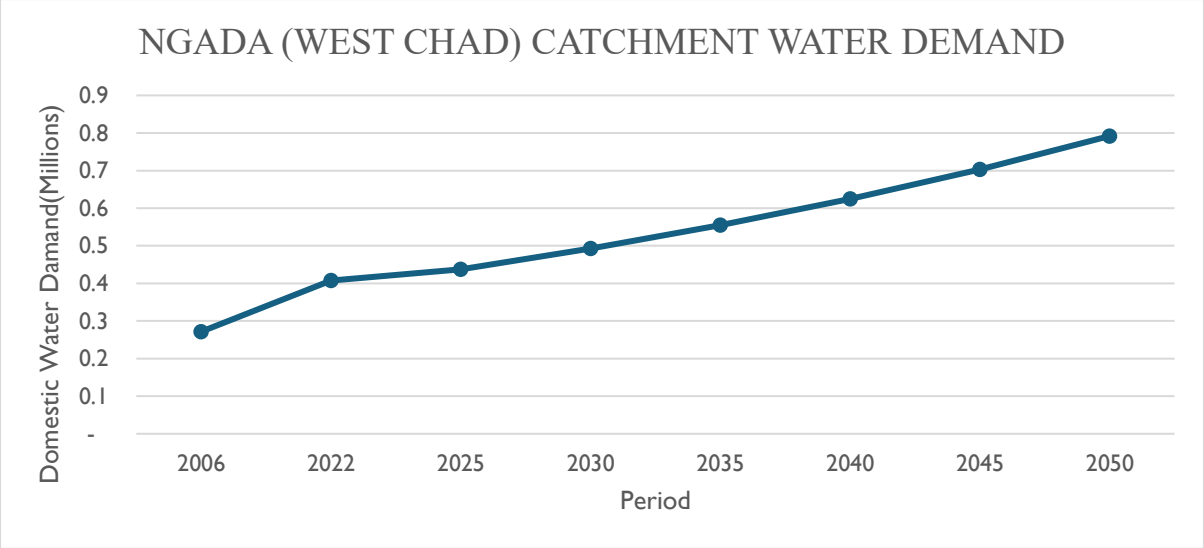

Figure 2.20: Ngada (West Chad) Catchment Water Demand

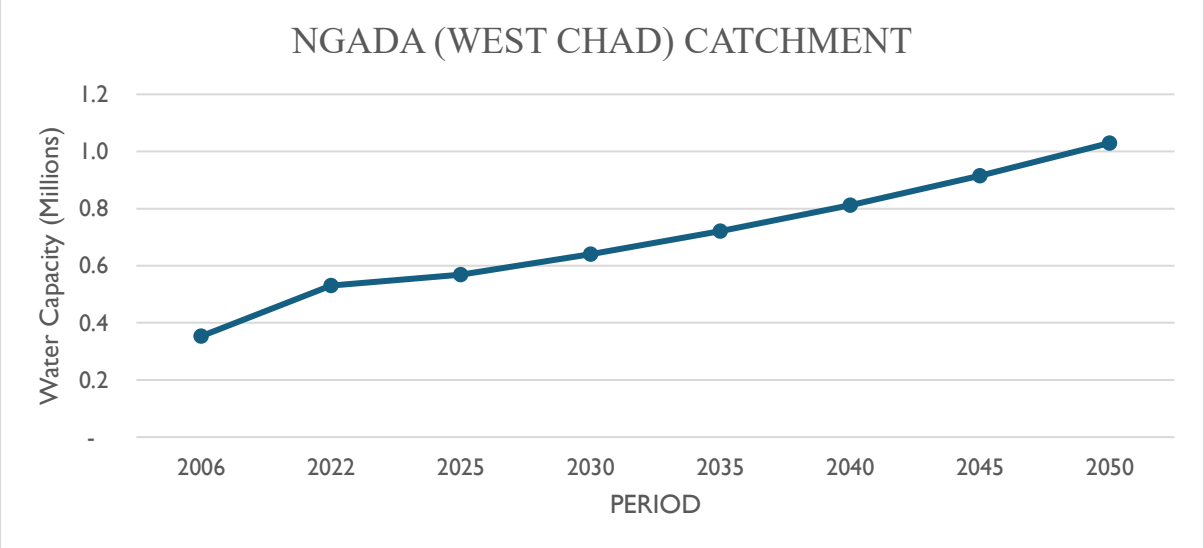

Figure 2.21: Ngada (West Chad) Catchment

Municipal water demand is mostly met by groundwater throughout the basin as shown in Annex 1.

2.6.1 Water use and Demands

Current and future water demands were estimated for the Ngada West Chad Catchment area using the methodology applied in the NWRMP (JICA, 2014 and SAP 2019 of SMEC). The demand-related data obtained were based on the State level. The States considered are part of Borno and Yobe as shown in Figure 2.22.

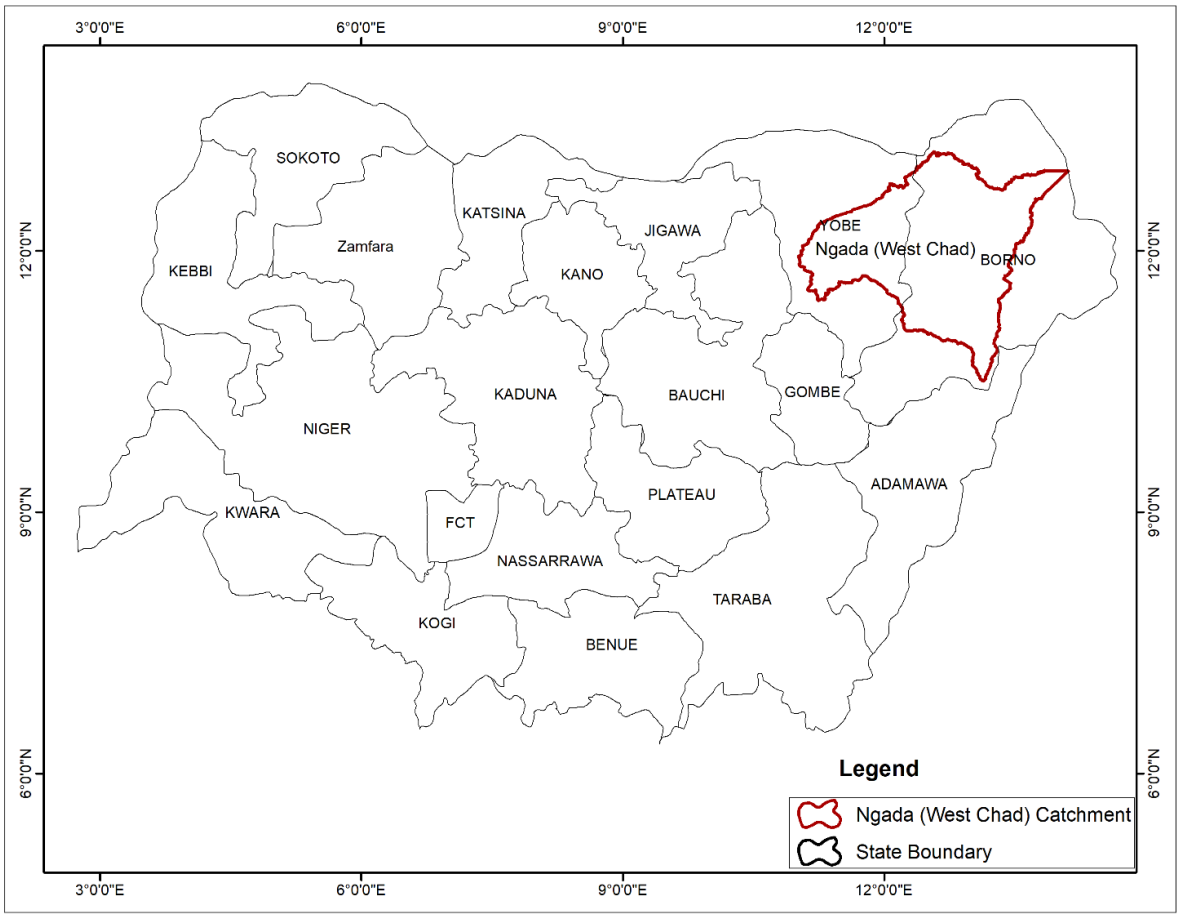

Figure 2.22: Ngada Catchment Reflecting on Nigeria Map

2.6.2 Livestock Water Demand

Number of livestock heads is by far larger in the north of the country than in the south because northern inhabitants too often suffer from droughts to rely on crop farming, naturally depending too heavily on livestock production (refer to Table 2.2 to Table 2.8 below).

- Due to scanty annual precipitation, surface water availability is particularly low during dry season, and even during rainy season sufficient water seldom runs in the streams.
- Livestock should use well water as a last resort. Water consumption depends on temperature, weight, and grass availability, as 80% of grazing grass is water. For instance, grazing 20 kg of grass provides about 16 liters of water daily for a 240 kg cow.
- In extreme drought years with less than 400mm rainfall, grass cover is thin, limiting adult cattle to 5kg of grazing per day. To maintain their body, they need at least 11 liters of water daily, with moving cattle requiring about double that amount. On average, adult cattle need 25-35 liters of water per day based on their weight and activity.
- Similar to cattle, goats and sheep have comparable water needs. A standard for livestock water requirements in the tropical zone is presented in a FAO livestock guidebook from the 1960s. It's important to note that domesticated and nomadic livestock have different standards.

Table 2.2: Case of water requirement per head of livestock

Livestock specie	Live Weight (kg)	Maintaining* need (L/day)	Uptake from grazing Grass/ feeds (L/day)	Gross water Drink (L/day)	Annual (m3) requirement
Cattle	250	60	38.4	21.6	**7.9**
Goat	30	6.6	4.3	2.3	**0.8**
Sheep	40	8.8	6.8	2.0	**0.7**
Pig	90	20	16.7	3.3	**1.2**
Donkey	110	24	15.6	8.4	**3.1**
Camel	350	80	55.4	24.6	**9.0**
Horse	300	70	47.8	22.2	**8.1**
Fowl	**2**	**0.4**	**0.292**	**0.108**	**0.039**

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

Table 2.3: Number of livestock heads/ fowls in 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Borno	2,200,000	4,899,501	3,764,829	0	317,072	11,428	0	**5,904**
Yobe	1,056,524	3,214,055	1,855,173	0	4,510,760	17,366	2,611	**16,786**

Total	3,256,524	8,113,556	5,620,002	4,827,832	28,794	2,611	22,690

Table 2.4: Corresponding livestock water requirement 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Borno	17,320,600	4,154,777	2,793,503	0	12,366	35,164	0	**47,409**
Yobe	8,318,013	2,725,519	1,376,538	0	175,920	53,435	23,444	**134,792**
Total	25,638,613	6,880,296	4,170,041	0	188,286	88,599	23,444	182,201

Source JICA 2014 MP

Table 2.5: Estimated growth rate of livestock heads during the period 2010 ~ 2030

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

Source JICA 2014 MP

Table 2.6: Number of livestock heads/ fowls projected in 2030

Livestock Water	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Borno	19,857,587	6,144,681	4,872,704	0	14,974	35,038	0	**47,840**
Yobe	9,536,371	4,030,889	2,401,094	0	213,024	53,244	23,444	**136,017**
Total								

Source JICA 2014 MP

Table 2.7: Corresponding livestock water requirement projected in 2030

Livestock Water	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Borno	19,857,587	6,144,681	4,872,704	0	14,974	35,038	0	**47,840**
Yobe	9,536,371	4,030,889	2,401,094	0	213,024	53,244	23,444	**136,017**
Total								

Source JICA 2014 MP

Table 2.8: Water Demand (Cubic Meter) For Each Livestock In The Ngada Catchment Projected To 2050

WATER DEMAND (CUBIC METER) FOR EACH LIVESTOCK IN THE NGADA CATCHMENT PROJECTED TO 2050									
	2010	2015	2020	2025	2030	2035	2040	2045	2050
Cattle	25638613	26523579	27439092	28386205	29366010	30379634	31428246	32513052	33635303
Goats	6880296	7600500	8396092	9274963	10245832	11318327	12503087	13811864	15257638
Sheep	4170041	4834220	5604186	6496788	7531558	8731140	10121784	11733922	13602831
Pigs	0	0	0	0	0	0	0	0	0
Poultry	188286	206001	225382	246586	269786	295168	322938	353322	386563
Donkeys	88599	98301	109065	121008	134259	148961	165273	183371	203450
Camels	23444	26011	28860	32020	35526	39416	43732	48521	53835
Horses	182201	202153	224289	248850	276099	306333	339878	377096	418389
TOTAL	37171480	39490765	42026965	44806420	47859070	51218980	54924939	59021148	63558010

Source JICA 2014 MP

2.6.3 Inland Fishery

Basic Data for 2030 projection: Area of farm ponds by Fishery Statistics of Nigeria, Inventory of Private and Government Fish Harm and Hatcheries (Dec. 2004) published in 2007 (see Table 2.9, **Error! Reference source not found.**, and Table 2.10: Projected Water Demand for Inland Aquaculture)

Table 2.9: Fish Farm Pond

State	Number of Fish Farm	Water Area of Farm Pond (ha)	Brackish Water Area of Farm Pond (ha)
BORNO	12	12.1	**0.0**
YOBE	13	9.9	**0.0**
TOTAL	**25**	**22**	**0.0**

Source JICA 2014 MP

Table 2.10: Projected Water Demand for Inland Aquaculture

HA	Water Demand (MCM)	
	2010	2030
8	23.8	151.1

Source: JICA 2014

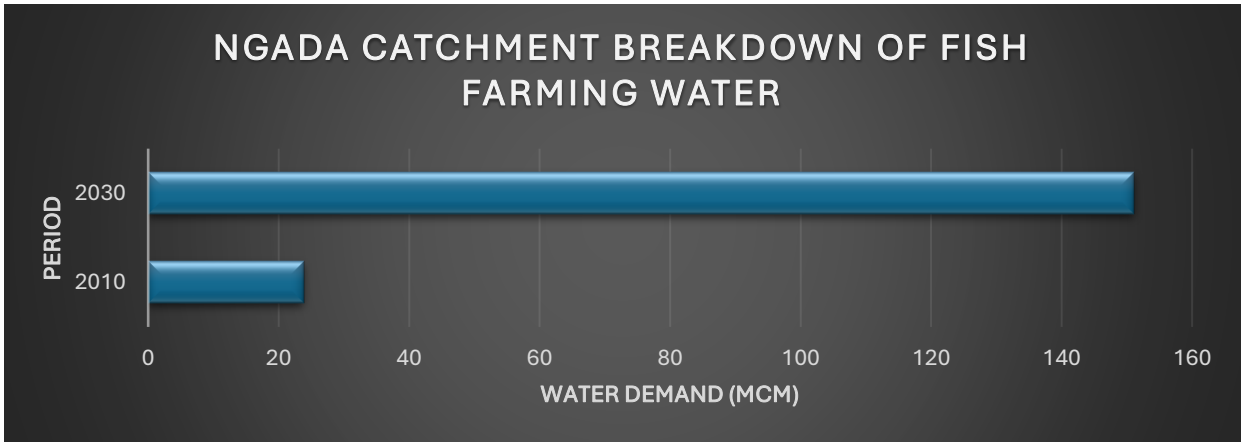

Figure 2.23: Breakdown of fish farming water

2.6.4 Irrigation water demand

2.6.4.1 Irrigation Water Use

Small-scale irrigation systems, both formal and informal, are present in river basins. Local communities develop Fadama irrigation schemes using surface water, either diverted by gravity from streams or lifted with small diesel pumps.

- In addition, there are comparatively large-scale irrigation systems that are normally developed by public agencies and managed jointly with users. The irrigation schemes vary in size from 40 ha to 16,000 ha. Most of the schemes are operational.
- The irrigation water demand was extracted from the Irrigation Thematic Report (SMEC 2019) and Nigeria National Water Resources Master Plan (NNWRMP 2013).
- The irrigation water demands in this table are for rice only (the most conservative estimate) and vegetables only which is the most optimistic water demand requirement for irrigation.
- Public irrigation schemes mostly utilize surface water, whereas Fadama farming and some small-scale private irrigation systems in floodplains mainly use groundwater

flows that occur after flood recession. The small-scale private irrigation systems outside floodplains mostly utilize groundwater for irrigation purposes.

2.6.5 Irrigation Water Demand Projection

The irrigation water demand was computed as a product of the gross irrigation water requirement multiplied by the cropped area for that particular crop. An irrigation efficiency of 50% was assumed in the computation of the irrigation water demand, which was applied to the whole basin. Assuming that all irrigation schemes are equipped with drainage systems, half of the water abstracted rejoins the surface water.

- Tables 2.11 Show a projection of the water demand for Irrigation in the Ngada Catchment.

Table 2.11: Water Demand of Existing, Proposed Irrigation Schemes and Climate Change

Water Demand of Existing Irrigation Schemes

Catchment	Water Source	Irrigated Area (ha)	Wet Season Water Demand (MCM)	Dry Season Water Demand (MCM)	Total Water Demand (MCM)
Ngada	Surface Water	**2,880**	**27.5**	**4.3**	**31.8**
	under flow	**0**		**0**	**0**
	Ground Water	1100	**4.6**	**3.9**	**8.5**
Total					**40.3**

Water Demand of Proposed Irrigation Schemes

Catchment	Water Source	Irrigated Area (ha)	Wet Season Water Demand (MCM)	Dry Season Water Demand (MCM)	Total Water Demand (MCM)
Ngada	Surface Water	**2,000**	**18.7**	**6.1**	**24.8**
	under flow	**0**		**0**	**0**
	Ground Water	3805	**18.4**	**15.4**	**33.8**
Total					**58.6**

Water Demand of Climate change

Catchment	Water Source	Irrigated Area (ha)	Wet Season Water Demand (MCM)	Dry Season Water Demand (MCM)	Total Water Demand (MCM)
Ngadda	Surface Water	**2,000**	**21.5**	**6.9**	**28.4**
	under flow	**0**		**0**	**0**
	Ground Water	**2396**	**14**	**11**	**25**
Total					**53.4**

Four crop patterns were recommended in the Agriculture Thematic Report (SMEC, 2017) as shown in the Table 2.12 below:

Table 2.12: Recommended Crop Pattern (Agronomy Thematic Report, SMEC 2019)

No	Irrigated Crop Pattern	Dry Season		Wet Season					Dry Season				
		Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
1	Crop Pattern 1			Green Manure	TPR/WSR/DSR Rice				Sow wheat on residual soil moisture				
2	Crop Pattern 2			Green Manure	TPR/WSR/DSR Rice				Vegetables (bulb onions, green onions tomatoes, leafy vegetables, sweet peppers, chilli papers, eggplant)				
3	Crop Pattern 3			Green Manure	Rice + Groundnut + Maize				Vegetable Eggplants				
4	Crop Pattern 4	Perennial Fruits											
**	Rainfed Agriculture												
No		Dry Season		Wet Season					Dry Season				

	Irrigated Crop Pattern	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec	Jan	Feb	Mar
5	Cropping Pattern 5			Millet + sorghum + maize									
6	Cropping Pattern 6			Millet + sorghum + Cowpea									
7	Cropping Pattern 7			Millet + sorghum + Cowpea or groundnut									
8	Cropping Pattern 8			Millet + sorghum + sesame									
9	Cropping Pattern 9			Upland rice + millet + Sorghum									
10	Cropping Pattern 10			Millet + cowpea + maize									

TRP = transplanted rice, WSR = wet-seeded pre-germinated rice broadcast onto the field, DSR = dry-seeded rice broadcast on the field as in wheat. The rainfall pattern for a given year determines the planting method. TPR when heavy rains come in July, WSR can also be the same but is a way of reaching quickly say when rains come early, and the farmer wants to sow the field quickly without a seedbed.

DSR is for years where the rains are late and the farmer sows depending on a calendar date.

** Farmers often have several small fields and these cropping patterns may be in different fields.

Source JICA 2014 MP

The crop water requirement for these crop patterns was estimated using CROPWAT and available climatic data. The net and gross irrigation water requirements for each sub-basin are tabulated here under for the Crop Pattern. Therefore, in line with the above component requirements and demands, the water balance for the Ngada catchment is as analysed in table 13 below:

Table 2.13: Water Balance of Ngada Catchment

WATER BALANCE ANALYSIS FOR NGADA CATCHMENT			
WATER DEMAND (CUBIC METER)		**2025**	**2050**
MUNICIPAL		159,773,476	289,070,384
LIVESTOCK		44806420.01	63558010.13
AQUACULTURE		1,848,677	2,134,863
IRRIGATION		58,600,000	53,400,000
TOTAL		**265,028,573**	**408,163,257**
AVAILABLE WATER RESOURCES (CUBIC METER)		**501,841,800**	**501,841,800**
WATER BALANCE (CUBIC METER)		**236,813,227**	**93,678,543**

SOURCE: JICA 2014 MP AND SMEC 2019 AS ANALYSED

2.7 Water Quality

Data on Water Quality for Surface and Groundwater from the Regional Laboratories

Table 2.14, Table 2.15 and Table 2.16 shows drinking water standards and Chemical, Physical Limits for Drinking Water Sources and Standards for Metals in Irrigation Water for the Ngada-West-Chad catchment.

