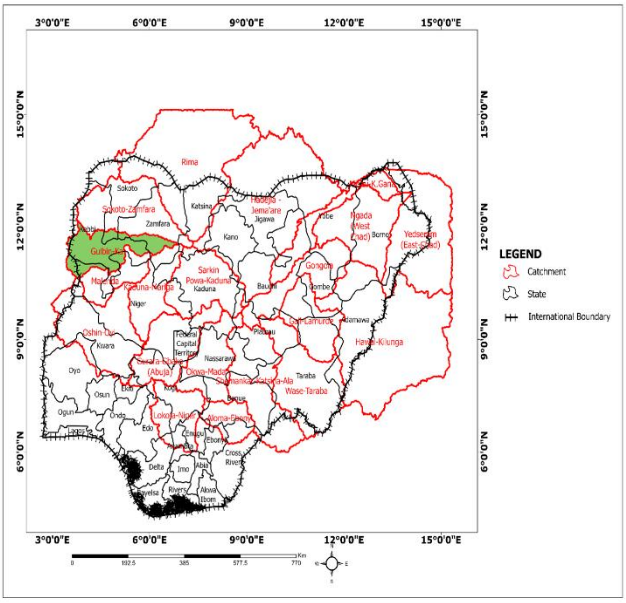
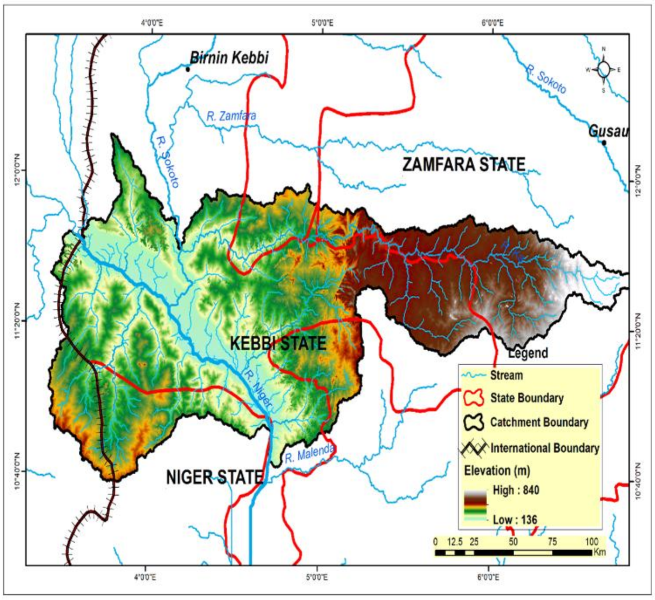
GULBIN-KA STRATEGIC CATCHMENT

MANAGEMENT PLAN REPORT





MARCH, 2025

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ACRONYMS AND ABBREVIATIONS

Symbols	**Description**
°C	Degree Celsius
°F	- Fahrenheit
Abbreviation/ Acronym	**Description**
ACReSAL	Agro Climatic Resilience in Semi- Arid Landscapes
AfDB	African Development Bank
ADP	Agriculture Development Program
AMSL	Above Mean Sea Level
ATA	Agricultural Transformation Agenda
AWF	African Water Facility
BCM	Billion Cubic Metre
CBDA	Chad Basin Development Authority
CCAFS	Climate Change, Agriculture and Food Security
CHIRPS	Climate Hazards Group InfraRed Precipitation with Station.
CJTF	Civilian Joint Task Force
CMCs	Catchment Management Committees.
CN	Curve Number
DEM	Digital Elevation Model
EA	Executing Agency
EC	Electrical Conductivity
EIA	Environmental Impact Assessment
ESIA	Environmental and Social Impact Assessment
EU	European Union

FAO	Food and Agriculture Organization of United Nations
FDC	Flow Duration Curve
FEPA	Federal Environment Protection Agency
FGD	Focus Group Discussion
FMEnv	Federal Ministry of Environment
FMAFS	Federal Ministry of Agriculture and Food Security
FMWR	Federal Ministry of Water Resources
GBV	Gender-based violence
GCM	Global Climate Model
GEFC	Global Environmental Flow Calculator
GIS	Geographic Information System
GPS	Global Positioning System
GRDB	Global Runoff Data Base
GRDC	Global Runoff Data Centre
Ha	Hectares
IAR	Institute of Agricultural Research
ICRC	International Committee of the Red Cross.
IDPs	Internal Displace Person's
IP	Irrigation Project
IUCN	International Union for Conservation of Nature
IWRM	Integrated Water Resources Management
IWRMD	Integrated Water Resources Management and Development
IWRMP	Integrated Water Resources Management and Planning
JICA	Japan International Cooperation Agency
KII	Key Informant Interview
LCBC	Lake Chad Basin Commission

LGP	Length of Growing Period
LUA	Land Use Act
LULC	Land Use Land Cover
M	Metres
masl	Metres above sea level
MCM	Million Cubic Metre
MDG	Millennium Development Goal
MSF	And Médecins Sans Frontières
MSL	Mecon Services Limited
M&E	Monitoring & Evaluation
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
NNJC	Nigeria-Niger Joint Commission
NRW	Non-Revenue Water
NRCS	Natural Resources Conservation Service
NSE	Nash-Sutcliffe Efficiency

NW	North West
NWRMP	National Water Resource Master Plan
OSGOF	Office of Surveyor General
PET	Potential Evapotranspiration
PIM	Participatory Irrigation Management
PMT	Project Management Team
PPT	Precipitation
PSC	Project Steering Committee
PWD	Projected Water Demand
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
SCS	Soil Conservation Service
SESA	Strategic Environmental and Social Assessment
SHA	Sub Hydrologic Area
SGS	Streamflow Gauging Station
SMA	State Ministry of Agriculture
SME	Small Medium Enterprise
SMM	Soil Moisture Method *(Hydrology rainfall-runoff model within WEAP)*
SMWR	State Ministry of Water Resources
SUBEB	Small Medium Enterprise
SWA	State Water Agencies

SSEA	Strategic Social and Environmental Assessment
TAP	Technical Advisory Panel
TOR	Terms of Reference
TRIMING	Transforming Irrigation Management in Nigeria
UBE	Universal Basic Education
UNESCO	United Nations Educational Scientific & Cultural Organization
UNICEF	United Nations Children's Fund
UTM	Universal Traverse Mercator
VAPP	Violence against Persons Prohibition
WASH	Water, Sanitation, and Hygiene
WEAP	Water Evaluation and Planning
WBG	World Bank Group
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 Gulbin-Ka Catchment, an important hydrological sub-basin in northwestern Nigeria, extends across parts of Kebbi, Sokoto, Niger, and Zamfara states. Covering approximately 29487 km^2 (2,948,700 hectares), the catchment supports agriculture, livestock production, fishing, and rural livelihoods. Seasonal river flows and floodplain dynamics shape the landscape, sustaining wetlands and diverse ecological systems. However, environmental challenges such as land degradation, water scarcity, and unsustainable land use practices threaten the catchment's long-term sustainability.

The Gulbin-Ka Catchment's topography ranges from the elevated rocky areas of Zuru and Danko-Wasagu to the low-lying floodplains near Yauri and Shanga, with altitudes descending from about 600 meters in the southeast to 150 meters towards the northwest. The catchment is characterized by the Gulbin-Ka River, a major tributary of the Niger River. Rainfall is highly seasonal, with most precipitation occurring between May and September. The construction of dams, including the Yauri Dam, has altered natural river flows, affecting water availability and ecosystem dynamics.

Vegetation patterns vary from Northern Guinea Savannah woodlands in the south to Sudan Savannah grasslands in the north, influenced by climate and soil conditions. Pressures from agricultural expansion, deforestation, and overgrazing contribute to widespread land degradation. Security challenges, particularly in the southern parts of the catchment, have further disrupted traditional land use and migration patterns. Population growth, expected to rise steadily by 2050, will increase competition for land and water resources.

Geologically, the Gulbin-Ka Catchment includes two main formations: the Basement Complex rocks dominating the southeastern uplands and the Sokoto Basin Sediments prevalent in the northwest. Soil types range from lithosols and leptosols in rocky uplands to fluvisols and gleysols along floodplains and river valleys. These variations influence land productivity, runoff behavior, and erosion risks, requiring site-specific land and water management strategies.

Land use and land cover reflect a blend of natural and human-modified landscapes. The upland regions are dominated by mixed woodland and grazing areas, while the floodplains support rice cultivation, fishing, and vegetable farming. Wetlands provide critical ecosystem services but are increasingly threatened by agricultural encroachment and water regulation structures.

Urban growth is limited but emerging in towns like Yelwa-Yauri, putting additional strain on local resources.

Sustainable land and water management is critical to combat soil erosion, enhance groundwater recharge, and maintain ecosystem services. Remote sensing tools such as the Normalized Difference Vegetation Index (NDVI) offer valuable insights for monitoring vegetation trends, land degradation, and resource use changes over time.

The Gulbin-Ka Catchment experiences a tropical climate with distinct wet and dry seasons. Rainfall distribution is uneven, with southern areas receiving higher rainfall than the drier northern zones. High temperatures and prolonged dry periods increase evapotranspiration, intensifying water scarcity during the dry season.

Climate projections suggest rising temperatures and erratic rainfall patterns, with potential negative impacts on water availability, agriculture, and soil stability. Hydrological assessments using CHIRPS rainfall data and SCS Rainfall-Runoff models indicate substantial seasonal variability across the catchment's sub-regions, including Zuru, Yelwa-Yauri, Argungu, and Ngaski.

Each sub-catchment exhibits unique hydrological features:

- **Zuru** is characterized by steep slopes, leading to rapid runoff and high erosion risks.
- **Yelwa-Yauri** has moderate rainfall and benefits from flood-recession agriculture but faces water storage challenges.
- **Argungu** features extensive floodplains that support seasonal farming but are vulnerable to flood damage.
- **Ngaski** has lower rainfall and depends heavily on groundwater for agricultural activities.

Targeted interventions such as watershed protection, rainwater harvesting, and small-scale irrigation systems are needed to balance water surpluses and shortages. Strengthened governance, investment in water infrastructure, and community engagement are essential for building resilience.

Water quality concerns arise from agricultural runoff, sedimentation, and waste discharge. Seasonal water shortages exacerbate pollution risks, impacting both human health and aquatic ecosystems. Water quality assessments focus on parameters such as turbidity, electrical conductivity, nitrates, heavy metals, and microbial contaminants.

The catchment's hydrogeology includes shallow alluvial aquifers along river valleys and deeper sedimentary aquifers within the Sokoto Basin. Surface water contributions to the Niger River are declining due to sedimentation and reduced wet season flows. Poor water management practices and competition among users have intensified resource conflicts.

Streamflow in Gulbin-Ka peaks during the rainy season (June–September) and declines sharply during the dry months, relying heavily on groundwater discharge and wetland storage. Nigeria's national surface water resources are underutilized, and Gulbin-Ka's contribution is estimated at 5.8 BCM/year, with groundwater recharge playing a critical supplementary role.

Climate change is expected to further stress groundwater systems, particularly in rocky upland areas with low infiltration capacities. In contrast, floodplain aquifers retain more stable water levels. Adapting to these trends requires integrated surface and groundwater management approaches.

Water demand projections indicate significant increases driven by urbanization, irrigation expansion, and population growth. Most rural communities depend on shallow wells and seasonal streams, with towns like Yelwa-Yauri also tapping surface water reservoirs. Without improved resource management, future water scarcity could threaten food security and livelihoods.

The livelihood water requirements for the catchment are rising due to increased agricultural activity and domestic needs. Implementing sustainable water use policies, expanding irrigation efficiency, and promoting alternative livelihoods will be key to managing future demand sustainably.

Water pollution risks are linked to fertilizer use, livestock waste, and untreated domestic wastewater. Surface water contamination by agrochemicals and microbial pollutants is a growing concern, particularly near agricultural zones and urban settlements. Groundwater is generally of better quality but is vulnerable to localized contamination from latrines and waste dumps.

Over the past 50 years, the catchment has experienced rising temperatures and increasingly variable rainfall patterns. Future climate models predict a temperature increase of 2–4°C by

2100, with uncertain rainfall trends. These changes are likely to heighten water insecurity and necessitate climate-smart agriculture and water conservation measures.

A GIS-based flood risk assessment identified vulnerable areas based on slope, elevation, proximity to rivers, land use, and rainfall intensity. Flood risk is highest along the floodplains of Yelwa-Yauri and Shanga, where seasonal overflows cause significant damage to farms and settlements. Agricultural fields, especially rice farms, and small towns are the most vulnerable land uses, underscoring the need for better flood management infrastructure and early warning systems.

Historical flood events have disrupted farming and displaced communities, highlighting the importance of proactive flood risk management.

Stakeholder consultations revealed pressing concerns over resource degradation, water scarcity, and governance gaps. Institutional capacity building, policy harmonization, and community-driven natural resource management are critical for sustainable catchment development.