Table 2.14: Drinking Water Standards – Microbiological

Class of Piped Water / Type of Test Count	Coliform Count per 100 ml at 37oC	E. Coli Count per 100 ml at 44oC
Excellent	0	0
Satisfactory	1 – 3	0
Suspicious	4 – 10	0
Unsatisfactory	> 10	1 or more

SOURCE: JICA 2014 MP

Table 2.15: Chemical and Physical Limits for Drinking Water Sources

Constituent	Symbol	Units	Limits
Lead	Pb	mg/l	0.01
Arsenic	As	mg/l	0.05
Selenium	Se	mg/l	0.05
Chromium	Cr	mg/l	0.05
Cyanide	Cn	mg/l	0.20
Cadmium	Cd	mg/l	0.05
Barium	Ba	mg/l	1.00
Mercury	Hg	mg/l	0.001
Fluoride	F	mg/l	1.5 – 4.0
Nitrate	NO3	mg/l	10 – 75
Colour		Mg/l	15 – 50
Turbidity		Mg/l	5 – 25
Taste			Not objectionable
Odour			Not objectionable
PH			6.5 – 9.2
Total filterable residue		mg/l	500 – 2,000
Total hardness	CaCO3	mg/l	500 – 600
Calcium	Ca	mg/l	75 – 300
Magnesium	Mg	mg/l	50 – 100
Magnesium + sodium sulphate	Mg + Na2SO4	mg/l	500 – 1,000
Sulphate	SO4	mg/l	200 – 600
Chloride	Cl	mg/l	200 – 800
Iron	Fe	mg/l	1.0
Manganese	Mn	mg/l	0.5
Copper	Cu	mg/l	3.0
Zinc	Zn	mg/l	15.0
BODs (5 days)	O2	mg/l	6.0
PV (oxygen abs. KMnO4)	O2	mg/l	20
Ammonium	NH3	mg/l	2.0
Total nitrogen exc. nitrate		mg/l	1.0
Surfactants ABS		mg/l	2.0
Organic matter as carbon		mg/l	0.5
Phenolic substances		mg/l	0.002

SOURCE: JICA 2014 MP

Table 2.16: Standards for Metals in Irrigation Water

Constituent	Symbol	Units	Limits	
			Long Term Use	Short Term Use
Aluminium	Al	mg/l	5	20
Arsenic	As	mg/l	0.1	2.0
Beryllium	Be	mg/l	0.1	0.5
Cadmium	Cd	mg/l	0.01	0.05
Chromium	Cr	mg/l	0.1	1.0
Mercury	Hg	mg/l	0.002	0.002
Fluoride	F	mg/l	1	42
Iron	Fe	mg/l	0.2	10
Lead	Pb	mg/l	2	5
Lithium	Li	mg/l	2.5	2.5
Manganese	Mn	mg/l	0.2	10
Selenium	Se	mg/l	0.02	0.05
Zinc	Zn	mg/l	2	5

Source: JICA 2014 MP

2.7.1 Groundwater Quality

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

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

2.7.1.1 Groundwater Electrical conductivity

Electrical conductivity (EC) of a liquid (water in this case) gives an indication of the amount of soluble salts contained in the liquid.

- The high concentration of salt ions in water gives it the ability to conduct electricity. As such, a high electrical conductivity reading indicates high concentrations of total dissolved salts (TDS) in solution and vice versa.

- Most fresh drinking water will have less than 100 µS/cm conductivity, whereas the seawater has conductivity of around 54,000 µS/cm.
- Highest groundwater EC is prevalent within the basement aquifer and around large settlements in the basement with EC of more than 1,000 µS/cm.

2.7.1.2 Fluoride distribution

- Mapping fluoride concentration in the basin is crucial for identifying high levels and implementing treatment measures to prevent fluorosis. WHO and Nigerian standards set the maximum permissible fluoride level in drinking water at 1.5 mg/L.
- Groundwater availability potential for the shallow unconfined aquifer in the basin is not limited by fluoride but this can be the case for the deeper aquifers where high fluoride concentrations have been observed.

2.7.1.3 Nitrates distribution

- Nitrates occur naturally in water, soil, plants, and food and are found more often in groundwater than in surface water.
- Most common and major sources of nitrates in groundwater are fertilizers, septic tank waste, livestock and pit latrines mostly in urban areas.
- Both the NIS and WHO set the maximum limit on nitrates for drinking water at 50mgl/l. The figure below shows statistical distribution of nitrate from 168 groundwater samples data collected for the basin.
- The relationship between high nitrate concentration and metropolises indicate nitrate contamination from poor sanitation practices.

2.7.1.4 Heavy metals and other metals

- Presence of heavy metals in groundwater is a result of release of metals such as Lead, Chromium, Zinc, Copper, Nickel, Cadmium, Arsenic and Mercury into the groundwater environment.
- This occurs where metals are by products in industrial processes. Although these metals (refer to Table 2.17)occur in concentration of micrograms in the groundwater, these concentrations can be enough to cause serious health complications in humans if periodically consumed in excess.
- Maximum allowable limits and health implications of continuous ingestion of high quantities of heavy metals are presented in the table below:

Table 2.17: 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	Renal dysfunction, 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 and smec 2017

- 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.
- The figures below 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 a 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:

- Major urban centres in the basin, especially, Damaturu and Maiduguri.

- 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 Maiduguri.

Table 2.18 Shows the Preliminary Conclusion of Water Quality Status of Some Rivers in the Northern States of Nigeria

Table 2.18: Preliminary Conclusion of Water Quality Status of Some Rivers in the Northern States of Nigeria

S/No.	State	River Name	Code	Wet Season	Dry Season	NFA
1	Borno	River Ngada at Alau Dam intake to Maiduguri WTP	SW/001	Good	Good	
2		River Banki at Banki town	SW/001	Good	Good	Ni, Zn

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

Criteria:

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

Moderate : 3<BOD = <6 and 4=<DO < 6 (based on Nigeria Standard Values for surface water- irrigation & reuse)

Poor : BOD > 6 or DO < 4 (proposed by JICA Project Team)

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

2.7.2 Infrastructure and Assets

Catchment infrastructure and assets are shown in **Error! Not a valid bookmark self-reference.** below.

Table 2.19: Catchment Infrastructure and Assets

S/No.	Infrastructure	Location	Importance	Risk Factors
1	Dams and Reservoirs	Borno, Yobe	Store and regulate water for agriculture, domestic use, and flood control	Sedimentation, poor maintenance, structural failure, and climate change impacts
2	Boreholes and Wells	Scattered across rural and urban areas	Provide groundwater for drinking, irrigation, and livestock	Over-extraction, declining water tables, and contamination risks
3	Irrigation Canals	Borno, Yobe	Enable dry-season farming and increase crop productivity	Leakages, blockages, inefficient water use, and evaporation losses
4	Hydropower Stations	Borno, Yobe	Renewable energy source and electricity supply	Low water availability, infrastructure limitations, and operational inefficiencies
5	Water Treatment Plants	Urban centers like Maiduguri and Damaturu	Ensure clean water supply for domestic and industrial use	Aging infrastructure, pollution, and inadequate capacity
6	Rainwater Harvesting Systems	Scattered in rural communities	Improve water security in arid areas	Limited adoption, low storage capacity, and evaporation losses

2.8 Climate Change

Climate change may significantly impact the water balance in the Ngada Basin by altering the seasonal movement of the Inter-Tropical Convergence Zone (ITCZ). If the ITCZ shifts north, rainfall will increase, while a southern shift may reduce it. Additionally, global warming will heighten evaporation, further decreasing runoff even if precipitation levels stay the same.

- The NWRMP (JICA, 2014) carried out an investigation into the climate change effects for Nigeria.
- The long-term trend of rainfall and air temperature in the past in Nigeria has been considered based on meteorological datasets collected from NIMET and was summarised as follows:
- There is a linear tendency of increase in air temperature in the last 50 years.
- There is a linear tendency for a decrease in rainfall in the last 50 years. However, the variation by decades is much larger than the linear decreasing rate.
- Generally, most parts of the country showed evidence of long-term temperature increase.
- Annual rainfall showed a decrease of 2 to 8 mm/year across many parts of the country.
- The JICA (2014) study analysed the statistically down-scaled output of seven Global Climate Models (GCMs) to explore the possible changes in climate conditions in the future.
- This scenario assumes high economic growth with globalization utilizing balanced energy sources.
- The changes in rainfall and temperature were averaged over 7 GCM results. It was found that the annual rainfall does not change over the coming 35 years. However, the temperature changes by 2.6 °C over a time frame.

2.8.1 Climate Change Impact on Water and Land Resources

2.8.1.1 Historical and Future Climatic Trend

Temperature Trends for The Ngada-West Chad Catchment

Overall, the mean annual temperature rises from 26.94°C in the historical period to 27.66°C in the projected period, with the maximum monthly temperature increasing from 31.94°C to 33.37°C, while the minimum rises from 22.91°C to 23.17°C. This increase, particularly during the hottest months, could have implications for agriculture (through increased evaporation and crop stress), human health (due to heat-related illnesses), and water resources (through higher demand and reduced availability). The warming trend suggests that Ngada-West Chad may face

heightened climate-related challenges in the future, aligning with broader regional warming patterns due to climate change.

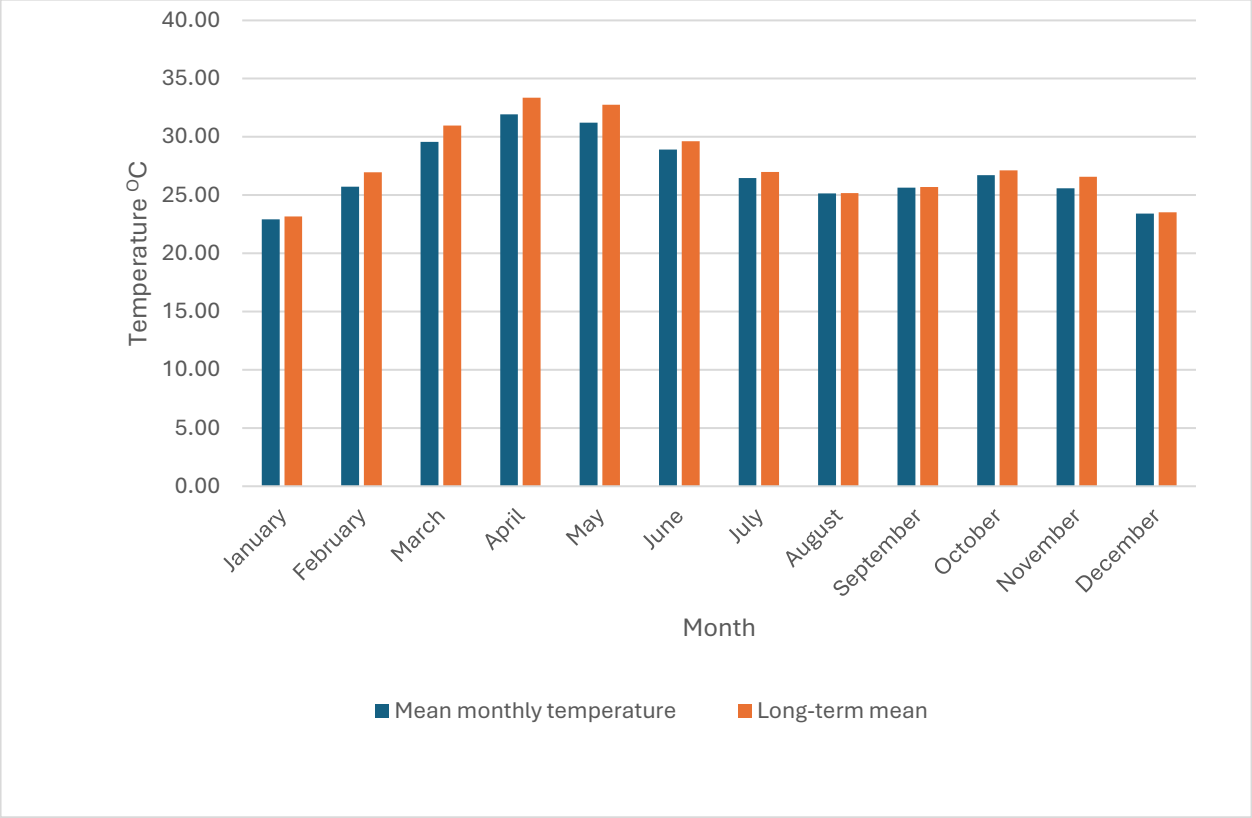

Figure 2.24: Mean monthly temperatures from 1981 to 2022 and 2023 to 2050 for Ngada-West Chad

2.8.1.1.1 Effects of climate change on annual rainfall

The bias-corrected daily rainfalls were aggregated into monthly and annual time steps. The aggregation was done over the planning horizon from 2018 to 2050. These aggregations were done for all SHAs (sub-hydrologic areas).

- The average annual rainfall (1950 to 2015) was used as a baseline value to compare changes in annual rainfall over the planning period.
- These changes were computed and plotted. The annual rainfall shows a decrease in 17 sub-catchments in the case of CNRM output, 16 sub-catchments in case of CSIRO, 16 sub-catchments in the case of GFDL, 19 sub-catchments in case of INM, 14 sub-catchments in case of CCMA, 12 in case of NCAR and 10 in case of BCM_1_1 out of 24 sub-catchments.
- On average, 15 sub-catchments show a decline in annual rainfall, whereas in the rest an increase in annual rainfall is predicted over the planning horizon.

2.8.1.1.2 Effect of Climate change on PET

The bias-corrected daily maximum and minimum temperatures were aggregated (averaged) into monthly and annual time steps. The aggregation was done over the planning horizon from 2017 to 2040. These aggregations were done for all SHAs (sub-hydrologic areas).

- The PET was computed using the Hargreaves formula. The average annual potential evapotranspiration (PET) (1950 to 2015) was used as a baseline value to compare changes in annual PET over the planning period.

2.8.2 Projected Mean Annual Temperature for The Ngada-West-Chad Catchment

Figure 2.25 shows the projected mean annual temperature trend for the Ngada-West Chad catchment from 1981 to 2050,

Figure 2.26 shows variability but a clear upward trend over the period in the mean annual temperature. The slope of the mean annual temperature is positive indicating a warming trend. The trend equation $y = 0.0212x + 26.471$ suggests an annual increase of approximately 0.0121°C, which indicates gradual warming. The R^2 value of 0.4946 suggests that the trend line explains around 50% of the variation in the mean annual temperature, indicating a strong correlation and reliable warming trend despite fluctuations. The historical record from 1981 to 2022 shows notable year-to-year temperature variability with peaks and dips. However, projected values from 2023 to 2050 show a steadier rise, closely following the trend line.

The overall increase in temperature aligns with broader climate change patterns. By 2050, the trend line will reach above 27°C, indicating significant warming compared to the starting period around 24.5°C in 1981. This gradual warming trend could affect Ngada-West Chad agriculture, water resources, and local ecosystems, as rising temperatures may increase evaporation rates and stress water availability.

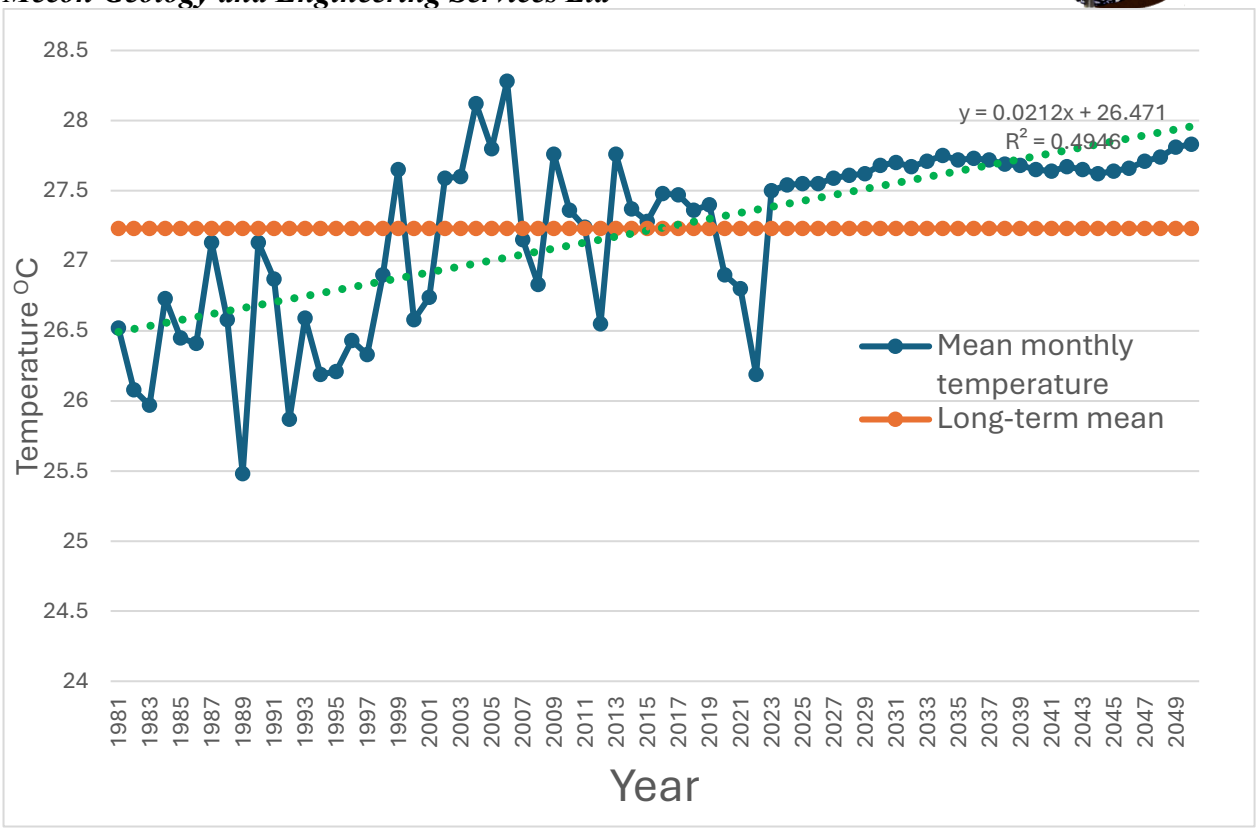

Figure 2.25: Projected Mean Annual Temperature Trend (1981-2050) for NGADA-WEST CHAD

2.8.3 Projected Annual Rainfall for Ngada-West Chad Catchment.

The figure 2.26 shows substantial interannual variability, where rainfall sometimes peaks close to or above 900 mm and drops to as low as around 400 mm. This is because the catchment experiences years with both excessive rainfall and drought conditions. Such variability can make water resource management challenging, as both unusually high and low rainfall years could impact agricultural productivity, groundwater recharge, and ecosystem balance.

The trend line equation, $y=-2.4115x+687.99$ gives a negative slope of -2.4115. This indicates that on average, annual rainfall is projected to decrease by about 2.4 mm each year. Over the period from 1981 to 2050, this adds up to a substantial overall reduction.

The R^2 (0.1798) is relatively low, suggesting that the linear trend explains only 18% of the variability in the data. This implies that while there is a general downward trend, annual rainfall is highly variable and influenced by multiple factors not captured by this linear model alone.

The declining trend in rainfall has implications for rainfed crops which rely on consistent rainfall. A reduction in rainfall could lead to water stress, impacting crop yields, livestock, and food security. The high interannual rainfall variability, which may increase in response to climate change can be problematic as it leads to unpredictable growing conditions, making it harder for farmers to plan the timing of planting and harvesting. Years with excessive rainfall could lead to flooding, soil erosion, and crop damage, while years with significantly low rainfall could result in drought, affecting water availability and increasing the risk of crop failure and loss of livestock.

The projected annual rainfall values (especially post-2030) fall below the long-term mean of around 600 mm. This may indicate a shift towards a drier climate, where the typical rainfall levels are lower than in the historical period. This long-term reduction in rainfall, coupled with increased temperature as seen in Figure 3.5, could exacerbate water scarcity, impacting not only agriculture but also drinking water supplies and natural ecosystems in Ngada-West Chad.

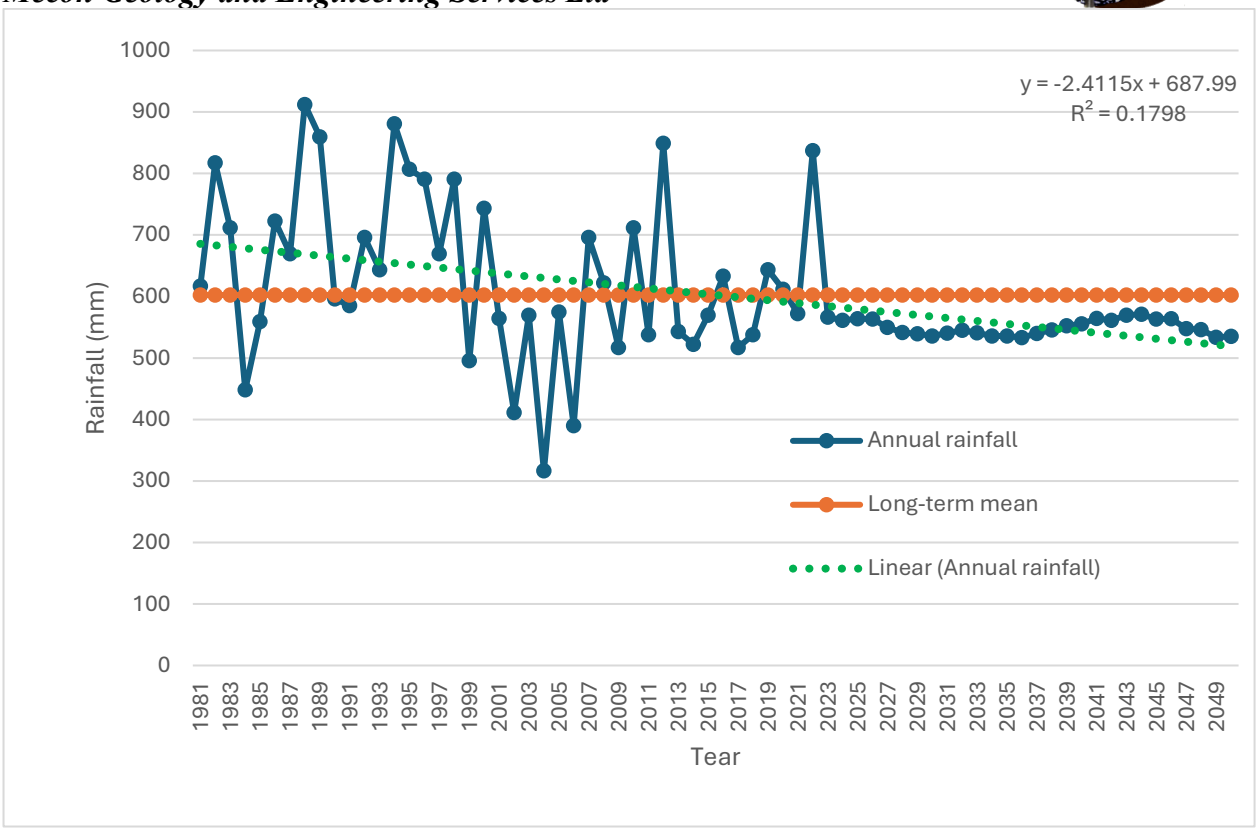

Figure 2.26: Projected annual rainfall trend (1981-2050) for the Ngada-West Chad catchment.

2.8.4 Analysis of Downscaled Output of GCMs

In order to explore the possible change in climate conditions in future, the statistically downscaled output of GCMs, which is provided by CCAFS2, are analyzed. The statistical downscaling as well as bias correction was conducted utilizing the spatial distribution of parameters provided by Worldclim3 dataset. The available dataset by CCAFS includes the average monthly precipitation and air temperature with 30 year running averages from 2020s to 2080s. As for the emission scenarios, the followings are available.

A1B: High economic growth with globalization utilizing balanced energy sources

A2: High economic growth with regionalization

B1: Low economic growth with globalization

At this moment, the downscaled output of the following seven (7) GCMs are available for download.