The Gulbin-Ka Catchment is rich in natural resources, including arable land, fisheries, forests, and mineral deposits such as gold and limestone. However, these assets are under threat from overexploitation, insecurity, and weak institutional frameworks. Protecting and sustainably managing these resources will require integrated land and water management, climate adaptation strategies, enforcement of environmental regulations, and inclusive stakeholder engagement.

To foster sustainable development, key recommendations include strengthening water governance, promoting climate-resilient agriculture, restoring degraded ecosystems, and investing in infrastructure that supports livelihoods and environmental conservation.

Past and Ongoing Development Initiatives in the Catchment Area

To put the Plan in proper perspective, **Error! Reference source not found.** depicts some past and ongoing development initiatives by different partners in the Gulbin-Ka Catchment.

Table ES 1: Past and Ongoing Initiatives by Governments and Development Partners in the Catchment

S/No.	Location	Past Initiative	Ongoing Initiative
	KEBBI STATE	**Project :** Zauro Polder Project **Agency:** Federal Ministry of Agriculture & Water Resources **Focus:** Irrigation Development	**Project:** ACReSAL (Kebbi Component) **Agency:** World Bank & Kebbi State Government **Focus:** Climate Resilience & Watershed Management
		Project: Zuru Earth Dam **Agency:** Kebbi State Government **Focus:** Water Supply, Irrigation	**Agency:** Zuru Agricultural Research Centre **Agency:** Kebbi State Government **Focus:** Dryland Farming, Livestock
		Project: Zuru Earth Dam **Agency:** Kebbi State Government **Focus:** Water Supply, Irrigation	**Project:** Water Resources Management **Agency:** Kebbi ACReSAL **Focus:** Construction/Rehabilitation of Dams, Boreholes, Irrigation Networks
		Project : Small-Scale Irrigation Schemes **Agency:** Kebbi State Government **Focus:** Agricultural Water Management	**Project :** Solar Power Expansion **Agency:** Rural Electrification Agency **Focus:** Sustainable Energy
		Project: Reforestation Projects (Zuru) **Agency:** Kebbi Ministry of Environment **Focus:** Environmental Conservation	
	Zamfara State	**Project:** Bakolori Dam **Agency:** Federal Government **Focus:** Irrigation & Water Supply	**Project:** ACReSAL (Zamfara Component) **Agency:** World Bank & Zamfara State Government **Focus:** Climate Resilience & Watershed Management

			Project : Water Infrastructure Upgrades **Agency:** RUWASA **Focus:** WASH
		Project: Small Earth Dams **Agency:** Zamfara State Government **Focus:** Water Harvesting for Agriculture	**Project:** Community Climate Resilience **Agency:** Zamfara ACReSAL **Focus:** Dryland Management, Institutional Strengthening
	Niger State	**Project:** Kainji Dam **Agency:** Federal Government **Focus:** Hydropower & Water Regulation	**Project:** ACReSAL (Niger Component) **Agency:** World Bank & Niger State Government **Focus:** Climate Resilience & Watershed Management
		Project: Small-Scale Irrigation Projects **Agency:** Niger State Government **Focus:** Agricultural Water Management	**Project:** Farmer Support Programs **Agency:** Niger ACReSAL **Focus:** Training on Power Tiller Use, Agricultural Support
			Project : Rural Water Supply Projects **Agency:** Niger RUWASSA **Focus:** Water Supply
	Sokoto State	**Project:** Goronyo Dam **Agency:** Federal Government **Focus:** Flood Control & Irrigation	**Project :** ACReSAL (Sokoto Component) **Agency:** World Bank & Sokoto State Government **Focus:** Climate Resilience & Watershed Management
		Project: Sokoto Erosion and Watershed Management Agency (SEWMA) **Agency:** Sokoto State Government **Focus:** Erosion Control & Watershed Management	**Project:** Strategic Catchment Management Plans **Agency:** ACReSAL & Sokoto State Government **Focus:** Sustainable Water and Land Management

Although numerous initiatives have been implemented across the Gulbin-Ka Catchment, concerns persist regarding their overall effectiveness in delivering holistic and sustainable development outcomes. Many interventions appear to operate in isolation, lacking the integrated frameworks necessary to address the intricate interdependencies among environmental degradation, water resource stress, and socio-economic vulnerability. As a result, the catchment continues to experience enduring biophysical and social challenges that compromise its long-term resilience and development potential.

Main Biophysical and Socio-economic Challenges

Drawing from biophysical assessments and insights gathered through stakeholder engagement, the following outlines the principal biophysical and socio-economic challenges confronting the Gulbin-Ka Catchment:

Biophysical Challenges

i. **Land Degradation:** Widespread deforestation, overgrazing, and poor farming techniques have led to accelerated soil erosion, reduced fertility, and landscape destabilization. Floodplains, where over 90% of land is cultivated, are especially vulnerable due to the removal of natural vegetation buffers. In several areas, gully erosion has already made land uncultivable.

ii. **Water Resource Stress:** The catchment experiences highly seasonal water availability. During the dry season, baseflows drop significantly sometimes below 10 m^3/s making access to water for agriculture and domestic use unreliable. With only 24% of annual rainfall converted to surface runoff, the mismatch between supply and demand is a growing concern.

iii. **Flooding and Erosion:** Increased rainfall intensity, combined with land use changes and degraded vegetation cover, has escalated flash flooding risks. Areas like Yauri and Zuru experience recurrent flood damage, affecting homes, farms, and infrastructure. Erosion, both sheet and gully, further exacerbates land degradation.

iv. **Wetland and Ecosystem Degradation:** Wetlands that once provided flood buffering, fish breeding grounds, and water filtration are under pressure from agricultural expansion and the spread of invasive species like Typha grass. These changes threaten biodiversity and reduce the natural ecological functions that regulate hydrology and water quality.

v. **Climate Variability:** Rising temperatures (+2–4°C projected by 2100) and erratic rainfall patterns are increasing evapotranspiration and reducing the effectiveness of rain-fed systems. These conditions not only affect crop yields but also compound the pressure on groundwater and surface water systems.

vi. **Biodiversity Loss:** Habitat fragmentation, deforestation, and overexploitation of aquatic resources have led to a marked decline in species richness. Forest reserves are shrinking, and overfishing compounded by wetland degradation is threatening local fisheries, a vital livelihood source.

Socio-Economic Challenges

i. **Livelihood Vulnerability:** Most rural households depend on subsistence farming and pastoralism, both highly sensitive to climate variability and environmental degradation. Low access to extension services, improved inputs, and irrigation technology limits adaptive capacity and income generation.

ii. **Insecurity and Conflict:** Farmer-herder conflicts, banditry, and displacement are major barriers to stability and development in the catchment, particularly in Zamfara and parts of Niger. These security threats disrupt agricultural activities, weaken social cohesion, and reduce investment in productive assets.

iii. **Urbanization Pressure:** Rapid population growth and city expansion in areas like Birnin Kebbi and Gusau are displacing agricultural land and wetlands, increasing the risk of urban flooding and straining already limited public services and infrastructure.

iv. **Infrastructure Deficits:** Poor rural roads, limited access to potable water, and weak energy infrastructure inhibit market access, value addition, and service delivery. These gaps disproportionately affect remote communities and hinder development interventions from scaling effectively.

v. **Gender Inequality:** Women are particularly disadvantaged in access to land ownership, financial services, education, and participation in governance. Their exclusion from decision-making limits household and community resilience to environmental and economic shocks.

vi. **Institutional and Governance Weaknesses:** The catchment suffers from fragmented institutional mandates and poor inter-agency coordination. Stakeholders report weak enforcement of existing environmental regulations and a lack of integrated planning across sectors. This undermines the efficiency and sustainability of development efforts.

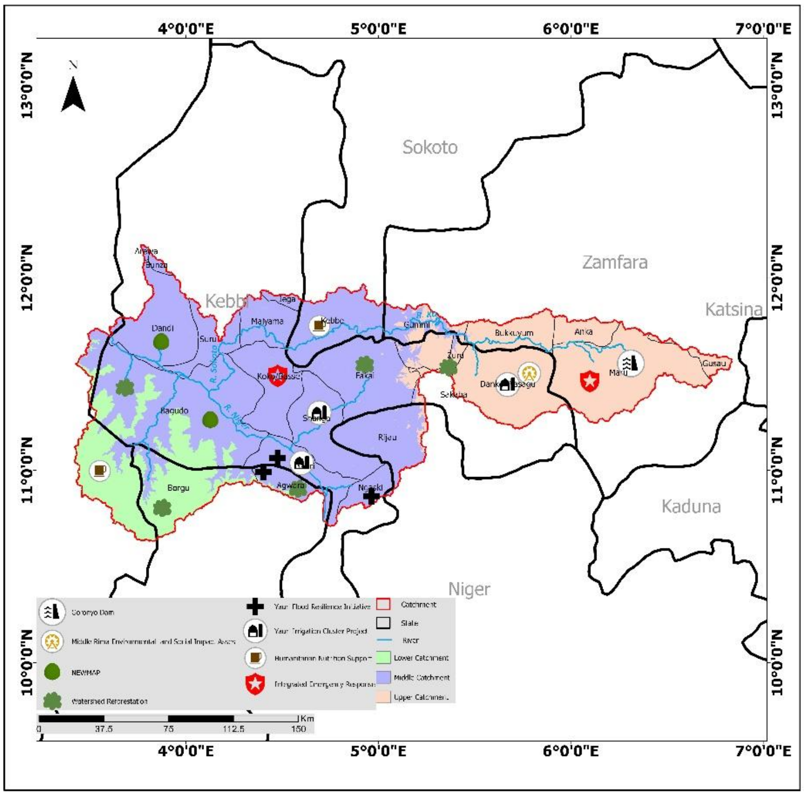


Figure E.S.1: Gulbin-Ka Catchment Showing the Past Interventions (Source: MSL, 2025)

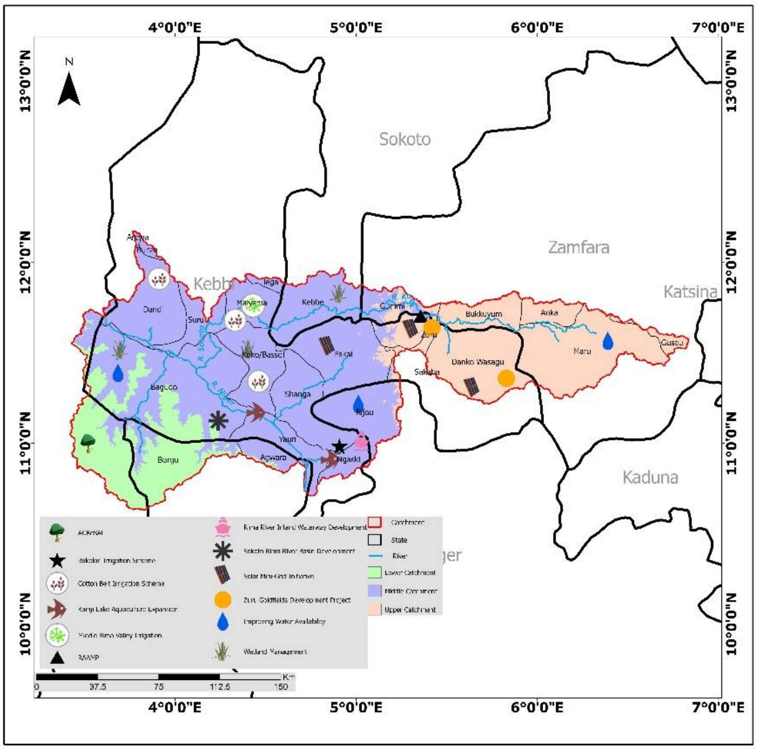


Figure E.S.2: Gulbin-Ka Catchment Showing the Ongoing Interventions (Source: MSL, 2025)

Elements of the Catchment Management Plan

The elements of the Gulbin-Ka Catchment Management Plan are captured through the lenses of the following strategic vision and objectives:

Strategic Vision

To ensure the sustainable utilization, conservation, and integrated management of land, water, and ecological resources within the Gulbin-Ka Catchment—enhancing resilience, improving livelihoods, and promoting inclusive development for present and future generations.

Strategic Objectives

The catchment management plan defines eight core objectives:

a. **Promote Climate-Smart Agriculture:** Implement resilient farming systems to improve food and nutrition security while reducing environmental impacts. Support farmers with improved seeds, drought-resistant crops, and adaptive irrigation technologies.

b. **Restore Ecosystems and Enhance Natural Capital:** Reforest degraded lands, rehabilitate wetlands, and protect biodiversity. Strengthen land use enforcement, especially in erosion-prone and overgrazed areas.

c. **Build Climate Resilience through Clean Energy and Innovation:** Scale up the use of solar-powered infrastructure in irrigation and rural electrification. Encourage eco-innovation for energy access and climate mitigation.

d. **Integrate Water Resources Management (IWRM):** Map and monitor surface and groundwater resources. Strengthen Water User Associations and establish standard procedures for water facility maintenance.

e. **Mainstream Gender and Social Inclusion:** Ensure meaningful participation of women, youth, and vulnerable populations in planning, implementation, and decision-making processes. Address systemic barriers to land and financial access.

f. **Institutionalize Participatory Monitoring and Evaluation (M&E):** Develop inclusive, transparent M&E frameworks to assess project outcomes. Conduct regular stakeholder reviews and feedback sessions.

g. **Strengthen Community Stewardship of Natural Resources:** Foster local ownership and accountability through community-led conservation and land management initiatives.

h. **Develop Effective Conflict Resolution Mechanisms:** Create institutional platforms to mediate farmer-herder conflicts and resource use disputes, particularly in high-risk LGAs such as Dandi, Danko Wasagu, and Argungu.

Catchment Policies

For harmonious relationship and engagement of stakeholders regarding equitable utilization of inter-state water resources 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

- 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)
- Nigeria's Agricultural Transformation Agenda (ATA)
- Nigeria's National Forest Policy (2006)

Plan Components

To achieve the outlined goal and objectives to ameliorate the challenges in the Gulbin-Ka catchment, the following are the strategic components or intervention areas of the Plan:

Component 1: Sustainable conservation, management, and use of water resources: Implementing modern irrigation systems, promoting water-saving technologies, and enforcing water allocation plans will enhance water use efficiency and support regional development. Establishing water user associations, developing fair water pricing policies, and promoting community-based water management will ensure equitable water distribution, minimizing conflicts among user groups. Soil conservation, reforestation, and pollution control regulations are essential to protect the catchment's ecological health and natural resources. Flood management plans, water storage infrastructure, and community resilience programs will mitigate the impacts of floods and droughts, enhancing the catchment's resilience. Comprehensive monitoring systems, leveraging advanced technologies like remote sensing and GIS, will support data-driven decision-making and ensure the long-term sustainability of water resources.

Component 2: Preservation and restoration of critical ecosystems and services for sustainable land use; including sustainable agricultural and livestock practices: The ecological health of the Gulbin-Ka Catchment is crucial for the sustainability of its land and water resources, but increasing human activities particularly agriculture, pastoralism, and fuelwood collection have led to severe ecosystem degradation. Heavy reliance on forest biomass for energy has caused unsustainable deforestation in key ecological areas, resulting in forest fragmentation, biodiversity loss, and declining water quality due to erosion and pollution.

To address this, the Catchment Management Plan will focus on restoring degraded ecosystems through reforestation, wetland protection, and sustainable land-use practices. These actions will be complemented by climate-smart agriculture and sustainable livestock management to reduce environmental pressure while boosting productivity.

The goal is to restore ecological resilience, safeguard water resources, and secure vital ecosystem services for long-term sustainability and climate adaptation.

Component 3: Improved diversification for enhanced sustainable livelihoods and well-being: Agriculture is the main livelihood in the Gulbin-Ka Catchment, but small-scale subsistence farming and unsustainable practices have led to low productivity, income insecurity, and overuse of natural resources. This economic vulnerability drives youth migration to urban areas, reducing labour for agriculture and weakening community resource management.

To address these issues, the Catchment Management Plan emphasizes sustainable livelihood diversification. Key actions include building capacity for climate-smart agriculture, agro-processing, and entrepreneurship, improving access to finance, land, and markets, especially for women and youth, strengthening local value chains for income stability and promoting community-led planning and equitable resource governance.

These measures aim to reduce pressure on natural resources, curb migration, and support resilient, inclusive economic development in the catchment.

Component 4: Climate change, disaster risk management, and climate-resilient infrastructure: The Gulbin-Ka Catchment faces growing climate change threats, including rising temperatures, erratic rainfall, droughts, and intensified flooding—putting rain-fed agriculture, fisheries, and pastoral livelihoods at risk. These challenges are worsened by degraded ecosystems, poor infrastructure, and weak institutional capacity, with unplanned land use and lack of protective measures further increasing community vulnerability.

To address this, the Catchment Management Plan will integrate climate adaptation and disaster risk reduction into development efforts. Key actions include building climate-resilient infrastructure like irrigation systems and erosion controls, establishing early warning systems and emergency response protocols, enhancing local capacity for risk-aware natural resource management, promoting nature-based solutions such as reforestation and wetland restoration and providing localized climate information to guide agricultural and economic decisions.

These measures aim to boost the region's adaptive capacity, reduce vulnerability, and protect both livelihoods and ecosystems over the long term.

Component 5: Strengthening institutional mechanisms and project coordination mechanisms: The Gulbin-Ka Catchment spans multiple administrative areas and involves diverse stakeholders across sectors like water, agriculture, environment, and rural development. However, fragmented mandates, poor inter-agency coordination, and a lack of unified governance hinder effective collaboration, leading to duplication of efforts and reduced impact of watershed initiatives.

To address this, the Gulbin-Ka Catchment Management Plan will establish a coordinated and inclusive institutional framework. Key actions include clarifying institutional roles, creating multi-stakeholder coordination platforms, strengthening capacities at state and local levels, empowering community governance structures, and aligning catchment goals with broader development plans.

This approach aims to enhance coordination, improve institutional efficiency, and ensure the long-term success and sustainability of interventions in the catchment.

Component 6: Mainstreaming gender equality and social inclusion (GESI) mechanism: In the Gulbin-Ka Catchment, increased male migration to urban areas has shifted gender roles, with women taking on greater responsibilities in households, agriculture, natural resource management, and community leadership. This shift brings both opportunities for women's empowerment and economic growth, particularly through market-oriented agriculture, and challenges due to persistent barriers such as limited access to land, credit, education, and decision-making.

To address this, the Gulbin-Ka Catchment Management Plan integrates Gender Equality and Social Inclusion (GESI) across all stages of planning and implementation. The plan aims to empower women, youth, and marginalized groups as active participants in watershed governance. Key actions include improving women's access to financial services and training, ensuring their representation in governance structures, creating inclusive livelihood programs, tackling social and institutional barriers, and incorporating GESI-sensitive indicators into monitoring frameworks.

This approach seeks to ensure equitable resource distribution, enhance resilience, and promote the long-term success of catchment interventions.

Component 7: Research and extension: Sustainable management of the Gulbin-Ka Catchment depends on locally relevant, evidence-based research. This component prioritizes action-oriented studies and adaptive extension systems to support integrated watershed planning aligned with the region's biophysical and socio-economic context.

Core research areas include the integration of indigenous knowledge, validation of nature-based solutions (e.g., reforestation, agroforestry, wetland restoration), and the assessment of soil and water conservation effectiveness. Additional studies will focus on sediment yield modelling, climate impacts on ecosystems and agriculture, and the role of microfinance in building livelihood resilience.

Findings will be translated into practical extension tools and shared through farmer field schools, digital platforms, and partnerships, with inclusive outreach to women, youth, and marginalized communities to ensure equitable access to innovations and best practices.

Component 8: Effective coordinated monitoring, evaluation, and reporting mechanism and system: This component focuses on establishing a robust, inclusive, and transparent MER system to support the adaptive management of the Gulbin-Ka Catchment. It emphasizes building institutional and technical capacity at all governance levels to regularly monitor watershed services and evaluate the effectiveness of the Catchment Management Plan.

Key priorities include standardizing indicators and data protocols, developing a centralized digital platform for real-time reporting, training stakeholders in participatory M&E, and integrating geospatial tools for tracking environmental changes. Periodic performance reviews and knowledge products will guide adaptive planning and support coordination with partners.

Ultimately, the MER system will enhance accountability, strengthen decision-making, and ensure that interventions deliver measurable and equitable outcomes across the catchment.

Table ES 1 shows the significant issues in the watershed and the proposed solutions, including the local, state, and national implementing partners.

Table ES 1: Summary of Components and Activities of the Gulbin-Ka Catchment Plan

Component	Activities	Key Indicators	Responsibility/Partners
1. Sustainable conservation, management, and use of water resources	Mapping and inventory of water resources Strengthening Water User Associations Policy review and enforcement	Percentage of functional water facilities- Volume of water abstracted sustainably Numbers of WUAs established	State Ministries of Water Resources (SMWR), RUWASA, Nigeria Integrated Water Resources Management Commission (NIWRMC)

	Establishment of SOPs for water facility management		
2. Preservation and restoration of critical ecosystems and services for sustainable land use (incl. agriculture/livestock)	Reforestation and afforestation Enforcement of mining and land use policies Promotion of soil fertility practices Rotational grazing schemes	Area (ha) of restored land- Vegetation cover index (NDVI) Percentage decrease in land disputes	Ministries of Environment and Agriculture, Forest Departments, Community Forest Committees
3. Improved diversification for enhanced sustainable livelihoods and well-being	Agricultural Free Trade Zone (AFTZ) establishment- Support to rural SMEs Access to credit facilities- Skills training for youth and vulnerable groups	Number of SMEs supported Percentage increase in household income- AFTZ operational status	State Ministries of Commerce & Industry, NGOs, Microfinance Banks, Community Development Committees
4. Climate change, disaster risk management, and climate-resilient infrastructure	Installation of meteorological stations Early warning systems- Climate-smart agriculture promotion- Flood control infrastructure	Number of early warning systems operational- Area (ha) under climate-resilient farming Number of disaster response plans enacted	Nigerian Meteorological Agency (NiMet), NEMA, SMWR, ACReSAL Project Units

5. Strengthening institutional mechanisms and project coordination	Stakeholder mapping and engagement- Capacity building workshops Harmonization of sectoral policie Conflict resolution platforms	Number of multi-stakeholder forums Percentage of policies harmonized Number of resolved resource conflicts	Sokoto Rima River Basin Dev. Authority, Ministries of Environment & Lands, LGAs, NGOs
6. Mainstreaming gender equality and social inclusion (GESI)	Gender-responsive project planning Inclusion of women and PWDs in leadership roles GESI awareness campaigns	Percentage of women in project committees Number of GESI-compliant projects- GESI policy adoption rate	State Ministries of Women Affairs, GESI Focal NGOs, UNICEF
7. Research and extension	Collaboration with research institutes- Development of innovation platforms Deployment of extension officers	Number of research publications adopted- Farmer adoption rates of new practices- Extension service coverage	Agricultural Machinery Dev. Institute (AMEDI), Livestock R&D Centre, NIFR Yauri
8. Effective coordinated monitoring, evaluation, and reporting (M&E) system	Real-time database development- Design of logical frameworks and KPIs Feedback loops from stakeholders	M&E reports produced annually- Stakeholder satisfaction score- % of indicators on track	Project Steering Committees, ACReSAL M&E Units, State M&E Offices

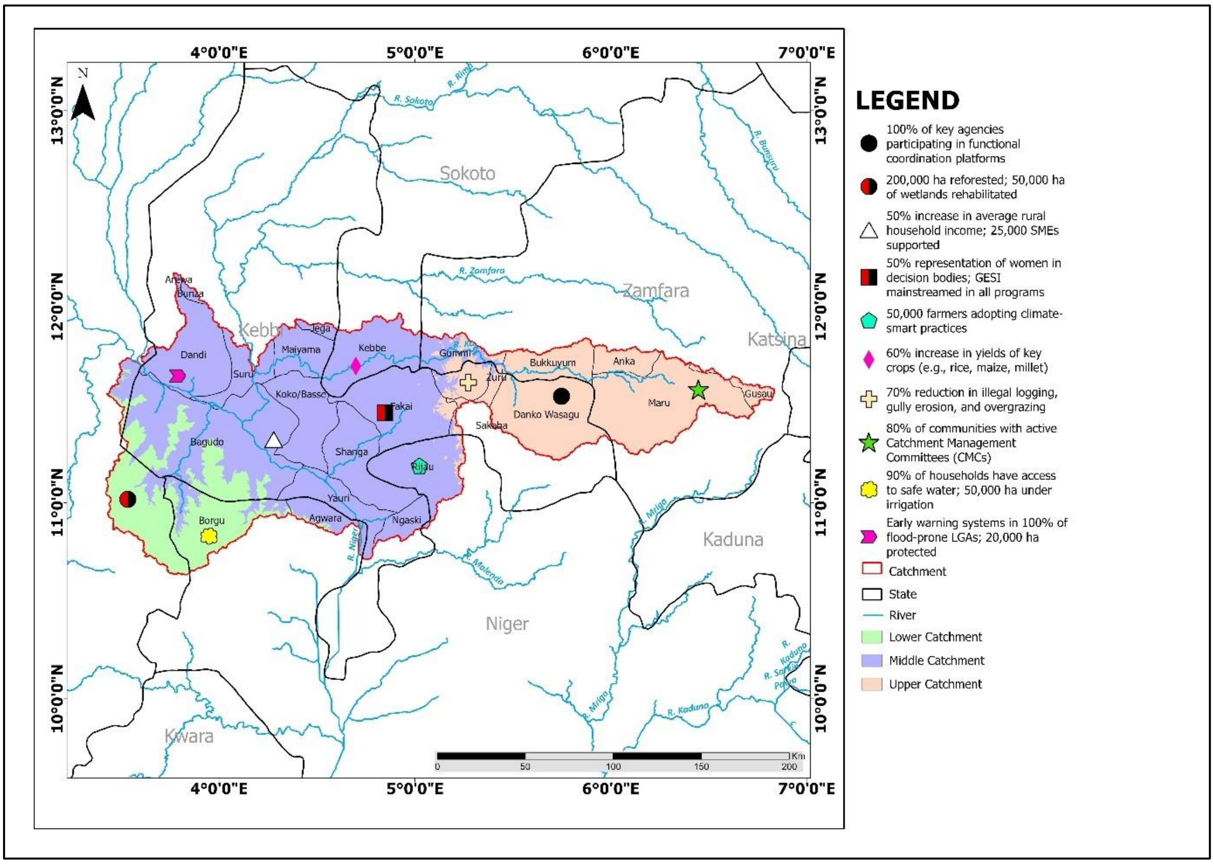


Figure E.S.3: Gulbin-Ka Catchment Showing the Recommended Interventions (Source: MSL, 2025)