CCCMA-GCM3.1

CRIRO-MK3.0

IPSL-CM4

MPI-ECHAM5

MRI-CCSM3.0

UKMO-HADCM3

UKMO-HADGEM1

The downscaled data for A1B scenario with grid scale of 10 minute are spatially averaged for each HA and other related catchment areas outside Nigeria for further analysis.

In general, the average change among the different outputs from the GCMs is much smaller than the standard deviation. This indicates that there is a lot of uncertainty on the change in precipitation.

For all HAs, the precipitation tends to decrease during MAM (March, April, May) and increase during JJA (June, July, August) and SON (September, October, November).

For the southern areas such as HA-5, -6 and-7, the precipitation tends to decrease during DJF (December, January, February), whereas it tends to increase in the central and northern areas.

These tendencies could bring about a drier dry season and wetter wet season, especially in the southern area.

The rate of change increases gradually with time in general, which amplifies the initial direction of change.

2.8.5 Evapotranspiration

Figure 2.27 shows the trend in evapotranspiration (ET) for the Ngada-West Chad Catchment, illustrating changes over the historical (1990–2023) and projected (2024–2050) periods.

The annual evapotranspiration displays annual fluctuations in ET, showing an increasing trend over time. The linear trend indicates a statistically significant upward trend in ET, with an R^2 value of 0.7285, demonstrating that 72.85% of the variability in annual ET is explained by this linear trend.

The historical period shows significant interannual variability, with alternating peaks and dips in ET values. Despite the variability, there is a clear upward trend in ET, attributed to factors such as climate change, rising temperatures, and changes in land use. Increasing ET means greater water loss from soil and vegetation, which could lead to stress on crops and water resources, especially during dry years.

Projections from 2024-2050 indicate a continued rise in ET at a steeper rate, as shown by the trend line extension. The ET consistently exceeds the historical long-term mean, posing challenges for water availability. This increasing trend will exacerbate water scarcity, particularly in catchment.

In terms of agricultural productivity, increased ET will lead to higher water demand for crops, necessitating enhanced irrigation strategies. Crop yields might decline if water availability does not meet demand, particularly during critical growth stages. The water resources will also be affected intensifying competition for water among agriculture, domestic use, and ecosystems. This could also affect reservoirs and groundwater systems which might experience more rapid depletion, impacting sustainability.

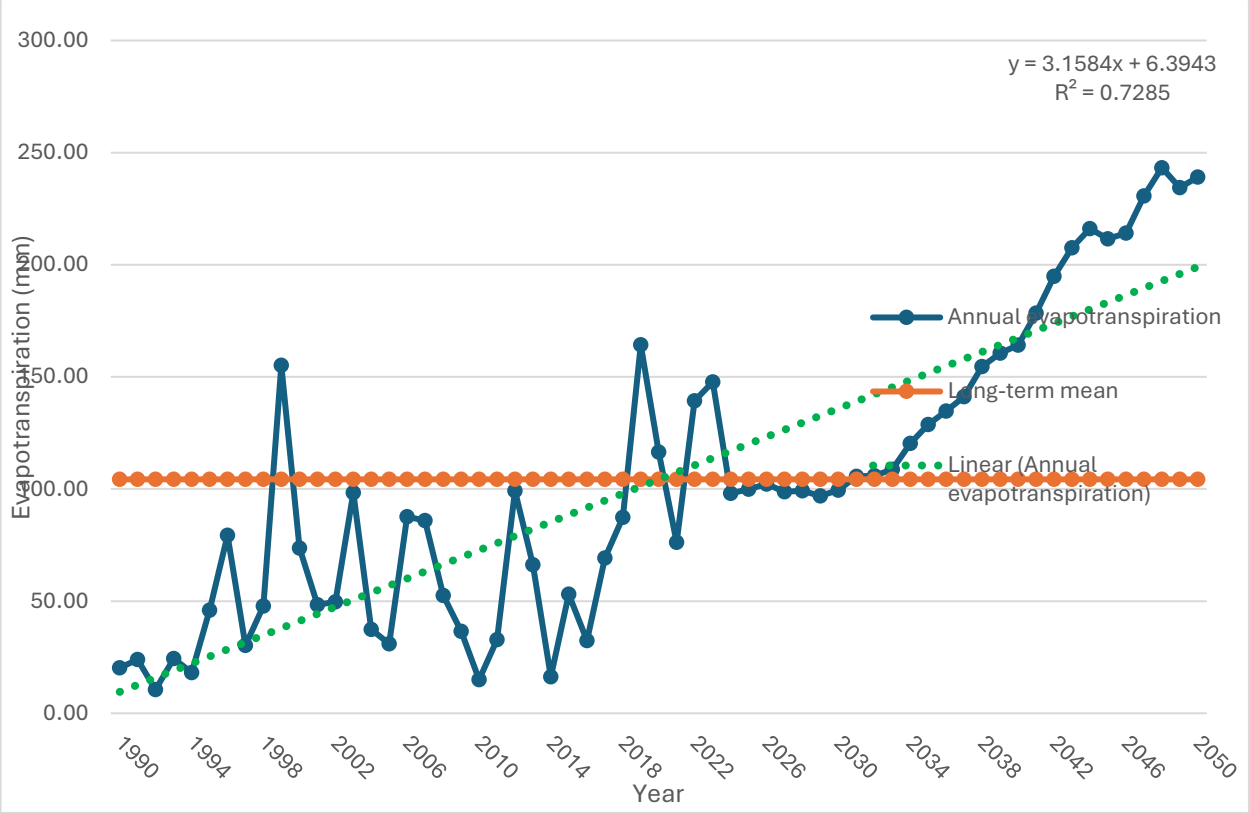

Figure 2.27. Trend in Evapotranspiration for Ngada-West Chad Catchment.

2.8.6 Major Impacts of Climate Change

Climate change has devastating effects on several sectors of the environment, some of which include socio-economic, health, and infrastructure. Table 2.20 gives some of the details of these impacts mentioned

Table 2.20: Key Impacts of Climate Change

Impacts	Details
Economic	Damage to infrastructure Loss of property and assets Disruption of businesses and services Increased costs for emergency response and recovery
Social	Loss of life and injury Displacement and migration Psychological trauma and stress Social disruption and community cohesion
Environmental	Water pollution Soil erosion and sedimentation Loss of biodiversity Increased risk of waterborne diseases
Health	Waterborne diseases Vector-borne diseases Mental health impacts Injuries and trauma
Infrastructure and Service	Power Outage Transportation disruption Water and sanitation disruption Communication disruption

2.8.7 National and International Climate Change Frameworks/Agreements

Temperature Trends: Air temperature in Nigeria has increased linearly over the past 50 years.

Rainfall Trends: Rainfall has shown a declining trend, decreasing by 2 to 8 mm per year in many areas.

Decadal Variability: Rainfall fluctuations vary significantly by decade, exceeding the overall declining trend.

Future Projections (JICA, 2014): Annual rainfall is expected to remain stable over the next 35 years, while temperature may increase by 2.6°C.

2.8.7.1 Climate Change Scenarios

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

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

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

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 SubSaharan 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 conditions 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 marks a key step in addressing the impacts of climate change in line with the Paris Agreement and UNFCCC. It provides a comprehensive analysis of greenhouse gas emissions, climate vulnerability, and tailored adaptation and mitigation strategies for Nigeria's unique circumstances.

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.

- Greenhouse Gas (GHG) Inventory and Emissions Trends
- Vulnerability and Impacts of Climate Change
- Adaptation Measures and Challenges
- Mitigation Strategies and Potential
- Barriers to Climate Action
- International Cooperation and Support Needs
- Some of the outcomes and Future Steps are also presented below.
- Strengthening Policy Frameworks
- Public Awareness and Community Engagement
- Focus on Renewable Energy Expansion
- Capacity Building and Research Development

2.8.7.4 Nigeria's Third National Communication on Climate Change

The Third National Communication on climate change highlights Nigeria's commitment to climate action and sustainable development. It reviews GHG emissions, climate vulnerabilities, and adaptation strategies, noting that the AFOLU sector contributes 60.1% of emissions. Without intervention, emissions could rise over 58% by 2035, exacerbating droughts, desertification, flooding, and water scarcity.

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

- Capacity Building, Technology Transfer, and Financial Needs
- Enhanced Policy Framework and Institutional Coordination
- Scaling Up Renewable Energy and Green Economy Initiatives
- Strengthening Community Engagement and Resilience Building
- 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 a weighted overlay process, allowing for nuanced ranking of locations based on various factors. This method provides more detailed information than binary analysis by identifying vulnerability levels. We need to break down the flood vulnerability problem into smaller sub-models for better assessment sub-models.

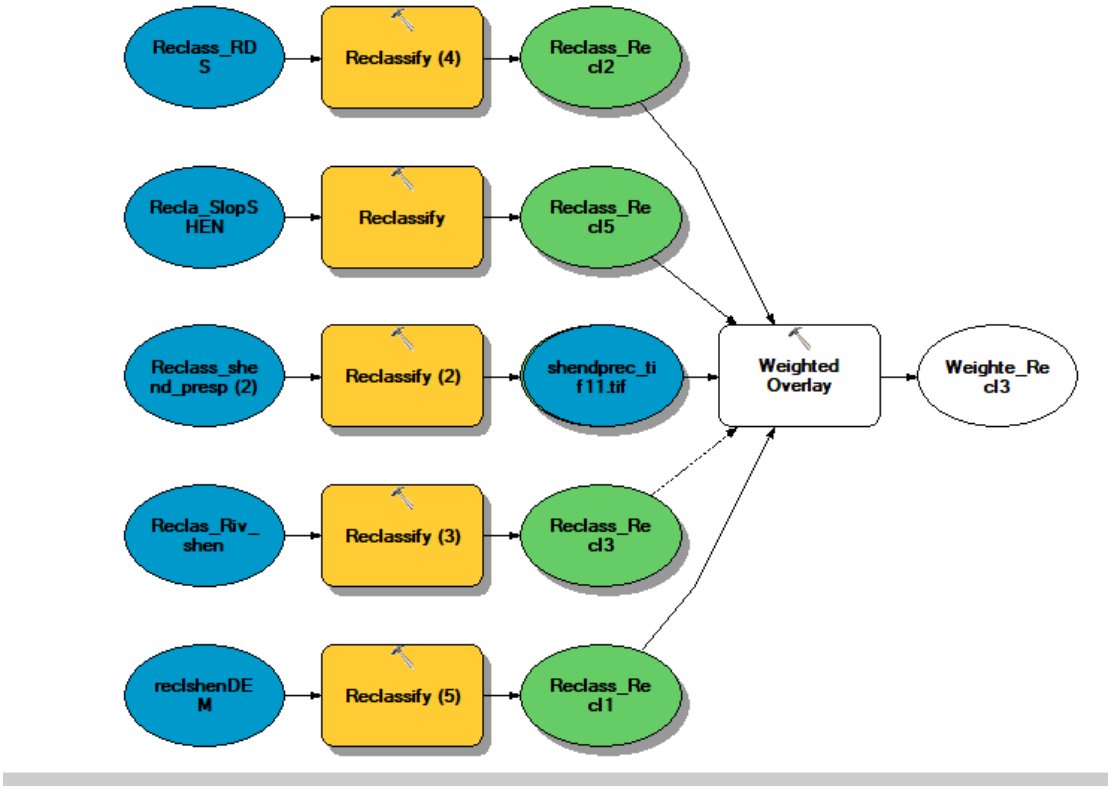

Figure 2.28: The flow chat of the Methodology

We identify key factors in determining vulnerable areas, using datasets such as slope, elevation, proximity to rivers, land use, and rainfall. Each layer is standardized through reclassification for a common scale before performing a weighted overlay. We assign weights to the layers, combine them, and analyze the results.

2.9.1 The Digital Elevation Map (DEM)

The digital elevation map (DEM) of the Ngada Catchment area highlights distinct elevation variations, with the highest point at 757m near southern Borno and Yobe states and the lowest at 194m. This indicates steep slopes and significant disparities in elevation, while much of the catchment features generally flat terrain. Figure 2.29 shows the DEM of the strategic catchment.

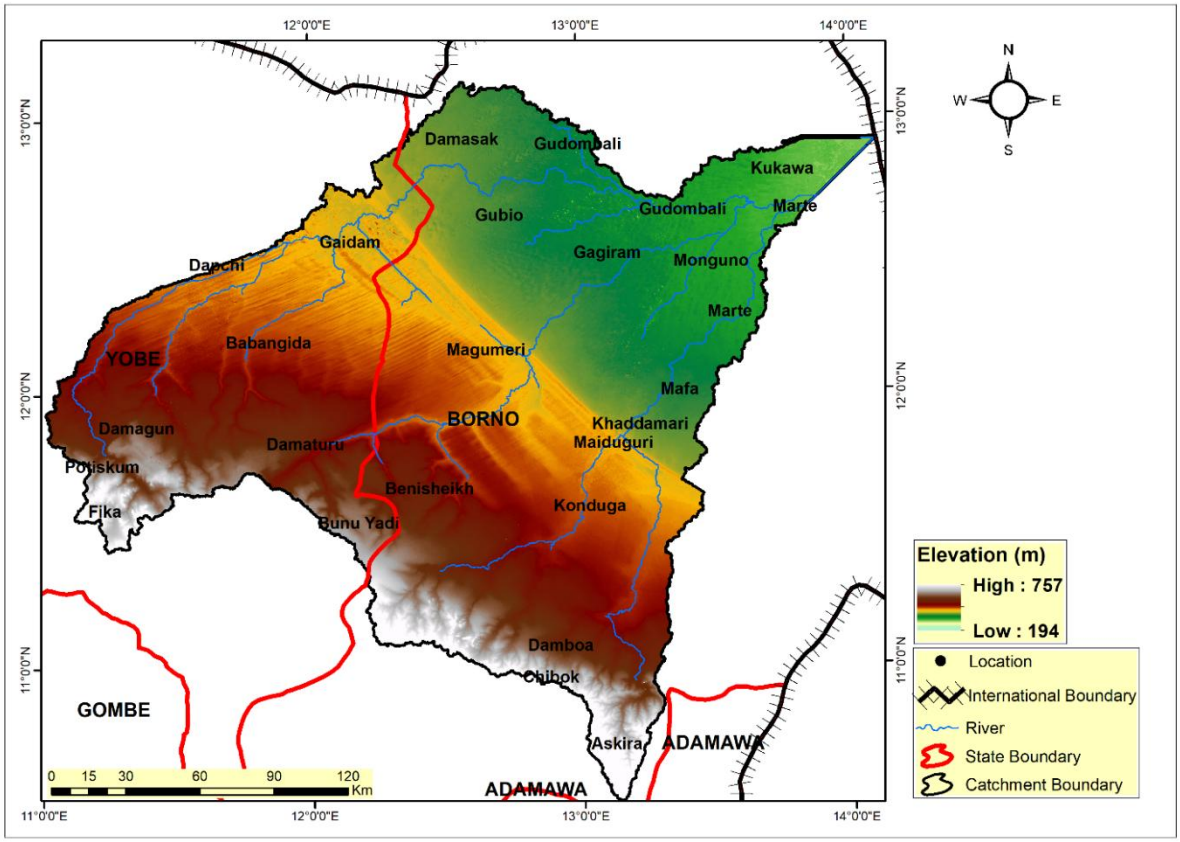

Figure 2.29: Digital Elevation Model of the Catchment (Source: MSL, 2024)

2.9.2 Slope map

The slope map is essential for understanding the catchment's topography, showing levels of terrain inclination. Flat to gentle slopes (0–60) increase water pooling and flood risk, especially in the northern part. Moderate slopes (7–130) enhance runoff and reduce water retention, raising soil erosion risk

- Steep slopes (14–220) are susceptible to swift runoff and increased erosion and flooding, potentially causing the displacement of sediment and accelerated downstream water flow.
- Very steep slopes (25-580) represent the steepest gradients in the area where the velocity of runoff is at its maximum.

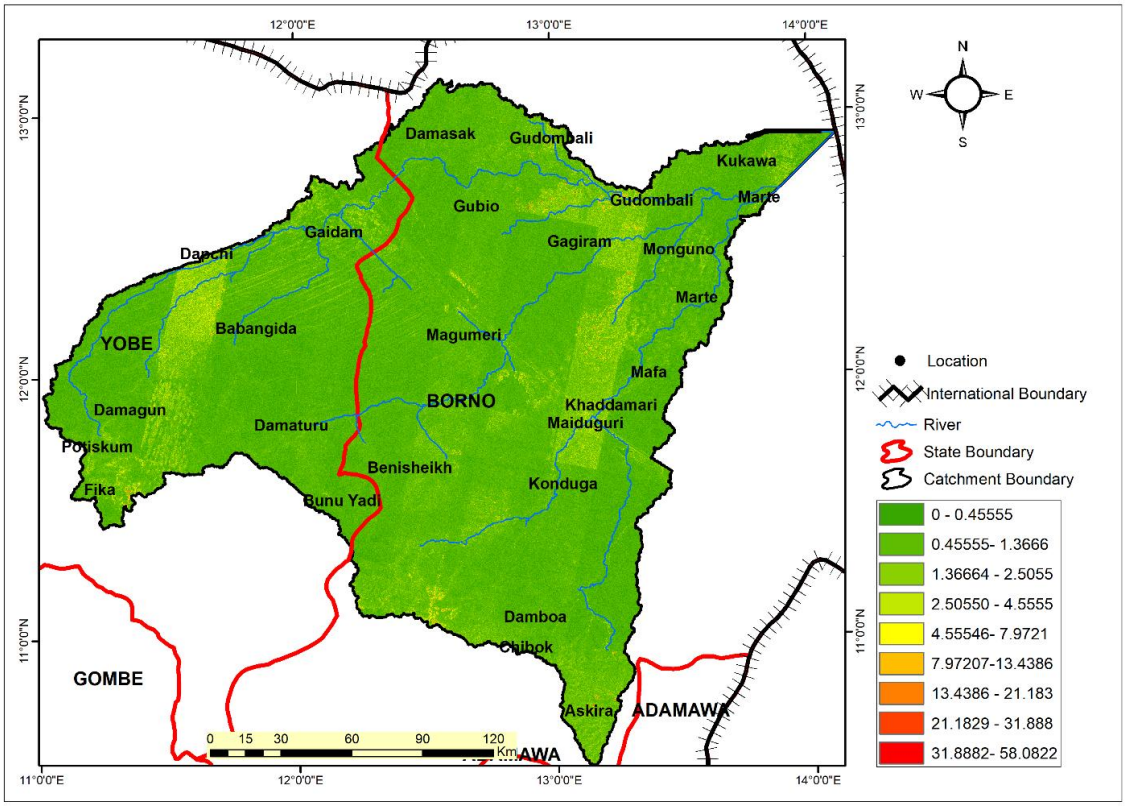

Figure 2.30: Slope Map of The Catchment (Source: MSL, 2024)

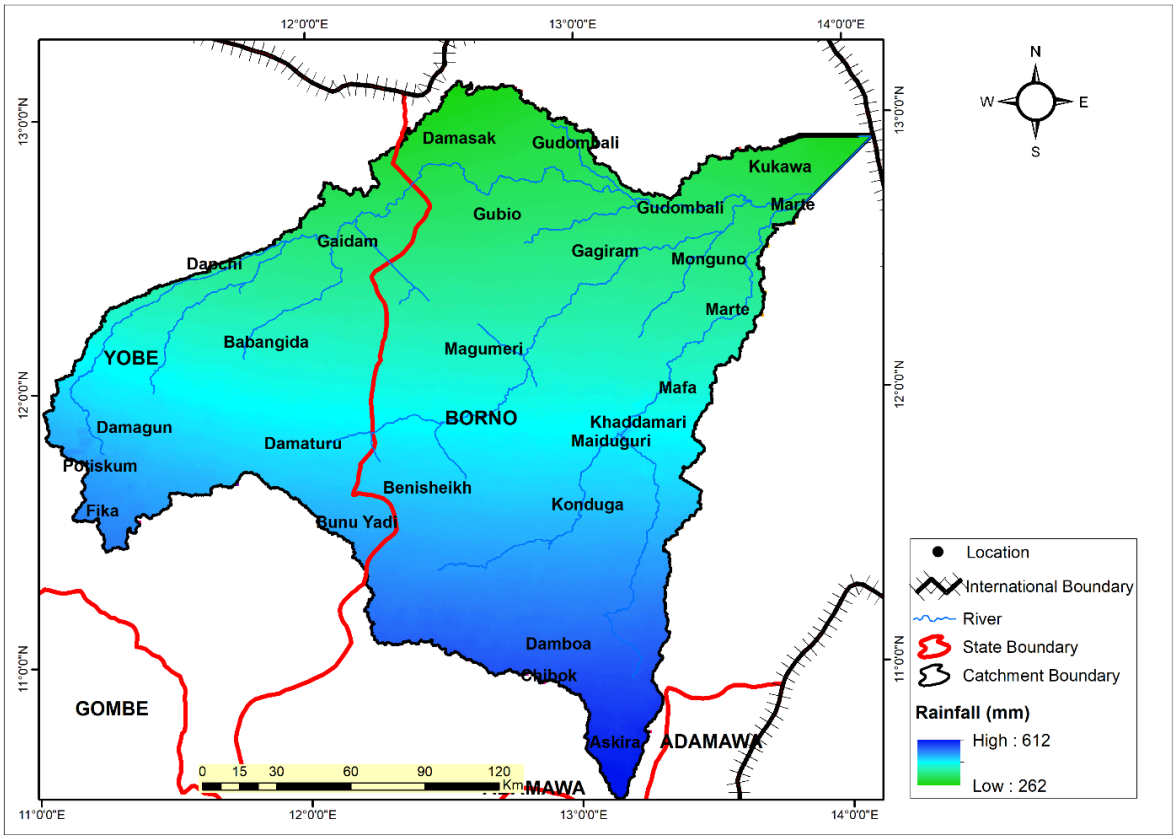

Figure 2.31: Rainfall Map of The Catchment (Source: MSL, 2024)

2.9.3 Proximity to water sources

Proximity to streams is crucial in flood vulnerability analysis, as being near rivers increases flood risk. The study indicates that areas within 0-9 km from the river are at higher risk, while those 38-48 km away are less vulnerable.