Table E.S.3: Upper Catchment of the Gulbin-Ka Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Town	Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Upper Catchment	**Bukkuyum**	Severe gully erosion on hilly terrain	Gully reclamation (check dams, vegetative barriers)	GIS erosion mapping, drone surveys	ACReSAL, State Ministry of Environment, FMEnv	Stabilized landforms, reduced loss of farmland
	Anka	Illegal mining leading to land degradation	Land reclamation, enforcement of mining regulations	Remote sensing for land degradation, mining site mapping	Min. of Mines, NESREA, State Min. of Env.	Restored land, safer environment
	Gusau	Rapid urbanization causing deforestation	Urban greenbelt creation, afforestation programs	NDVI satellite imagery, urban planning GIS Urban land use planning tools, satellite imagery	State Urban Dev. Board, FMEnv	Improved green cover, sustainable urban growth
	Maru	Deforestation from fuelwood collection	Promotion of alternative energy (clean cookstoves, LPG), community woodlots	Community nursery programs, household energy surveys	State Forestry Dept, Energy Commission	Reduced tree loss, improved household energy security

	Danko-Wasagu	Flash floods in valley areas	Construction of small dams, stormwater drainage systems	Hydrological flood models, hazard maps	NIHSA, NEMA, Local Govts, FMAFS, ACReSAL	Reduced flood impact, protected communities
	Zuru	Soil erosion from unsustainable farming on slopes	Farmer training, agroforestry, terracing	Agroforestry demonstration sites, slope analysis maps	Agric Extension, State Min. of Agriculture	Enhanced soil stability, sustainable land management
	Sakaba	Biodiversity loss due to habitat encroachment	Community-based conservation, protected area establishment	Biodiversity surveys, participatory land-use planning	Nat. Park Service, FMEnv	Protected habitats, preserved biodiversity

Table E.S.4: Middle Catchment of the Gulbin-Ka Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Town	Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Middle Catchment	**Arewa**	Flooding from seasonal rivers	Construction of embankments, community flood	Hydrological models, community-based risk mapping	NIHSA, NEMA, State Min. of Environment, ACReSAL. FMW, NIWRMC	Reduced flood risk, enhanced community safety

			early warning systems			
	Bunza	Water scarcity during dry season	Small-scale irrigation schemes, water harvesting structures	Borehole siting with GIS, rainfall-runoff modeling	RUWASSA, Agric Dev Program, NIWRMC, NIHSA	Improved water access, enhanced dry-season farming
	Dandi	Land degradation due to overgrazing	Rangeland management, controlled grazing, fodder bank establishment	Range condition surveys, satellite monitoring	State Livestock Dept, Agric Extension	Restored pasture lands, sustainable livestock rearing
	Suru	Soil erosion on moderate slopes	Contour bunding, agroforestry, farmer field schools	Erosion risk mapping, field demonstration plots	State Agric Ministry, ACReSAL, FMEnv	Improved soil conservation, better farm yields
	Jega	Sedimentation of small water bodies	Desilting of reservoirs, catchment protection with tree planting	Sediment load monitoring, watershed mapping	State Water Resources, FMEnv, ACReSAL,	Enhanced water storage capacity, reduced siltation
	Maiyama	Deforestation due to fuelwood demand	Community woodlots, promotion of clean energy (LPG, improved stoves)	Household energy surveys, woodlot inventory	State Forestry Dept, Energy Commission, FMEnv, LGA	Reduced tree felling, alternative energy adoption

	Koko/Besse	Floodplain encroachment by farming	Zoning and enforcement of buffer zones, wetland restoration	Participatory land use planning, GIS wetland maps	State Min. of Land, FMEnv. ACReSAL, LGA	Protected floodplain, sustainable wetland use
	Fakai	Poor soil fertility affecting productivity	Soil fertility improvement programs, promotion of organic manure	Soil testing kits, precision farming advisory	Agric Extension, Fertilizer Dept, FMWR, LGA, ADP	Increased crop yields, improved soil health
	Rijau	Uncontrolled artisanal mining degrading land	Reclamation of mined sites, formalization of artisanal mining	Mine site mapping, remote sensing	Min. of Mines, NESREA, State Min. of Env.	Restored land, safer mining practices
	Ngaski	Overfishing in river systems	Community fisheries management, fish hatchery development	Fish stock assessment surveys, GIS aquatic habitat maps	Fisheries Dept, Agric Extension	Sustainable fisheries, improved fish stocks
	Agwara	Seasonal food insecurity	Dry-season farming support, market access improvements	Crop suitability maps, mobile market information systems	Agric Dev Program, State Commerce Ministry,LGA,FMWR	Improved food security, higher farmer incomes
	Yauri	Riverbank erosion	Riverbank stabilization with	Riverbank erosion hazard maps, drone monitoring	NIHSA, ACReSAL, State Min. of Works	Stabilized riverbanks,

		threatening settlements	vetiver, stone pitching			protected settlements
	Shanga	Waterborne disease outbreaks during floods	Improved sanitation facilities, clean water provision	Water quality testing, public health surveys	RUWASSA, State Min. of Health	Reduced disease incidence, improved public health

Table E.S.5: Lower Catchment of the Gulbin-Ka Strategic Catchment – Spatial Challenges and Intervention Matrix

Section	LGA/Town	Challenge	Proposed Intervention	Appropriate Tool(s) For Sustained Monitoring and Evaluation	Responsible Agency	Expected Outcome
Lower Catchment	**Bagudo**	Frequent floodplain inundation damaging farmlands	Construction of levees, promotion of flood-resilient crop varieties	Hydrological flood modelling, participatory land use maps	NIHSA, State Min. of Agriculture, NEMA, FMWR, NIWRMC, ACReSAL	Reduced crop loss, improved flood management
	Bagudo	Cross-border grazing conflicts (due to proximity to Benin)	Establishment of grazing reserves, peace-building and dialogue platforms	Conflict mapping tools, GIS-based grazing route maps	State Livestock Dept, National Boundary Commission	Reduced farmer-herder conflicts, secured grazing routes

	Borgu	Loss of biodiversity in riverine ecosystems (Niger River)	Community-based conservation, eco-tourism promotion	Biodiversity surveys, habitat mapping	National Parks Service, NESREA	Conserved biodiversity, increased community livelihoods
	Borgu	Illegal fishing practices reducing fish stocks	Strengthening fishing regulation enforcement, fishery co-management	Fish stock monitoring tools, aquatic ecosystem GIS maps	Fisheries Dept, State Min. of Environment	Recovered fish populations, sustainable fishing

Expected Outcomes

The successful implementation of the interventions in the Gulbin-Ka SCMP will result in:

- **Improved Water Availability and Quality**: Through infrastructure rehabilitation, rainwater harvesting, and integrated water management practices, ensuring sustainable water resource management.
- **Restored Ecosystems**: Stabilizing hydrological cycles, enhancing biodiversity, and reinforcing ecological integrity through afforestation and wetland restoration.
- **Reduced Flood and Drought Vulnerability**: Implementing flood risk assessments, improving drainage systems, and developing early warning systems.
- **Enhanced Livelihoods**: Empowering local communities through training programs, access to credit, and improved market opportunities for farmers and fisherfolk.
- **Improved Food Security**: Increasing agricultural productivity via climate-smart agriculture, improved soil fertility management, and micro-irrigation adoption.
- **Diversified Economic Activities**: Developing community-based tourism and eco-friendly economic activities to boost local economies.
- **Strengthened Climate Adaptation**: Building resilience to climate change impacts through community-based initiatives, afforestation, and drought-resistant crop promotion.
- **Sustainable Natural Resource Management**: Ensuring long-term ecological and socio-economic stability by addressing desertification and climate-induced vulnerabilities.
- **Strengthened Governance Structures**: Establishing integrated water resource management frameworks and enhancing inter-agency coordination.
- **Inclusive Stakeholder Engagement**: Ensuring community representation in decision-making processes and strengthening institutional mechanisms for effective governance.
- **Equitable Participation**: Promoting gender equality by ensuring women's involvement in decision-making and resource management.
- **Economic Empowerment**: Providing women with greater opportunities through training and access to economic resources.

CHAPTER 1 : INTRODUCTION

1.1 Purpose of the Plan

The Gulbin-Ka Catchment Management Plan aims to provide a comprehensive framework for the sustainable management of the catchment's natural resources, addressing the complex environmental, socio-economic, and governance challenges faced by the region. The plan seeks to promote sustainable development by balancing ecological preservation with socio-economic development. Its specific objectives include:

i. **Improving Water Resource and Flood Risk Management**: Ensuring sustainable water resource management, including the protection of water sources, efficient water use, and mitigation of flood and drought risks. The plan emphasizes the rehabilitation of critical water infrastructure, such as dams and reservoirs, and the development of small-scale water storage systems. It also advocates for enhanced drainage systems, regular flood risk assessments, and public awareness campaigns to safeguard communities against water-related hazards.

ii. **Preserving and Restoring Critical Ecosystems and Services**: Protecting and restoring ecosystems, including forests, wetlands, and wildlife habitats, to maintain biodiversity, support ecosystem services, and promote ecological resilience. The plan sets ambitious goals for afforestation and wetland restoration to stabilize hydrological cycles, bolster biodiversity, and reinforce the ecological integrity of the catchment.

iii. **Promoting Sustainable Agricultural and Livestock Practices**: Enhancing food security and economic resilience through sustainable agriculture and livestock practices. The plan aims to increase agricultural productivity through climate-smart approaches, improve soil fertility, and support smallholder farmers with training and technology. It also encourages the adoption of micro-irrigation and erosion control measures.

iv. **Enhancing Climate Resilience**: Building climate resilience through community-based initiatives, afforestation programs, and the promotion of drought-resistant crop varieties. The plan focuses on addressing desertification and climate-induced vulnerabilities, ensuring long-term ecological and socio-economic stability.

v. **Improving Livelihoods and Human Well-being**: Empowering local communities, particularly smallholder farmers and fisherfolk, through sustainable practices, access to credit, and eco-friendly economic activities. The plan aims to enhance livelihoods by providing training programs, facilitating market access, and developing community-based tourism.

vi. **Strengthening Governance and Stakeholder Collaboration**: Establishing integrated water resource management frameworks, improving inter-agency coordination, and ensuring inclusive community representation in decision-making processes. The plan advocates for the establishment of regulatory frameworks for integrated water resource management at the catchment level and the strengthening of institutional mechanisms to enhance governance structures.

1.2 Rationale for a Strategic Catchment Plan

The strategic vision of the Gulbin-Ka Catchment Management Plan is to manage natural resources sustainably, promote ecosystem services, and improve local livelihoods while preserving the ecological integrity of the catchment. Aligning with this vision, the plan outlines the following strategic objectives:

- Improve water resource and flood risk management to ensure sustainable water resource management, including the protection of water sources, efficient water use, and mitigation of flood and drought risks.
- Preserve and restore critical ecosystems and services by protecting and restoring ecosystems, including forests, wetlands, and wildlife habitats, to maintain biodiversity and support ecosystem services.
- Promote sustainable agricultural and livestock practices, including conservation agriculture, agroforestry, and integrated water management, to reduce environmental degradation and improve livelihoods.
- Enhance climate resilience by implementing climate-resilient practices, including climate-smart agriculture, disaster risk reduction, and ecosystem-based adaptation, to strengthen the catchment's resilience to climate change.
- Improve the livelihoods and well-being of stakeholders in the catchment, including women and youth, through enhanced access to education, healthcare, and economic opportunities.
- Strengthen inclusive governance and stakeholder partnerships for coordinated and effective catchment management by building institutional and technical capacity at all levels of governance (federal, state, local government, and communities).

1.3 Expected Outcomes

1. **Environmental Outcomes**

- **Improved Water Availability and Quality**: Through infrastructure rehabilitation, rainwater harvesting, and integrated water management practices, ensuring sustainable water resource management.
- **Restored Ecosystems**: Stabilizing hydrological cycles, enhancing biodiversity, and reinforcing ecological integrity through afforestation and wetland restoration.
- **Reduced Flood and Drought Vulnerability**: Implementing flood risk assessments, improving drainage systems, and developing early warning systems.

2. **Socio-Economic Outcomes**

- **Enhanced Livelihoods**: Empowering local communities through training programs, access to credit, and improved market opportunities for farmers and fisherfolk.
- **Improved Food Security**: Increasing agricultural productivity via climate-smart agriculture, improved soil fertility management, and micro-irrigation adoption.
- **Diversified Economic Activities**: Developing community-based tourism and eco-friendly economic activities to boost local economies.

3. **Climate Resilience Outcomes**

- **Strengthened Climate Adaptation**: Building resilience to climate change impacts through community-based initiatives, afforestation, and drought-resistant crop promotion.
- **Sustainable Natural Resource Management**: Ensuring long-term ecological and socio-economic stability by addressing desertification and climate-induced vulnerabilities.

4. **Governance and Institutional Outcomes**

- **Strengthened Governance Structures**: Establishing integrated water resource management frameworks and enhancing inter-agency coordination.
- **Inclusive Stakeholder Engagement**: Ensuring community representation in decision-making processes and strengthening institutional mechanisms for effective governance.

5. **Gender Equality and Social Inclusion Outcomes**

- **Equitable Participation**: Promoting gender equality by ensuring women's involvement in decision-making and resource management.
- **Economic Empowerment**: Providing women with greater opportunities through training and access to economic resources.

1.4 Environmental Roles

The Gulbin-Ka Catchment Management Plan outlines several critical environmental roles that are essential for the sustainable management of the catchment. These roles described below are designed to protect and enhance the natural resources and ecosystems within the Gulbin-Ka Catchment, ensuring their long-term viability and continued provision of essential services to the region's communities.

1. **Conservation of Natural Resources**: The plan emphasizes the importance of conserving natural resources such as water, soil, and biodiversity for future generations. This involves sustainable practices that prevent overexploitation and degradation of these resources. Key actions include the protection of water sources, efficient water use, and the mitigation of flood and drought risks through sustainable water resource management.
2. **Protection of Ecosystem Services**: The plan recognizes the need to protect ecosystem services, including water filtration, flood control, and carbon sequestration. These services are vital for maintaining the ecological balance and providing benefits to human communities. The plan advocates for the restoration of degraded ecosystems, such as forests, wetlands, and wildlife habitats, to ensure the continued provision of these services.
3. **Climate Change Mitigation**: The plan highlights the role of the catchment in mitigating climate change impacts. By promoting sustainable land use practices, conserving water, and protecting biodiversity, the catchment can contribute to reducing greenhouse gas emissions and enhancing carbon sequestration. This is achieved through afforestation, wetland restoration, and the adoption of climate-smart agriculture practices.
4. **Soil and Water Conservation**: The plan focuses on soil and water conservation to prevent erosion, reduce sedimentation in water bodies, and maintain soil fertility. This is crucial for agricultural productivity and the overall health of the catchment's ecosystems. Practices such as contour farming, agroforestry, and the use of cover crops are promoted to enhance soil and water conservation.
5. **Biodiversity Conservation**: The plan underscores the importance of preserving the catchment's rich biodiversity. This involves protecting habitats, preventing habitat

fragmentation, and combating invasive species. The conservation of biodiversity not only supports ecological balance but also provides aesthetic, cultural, and economic benefits to the communities living within the catchment.

1.5 Socio-Economic Roles

The socio-economic roles of the catchment are as follows:

1. **Livelihood Support**: The catchment provides water for agriculture, livestock, fishing, and other economic activities, underpinning local livelihoods and food security.
2. **Economic Diversification**: It supports a range of economic activities beyond agriculture, such as fishing, trade, and commerce, and holds potential for eco-tourism.
3. **Employment Generation**: The catchment generates employment across various sectors, from agricultural and livestock activities to processing and trading.
4. **Poverty Alleviation and Infrastructure Development**: By enhancing agricultural productivity and providing economic opportunities, the catchment alleviates poverty and supports infrastructure development, including irrigation systems and water supply systems.

1.6 Governance and Institutional Roles

The four Governance and Institutional Roles are as follows:

1. **Enhanced Institutional Coordination**: Strengthen coordination among federal, state, and local agencies to ensure cohesive catchment management.
2. **Stakeholder Engagement**: Ensure active participation of all stakeholders, including local communities, civil society, and private entities, in decision-making processes.
3. **Policy and Legislative Framework**: Develop and enforce policies and legislation that support sustainable resource management and equitable resource use.
4. **Capacity Building and Knowledge Management**: Build institutional capacity through training and knowledge sharing to improve governance and management of the catchment.

CHAPTER 2 : CHARACTERISTICS OF THE CATCHMENTS

2.1 Location

2.1.1 Location and Boundary

The Gulbin-Ka Catchment is located in northwestern Nigeria and covers parts of Kebbi, Zamfara, Niger, and Sokoto states. It is part of the Sokoto-Rima River Basin and politically covers parts of the following four states:

- **Kebbi State**: Including areas such as Yauri and Suru.
- **Zamfara State**: Including areas such as Bukkuyum and Maru.
- **Niger State**: Including areas such as Argungu and Shanga.
- **Sokoto State**: Including areas such as Yabo and Sokoto.

The catchment shown in Figure 2.1 is geographically bounded by the Sokoto Zamfara catchment to the north, Malenda catchment to the south, and Kaduna-Mariga catchment to the east. It spans an area of approximately 2,948,700 hectares and is characterized by its diverse topography, ranging from elevated rocky areas in the southeast to low-lying floodplains in the northwest. The catchment includes the Gulbin-Ka River, which is a major tributary of the Niger River, and its network of rivers and seasonal wetlands.

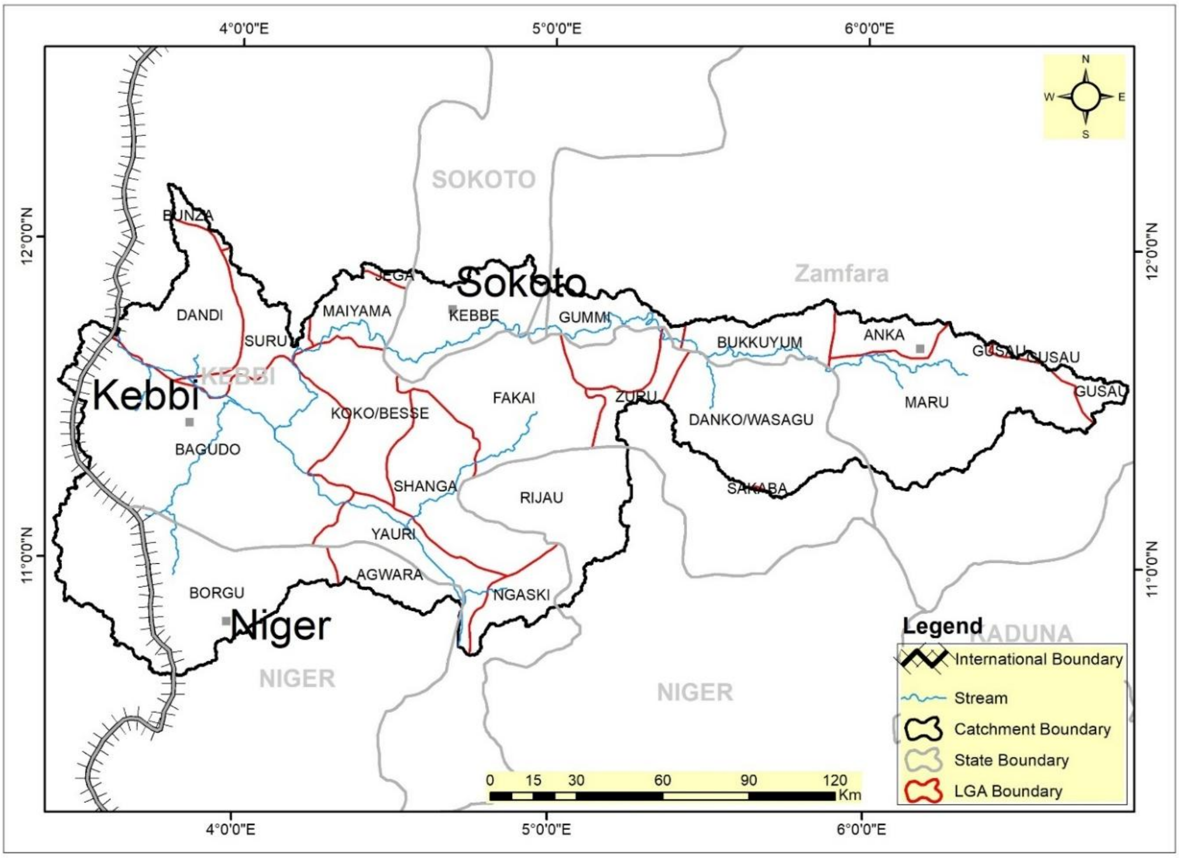


Figure 2.1: Gulbin Ka catchment showing the LGA's (Source: MSL, 2025)

2.2 Precipitation, Temperature, Sunshine and Relative Humidity

The catchment spanning parts of kebbi, Zamfara, Niger and Sokoto states, is situated within the Sudan and Northern Guinea savanna ecological zones of Nigeria. The climate of the catchment is characterized by distinct wet and dry seasons, driven by the movement of the Inter-Tropical Convergence Zone (ITCZ).

2.2.1 Precipitation

Rainfall in the catchment is markedly seasonal, occurring primarily between May and October, with the peak typically recorded in July or August. Annual precipitation ranges from approximately 800mm in the northern fringes to over 1,200mm in the southern parts, reflecting a north-south gradient. Rainfall distribution is influenced by topography, vegetation cover, and prevailing wind patterns. Most of the rainfall occurs in intense, short-duration storms, which often result in high runoff and localized flooding. The variability of rainfall from year to year poses a challenge for rain-fed agriculture and water resource planning in the catchment.

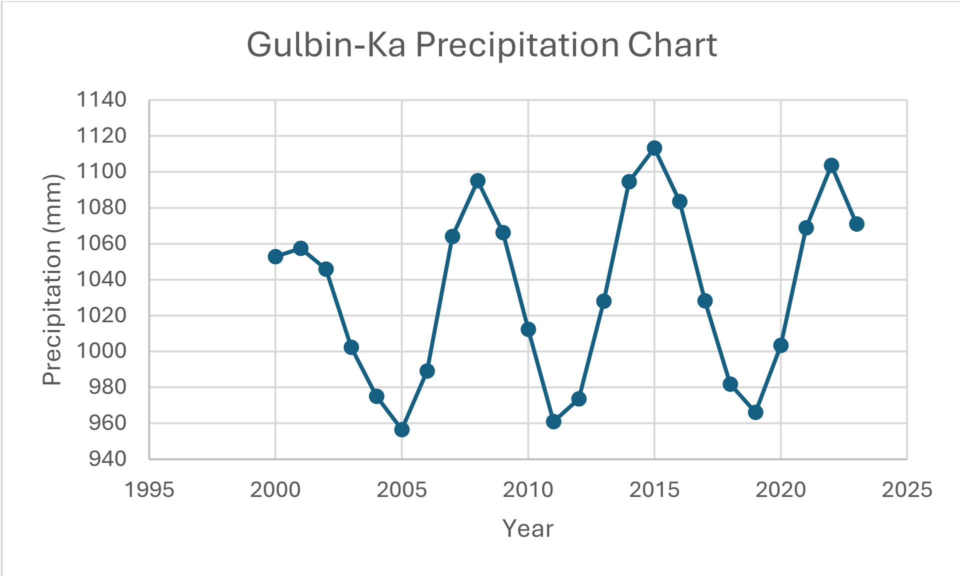


Figure 2.2: Annual Precipitation Graph of the Catchment (Source: MSL, 2025)

2.2.2 Temperature

Temperatures in the Gulbin-Ka Catchment remain consistently high throughout the year, with average annual temperatures ranging from 26°C to 32°C. The hottest period occurs from March to May, where temperatures can often exceed 40°C, particularly in the northern regions. The cooler months are during the harmattan season, from December to February, during which daytime temperatures remain relatively warm but can drop significantly at night, especially in northern parts of the catchment.