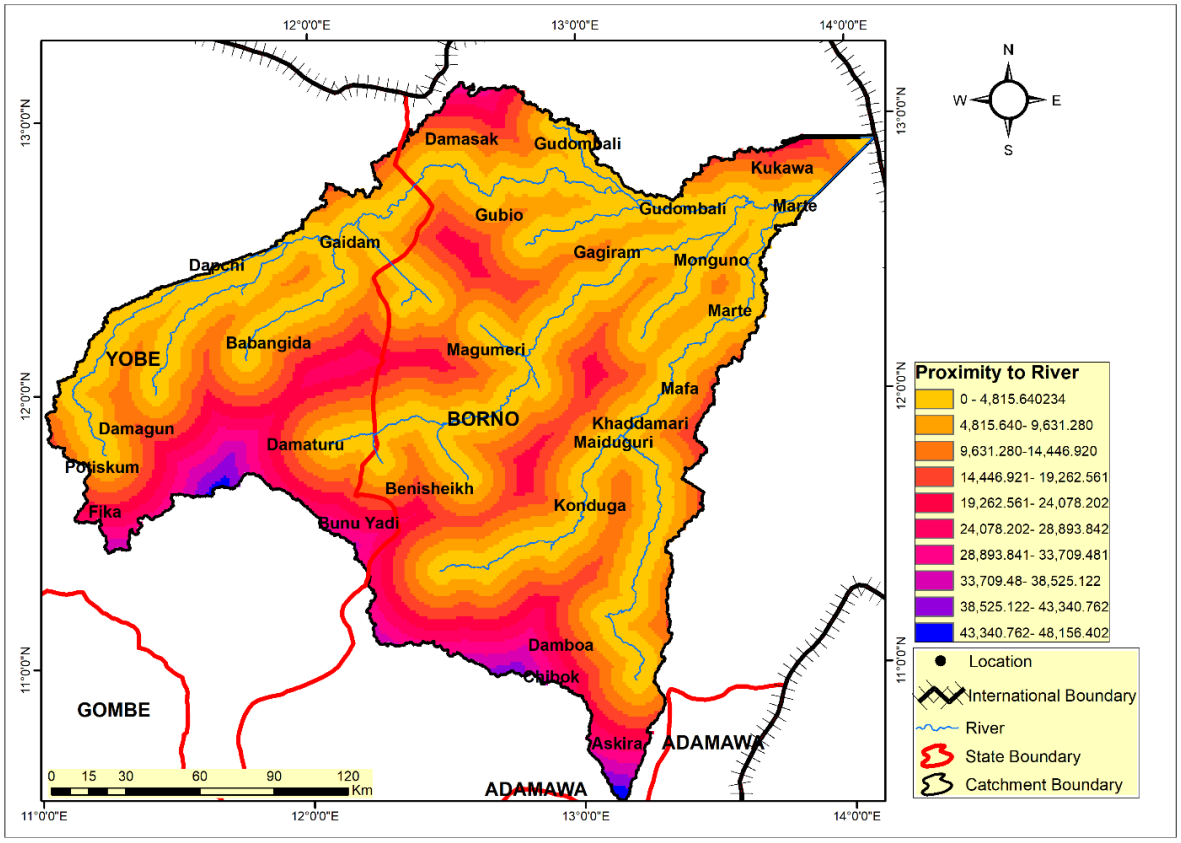

Figure 2.32: Proximity to River Map of the Catchment (Source: MSL, 2024)

2.9.4 LULC

Land use is a key factor in flood vulnerability analysis, with the following vulnerability ratings assigned:

- Water body (5): Extremely vulnerable due to overflow and flooding.
- Riparian/wetland (5): Highly susceptible to flooding.
- Settlement/built-up (4): High vulnerability from impermeable surfaces increasing runoff.
- Cropland (3): Moderate vulnerability; can retain some water, but runoff is possible.
- Bare surface (3): Moderate vulnerability; limited vegetation leads to higher runoff and erosion.
- Shrubland (2): Low vulnerability; some vegetation reduces runoff.
- Vegetation/forest (1): Least vulnerable; dense vegetation enhances water absorption and reduces runoff.

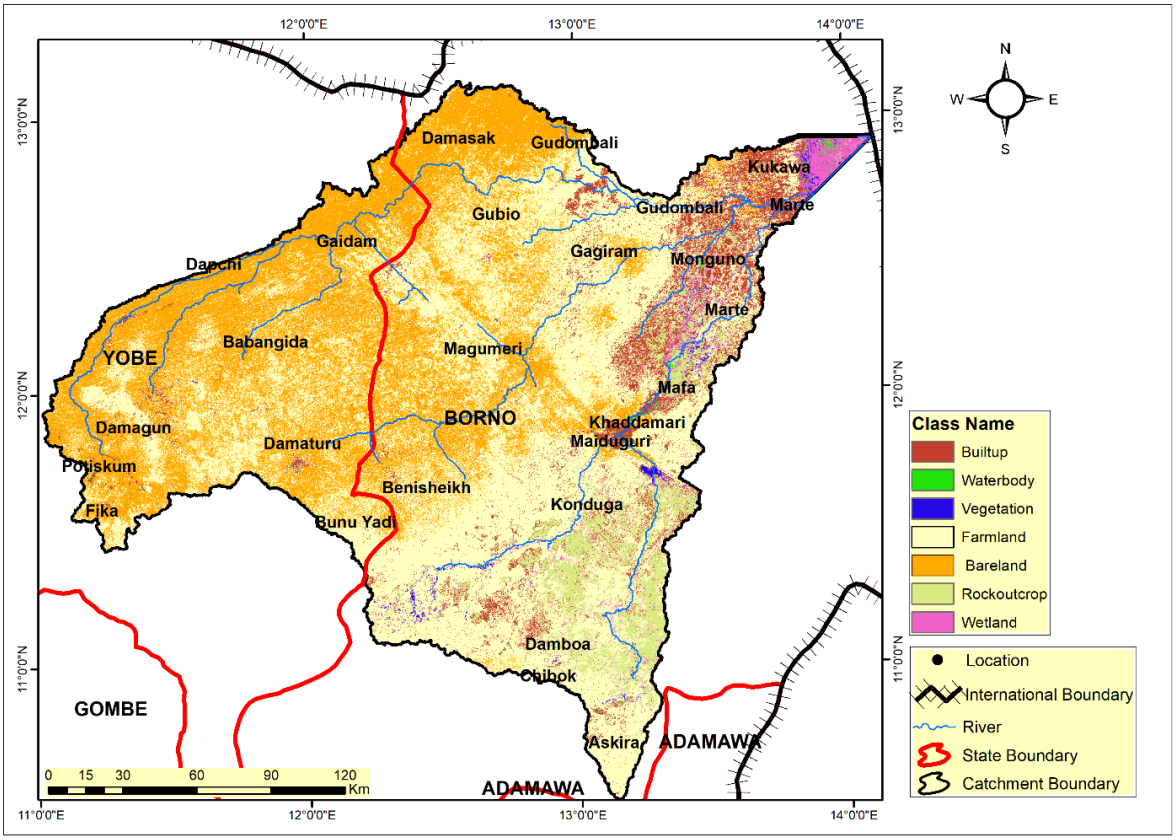

Figure 2.33: LULC Map of The Catchment (Source: MSL, 2024)

2.9.10 Flood Risk

The study utilized a weighted overlay analysis to assess flood vulnerabilities across the catchment, creating a composite flood vulnerability map by overlaying datasets such as DEM, proximity to rivers, precipitation, slope, and land use.

- Each layer was categorized, weighted, and scored on a 1-9 scale, with proximity to rivers receiving the highest weight.
- The map identifies five risk levels: Highly not vulnerable, Not Vulnerable, Moderate, Vulnerable, and Highly Vulnerable, covering a total area of 4.35 km².
- Low-risk areas are predominantly in high-elevation regions and around Lake Chad, while moderate flood zones are found near the Adamawa mountains.
- High and very high vulnerability zones are mainly in lower-elevation areas, which are at increased risk due to their proximity to highland.

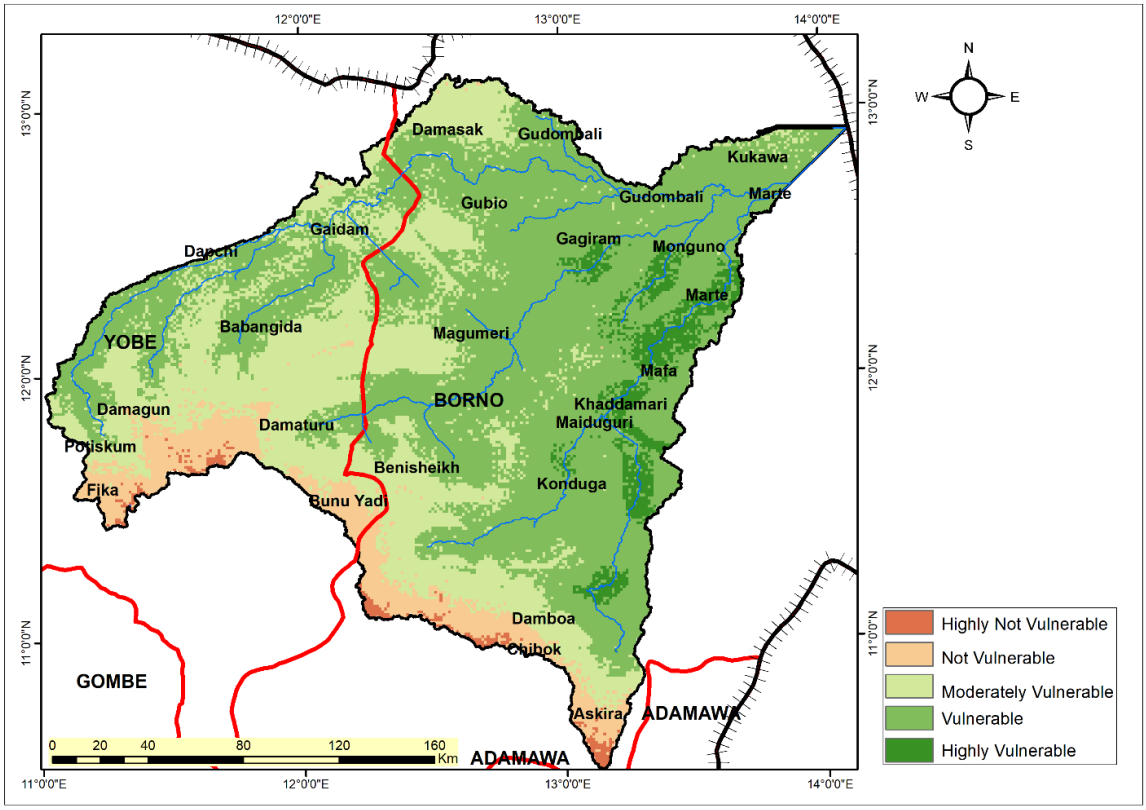

Figure 2.34: Flood Vulnerability Map of the Catchment (Source: MSL, 2024)

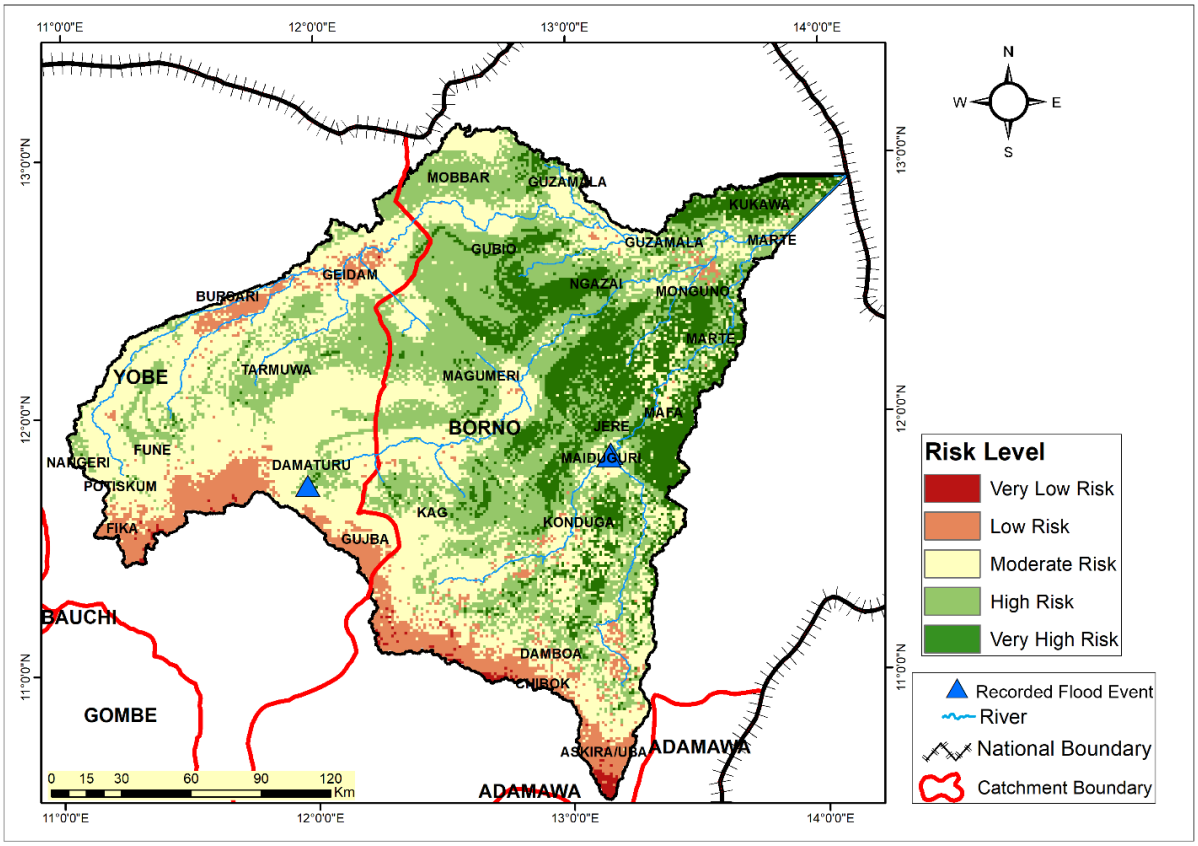

Figure 2.35: Flood Risk Level Map. (Source. MSL 2024)

Table 2.21: Flood Risk Analysis of the Catchment

CLASS_NAME	Ha	%
Builtup	167522.8	10.59725
Waterbody	4456.62	0.281919
Vegetation	4595.31	0.290693
Farmland	988405.8	62.52515
Bareland	306432.5	19.38448
Rockoutcrop	72577.17	4.591129
Wetland	36823.05	2.329374

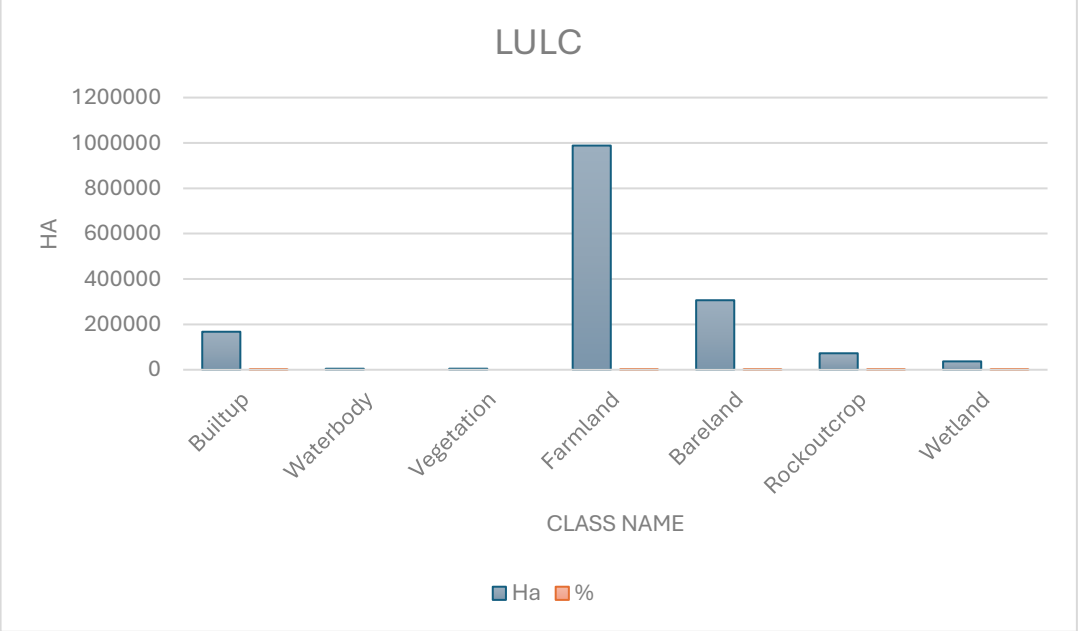

Figure 2.36: Flood Risk LULC analysis of the Catchment (Source: MSL, 2024)

Flooding in this catchment area is a recurring phenomenon, causing property destruction, disruption of human activities, and in some cases, fatalities.

- The September 2015 flooding severely impacted Maiduguri, displacing many families and damaging vital infrastructure. In September 2017, intense rainfall, rising river levels, and ongoing insurgency led to widespread flooding, overwhelming the local health system and resulting in a cholera outbreak.
- Similarly, the September 2022 flood devastated communities around Damaturu and Nguru, displacing thousands and destroying significant infrastructure like schools, roads, and health facilities.

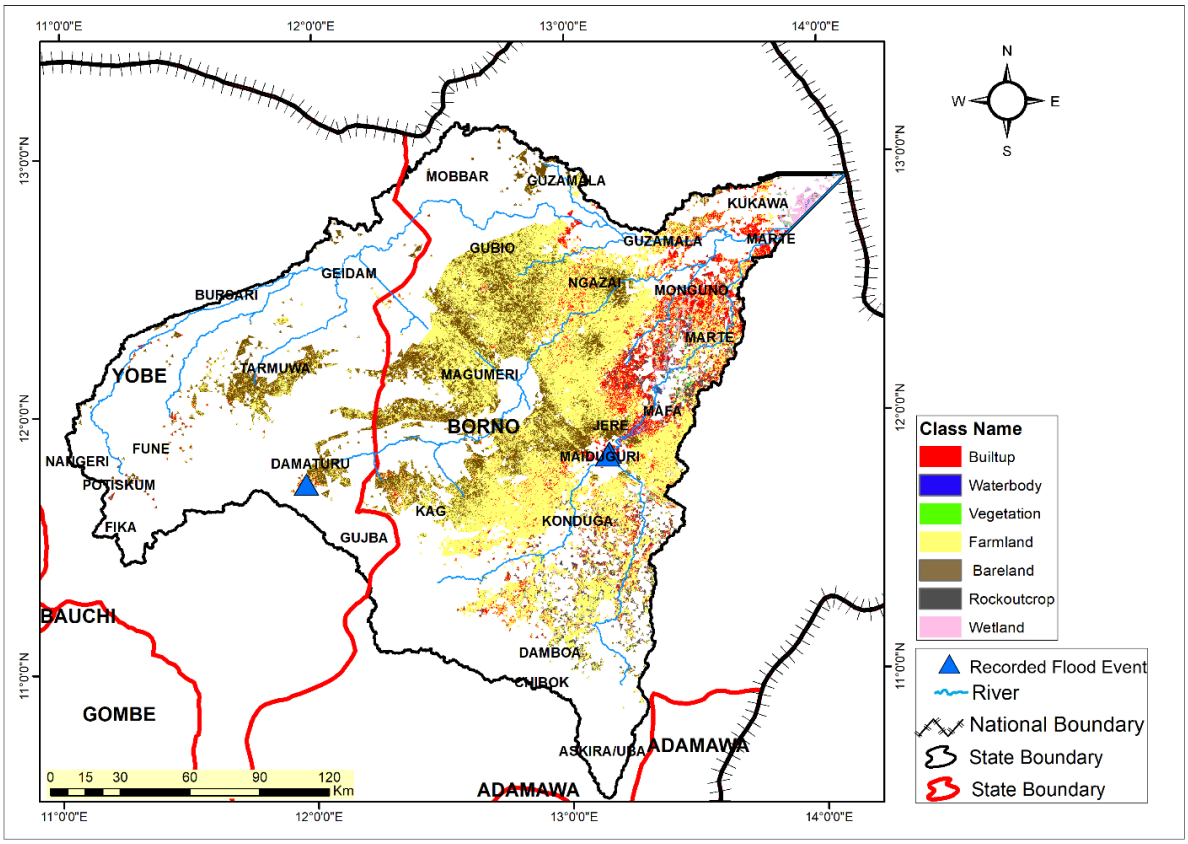

Figure 2.37: Flood Event Map (Source. MSL 2024)

- The August, 2023 flooding event in Borno State also affected various communities such as Maiduguri and Jere.
- This flooding was also attributed to heavy rains and inadequate drainage systems which led to widespread inundation, displacing thousands of people and destruction to properties worth millions of naira.
- In response to this disaster, camps were established for the internally displaced persons.
- The most recent catastrophic flooding of September, 2024 which affected various communities across Maiduguri, Bama and Jere towns caused massive destruction in the affected communities.
- This devastating event was attributed to heavy rainfall and the collapse of the already failing Alau dam that led to the displacement of over 1,000,000 people, destruction of infrastructure, and at least 30 fatalities.
- The flood risk analysis shows farmland of 988,405.8Ha at 62.53% at high-risk and built up at 167522.8 representing about 11%.
- This shows that the urban/settlement areas are at high risk to flooding in this catchment after farmlands.