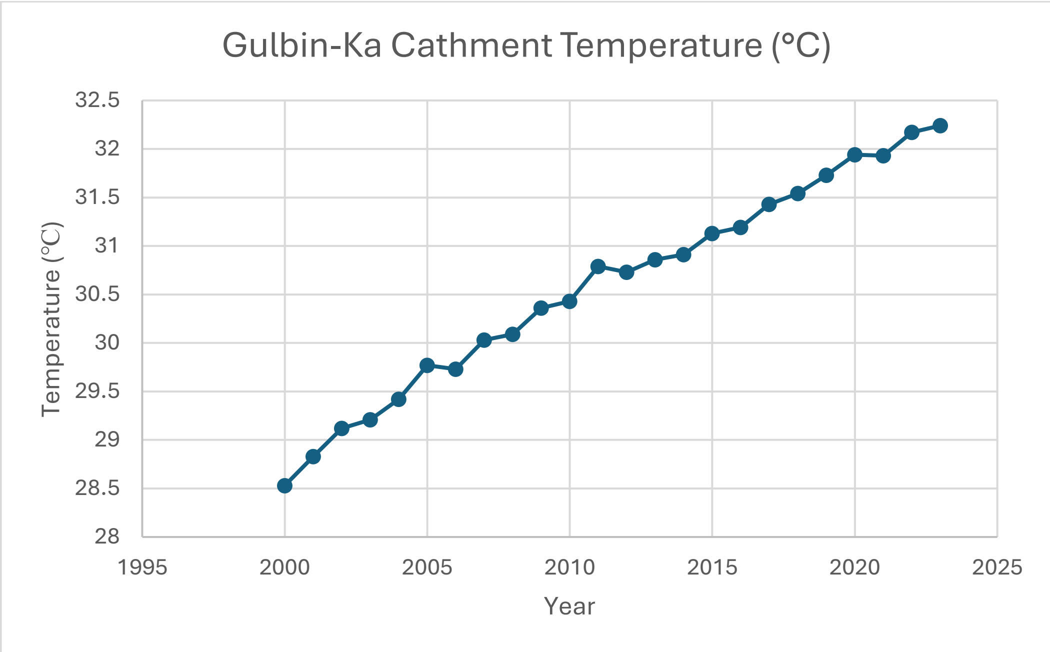


Figure 2.3: Annual Temperature of the Catchment (Source: MSL, 2025)

2.2.3 Sunshine Duration

The region receives abundant sunshine, with an annual average of 7–9 hours of sunshine per day. Sunshine duration is most pronounced during the dry season, contributing to high evaporation rates and potential water loss from reservoirs and soil. This climatic factor plays a critical role in crop growth and influences the selection of drought-resistant crop varieties for agricultural activities within the catchment.

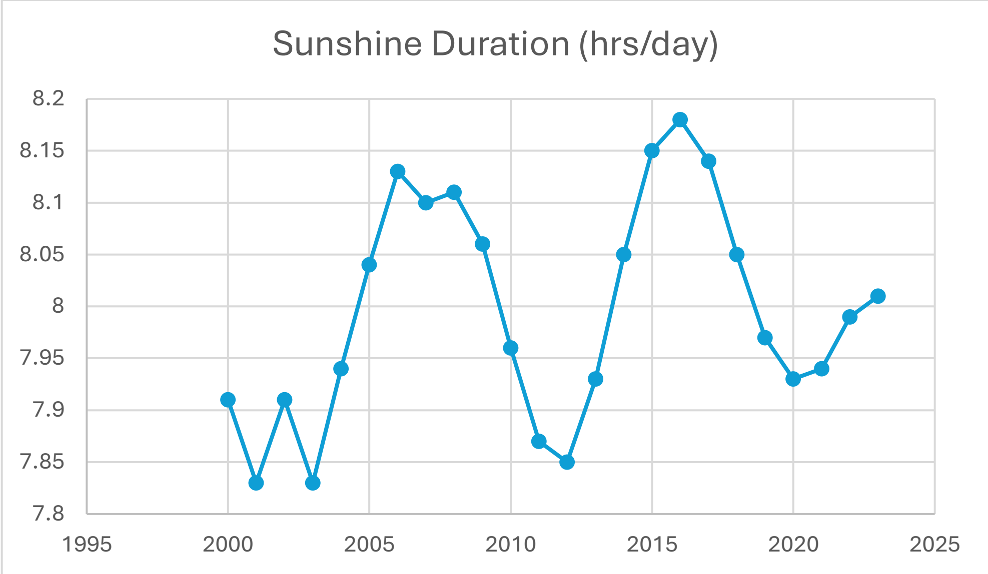


Figure 2.4: Annual Sunshine Duration of the Catchment (Source: MSL, 2025)

2.2.4 Relative Humidity

Relative humidity in the catchment varies seasonally, reflecting the dominance of either dry continental air or moist maritime air. During the wet season, relative humidity can reach 60–80%, contributing to the sultry conditions providing favourable conditions for rain-fed agriculture and replenishing groundwater. However, during the dry season, humidity drops significantly to as low as 10–20%, leading to increased evapotranspiration and water stress for both crops and livestock. This seasonal variation in humidity has direct implications for agricultural planning and water resource management.

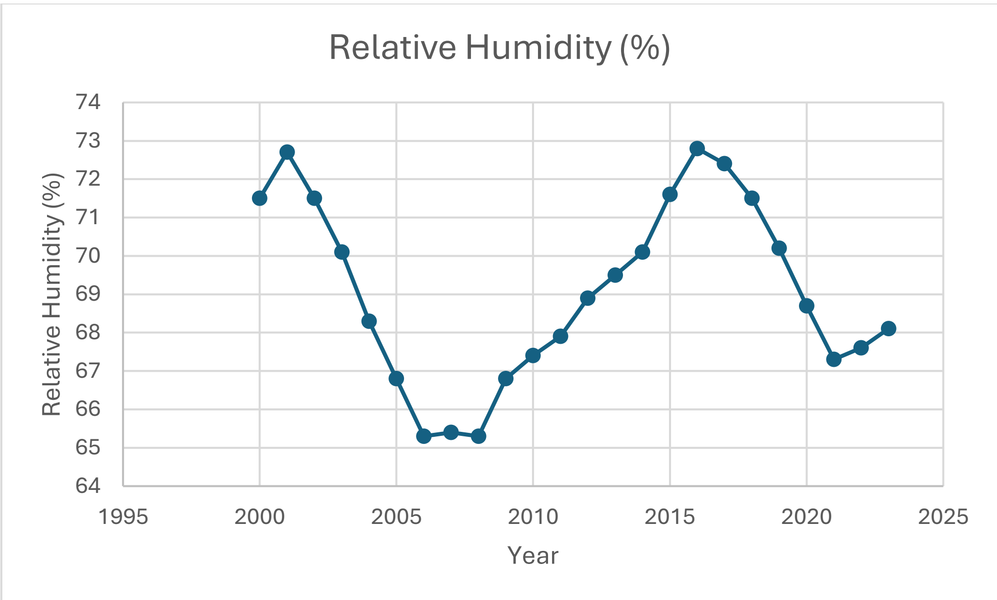


Figure 2.5: Annual Relative Humidity of the Catchment (Source: MSL, 2025)

2.3 Topography, Drainage, Geology and Soils

2.3.1 Topography

The Gulbin-Ka Catchment is characterized by diverse topographical features (see Figure 2.6). The terrain generally exhibits low to moderate relief, with elevations ranging from approximately 500 meters in the upper parts of the basin, such as in Niger and Zamfara States, to around 250 meters in the lower parts near Kebbi and Sokoto States. The catchment is predominantly flat, with scattered hills and inselbergs (isolated rocky outcrops) that influence localized water flow patterns. The southern portions of the catchment in Niger and Zamfara States feature more elevated terrains, with occasional hills and ridges that affect water flow dynamics. In contrast, moving northward, the terrain becomes increasingly flat, forming expansive floodplains, especially within Kebbi and Sokoto States, which are prone to seasonal flooding. These floodplains play a crucial role in the region's hydrology, supporting wetland agriculture and sustaining fisheries.

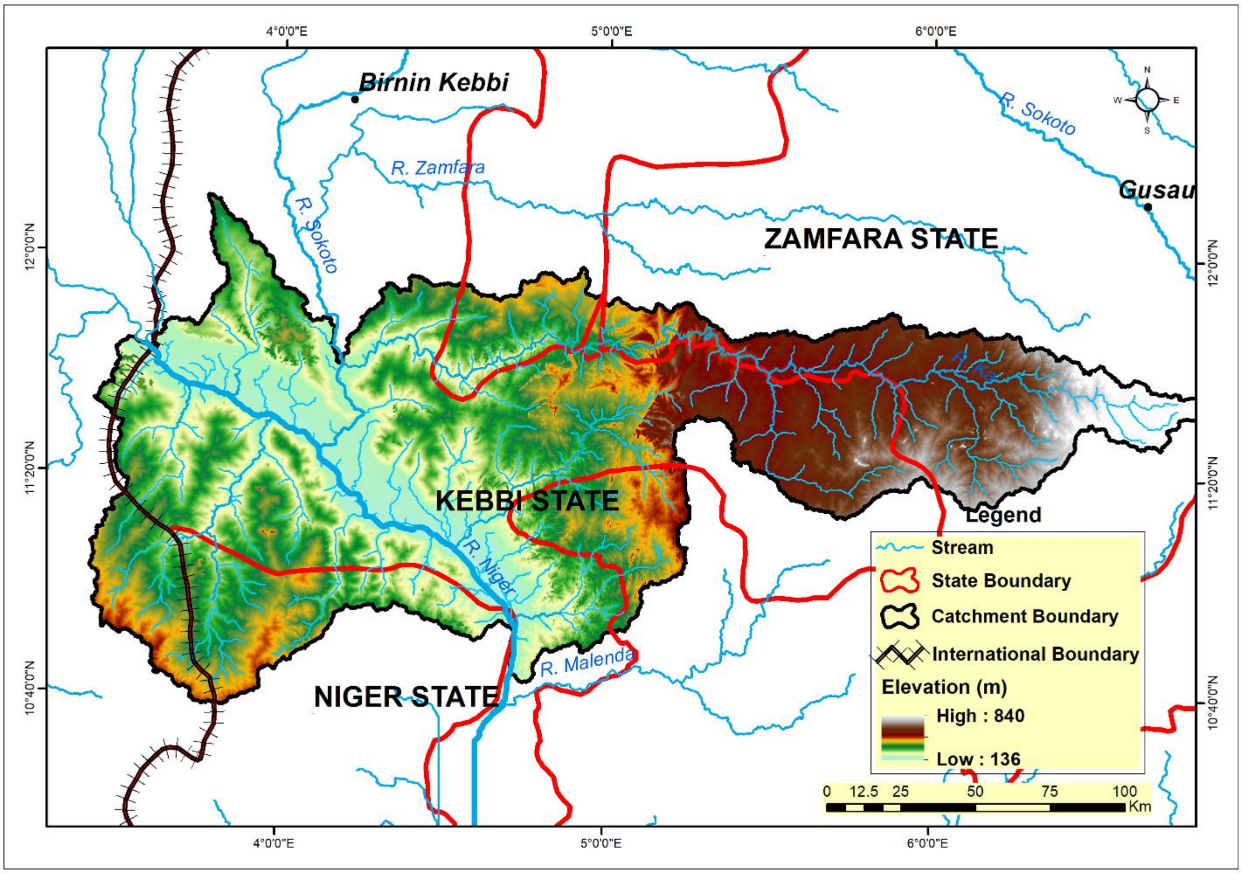


Figure 2.6: Digital Elevation Model (DEM) of the catchment (Source: MSL, 2025)

2.3.2 Drainage

The drainage system of the Gulbin-Ka Catchment is defined by the Gulbin-Ka River and its tributaries (refer to Figure 2.7), which form a significant part of the Sokoto-Rima River Basin. The Gulbin-Ka River originates from the highlands of Niger State and flows through Kebbi and Zamfara States, eventually joining the Niger River. The catchment's drainage network includes numerous seasonal streams and wetlands that contribute to its hydrological dynamics. River flow is highly seasonal, with peak flows occurring during the rainy season (June to September) and significantly reduced discharge during the dry season. Human activities, such as the construction of dams and irrigation schemes, have altered natural river flows, impacting downstream hydrology and water availability. Notable infrastructure within the catchment includes the Yauri Dam, which regulates water flow and supports local agriculture and water supply. The drainage system is critical for sustaining agricultural productivity, supporting livelihoods, and maintaining ecological balance within the catchment.

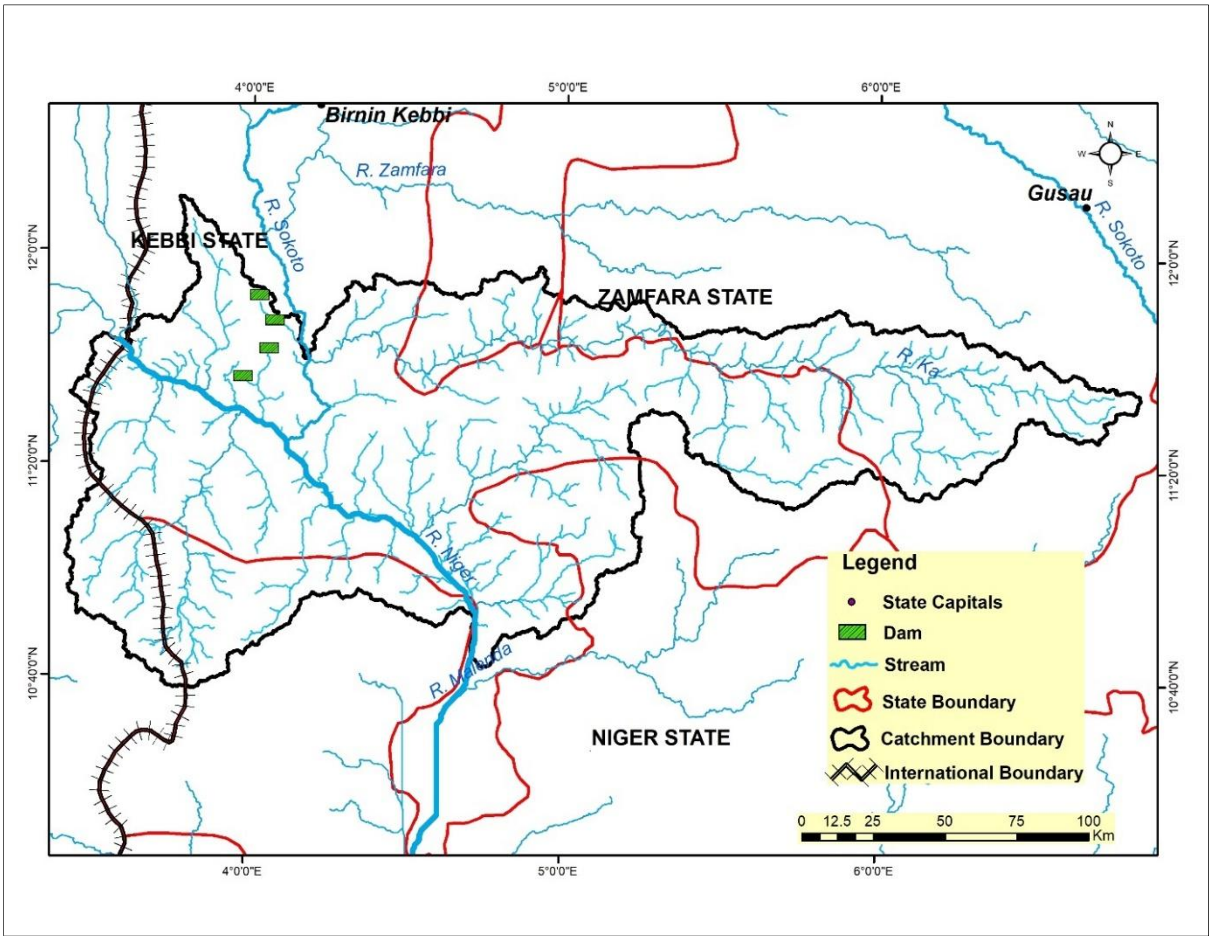


Figure 2.7: Drainage Map of Gulbin-Ka Catchment showing dams (Source: MSL, 2025)

Table *2.1* provides a comprehensive overview of the morphometric parameters of the Gulbin-Ka Catchment. These parameters are crucial for understanding the catchment's hydrological behaviour and for planning effective water resource management strategies. The catchment covers an area of approximately 2,948,700 hectares (29,487 km²) and has a perimeter of about 1,700 km. The longest flow path within the basin, known as the basin length, is approximately 270 km. The catchment features a mature and dendritic drainage network, with a stream order of 6th order. The total length of all streams within the catchment is about 3,900 km. The bifurcation ratio, which indicates the structural control over drainage, averages 3.6. The drainage density is relatively low at 0.13 km^{-1}, suggesting permeable soils and low runoff. The stream frequency is also low at 0.15, indicating high infiltration capacity. The form factor and elongation ratio suggest an elongated basin shape with moderate flood risk. The circularity ratio indicates a slow runoff response due to the elongated shape of the catchment. The relief, or vertical variation, is about 450 meters, with a relief ratio that suggests a gentle terrain. The ruggedness number indicates moderate terrain ruggedness and erosion risk. The slope analysis shows that the terrain is generally gentle, with slopes ranging from 0 to 12%. These morphometric characteristics collectively influence the catchment's water flow, storage capacity, and susceptibility to erosion and flooding.

Table 2.1: Morphometric Parameters of Gulbin-Ka Catchment

Parameter	**Formula / Method**	**Value**	**Description / Interpretation**
Catchment Area (A)	GIS-based area calculation	~2,948,700 ha (29,487 km²)	Total surface area draining to the outlet point.
Catchment Perimeter (P)	GIS-based perimeter tracing	Approx. 1,700 km	Outer boundary of the catchment.
Basin Length (Lb)	Line from outlet to farthest watershed point	~270 km	Indicates the longest flow path within the basin.
Stream Order (u)	Strahler method	6th Order	Indicates a mature and dendritic drainage network.
Total Stream Length (Lu)	Summation of lengths of all stream orders	Approx. 3,900 km	Reflects the total channel length contributing to flow.
Bifurcation Ratio (Rb)	Rb = Nu/Nu+1	Avg. 3.6	Indicates moderate structural control over drainage.
Drainage Density (Dd)	Dd = Lu / A	0.13 km^{-1}	Low drainage density suggests permeable soils and low runoff.

Stream Frequency (Fs)	$Fs = \Sigma Nu / A$	0.15	Low stream frequency indicating high infiltration capacity.
Form Factor (Ff)	$Ff = A / Lb^2$	0.40	Indicates an elongated basin shape; lower peak flows.
Elongation Ratio (Re)	$Re = (2\sqrt{(A/\pi)}) / Lb$	0.72	Semi-elongated basin; implies moderate flood risk.
Circularity Ratio (Rc)	$Rc = 4\pi A / P^2$	0.40	Indicates elongated shape; slow runoff response.
Relief (H)	Max - Min Elevation	~450 m (600m - 150m)	Indicates vertical variation; influences erosion potential.
Relief Ratio (Rr)	$Rr = H / Lb$	0.0017	Low relief ratio; suggests gentle terrain.
Ruggedness Number (Rn)	$Rn = H \times Dd$	58.5	Moderate terrain ruggedness and erosion risk.
Slope	GIS-based slope analysis	0–12% (generally gentle)	Affects runoff velocity and erosion potential.

*Table 2.2***Error! Reference source not found.** presents the stream order characteristics of the Gulbin-Ka Catchment, which is essential for understanding the catchment's drainage network and hydrological behavior. The stream order, determined using the Strahler method, ranges from 1st to 5th order, indicating a well-developed and complex drainage system. The number of streams decreases as the stream order increases, which is typical for dendritic drainage networks. For example, there are 302 streams of the 1st order with a total length of 2,146.71 km, while there are only 23 streams of the 5th order with a total length of 117.32 km. The logarithmic values of the number of streams (Log Nu) and the total length of streams (Log Lu) are also provided, which can be useful for further hydrological analysis and modeling. These characteristics are crucial for assessing the catchment's water flow dynamics, potential for flooding, and overall hydrological response.

Table 2.2: Stream Order Characteristics of Gulbin-Ka Catchment

Stream Order (u)	Number of Streams (Nu)	Total Length of Streams (Lu) [km]	Log (Nu)	Log (Lu)
1	302	2,146.7147	2.4800	3.3317

2	152	1,202.2450	2.1818	3.0799
3	56	428.8778	1.7481	2.6322
4	64	409.7011	1.8061	2.6124
5	23	117.3248	1.3617	2.0698

The bifurcation ratio (Rb) shown in Table *2.3* is a measure of the average number of streams of a given order that join to form a stream of the next higher order.

The mean bifurcation ratio (Rb_mean) is 2.0896. This value indicates a moderate structural control over the drainage network. A higher bifurcation ratio suggests a more complex and developed drainage system, while a lower ratio indicates a simpler network. The values observed in the Gulbin-Ka Catchment suggest a relatively well-developed drainage system, with a significant number of smaller streams merging to form larger ones.

Table 2.3: Bifurcation Ratio (Rb) Summary

Bifurcation Between Orders	**Bifurcation Ratio (Rb)**
1st Order / 2nd Order	1.9868
2nd Order / 3rd Order	2.7142
3rd Order / 4th Order	0.875
4th Order / 5th Order	2.7826
Mean Bifurcation Ratio (Rb_mean)	**2.0896**

The mean stream length (Lsm) shown in Table *2.4* for each stream order provides information about the average length of streams at each order.

These values indicate that the average length of streams decreases as the stream order increases. This is typical for dendritic drainage networks, where smaller streams merge to form longer, larger streams. The relatively consistent lengths across the different orders suggest a well-distributed and interconnected drainage system.

Table 2.4: Mean Stream Length (Lsm)

Stream Order (u)	Mean Stream Length (Lsm) [km]
1	7.1066
2	7.9069
3	7.6596
4	6.4016
5	5.1002

The length ratio (Rl) shown in Table *2.5* is the ratio of the mean length of streams of one order to the mean length of streams of the next higher order.

These ratios indicate how the average length of streams changes as they merge to form higher-order streams. The values suggest that the length of streams decreases significantly as they merge, particularly from the 1st to 2nd order and from the 4th to 5th order. This pattern is consistent with the observed decrease in the number of streams and the increase in stream order.

Table 2.5: Length Ratio (Rl)

Transition	Length Ratio (Rl)
1st to 2nd Order	0.5600
2nd to 3rd Order	0.3568
3rd to 4th Order	0.9553
4th to 5th Order	0.2864

Figure 2.8 and 2.9 shows the Catchment Map Showing the recorded Gauging Stations and Map of Meteorological stations within the Gulbin Ka Catchment respectively.

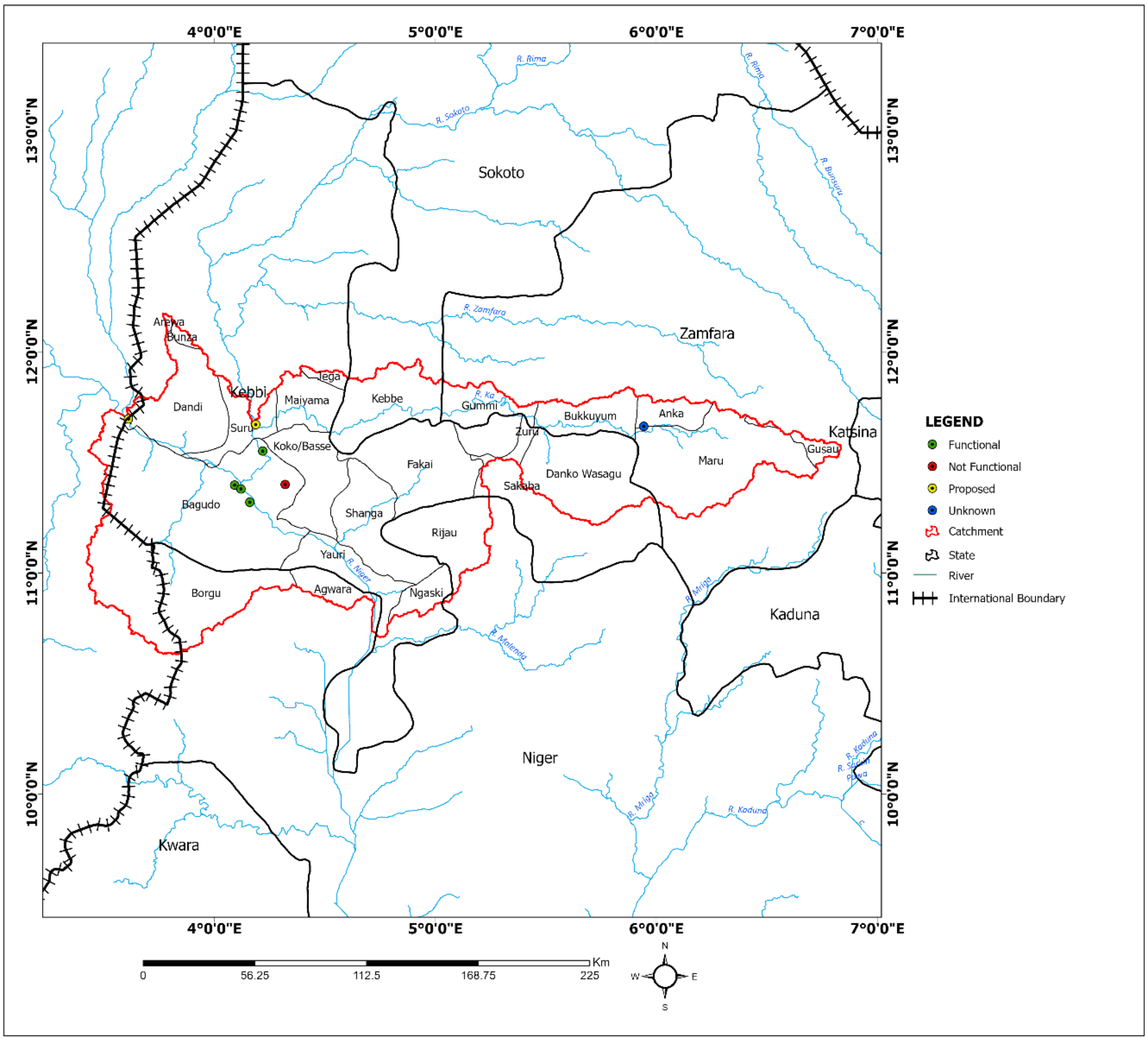


Figure 2.8: The Catchment Map Showing the recorded Gauging Stations (Source: MSL, 2025)