2.10 Socio-Economic Dynamics

2.10.1 Population Distribution and Growth

The catchment is among the largest in the country, facing significant challenges from the Boko Haram insurgency, which has impacted its socio-economic landscape. Understanding population demographics and growth trends is essential for planning and development aimed at revitalizing the state. The chart below, figure 2.38 Indicates the catchments population projection:

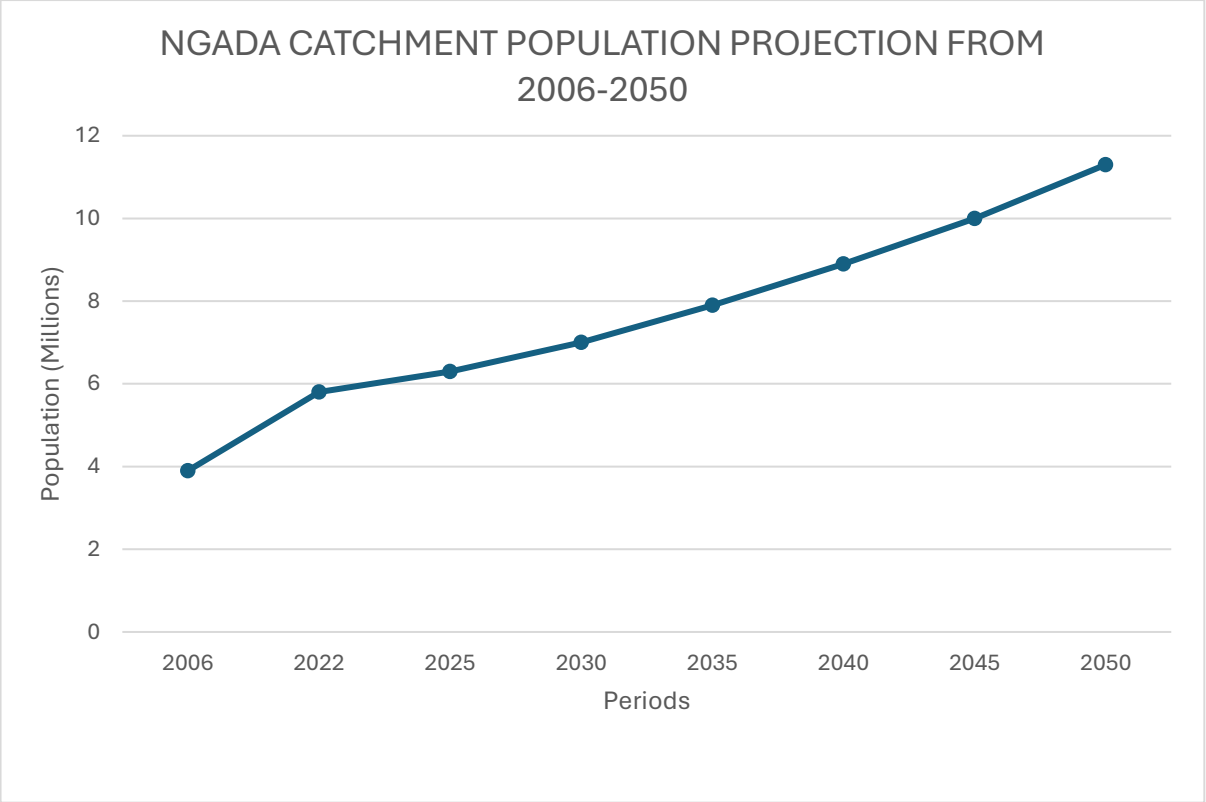

Figure 2.38: Population projection in the catchment

Table 2.22: Summary of the characteristics of Ngada-West-Chad Catchment Management plan.

NAME	STATE	POPULATION	GEOGRAPHY	GEOLOGY	HYDROLOGY HYDROGEOLOGY	VEGETATION	SOCIO-ECONOMICS
Ngada- West-Chad Catchment	Borno, Yobe	population projected to reach 11 million by 2050 Major Cities Borno, Maiduguri. Yobe(Potiskum, Damaturu	Location: North Eastern Nigeria. Covering part of Borno and Yobe. Size: Approximately 4.43 Million hectares. Topography: The catchment is predominantly flat terrain features with vast plains and	The geology of the Ngada West-Chad catchment is diverse, with distinct variations across its regions. In the northern section, the Chad Basin is dominated by sedimentary rocks, including alluvial deposits,	Drainage System. The Ngada catchment exhibits a dendritic drainage pattern where several tributaries join the main river at various locations creating a convergence towards a single channel Groundwater Resources: Aquifer provide essential water, but face pressure due to demand and potential salinization.	Predominantly Vegetation: Sudanian Savanna With transition toward Sahel vegetation. Vegetation degradation Overgrazing deforestation and desertification threaten the natural vegetation cover, impacting	Livelihood activities in the Ngada West Chad Catchment are vital for economic survival and food security, but many are unsustainable, leading to environmental degradation, water resource depletion, and socio-economic instability

			low-lying areas, with altitudes ranging from about 200 meters above sea level in the southwest to approximately 500 meters near the northeastern border with Chad.	sandstones, and clays, contributing to the formation of sandy soils.		soil quality and water retention.	Water dependence: Communities heavily rely on the Ngada River and groundwater for survival and economics activites.

2.10.2 Demographics and Poverty

Table 2.23. Catchment Demographics and Poverty.

State	Demographics and Poverty
Borno and Yobe	• The Ngada (West Chad) Catchment area encompasses a group of local governments in Borno and Yobe States, Nigeria, each facing unique yet interconnected challenges regarding poverty and food insecurity. This region has been significantly affected by protracted conflicts, economic downturns, and climatic shocks, resulting in alarming poverty levels that require urgent attention from policymakers, humanitarian organizations, and development agencies. • Based on the Cadre Harmonisé framework, the local governments within the Ngada (West Chad) Catchment area have been categorized into two main poverty classifications: High Poverty (51% - 70%) and Very High Poverty (71% and above). The data reveals a grim reality where a substantial portion of the population experiences severe hardship, with many local governments falling into the extreme poverty category. • **High Poverty Local Governments:** • Jere, Maiduguri, Borsari, Damaturu, Fika, Fune, Geidam, Gujba, Nangere, Potiskum, and Tarmuwa fall within the high poverty category, with poverty percentages ranging from 51% to 70%. This level of poverty indicates that these areas face significant barriers to accessing basic needs such as food, healthcare, education, and clean water. The residents in these local governments often experience food insecurity, limiting their ability to maintain a stable and healthy diet. • In Jere and Maiduguri, which are urban centers, poverty manifests through inadequate infrastructure, insufficient healthcare services, and a high number of internally displaced persons (IDPs) due to ongoing conflicts. The influx of IDPs exacerbates the strain on

resources, making it challenging for local authorities to address the basic needs of both the local and displaced populations.

- **Very High Poverty Local Governments:**
- The local governments classified under extreme poverty include Askira/U, Chibok, Damboa, Gubio, Guzamala, Kaga, Konduga, Kukawa, Mafa, Magumeri, Marte, Mobbar, Monguno, and Nganzai. These areas have poverty rates exceeding 71%, indicating a critical need for immediate intervention.
- The extreme poverty levels in these local governments can be attributed to several factors, including a lack of economic opportunities, disrupted agricultural activities, and limited access to markets. Agriculture, which serves as the primary livelihood for many households, has been severely hampered by conflict and environmental changes, leading to diminished food production and increased reliance on food aid.
- For instance, Kukawa and Guzamala have experienced recurrent attacks from insurgent groups, which have displaced farmers and destroyed agricultural infrastructure. Consequently, families are unable to cultivate their lands, resulting in food shortages and heightened vulnerability to malnutrition.
- **Underlying Causes of Poverty**
- Several interconnected factors contribute to the high and extreme poverty levels observed in the Ngada (West Chad) Catchment area (refer to **Error! Reference source not found.** below):
- Conflict and Insecurity: The protracted conflict in northeastern Nigeria has resulted in widespread destruction of livelihoods, displacement of communities, and loss of access to essential services. The ongoing violence creates a cycle of poverty, as families are forced to abandon their homes and sources of income.
- Economic Decline: The local economies in these areas have been severely impacted by conflict, leading to high unemployment rates and reduced income-generating activities. The lack of economic

	diversification further exacerbates the situation, trapping communities in a cycle of poverty. • Climate Change: Climate variability and extreme weather events, such as droughts and flooding, have compounded the vulnerabilities faced by communities in the catchment area. These environmental changes adversely affect agricultural productivity, pushing more households into extreme poverty. • Limited Access to Education and Healthcare: Poor access to quality education and healthcare services perpetuates the cycle of poverty. Families unable to invest in their children's education face reduced opportunities for upward mobility, while inadequate healthcare systems contribute to poor health outcomes, further diminishing economic productivity.

2.10.2.1 Unsustainable Livelihoods

Livelihood activities in the Ngada West Chad Catchment are vital for economic survival and food security, but many are unsustainable, leading to environmental degradation, water resource depletion, and socio-economic instability. Some of these unsustainable livelihoods are outlined below:

Unsustainable Agricultural Practices: Over-Cultivation & Soil Degradation: Continuous farming without soil restoration depletes nutrients and reduces productivity. Relying on rainfed agriculture often leads to crop failures during droughts. Additionally, deforestation for farmland exacerbates climate change, soil erosion, and biodiversity loss.

Overgrazing and Pastoralism Challenges: Excessive Grazing Pressure: High livestock numbers exceed the land's carrying capacity, causing vegetation loss and desertification. Conflict Over Land & Water: Farmer-herder conflicts increase as pastoralists encroach on farmlands due to shrinking grazing lands.

Unsustainable Fishing Practices: Overfishing in Lake Chad & Rivers: Excessive fish harvesting reduces fish stocks, threatening food security and livelihoods. Use of Harmful

Fishing Methods: Practices like chemical poisoning and fine-mesh nets damage aquatic ecosystems.

Resource Over-Extraction (Deforestation & Mining): Unregulated Logging & Charcoal Production: Large-scale tree cutting for fuelwood contributes to deforestation and worsens climate change impacts. Sand & Mineral Extraction: Uncontrolled mining of sand, gravel, and limestone depletes land resources and leads to water pollution and habitat destruction.

Climate Change & Water Resource Stress: Reduced Rainfall & Droughts: Declining water availability intensifies competition for water resources, affecting livelihoods. Flooding & Land Erosion: Poor land management increases flood risks, damaging farmlands and settlements.

2.10.3 Gender Issues

2.10.3.1 Challenges

Women and girls bear the primary responsibility for water collection, often covering long distances due to scarce and unreliable sources.

- Inadequate infrastructure and climate change have further restricted access to clean drinking water, increasing health risks and sanitation challenges.
- Additionally, limited participation in water resource management prevents women from effectively addressing their water-related needs.
- Traditional inheritance laws and patriarchal structures restrict women's ability to own or inherit land, limiting their control over agricultural production and economic opportunities.
- Additionally, women face barriers to accessing credit, improved seeds, irrigation systems, and agricultural extension services, which significantly hampers their productivity.
- Conflict-induced displacement has further eroded women's land tenure security, exacerbating their vulnerability to poverty and economic instability.
- Women remain underrepresented in catchment management committees, water governance, and policy-making processes, limiting their influence in natural resource management.
- Deep-rooted gender norms often restrict women's access to leadership roles, reinforcing systemic exclusion. Although certain policies promote gender inclusion,

their implementation at the local governance level remains inadequate and inconsistent.

2.10.3.2 Opportunities

Enhancing women's participation in local water user associations can improve water security and resource distribution.

- Expanding boreholes, rainwater harvesting, and irrigation will reduce the time spent collecting water and boost productivity.
- Strengthening women's land rights can drive agricultural growth and economic empowerment.
- Supporting women-led cooperatives will improve access to resources and training.
- Increasing women's representation in water governance fosters inclusive decision-making.
- Additionally, capacity-building in water management, climate adaptation, and leadership will enhance community resilience and sustainability.

2.10.3.3 Recommendations

I. **Improving Women's Access to Water**: Expand boreholes, rainwater harvesting, and irrigation systems to reduce women's workload. Establish gender-inclusive water user associations for equitable water distribution. Improve sanitation and hygiene facilities, especially in rural and conflict-affected areas.

II. **Strengthening Women's Land Ownership and Agricultural Access:** Promote legal reforms for women's land ownership and inheritance rights. Enhance access to credit, seeds, irrigation, and support women-led farming cooperatives for resource sharing and market access.

III. **Increasing Women's Representation in Decision-Making**: Implement gender-inclusive policies in water management committees. Offer training in water management, climate adaptation, and leadership. Enhance policy enforcement at all levels.

IV. **Promoting Alternative Livelihoods for Women:** Promote eco-tourism, agro-processing, and renewable energy for diverse income. Offer vocational training in water conservation, agribusiness, and environmental management. Ensure financial inclusion via microfinance, savings groups, and small business loans.

V. **Addressing Gender-Based Barriers in Resource Management:** Raise awareness to challenge restrictive gender norms in land and water governance. Engage community leaders and policymakers to promote gender-sensitive approaches. Monitor and evaluate gender initiatives to track progress in achieving equity.

CHAPTER 3 : STAKEHOLDER ENGAGEMENT AND GOVERNANCE

3.1 Methodology

Considering that the strategic catchment management plan study was conducted on a macro level, stakeholder mapping for participants was done mainly on an institutional level. The institutions sent in representatives at a central location. Information was gathered through interviews, focus group discussions and outright enquires.

3.2 Key Stakeholders Engaged

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

- Natural Resources (Land, water, vegetation, wildlife, minerals etc.)
- Threats and Challenges
- Socio-economics
- Policies

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

Borno State:

i. Chad Basin Development Authority, Maiduguri-Borno
ii. Northern Borno Development Initiative Initiatives-Borno
iii. Kanem Borno Human Development Association (Kabhuda).-Borno
iv. Centre for Arid Zones Studies, Uni Maid-Borno
v. Farmers association/ pastoralists of the State
vi. Rural Water Supply and Sanitation Agency (RUWASA)
vii. State Ministries of Environment,
viii. State Ministry of Agriculture and food security
ix. State Ministry of Water Resources,
x. State Ministry of Min of Lands,
xi. State Ministry of Women Affairs,
xii. State Ministry of Solid Mineral Development
xiii. State Miners Association

Yobe State:

i. Hadejia Jama'are Komadugu Yobe Basin Trust Fund, Damaturu-Yobe
ii. Komadugu Yobe Basin Wetlands Development Initiative-Yobe
iii. Kumadugu Yobe Basin Development Initiatives Hadejia-Yobe
iv. Farmers association/ pastoralists of the State
v. Rural Water Supply and Sanitation Agency (RUWASA)
vi. State Ministries of Environment,
vii. State Ministry of Agriculture and food security
viii. State Ministry of Water Resources,
ix. State Ministry of Min of Lands,
x. State Ministry of Women Affairs,
xi. State Ministry of Solid Mineral Development
xii. State Miners Association

3.3 Major Topics for Stakeholder Discussions

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

Stakeholders participated in group discussions within each State to address important issues related to catchment development and explore opportunities for tackling these challenges. The FPMU team initially shared the findings from the catchment analysis, emphasizing both the biophysical and socio-economic factors. The meetings then aimed to build a consensus on a long-term vision, set strategic goals for catchment development, and ultimately identify priority actions.

The discussions covered issues and potential best practices around:

- Water management
- Land-Use
- Environmental protection
- Community benefits
- Economic development
- Climate change resilience

- Monitoring and evaluation alignment of policies governing the catchment

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
- Dam and reservoir operating guidelines
- River training
- Flow proportioning structures
- Restoration and expansion of the hydromet monitoring network

3.4 Key Points from the Stakeholder Engagement

Based on the stakeholder engagement information on strategic issues and opportunities, the following detailed points were developed around the key topics of interest identified in the previous section above:

1. **Water Management and Access**:
    - Stakeholders highlighted the necessity of managing water resources sustainably, especially in relation to the overexploitation and contamination resulting from activities upstream.
    - A strong emphasis was placed on establishing and enforcing operational guidelines for dams and reservoirs, as well as river training to efficiently manage sedimentation and flow distribution.
    - Improving climate resilience by utilizing rainwater harvesting and expanding hydrometeorological monitoring networks was considered critical.
2. **Land Use and Degradation**:
    - Concerns were raised about unsustainable farming practices, leading to soil degradation and reduced productivity.
    - Encroachment into forest reserves for agriculture was identified as a pressing issue, impacting biodiversity and contributing to deforestation.

3. **Environmental Protection**:
    - Restoration of degraded wetlands and afforestation initiatives were highlighted to improve ecosystem services and carbon sequestration.
    - Stakeholders emphasized the need for protecting riparian corridors and ensuring the sustainable use of natural resources.
4. **Community and Livelihoods**:
    - There was widespread acknowledgment of the socio-economic challenges linked to water resource access, including poverty and food insecurity.
    - Livelihood support through initiatives like providing farming equipment, credit facilities, and skills training was noted as a vital intervention.
    - Issues of insecurity in certain regions hinder the effective implementation of initiatives.
5. **Institutional Gaps and Policy Alignment**:
    - Weak coordination among agencies and gaps in policy implementation were recurring themes. Non-existing administrative institutions and largely ungoverned spaces.
    - Suggestions included harmonizing existing policies on land tenure, mining, and water resources, alongside developing costed action plans and budgets.

6. **Strengthening Coordination Mechanisms:**
    - Create a multi-stakeholder platform to improve collaborative decision-making.
    - Encourage capacity building for local institutions to enhance governance structures.
7. **Promoting Sustainable Practices:**
    - Roll out community-driven sustainable agricultural practices and integrated land management approaches.
    - Incentivize the use of organic farming methods to reduce chemical runoff into water systems.
8. **Enhancing Data and Monitoring Systems:**
    - Regularly collect and share water quality and hydrological data to inform planning and mitigate risks.
    - Utilize modern tools like GIS and remote sensing for better resource management.

9. **Engaging Communities:**
    - Strengthen community engagement through awareness campaigns about sustainable practices.
    - Include gender-sensitive approaches to empower marginalized groups, particularly women, in resource management activities.

In consideration of a clear understanding of the outcome of the valuable inputs from the stakeholders, as indicated above and listed in the components of the plan (Fig 5.1 to 5.9), interventions were suggested:

Most in concurrence with the stakeholder output,

- While others were slightly modified in line with existing data on related factors, as deduced from the study, the idea is to develop the most practicable intervention projects.
- By addressing these identified challenges and leveraging the opportunities highlighted, the catchment management plan can achieve sustainable development outcomes that balance ecological health with socio-economic goals.

It is pertinent to note that there were very few areas of none concurrence.

- An example is the area of afforestation and protection of the Forests and national parks within the strategic catchment.
- Also, participants preferred that the management of the catchment should be under the purview of the North East Development Commission (NEDC).

3.5 Coordination Mechanisms

The roles of federal, state, and local stakeholders in catchment plan Management and implementation are:

Federal Stakeholders

1. Federal Ministry of Environment: Provides overall guidance and coordination for catchment management in Nigeria. Supports the implementation of environmental aspects of the catchment plan, including conservation and sustainable use of natural resources (through the ACReSAL project)

2. Federal Ministry of Water Resources and Sanitation: Provides support in implementation and guidance.

3. Federal Ministry of Agriculture and Food Security

4. National Space Research and Development Agency (NARSDA): Provided Satellite data

5. National Centre for Remote Sensing (NCRS): Provided geospatial support

6. Nigerian Meteorological Agency (NIMET): Provides climate and weather data to support catchment planning and management.

7. National Emergency Management Agency (NEMA): Supports disaster risk reduction and management efforts in the catchment.

State Stakeholders

8. State Ministry of Water Resources: Implements state-level policies and programs for catchment management.

9. State Ministry of Environment: Supports the implementation of the catchment plan's environmental aspects at the state level.

10. State Ministry of Agriculture: Supports sustainable agriculture practices and water management in the catchment.

11. State Emergency Management Agency (SEMA): This agency supports disaster risk reduction and management efforts in the catchment.

Local Government Stakeholders

12. Local Government Councils: Implement catchment management plans at the local level, including waste management and environmental conservation.

Community Oriented Stakeholders

13. Community-Based Organizations (CBOs): Support community-led initiatives for catchment management, including water conservation and sustainable land use practices.

14. Traditional Rulers: Provide leadership and support for catchment management efforts at the local level.

15. Farmers and Water Users Associations: Support sustainable water management practices and conservation of natural resources in the catchment.

16. Civil Society Organizations (CSOs): Support advocacy and awareness-raising efforts for catchment management and conservation.

Private Sector Stakeholders

17. Private Sector: Supports the implementation of catchment management plans through corporate social responsibility initiatives and investments in sustainable water management practices.

Research Institutions

18. Research Institutions: Provide technical support and research expertise for catchment management and conservation efforts.

International Stakeholders

19. International Development Partners: Support catchment management efforts through funding, technical assistance, and capacity-building programs.

CHAPTER 4 : STRATEGIC VISION AND GOALS

Based on a comprehensive biophysical and socio-economic assessment, and stakeholder engagement, the agreed strategic vision for the Ngada West Chad Catchment is:

> *To* establish a sustainable, resilient, and community-driven catchment management system that balances environmental protection with socioeconomic progress.

The consensus for long-term and short-term strategic goals and expected outcomes are outlined in Table 4.1 below:

Table 4.1: Strategic Goals and Objectives for Sustainable Catchment Development

S/No.	Long-term Strategic Goals	Long Term (KPIs)	Short-term Strategic Goals	Short term (KPIs)	Targets (Expected Outcomes)
1	**Water Security**: Develop integrated water resource management strategies.	• Percentage increase in water availability • No. of water management plans adopted • Reduction in water conflicts	Construct and rehabilitate dams, reservoirs, and boreholes.	• No. of dams/reservoirs/boreholes built/rehabilitated • Percentage increase in water storage capacity • No. of households with improved access	Improved water availability for agriculture, domestic, and industrial use.

2	**Climate Resilience**: Implement long-term adaptation strategies for climate variability.	• Percentage reduction in economic losses from floods/droughts • No. of climate-resilient infrastructure projects • Percentage of communities adopting adaptation measures	Establish early warning systems and flood control measures.	• No. of early warning systems installed • Reduction in flood-affected areas (ha) • Disaster response time (hours)	Reduced flood risks and improved drought resilience.
3	**Ecosystem Conservation**: Restore degraded forests, wetlands, and riparian zones.	• Hectares of land restored • Percentage increase in biodiversity • Improvement in groundwater recharge rates.	Implement afforestation and soil conservation programs.	• No. of trees planted • Reduction on in soil erosion (tons/ha/year) • No. of community-led conservation initiatives	Enhanced biodiversity, reduced soil erosion, and improved groundwater recharge.
4	**Sustainable Livelihoods**: Promote climate-smart agriculture and alternative income sources.	• Percentage increase in agricultural productivity. • No. of households using climate-smart practices	Provide training and financial support for farmers and pastoralists.	• No. of farmers/pastoralists trained. • Financial support disbursed • Percentage income increase among beneficiaries	Increased food security and economic stability.

		• Percentage reduction in poverty levels			
5.	**Governance & Policy**: Strengthen water governance frameworks and enforcement mechanisms.	• No. of policies/laws enacted/updated • Percentage compliance with water regulations • No. of resolved water disputes	Establish catchment management committees with community involvement.	• No. of committees formed. • Percentage community participation in meetings • Meeting frequency per year	Transparent and effective resource management.
6	**Infrastructure**: Develop sustainable urban and rural infrastructure for water and land use.	• Percentage increase in clean water access • No. of jobs created • Reduction in water distribution losses (percentage)	Improve road networks, irrigation, and water supply systems.	• Km of roads built/rehabilitated • Hectares under improved irrigation. • No. of water supply systems upgraded	Enhanced access to markets, reduced transportation costs, and improved livelihoods.

CHAPTER 5 : STRATEGIC CHALLENGES AND PRIORITY INTERVENTIONS

5.1 Key Challenges

The Ngada West Chad Catchment faces several hydrological, environmental, socio-economic, and governance challenges that affect its sustainability and water security. These challenges are summarized as follows:

5.1.1 Hydrological Challenges

Climate Change Impacts: Altered streamflow and discharge patterns, increased variability in rainfall, and reduced water availability.

Water Scarcity: Persistent water deficits due to high evapotranspiration and low groundwater recharge.

Flooding and Droughts: Extreme weather events cause seasonal floods (June–September) and prolonged droughts (October–May), disrupting agriculture and livelihoods.

Declining Groundwater Levels: Over-extraction of groundwater for irrigation and domestic use, particularly in the Lake Chad Basin.

5.1.2 Environmental Challenges

Deforestation and Desertification: Unsustainable land use, overgrazing, and agricultural expansion accelerate soil degradation.

Water Pollution: Agricultural runoff, untreated wastewater, and open defecation contaminate water bodies.

Loss of Biodiversity: Habitat destruction due to deforestation, desert encroachment, and poaching of endangered species.

5.1.3 Socio-Economic Challenges

High Poverty Levels: The region has some of the highest poverty rates in Nigeria, with many dependent on subsistence farming and informal trade.

Conflict and Insecurity: Insurgency-related displacement limits access to agricultural land and disrupts livelihoods.

Poor Infrastructure: Inadequate road networks, weak flood control systems, and limited access to clean water, education, and healthcare.

Food Insecurity: Climate variability, soil degradation, and conflicts reduce agricultural productivity, leading to dependence on food aid.

5.1.4 Governance and Institutional Challenges

Weak Policy Enforcement: Poor implementation of environmental policies and water management regulations.

Limited Institutional Capacity: Inadequate local government resources hinder effective catchment management.

Corruption and Mismanagement: Misallocation of funds intended for infrastructure and resource management.

Data Gaps: Limited hydrological monitoring infrastructure affects decision-making and sustainable water resource planning.

5.2 Strategic Interventions

To ensure sustainable catchment management of the Ngada West Chad Catchment based on the assessment of the hydrological, environmental, socio-economic, and governance challenges, the following strategic interventions are recommended:

1. **Enhance Water Resources and Mitigate Flood Risk Management**:
    - Upgrade current dams and reservoirs to enhance water retention and release.
    - Build compact water storage systems and improve rainwater collection methods and techniques.
    - Develop water distribution strategies that ensure fairness for the needs of both upstream and downstream stakeholders.
    - Promote managed aquifer recharge through artificial wetlands, infiltration basins, and conservation agriculture
    - Implement catchment-based water allocation frameworks to balance domestic, agricultural, and industrial use.
    - Construct embankments and improve drainage systems in high-risk areas.
    - Establish early warning systems and conduct regular flood risk evaluations.

- Enhance the network of groundwater monitoring systems and hydrometeorological stations.
- Enhance public awareness and preparedness for flood events.
- Promote drip irrigation and efficient water-use practices for farming to reduce over-extraction.

2. **Safeguard and Revitalize Essential Ecosystems and Services**
    - Rehabilitation of at least 30% of degraded land through afforestation.
    - Restore degraded forests and riparian zones by planting drought-resistant tree species to combat desertification
    - Restore 25% and improve agricultural degraded land.
    - Implement contour farming, terracing, and agroforestry to reduce soil erosion and land degradation.
    - Strengthen wastewater treatment, regulate agricultural runoff, and enforce anti-pollution laws
    - Revitalize and preserve wetlands to stabilize water cycles and provide support biodiversity.
    - Introduce rotational grazing and develop livestock corridors to prevent overgrazing and conflicts between farmers and pastoralists.
    - Uphold the protective boundaries of national parks and treasured reserves and forests as carbon syncs and biodiversity sustainability.

3. **Encourage eco-friendly farming and livestock methodss**
    - Boost agricultural productivity by 40% using climate-smart practices, enhancing skills, and gathering data.Improve soil fertility management, and apply soil and water conservation to reduce erosion.
    - Assist small-scale farmers with training and access to enhanced technologies.
    - Promote the use of micro-irrigation systems.

4. **Improve Climate Resilience**:
    - Encourage the use of drought-resistant crops and promote efficient irrigation practices.
    - Encourage afforestation initiatives to address desertification and enhance stability soils.
    - Adopt community-driven strategies for managing floodplains and watersheds protection.

5. **Improve Livelihoods and Human Well-Being**:
    - Offer training courses in sustainable agriculture, fishing, and aquaculture practices.
    - Enhance credit and market access for smallholder farmers and fisherfolk.
    - Develop community-based tourism and eco-friendly economic activities.
    - Enhance access to sustainable natural resources, affordable energy, and improved sanitation and hygiene practices.
    - Promote alternative income sources such as eco-tourism, agro-processing, and renewable energy initiatives.
    - Improve road networks, storage facilities, and market linkages to reduce post-harvest losses and enhance trade.
    - Implement peacebuilding programs to address farmer-herder conflicts and support internally displaced persons (IDPs) with sustainable livelihood options.
    - Support farmers with improved seeds, climate-smart agriculture training, and access to microfinance.
    -

6. **Enhance Governance and Stakeholder Engagement Collaboration**:
    - Create a regulatory framework for integrated water resource management at the catchment level.
    - Enhance collaboration between federal, state, and local authorities agencies.
    - Ensure community representation in decision-making processes and management committees.
    - Develop a hydro-meteorological database to track water availability, land degradation, and ecosystem health.

- Establish Catchment Management Committees (CMCs) involving local communities, government agencies, and private sector stakeholders.
- Enforce land tenure rights for women and marginalized groups to promote inclusive development.
- Conduct training programs for local authorities on water governance, climate adaptation, and disaster risk management.

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

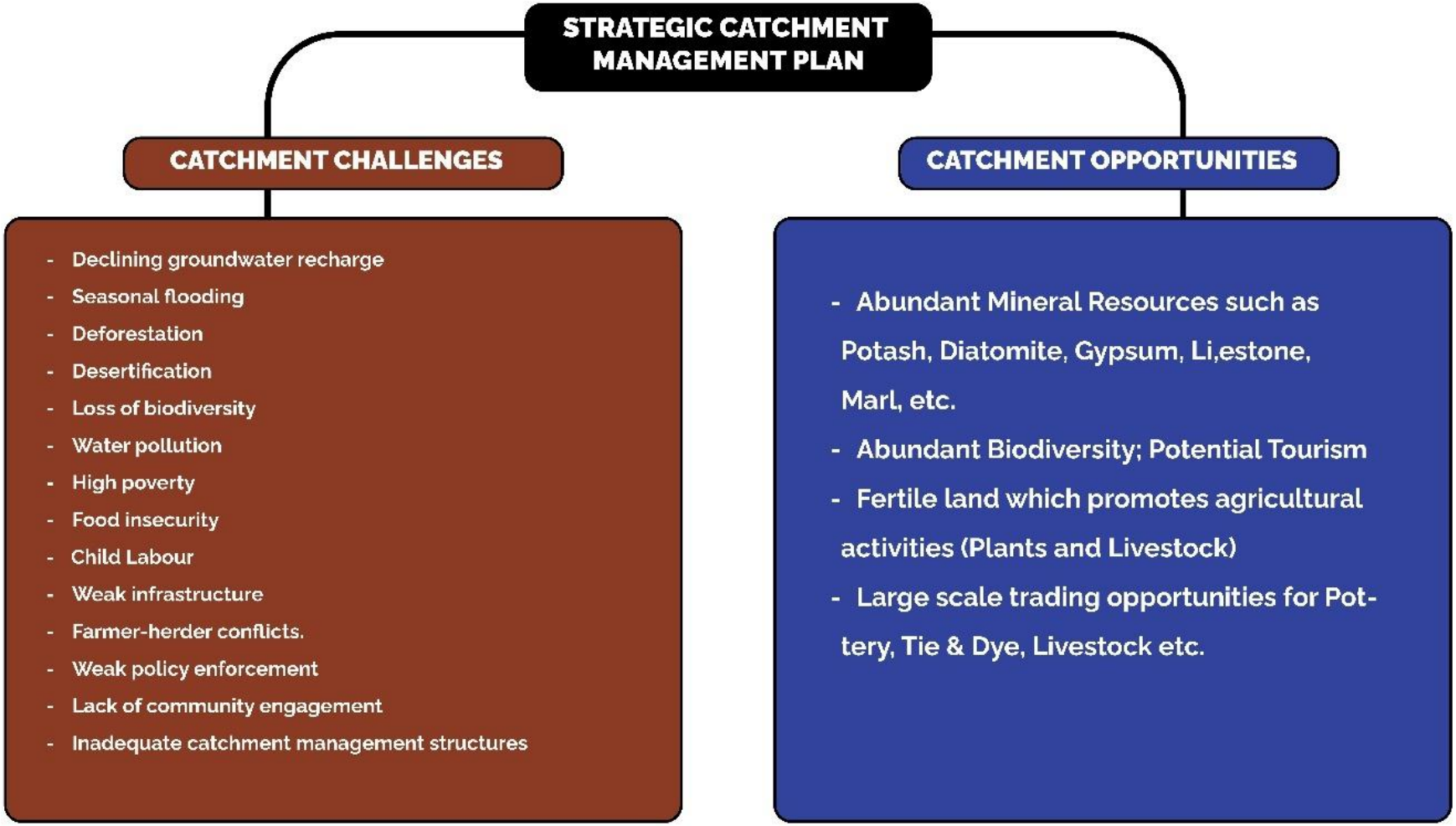

Figure 5.1: Strategic Catchment Management Plan

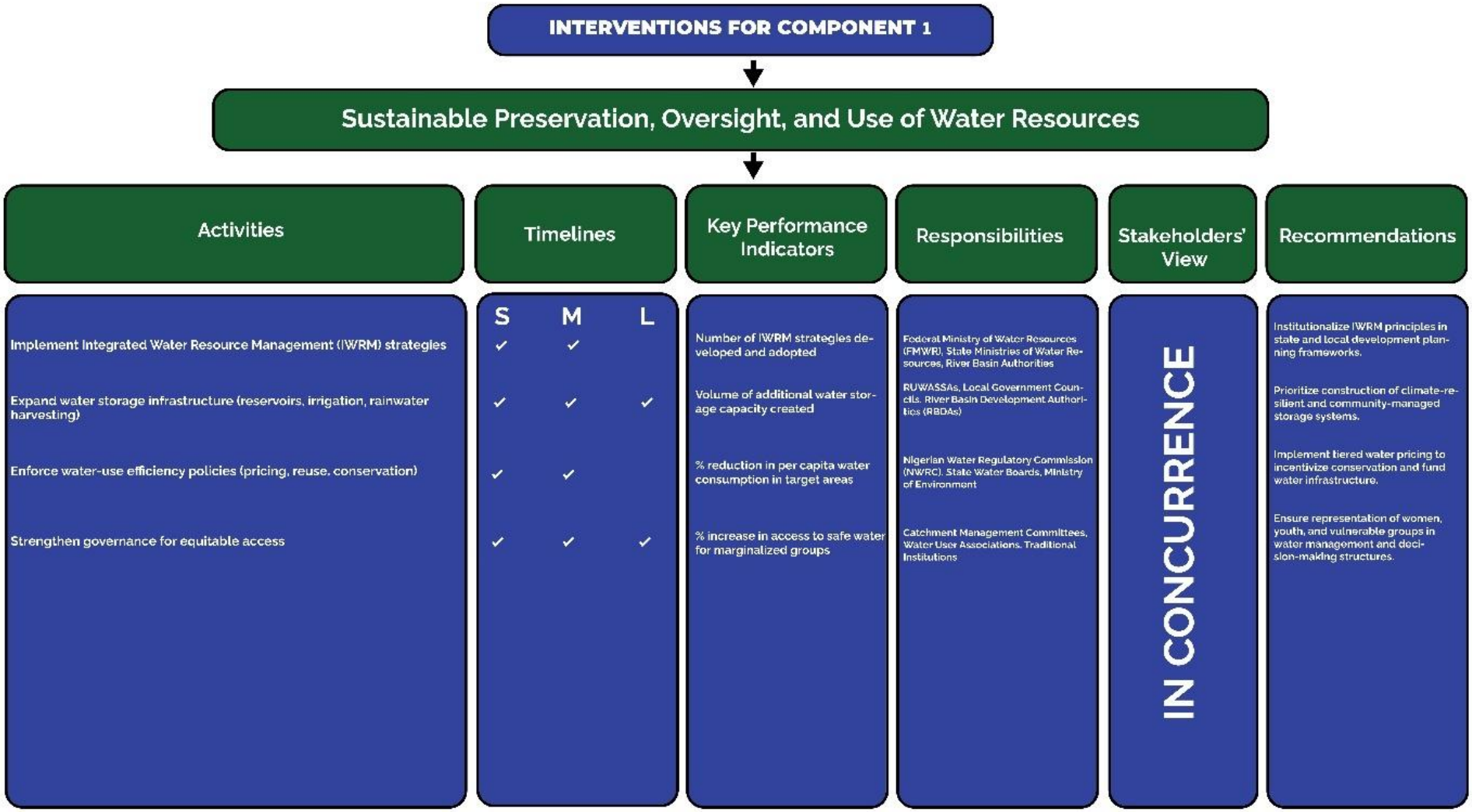

Figure 5.2: Component 1 (Sustainable Preservation, Oversight, and Use of Water Resources)

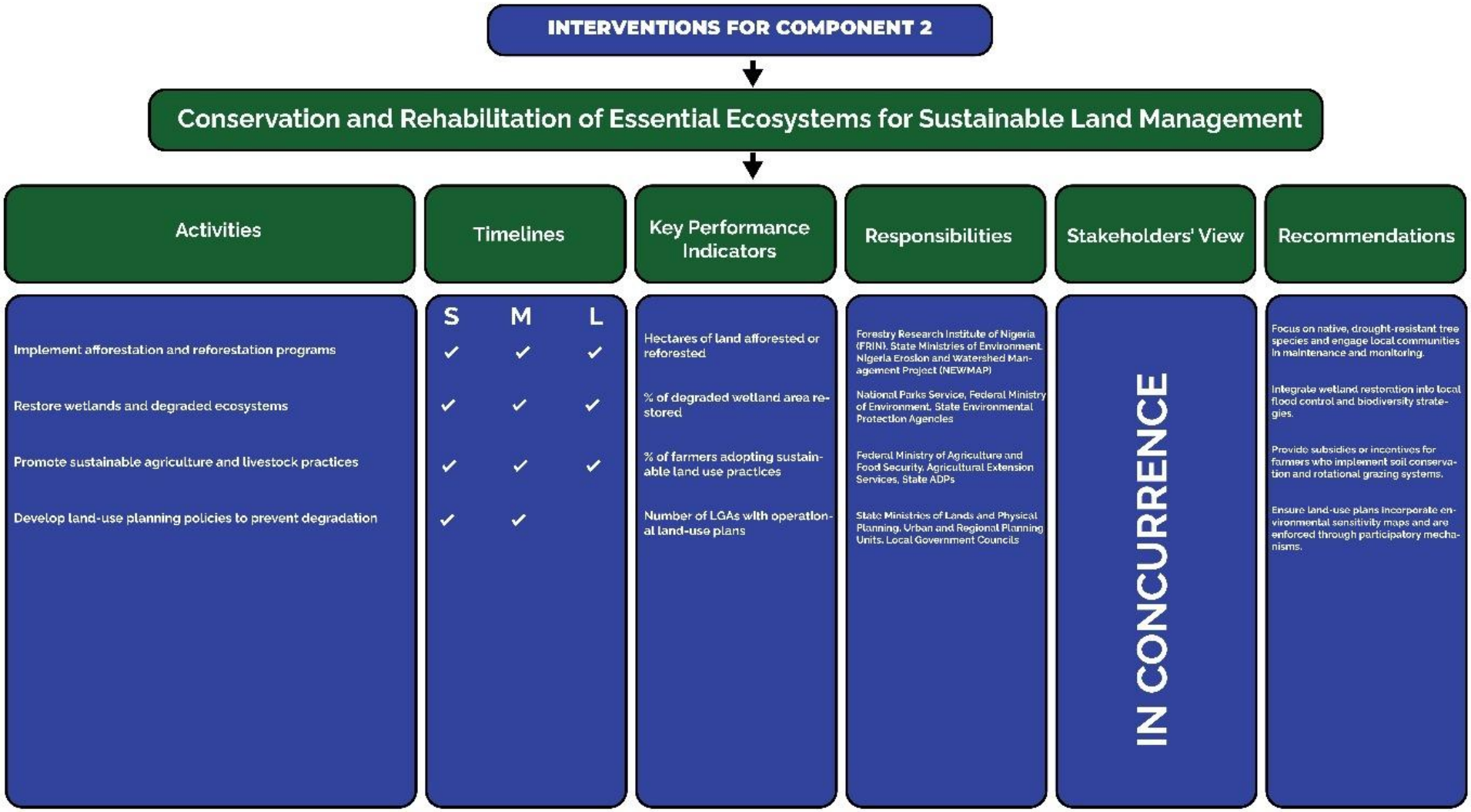

Figure 5.3: Component 2 (Conservation and Rehabilitation of Essential Ecosystems for Sustainable Land Management)

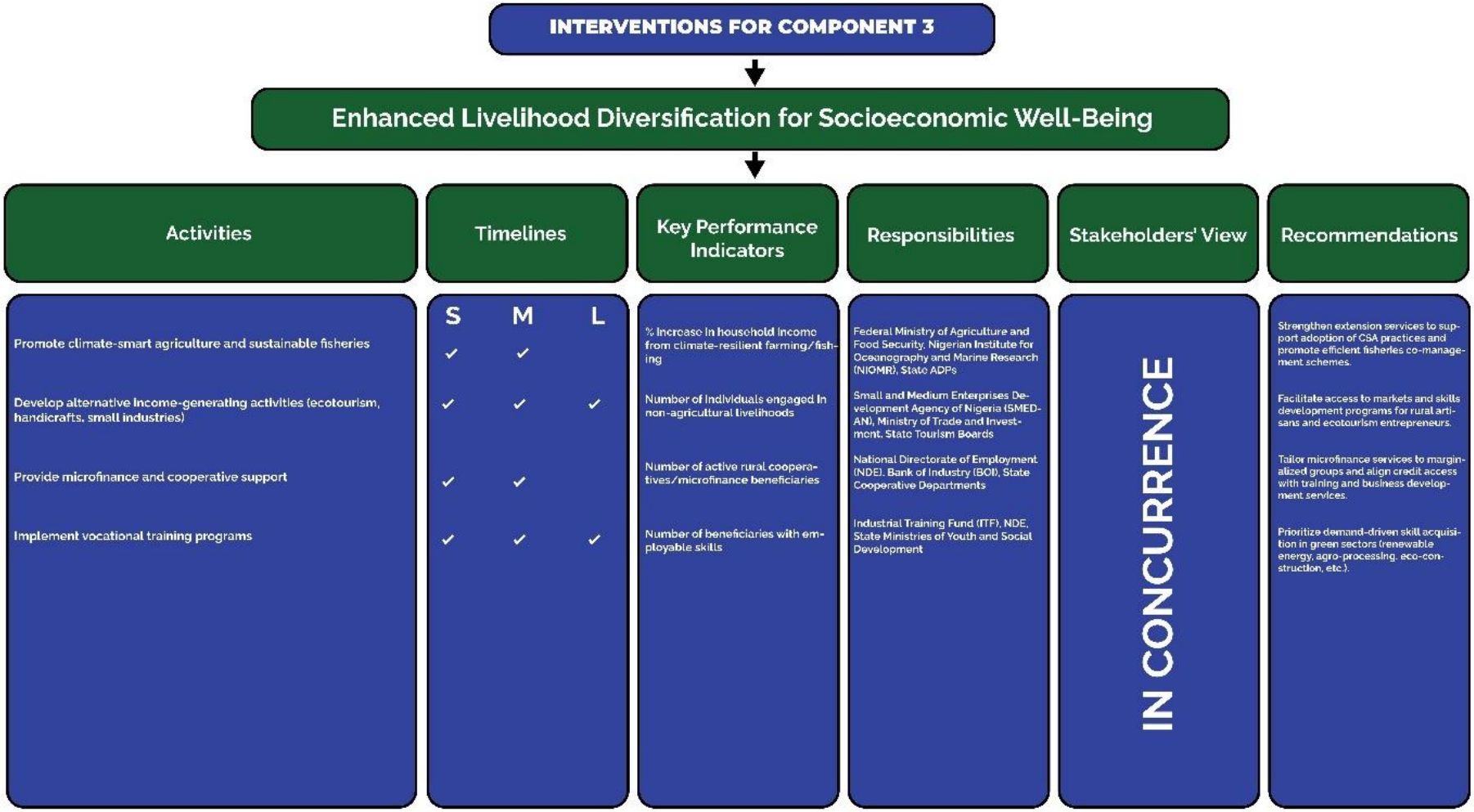

Figure 5.4: Component 3 (Enhanced Livelihood Diversification For Socioeconomic Well-Being)

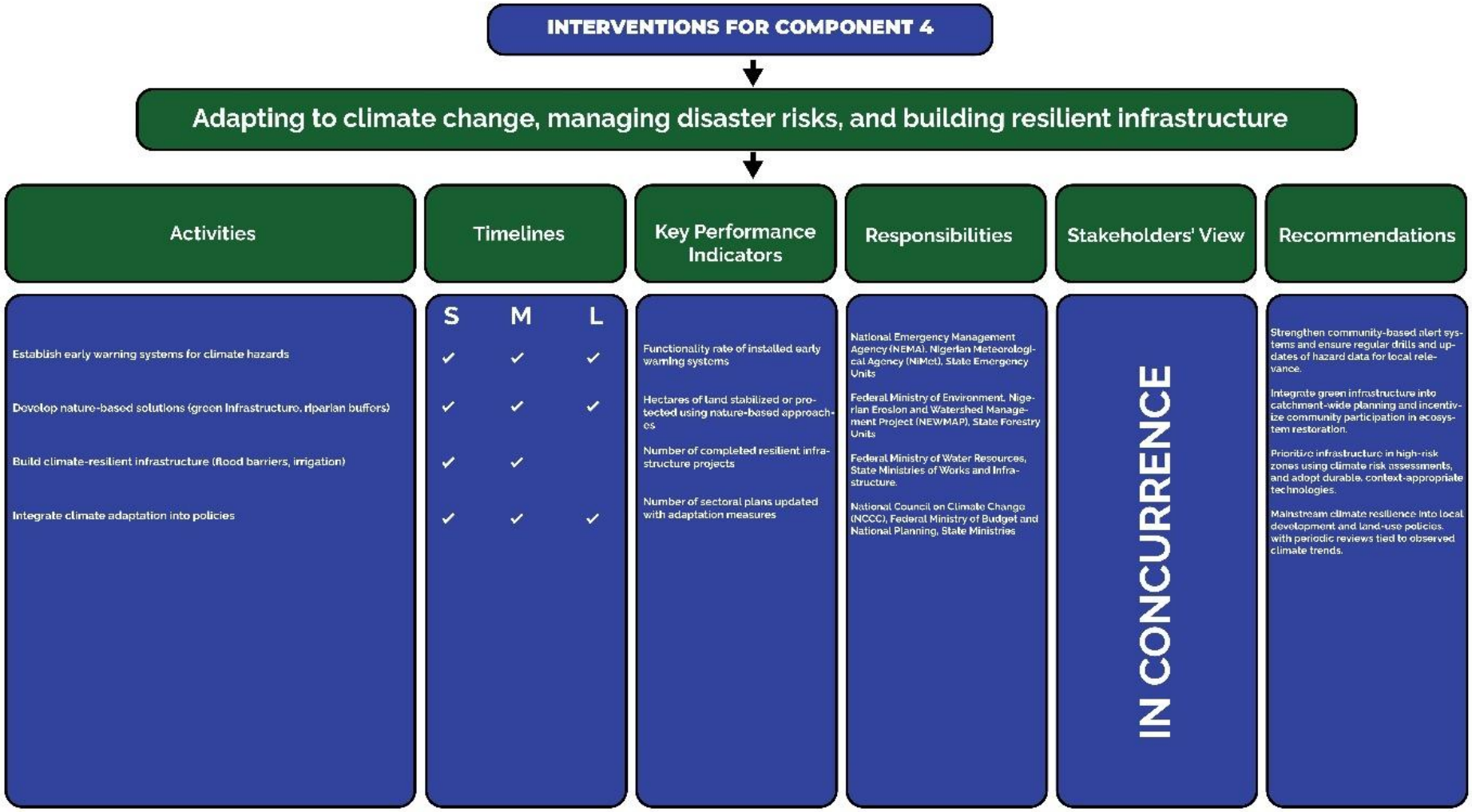

Figure 5.5: Component 4 (Adapting to Climate Change, Managing Disaster Risks, and Building Resilient Infrastructure)

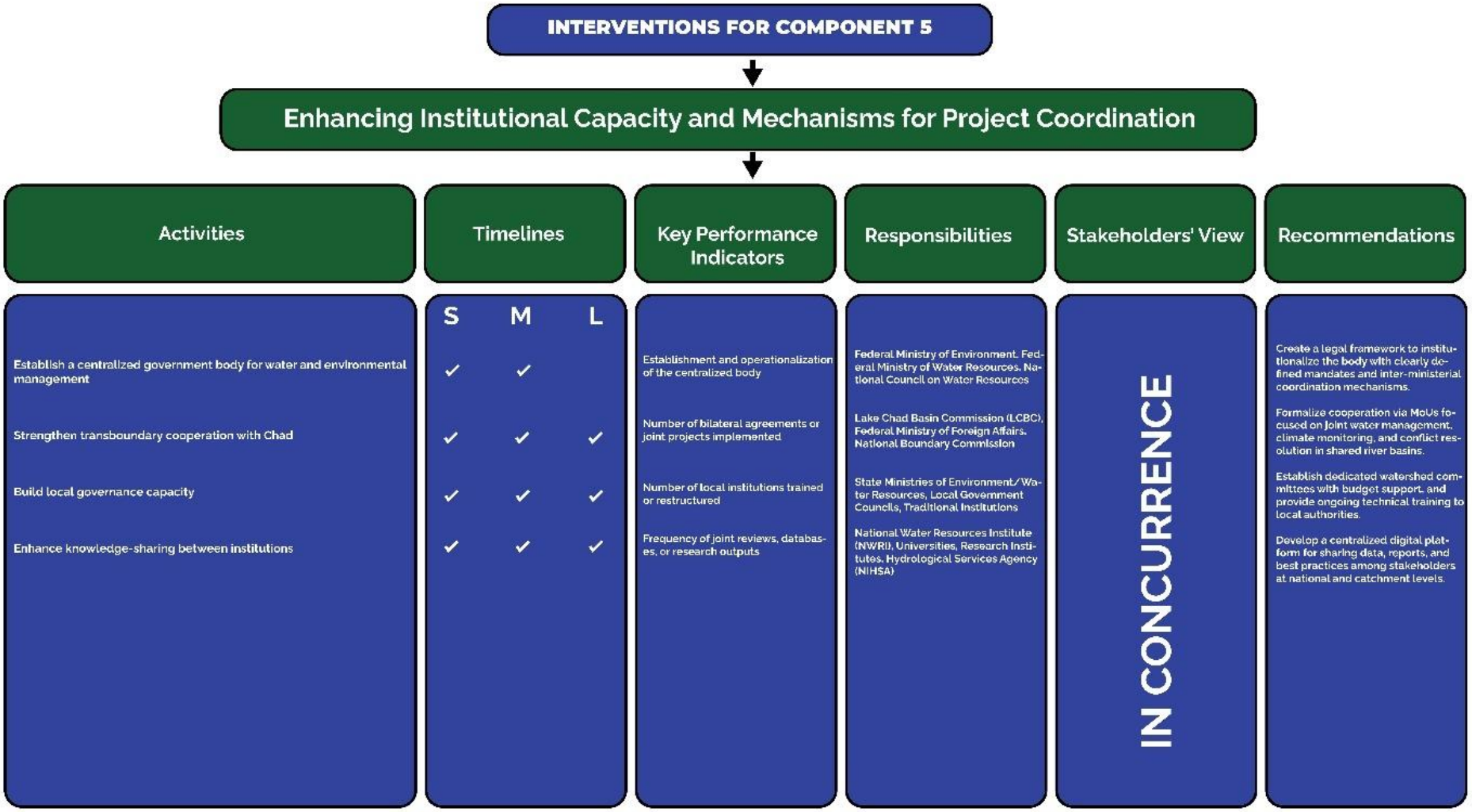

Figure 5.6: Component 5 (Enhancing Institutional Capacity and Mechanisms for Project Coordination)

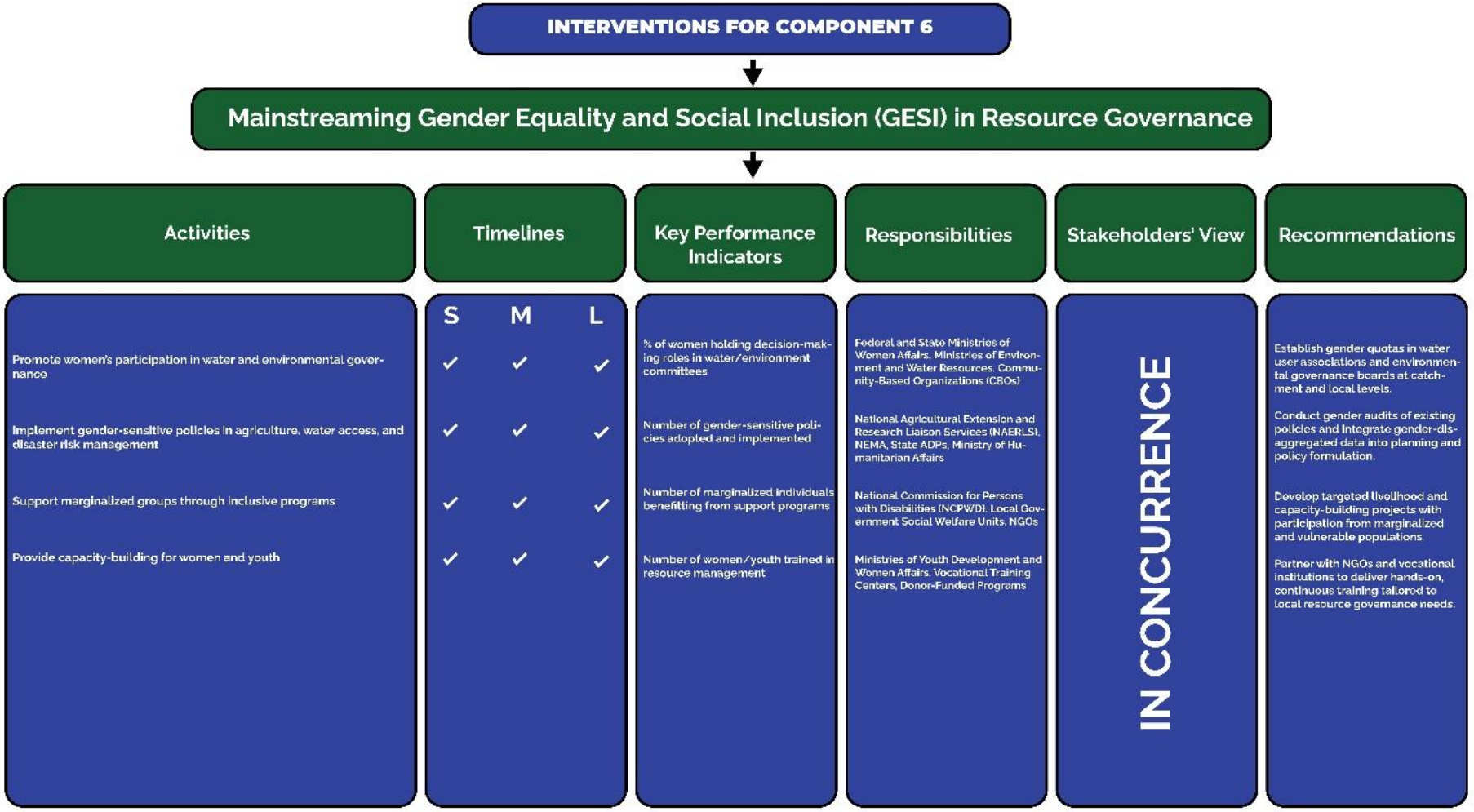

Figure 5.7: Component 6 (Mainstreaming Gender Equality and Social Inclusion (GESI) in Resource Governance)

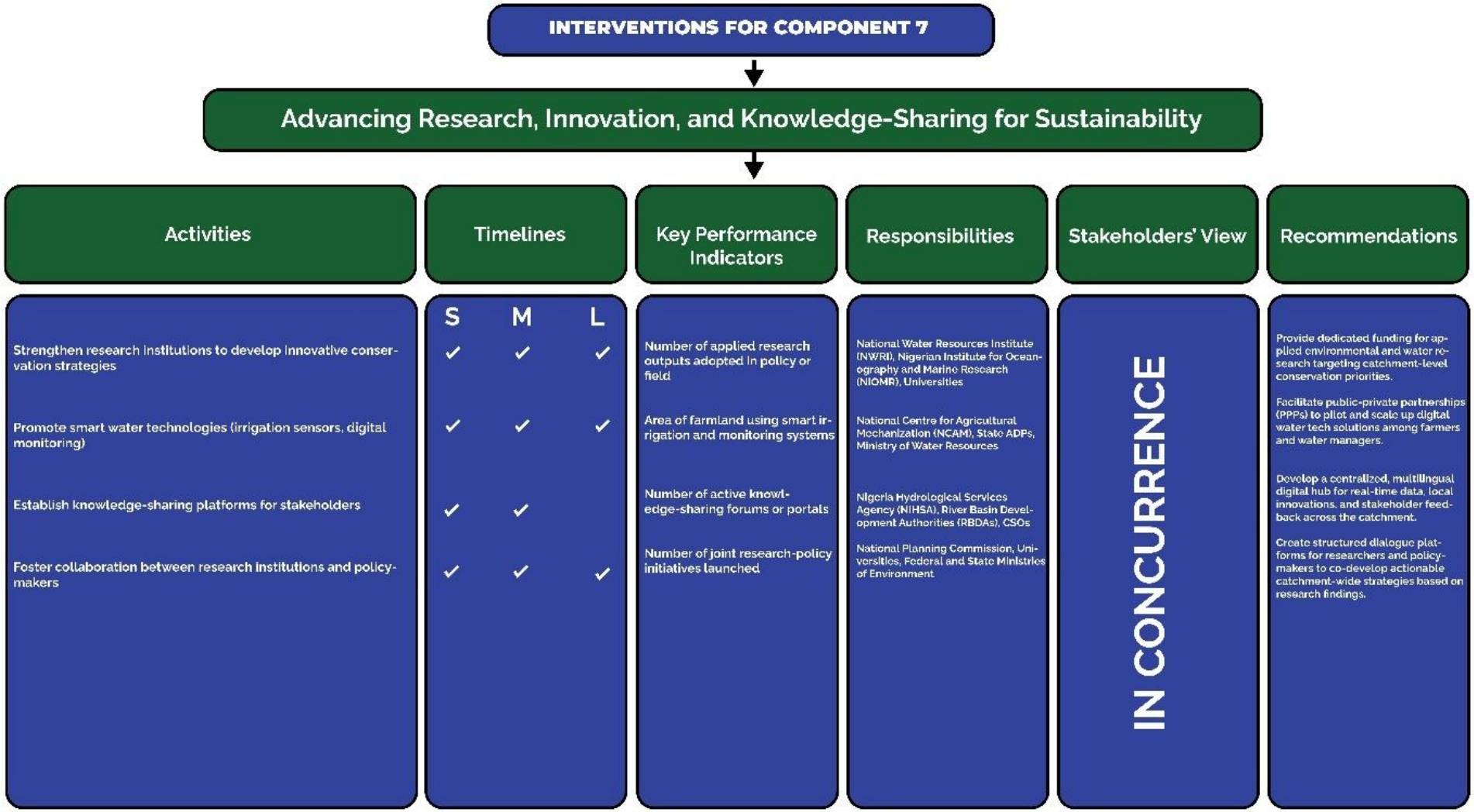

Figure 5.8: Component 7(Advancing Research, Innovation, and Knowledge-Sharing for Sustainability)

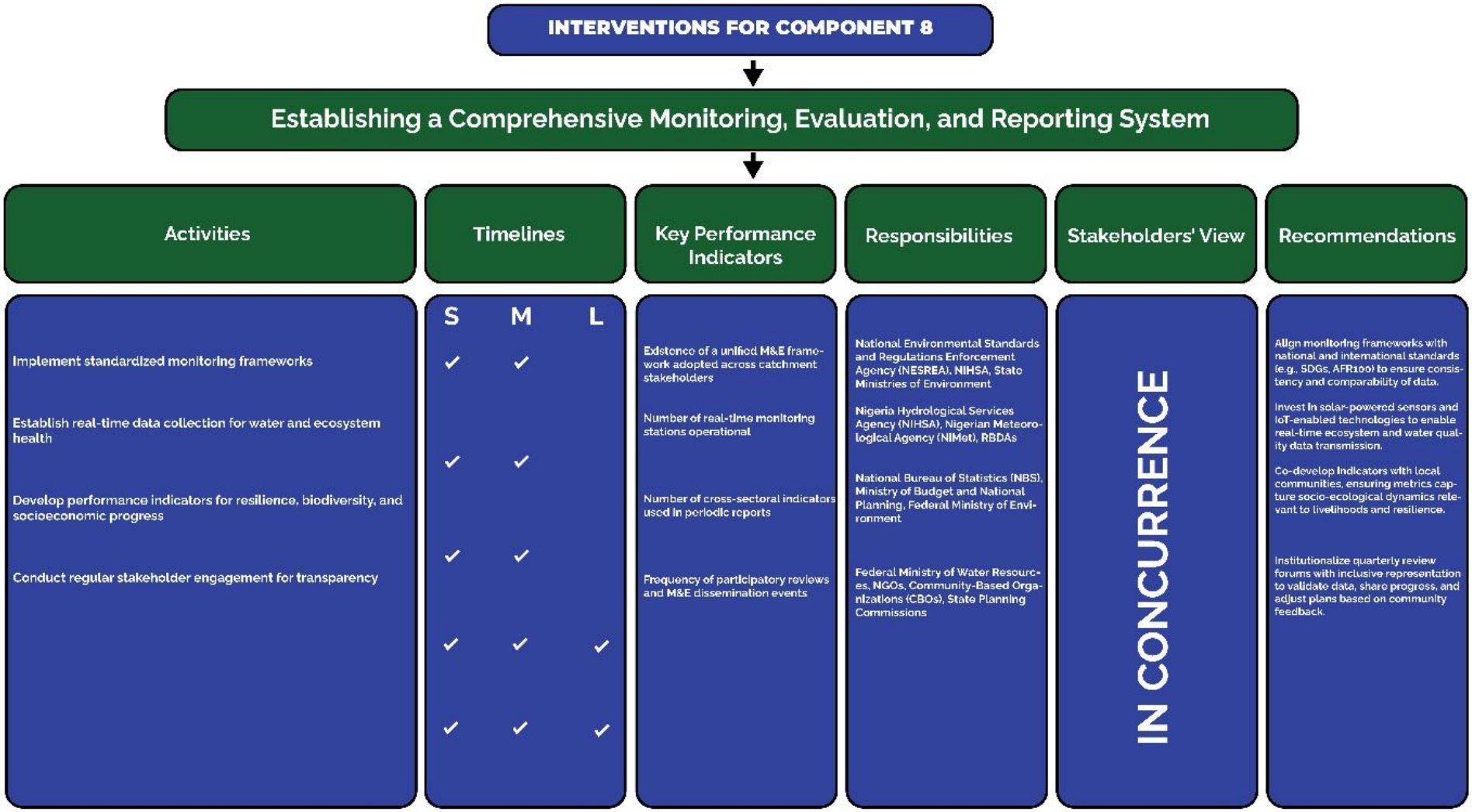

Figure 5.9: Component 8 (Establishing a Comprehensive Monitoring, Evaluation, and Reporting System)

5.3 Expected Outcomes and Feasibility of Implementation

Through the implementation of the above interventions that are science-based, community-driven, and policy backed, the catchment will ensure the following outcomes:

- Sustainable Water Resource Management
- Ecosystem Restoration & Biodiversity Conservation
- Climate Resilience & Disaster Risk Reduction
- Enhanced Livelihoods & Economic Diversification
- Improved Community Well-Being & Social Inclusion
- Strengthened Policy & Regulatory Frameworks
- Improved Institutional Capacity & Project Coordination

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. A comprehensive monitoring and evaluation framework should capture insights, challenges, and milestones, facilitating systematic progress reviews. 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

As this document serves as a dynamic operational guide, it is anticipated that actions will be modified to reflect evolving priorities. Any amendments shall be documented in the appendix of the original management plan. For the monitoring process, appropriate indicators will be identified to assess catchment management activities and their impacts, encompassing both biophysical and social dimensions. When relevant, these indicators will integrate multimedia elements, such as images, videos, and documents, and will capture both qualitative and quantitative data. The Monitoring and Evaluation Plan is shown in Table 6.1

6.1 Data Collection Methods

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

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.

Table 6.1: Monitoring and Evaluation Plan for Ngada-West Chad Catchment

S/NO	Monitoring Tools and Techniques	Target/Output	Monitoring	Evaluation	Responsibility
1	Geographical Information Systems Tools: software, ArcGIS, QGIS, Mapbox etc	Analyze and visualize spatial data use, water quality, and hydrological data.	Establish Key Performance Indicators to track progress. Analyse data and come out with outputs. Update visuals and maps on progress or otherwise.	Mid-Term and End Term: Conduct comprehensive evaluations at the midterm and end of implementations	WB/SPMU
2.	Remote Sensing/Drone technology. Tools: Multispectral and thermal imageries. Unmanned ariel vehicles and complimenting softwares.	Using remote sensing technology, such as satellite imagery to monitor land use and environmental changes	Water Quality Monitoring: Regularly collect and analyze water samples to assess changes. Analysis of past and present images, e.g., NDVI, the perimeter of water bodies, and degraded lands.	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 correlations.	Hydrological Monitoring: monitor precipitation, stream flow and ground water levels to understand hydrological trends.	Cost -Benefit analysis: an assessment of the economic and social costs.	SPMU/Consultant

4	Participatory Rural Appraisal (PRA)	Engage local communities in the evaluation of the process, E.g., FGD, surveys and stakeholder workshops	Land use and land cover monitoring are used 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 impact of the plan 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 progress of the implementation of BMPs	Consultant, SPMU, Ministry of Environment, FoNGO, community.

6.4 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:

6.4.1 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.

6.4.2 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.

6.4.3 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.

6.4.4 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.

CHAPTER 7 : CONCLUSION AND MOVING FORWARD

7.1: Summary of Strategic Issues and Priorities

The Ngada West Chad catchment encompassing Borno and Yobe States, is replete with diverse ecosystems and significant socio-economic potential.

The Ngada West Chad Catchment Management Plan offers a comprehensive approach to addressing the multifaceted challenges facing the region. The strategic interventions outlined in this plan prioritize sustainable management of natural resources, enhancement of livelihoods, and resilience to climate change, ensuring a balanced approach to socio-economic development and ecological conservation.

To improve water resource management and mitigate flood risks, the plan emphasizes the rehabilitation of critical water infrastructure, such as dams and reservoirs, and the development of small-scale water storage systems. These measures, coupled with enhanced drainage systems, flood risk assessments, and public awareness campaigns, aim to safeguard communities against water-related hazards while promoting equitable water allocation across the catchment. Strengthening groundwater monitoring networks and advancing rainwater harvesting further enhance the region's capacity to manage its water resources sustainably.

Restoration of critical ecosystems is another cornerstone of the plan, with ambitious goals to afforest up to 40% of degraded lands and restore wetlands. These efforts will stabilize hydrological cycles, bolster biodiversity, and reinforce the ecological integrity of the catchment. Protecting national parks and reserves also ensures the preservation of key habitats and natural resources for future generations.

Sustainable agricultural and livestock practices are at the heart of the strategy to enhance food security and economic resilience. By increasing agricultural productivity through climate-smart approaches, improving soil fertility, and supporting smallholder farmers with training and technology, the plan aims to transform the agricultural landscape. Initiatives such as micro-irrigation adoption and erosion control further underline the commitment to sustainability.

Building climate resilience is a critical priority. Community-based initiatives, afforestation programs, and the promotion of drought-resistant crop varieties are pivotal in addressing desertification and climate-induced vulnerabilities. Simultaneously, enhancing livelihoods

through sustainable practices, access to credit, and eco-friendly economic activities will empower local communities, particularly smallholder farmers and fisherfolk.

Achieving these ambitious objectives requires robust financial and institutional frameworks. The plan advocates for increased public-sector funding, urging state and federal governments to allocate dedicated budgets for water, agriculture, and environmental projects. Establishing catchment development funds will pool resources across agencies and stakeholders. International donor support from development partners like the World Bank and the African Development Bank is essential, with efforts to align projects with global funding mechanisms such as the Green Climate Fund. The private sector also plays a critical role through public-private partnerships to develop key infrastructure and renewable energy projects, while community contributions via cooperatives, savings schemes, and microfinance opportunities can support localized interventions.

Finally, robust governance and stakeholder collaboration underpin the success of these interventions. Establishing integrated water resource management frameworks, improving inter-agency coordination, and ensuring inclusive community representation in decision-making processes will strengthen the institutional foundation for long-term success.

In sum, the strategic interventions and funding strategies provide a roadmap for fostering resilience, sustainability, and prosperity in the Ngada west Chad catchment, ensuring its natural and human systems thrive in the face of future challenges.

7.2 Recommendations for Aligning with Broader National and Regional Programs

The catchment management plan should integrate with existing national and regional frameworks to maximize impact and ensure sustainability. Key recommendations include:

1. **Alignment with National Policies**:
    - Incorporate strategies into Nigeria's National Water Resources Policy and Agricultural Transformation Agenda.
    - Coordinate with the Great Green Wall Initiative to address desertification and land degradation.

2. **Regional Collaboration**:
    - Leverage partnerships with neighboring states to manage shared resources, such as water systems and wetlands, more effectively.
    - Align with regional development programs, such as ECOWAS agricultural and environmental initiatives, to foster cross-border cooperation.
3. **Community-Driven Development**:
    - Strengthen partnerships with local governments, traditional institutions, and civil society organizations to enhance grassroots participation.
    - Integrate gender-responsive approaches to empower women and youth in natural resource management.

7.3 Catchment Policy for Interstate River Systems

Several river basins in Nigeria are not only inter-state watercourses but also sub-basins of transboundary or shared watercourses. The implication is that uses and activities in the catchments affect the transboundary watercourse and so are subject of international water treaties that apply to the particular transboundary watercourse. Nigeria is member of the Niger Basin Authority with other eight other riparian states, Niger, Cameroun, Burkina Faso, Republic of Benin, Mali and Guinea, Chad and Cote d'Ivoire. Nigeria is also member of the Lake Chad Basin Commission with five other riparian states, Chad, Central Africa Republic, Cameroun, Niger, and Libya. Nigeria is party to the 2008 Niger Basin Water Charter, 2012 Lake Chad Basin Water Charter, 1997 UN Watercourses Convention and 1992 UNECE Water Convention. Accordingly, obligation to comply with provisions of the treaties under international law within Article 26 of Vienna Convention on the Law of treaties applies to Nigeria as a country that ratified the treaties.

Apart from the principles of international water law, other relevant instruments are the;

- National Water Resources Act,
- policies on water resources,
- environment and climate change. Other policies are international soft laws adopted under auspices of United Nations and ECOWAS Water Resources Policy.

Five Principles of International Water Law Enunciated in The Water Treaties

i. 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?
ii. Substantive Principles:
    a. Principle of equitable and reasonable utilization
    b. Obligation not to cause significant harm (no harm rule)
    c. Protection of the Ecosystems
iii. Procedural Principles
    a. Principle of cooperation
    b. Notification of any planned project
    c. Exchange of data and information
iv. Institutional Framework (river basin organization)
v. 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:

- 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,
- 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 and 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 or 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

a) National Water Resources Act vests the use and control of all surface and ground water affecting more than one state on the Federal Government. Schedule to the Act lists the affected water resources to include River Niger, Sokoto/Rima River from the border, Hadeija Jama'are Basin, all the tributaries of River Niger crossing the border of Benin Republic and the Sokoto sedimentary (Western) hydro-geological area.

b) National Water Resources Policy recommends coordinating committee for interstate river basins. It also states that international water resources shall be managed in a manner that optimizes the benefits for all parties in a spirit of mutual co-operation … Accordingly "transboundary or shared water resources shall be protected, developed,

conserved, used and managed in accordance with the existing national or international riparian Laws/conventions/Guidelines and shared equitably, while maintaining the ecosystem.

c) National Policy on Environment reflects guiding principles of sustainable environment and water resources such as polluter pays, user pays, precautionary principle, subsidiarity principle, pollution prevention principle, principle of inter-generational equity, principle of intra-generational equity, principle of participation, international cooperation, good environmental governance, and integrated ecosystem approach. It recommends domestication of transboundary water treaties and establishing river basin institutions for managing shared watercourse
d) National Climate Change Policy for Nigeria

7.4 High-Level Funding Strategies and Partnership Opportunities

Achieving the goals outlined in this plan requires sustainable financing and strategic partnerships. Key strategies include:

1. **Public Sector Funding**:
    - Advocate for increased budgetary allocation from state and federal governments for water, agriculture, and environmental projects.
    - Establish dedicated catchment development funds to pool resources from government agencies and stakeholders.
2. **International Donor Support**:
    - Engage development partners, such as the World Bank, African Development Bank, and UNDP, to secure grants and technical assistance.
    - Align projects with global funding mechanisms, such as the Green Climate Fund, for climate resilience initiatives.
3. **Private Sector Investment**:
    - Promote public-private partnerships (PPPs) to develop critical infrastructure, such as irrigation systems and agro-processing facilities.
    - Encourage investment in renewable energy projects, such as solar irrigation pumps and mini-hydropower plants.
4. **Community Contributions**:

- Mobilize community-based financing through cooperatives and savings schemes to fund localized interventions.
- Explore microfinance opportunities to support smallholder farmers and rural entrepreneurs.

7.5 Moving Forward with the Catchment Plan

The CMP is a living document that needs to be reviewed and updated regularly as part of an ongoing management process. It signifies the conclusion of the planning phase and the start of the actual catchment management implementation process. The FPMU and the national consultants should also have access to the plan and knowledge base so they can update it and turn it into an online ePlan.

The following tasks are necessary to maintain the catchment management plan as a living document: Table 7.1 indicates next steps and key actions points moving forward.

Table 7.1: 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

A committee comprising representatives from key stakeholders, including government agencies, local communities, and NGOs.

Other actions could include

- Educating people on the importance of the natural environment and what we can all do to restore and protect it.
- Work closely with the government to continue to improve and where required strengthen the regulatory framework to achieve greater protection for the environment.
- More joined-up thinking and enforcement from the different government agencies. The agencies should be funded to undertake their enforcement roles when the natural environment is damaged. Those groups with the biggest impact on the water environment should be focused on to gain the greatest benefits.
- Monitoring and sharing data with others to improve this evidence and make it more widely available.
- Acknowledging that biodiversity, environmental health, and water and soil quality are all closely interrelated. Policies need to link up well and be catchment-wide and long-term.

- Working in partnership with a wide range of organizations set at the appropriate scale for example catchment or coastal scales.
- Committed to an integrated and partnership approach that will attract funding from a wider range of sources including private funding and ensure that the benefits can be spread more widely, across sectors and the landscape.
- Ensuring that resources and environmental legislation should be simpler and enabling.
- Working towards tighter regulation and increased punishments, supported with funding for the Environment Agency to deliver this.
- Moving away from or reducing the use of pesticides by adopting organic, an integrated pest management system, genetic crop manipulation, and the use of highly targeted application of agrochemicals.
- Greater efforts should be made to educate and raise awareness of the issues, to understand how physical modifications impact the environment, how they can be managed, and what benefits they offer society.
- Providing strong support for nature-based solutions and their role in flood risk and coastal erosion management.
- Acknowledging the importance of broader landscape management and the value of looking at catchments as an entire system – all elements working together.
- The overwhelming majority of respondents recognize that well-designed drainage and green infrastructure provide multiple benefits for people and the environment, including better integration and connections across towns and cities.
- Identify appropriate riparian corridors for designation to protect the primary drainage paths and provide for riparian cover.
- Identifying floodplain areas and putting in place rules to avoid inappropriate development in those floodplains
- provide as far as possible for enhancement of groundwater and interflow to assist in maintaining stream base flows
- Protecting the important habitat qualities of streams including provision for fish passage

- Planning for appropriate measures for both primary (on-site control) and secondary (off-site backup) management of erosion and sediment runoff during the development phases
- Providing for both targeted source control of contaminants and general catchment-wide removal of contaminants in stormwater.
- Sustaining public support and stakeholder engagement under the CMP through open and honest communication about progress.
- Being prepared to revise strategies in response to new scientific findings or changes in socio-economic conditions affecting the catchment area.

In order to guarantee that a catchment management plan not only addresses current issues but also fosters the long-term sustainability of natural resources within the catchment area, these steps should be followed methodically while maintaining the flexibility to adjust as necessary.

7.6 Conclusion

The Ngada West Chad catchment is a critical resource for the socio-economic and environmental well-being of the region. The Strategic Catchment Management Plan has been developed through a collaborative and inclusive process, with valuable inputs and contributions from stakeholders. This plan provides a framework for managing the catchment in a sustainable and equitable manner, balancing the needs of different stakeholders and ensuring the long-term health and resilience of the catchment.

Through strategic prioritization, alignment with broader programs, and robust funding mechanisms, the plan sets a clear roadmap for sustainable development. Implementing these recommendations will enhance resource management, empower communities, and build resilience against environmental and socio-economic challenges, ensuring the catchment's long-term vitality and prosperity

Call to Action for Stakeholders

We call on all stakeholders to join us in implementing this plan and working towards a sustainable and prosperous future for our catchment. Specifically, we ask that:

Government agencies: Provide support and resources for the implementation of this plan, and work with us to develop and implement policies and regulations that support sustainable catchment management.

Local communities: Take an active role in implementing this plan, and work with us to develop and implement community-led initiatives that support sustainable catchment management.

Landholders and farmers: Adopt sustainable land management practices, and work with us to develop and implement initiatives that support sustainable agriculture and conservation.

NGOs and community groups: Provide support and resources for the implementation of this plan, and work with us to develop and implement initiatives that support sustainable catchment management.

Private sector: Invest in sustainable initiatives and practices that support the implementation of this plan, and work with us to develop and implement initiatives that support sustainable catchment management.

Together, we can achieve a sustainable and prosperous future for our catchment. Let us work together to implement this plan and make a positive impact on our environment, our communities, and our economy.

ANNEXES

Annex 1: Detailed Population Statistics for the Catchment

Table A-1-1: Population for Ngada West Chad Catchment

State	LGA	2006	2022	2025	2030	2035	2040	2045	2050
Borno	Askira/Uba	143,313	210,000	225486	253874	285837	321824	362342	407960
Borno	Chibok	66,333	97,200	104368	117508	132302	148959	167712	188827
Borno	Damboa	233,200	341,700	366898	413090	465098	523654	589582	663810
Borno	Gubio	151,286	221,700	238049	268019	301762	339754	382529	430690
Borno	Guzamala	95,991	140,600	150968	169975	191375	215469	242596	273139
Borno	Jere	209,107	306,400	328994	370415	417050	469557	528674	595234
Borno	Kaga	89,996	131,900	141627	159457	179533	202136	227585	256238
Borno	Konduga	157,322	230,500	247497	278657	313740	353240	397713	447785
Borno	Kukawa	203,343	297,900	319868	360139	405480	456530	514008	578721
Borno	Mafa	103,600	151,800	162994	183515	206619	232633	261921	294897
Borno	Magumeri	140,257	205,500	220654	248434	279712	314928	354577	399218
Borno	Maidugur	540,016	791,200	849545	956502	1076926	1212510	1365165	1537040
Borno	Marte	129,409	189,600	203581	229212	258070	290561	327143	368330
Borno	Mobbar	116,633	170,900	183502	206605	232617	261903	294877	332002
Borno	Monguno	109,834	160,900	172765	194516	219006	246579	277623	312575
Borno	Nganzai	99,074	145,200	155907	175536	197636	222518	250533	282076
Yobe	Borsari	109,692	172,500	185220	208540	234795	264355	297638	335110
Yobe	Damaturu	87,706	137,900	148069	166711	187700	211331	237938	267894
Yobe	Fika	136,736	215,000	230854	259919	292643	329487	370969	417674
Yobe	Fune	301,954	474,700	509705	573877	646128	727476	819065	922185
Yobe	Geidam	155,740	244,900	262959	296066	333341	375308	422559	475760
Yobe	Gujba	129,797	204,100	219151	246742	277807	312782	352162	396499
Yobe	Nangere	87,517	137,600	147747	166348	187291	210871	237420	267311
Yobe	Potiskum	204,866	322,100	345852	389395	438420	493617	555763	625734
Yobe	Tarmuwa	77,667	122,100	131104	147610	166194	187118	210676	237200
TOTAL		**3,880,389**	**5,823,900**	**6,253,365**	**7,040,663**	**7,927,082**	**8,925,101**	**10,048,770**	**11,313,909**

Source: NPC 2006 Population

Annex 2: Stakeholder Engagement Photographs

Annex 3

Shared Strategic Vision and Goals

Ngada-West-Chad Catchment Area

1. GOAL AND OBJECTIVES

Shared Vision/Interests refers to a common set of goals, values, or aspirations that are collectively embraced by a group of individuals, organizations, or stakeholders. It represents a unified direction and understanding, which helps align efforts and foster collaboration toward achieving mutual objectives. A shared vision provides clarity and motivation, while shared interests ensure that all parties involved benefit or work toward similar outcomes.

Based on the engagements with stakeholders, the following summarises the shared vision for the catchment.

Shared Vision

1) **Goal** : The main goal is to attain a comprehensive, sustainable, efficient and equitable use of all the resources within the catchment
2) **Objectives**: the specific objectives are to":
   a) Develop a sustainable livelihood within the catchment in the 5 years (2025-2030)
   b) Establishment of 3 Dams along River Yedseram in Bama, Mbulu River (Mainok & Ngamdu Axis) and Mega Dam in Alau (5years)
   c) Expansion/ Development of Arable lands for Agriculture, grazing & Agroforestry (in Jere bowl, Dusuman, Zabarmari, Bama- Dikwa, Ngala etc)
   d) Gender & Social Inclusion in all intervention
   e) Restoration of Forest Reserves/ Wildlife Parks (Sambisa, Chad Basin National Park & Chudgurumi)
   f) Establishment of Shelterbelts using drought resistance tree species & Economic Trees
   g) Development of water resources potential
   h) Ensure Community involvement (Participatory Approach) through Design, Planning & Implementation processes
   i) Develop a hydro- Meteorological database for monitoring Quantity & Quality of Water and early warning system and gauging Stations
   j) Ensure Sustainability & regulation of all resources

k) Develop community infrastructure e.g electricity,roads, health centers, market, schools, solar powered boreholes etc.
l) Development & implementation of guidelines regarding Dams
m) Enforce Floodplain Management

3) Stakeholder Engagement: Casceding stakeholder engagement from bottom top Approach (Communities, L.G.A, State, Federal, CSO/NGO/CBO, Traditional/gatekeepers
4) Water Management: Effective Utilization of water resources
   a) Establishment of 3 Dams along River Yedzaram in Bama, Mbulu River (Mainok & Ngamdu Axis) and Mega Dam in Alau (5years)
   b) Expansion/ Development of Arable lands for Agriculture, grazing & Agroforestry (in Jere bowl, Dusuman, Zabarmari, Bama- Dikwa, Ngala etc)
   c) Development of water resources potential
   d) Develop a hydro- Meteorological database for monitoring Quantity & Quality of Water and early warning system and gauging Stations
5) Land Use: Sustainable Utilization of Land for farming, foreset reserve, Urban development, Mining Activities within the scope of domesticated Land use act
6) Environment Protection
   a) Restoration of Forest Reserves/ Wildlife Parks (Sambisa, Chad Basin National Park & Chudgurumi)
   b) Establishment of Shelterbelts using drought resistance tree species & Economic Trees
   c) Development of water resources potential
   d) Development & implementation of guidelines regarding Dams
   e) Enforce Floodplain Management
7) Economic Development:
   a) Develop a sustainable livelihood within the catchment in the 5 years (2025-2030)
   b) Establishment of 3 Dams along River Yedzaram in Bama, Mbulu River (Mainok & Ngamdu Axis) and Mega Dam in Alau (5years)
8) Climate Change Resilience: to develop and implement an action plant for managing climate change impact

9) M&E: to develop M&E framework that involve all stakeholders (federal, state, local government, CSO/NGO/CBO, Communities/communities leaders

Chairman

Name: Prof. Mohd Abba Jimeta Signature/Date: 18/09/24

Secretary

Name: Samson Mishelia Signature/Date: for 18/09/24

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 (CO2), methane (CH4), and nitrous oxide (N2O).
Groundwater Recharge	The process by which water from precipitation or surface water percolates into the ground, replenishing aquifers and maintaining water availability.
Gully Erosion	Severe erosion where water cuts deep channels into the soil, often due to poor land management.
Hydraulic Conductivity	A measure of how easily water can move through soil or rock, important for groundwater studies.

Hydrological Cycle	The continuous movement of water on, above, and below the Earth's surface, including processes such as evaporation, condensation, precipitation, and runoff.
Hydrological Modeling	The use of mathematical models to simulate and predict the movement and distribution of water within a catchment or watershed.
Infiltration	The process by which water soaks into the soil from the surface.
Instream Flow	The water flow required to maintain aquatic ecosystems and downstream water needs.
Integrated Catchment Management (ICM)	A holistic approach to managing land, water, and other natural resources within a catchment, considering social, economic, and environmental factors.
Integrated Water Resources Management (IWRM)	A holistic approach to managing water resources that considers social, economic, and environmental factors, promoting sustainable and equitable use.
Land Degradation	The decline in land quality caused by human activities, such as deforestation, overgrazing, and poor agricultural practices, leading to reduced productivity and ecosystem health.
Land Tenure	The system of rights and institutions that govern access to and use of land, including ownership, leasing, and communal arrangements.
Land Use/Land Cover (LULC)	Categories describing how land is utilized (e.g., forest, agriculture, urban) and its surface characteristics.
Livelihood Diversification	The process by which households or communities expand their income sources to reduce dependence on a single activity, enhancing resilience to economic and environmental shocks.
Livelihood Resilience	The ability of households or communities to withstand and recover from economic, environmental, or social shocks, often through diversified income sources and adaptive strategies.
Microcredit	Small loans provided to low-income individuals or groups to support income-generating activities, often used to promote entrepreneurship and poverty alleviation.
Multidimensional Poverty Index (MPI)	A measure of poverty that considers multiple deprivations in health, education, and living standards, providing a comprehensive understanding of poverty beyond income levels.
Non-Governmental Organizations (NGOs)	Non-profit organizations that operate independently of government, often focused on social, environmental, or developmental issues.
Normalized Difference Vegetation Index (NDVI)	A remote sensing indicator used to assess vegetation health and density by measuring the difference between near-infrared (NIR) and red light reflectance. Higher values indicate healthier vegetation.
Participatory Approach	A methodology that involves stakeholders in decision-making processes, ensuring their perspectives and needs are considered.

Peak Flow	The highest discharge rate in a stream or river during a rainfall or snowmelt event.
Permeability	The ability of soil or rock to allow water to pass through it.
Public-Private Partnership (PPP)	A collaborative arrangement between government agencies and private sector entities to deliver public services or infrastructure projects.
Rainwater Harvesting	The collection and storage of rainwater for later use, such as irrigation, drinking water, or groundwater recharge.
Reforestation	The process of replanting trees in areas where forests have been depleted or degraded, aiming to restore ecosystem functions and biodiversity.
Resilience	The capacity of a system, community, or ecosystem to absorb disturbances, adapt to change, and continue to function effectively.
Riparian Zone	The interface between land and a river or stream, often rich in biodiversity and critical for water quality and ecosystem health.
Rotational Grazing	A livestock management practice where animals are moved between different grazing areas to allow vegetation recovery and prevent overgrazing.
Runoff	Water that flows over the land surface rather than infiltrating into the soil, often carrying pollutants.
Sediment Load	The amount of sediment carried by a river or stream, affecting water quality and aquatic habitats
Sedimentation	The deposition of soil, sand, and other particles carried by water, which can reduce water quality, clog waterways, and harm aquatic ecosystems.
Socio-Economic Indicators	Metrics used to measure the social and economic conditions of a population, such as income levels, education, health, and employment rates.
Soil Conservation	Practices aimed at preventing soil erosion and degradation, such as contour plowing, terracing, and cover cropping.
Soil Fertility	The ability of soil to sustain plant growth by providing essential nutrients, water, and a suitable physical structure.
Stakeholder Engagement	The process of involving individuals, groups, or organizations affected by or interested in a project or decision, ensuring their input and participation in planning and implementation.
Stakeholder Forum	A platform for dialogue and collaboration among stakeholders, often used to share knowledge, discuss challenges, and develop solutions.
Stakeholder Mapping	The process of identifying and analyzing stakeholders to understand their interests, influence, and potential impact on a project.
Streamflow	The flow of water in a natural channel, influenced by precipitation, groundwater, and land use.
Subsidence	The sinking of land due to groundwater over-extraction or soil compaction.

Sustainable Agriculture	Farming practices that meet current food needs without compromising the ability of future generations to meet theirs, often emphasizing soil health, water conservation, and biodiversity.
Sustainable Development	Development that meets the needs of the present without compromising the ability of future generations to meet their own needs, balancing economic, social, and environmental goals.
Traditional Knowledge	Knowledge, practices, and beliefs developed by indigenous and local communities over generations, often used to manage natural resources sustainably.
Total Dissolved Solids (TDS)	A measure of the combined content of inorganic and organic substances dissolved in water, affecting quality.
Transboundary Water Management	Cooperative management of shared water resources (e.g., rivers, aquifers) between countries or regions.
Water Allocation	The regulated distribution of water resources among competing users (e.g., agriculture, industry, households).
Water Balance	An accounting of all water inputs (precipitation) and outputs (evapotranspiration, runoff) in a catchment.
Water Footprint	The total volume of freshwater used to produce goods and services consumed by an individual, community, or organization.
Water Quality	The chemical, physical, and biological characteristics of water, determining its suitability for specific uses such as drinking, irrigation, or ecosystem health.
Water Scarcity	A condition where the demand for water exceeds the available supply, often exacerbated by population growth, climate change, and poor water management.
Water Table	The upper surface of the zone of saturation in the ground, where the soil or rocks are permanently saturated with water.
Water Use Efficiency (WUE)	The ratio of beneficial water use (e.g., crop yield) to total water applied, indicating sustainable practices.
Watershed	An area of land that drains all precipitation and surface water into a common outlet, such as a river, lake, or ocean. Synonymous with "catchment."
Wetland	An area of land that is saturated with water, either permanently or seasonally, supporting unique ecosystems and providing services such as flood control and water filtration.
Wetland Restoration	The process of returning a degraded wetland to its natural state to improve water quality and biodiversity.
Zoning	The process of dividing land into areas with specific land-use regulations, such as residential, agricultural, or conservation zones.

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