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

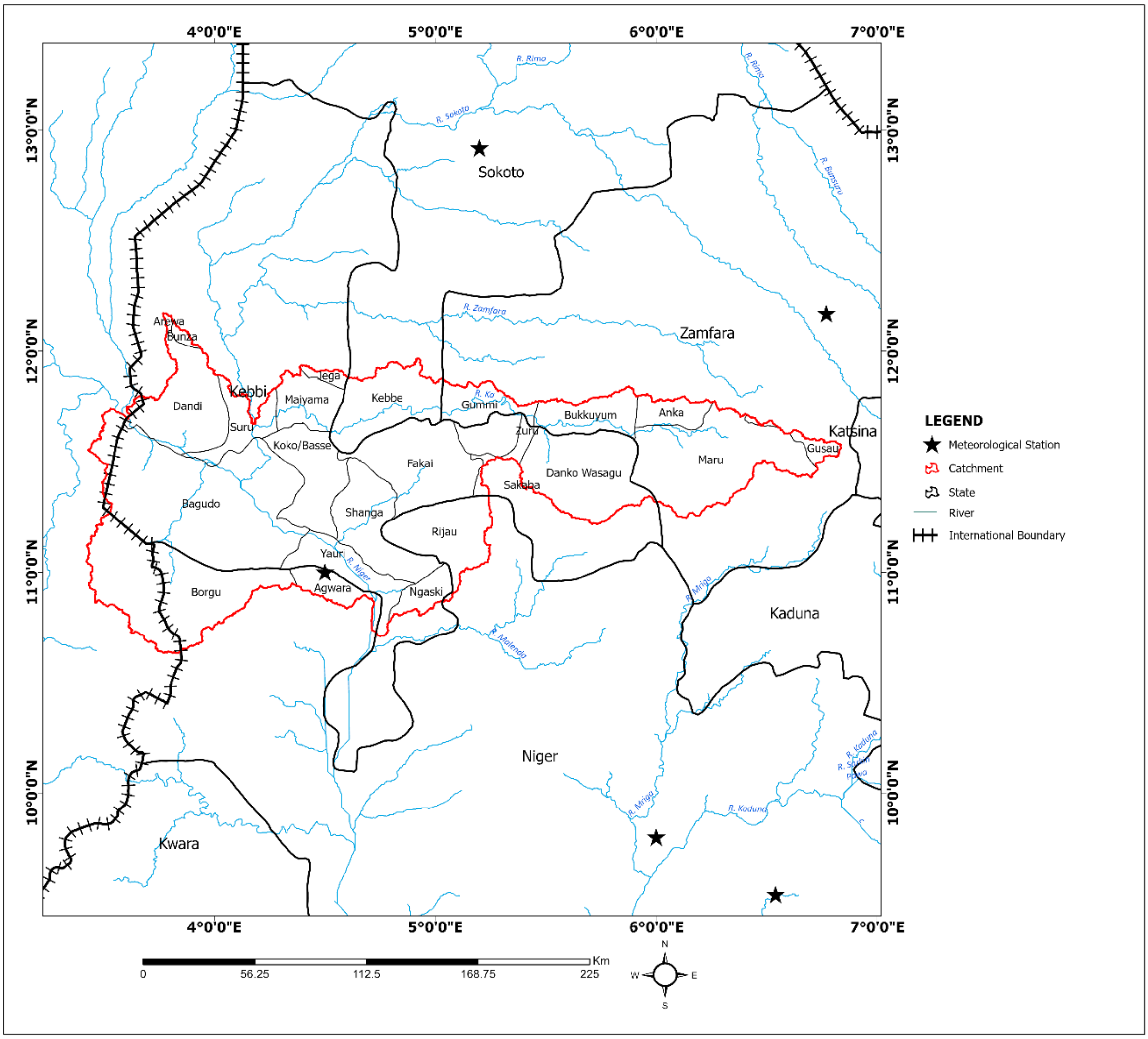


Figure 2.9: Map of Meteorological stations within the Gulbin Ka Catchment (Source: Mecon Services, 2025)

World Meteorological Organization (WMO) recommends 970 out of which 291 are recorded, however data is only received from 54(NIMET)

STATES OF INFLUENCE

1. Zamfara State
2. Kebbi state
3. Niger State
4. Sokoto State

2.3.3 Geology and Soil Types

2.3.3.1 Geology

The geology of the Gulbin-Ka Catchment (see Figure 2.10)is characterized by two major geological formations that significantly influence the landscape, soil development, and hydrological behaviour of the region. These formations are the Precambrian Basement Complex and the Sokoto Basin Sediments.

i. **Precambrian Basement Complex (Southern Area)**: This formation underlies the southern parts of the catchment, including areas in Niger and Zamfara States. The basement complex consists of ancient crystalline rocks such as granites, gneisses, and schists. These rocks are typically hard and resistant to weathering, leading to the formation of elevated terrains such as hills and ridges. The Precambrian Basement Complex has limited primary permeability, resulting in low groundwater recharge potential. However, it does support shallow groundwater in areas where weathering has occurred, creating fractured zones that allow for some groundwater infiltration. The topography in these regions is more rugged, with rocky outcrops and undulating landscapes.

ii. **Sokoto Basin Sediments (Northern Area)**: The northern part of the Gulbin-Ka Catchment is dominated by the Sokoto Basin, a major sedimentary basin in northwestern Nigeria. The geology here is primarily composed of Tertiary and Quaternary sediments, including sandstones, claystones, and unconsolidated alluvial deposits. These sediments have accumulated over millions of years through fluvial processes, creating a gently undulating landscape. The sedimentary nature of the Sokoto Basin contributes to its high groundwater potential, with aquifers providing essential water resources for domestic, agricultural, and industrial uses. The basin's geology also influences the region's agricultural productivity, as the sedimentary rocks weather to form fertile soils.

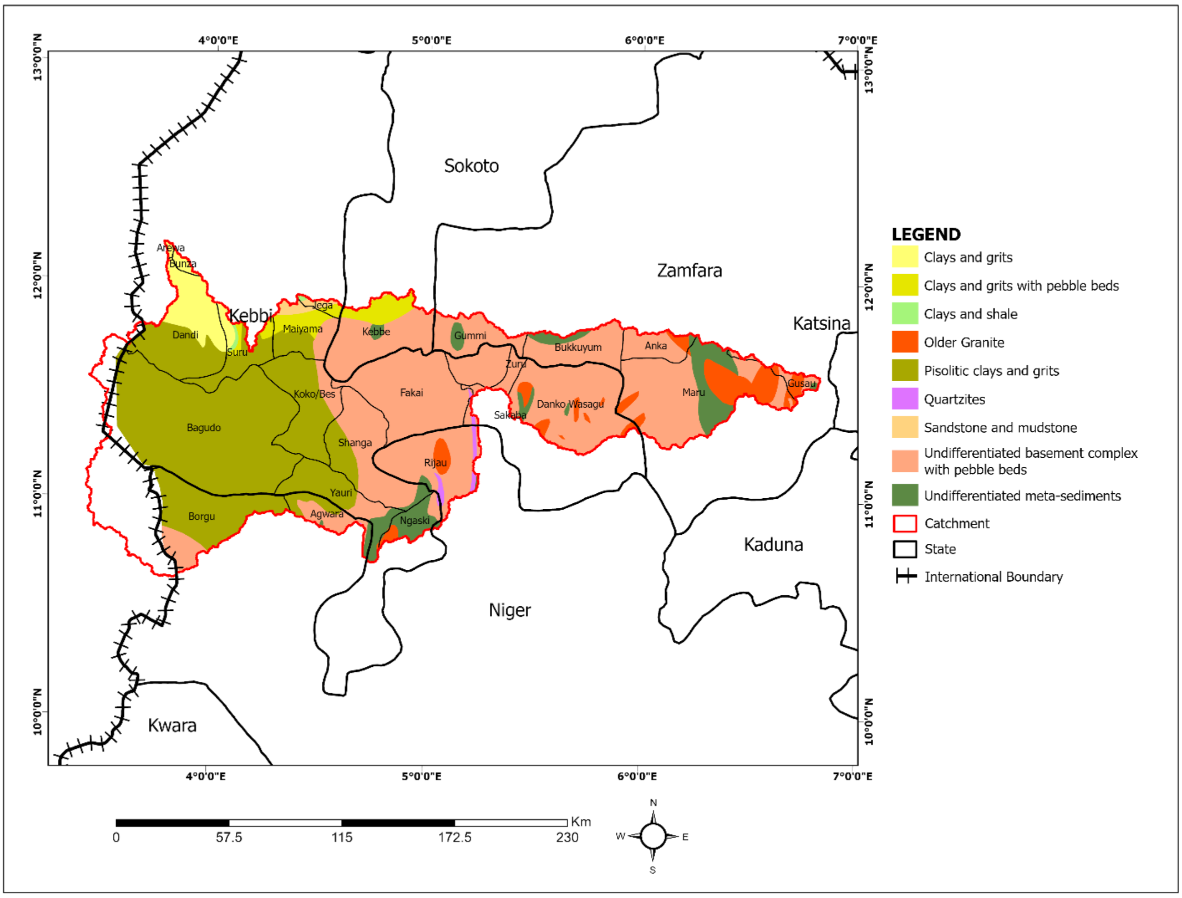


Figure 2.10: Geological Map of Gulbin Ka Catchment (Source: MSL, 2025)

2.3.3.2 Soil Types

The soils of the Gulbin-Ka Catchment (refer to Figure 2.11) are diverse and have been classified according to the FAO soil classification framework. These soil types vary across the catchment due to differences in parent material, climate, topography, and vegetation. The primary soil types identified in the catchment are Arenosols, Vertisols, Gleysols, Fluvisols, and Leptosols. Each of these soil types has distinct properties that influence land use, agricultural productivity, and water management.

i. **Arenosols**: These are sandy soils found predominantly in the northern parts of the catchment, particularly in Kebbi and Sokoto States. Arenosols have low water-holding capacity and low fertility, making them suitable for drought-resistant crops like millet and sorghum. Due to their coarse texture and poor water retention, these soils require irrigation for productive agriculture. They are prone to wind and water erosion, necessitating soil conservation measures such as contour farming and agroforestry.

ii. **Vertisols**: Vertisols are clay-rich soils that occur in floodplain areas and depressions within the catchment. They exhibit high shrink-swell capacity, which can create challenges for agriculture due to cracking during dry periods. Despite these challenges, Vertisols are fertile and suitable for rice cultivation and other crops that can tolerate wet conditions. The cracking of Vertisols can also lead to waterlogging and poor aeration, requiring proper drainage management.

iii. **Gleysols**: Gleysols are hydromorphic soils found in waterlogged areas, particularly near riverbanks and in floodplains. They are characterized by poor drainage and prolonged water saturation, which can limit their suitability for conventional agriculture. However, Gleysols are ideal for paddy rice cultivation and can support other crops with appropriate drainage improvements. These soils also play a vital role in the catchment's hydrology by storing water during the rainy season and gradually releasing it during the dry season.

iv. **Fluvisols**: Fluvisols are young, fertile soils formed from recent river deposits. They are commonly found along the Gulbin-Ka River and its tributaries. These soils are highly productive and suitable for a wide range of crops, including rice, maize, and vegetables. Their fertility makes them valuable for both rain-fed and irrigated agriculture. However, Fluvisols are susceptible to erosion and sedimentation, requiring careful management to maintain their productive capacity.

v. **Leptosols**: Leptosols are shallow, stony soils found on hard rock substrates in the elevated areas of the catchment, such as parts of Niger and Zamfara States. These soils have limited agricultural potential and are primarily used for grazing and forestry. Their shallow depth and rocky nature make them unsuitable for crop cultivation but ideal for supporting natural vegetation cover and maintaining ecological balance.

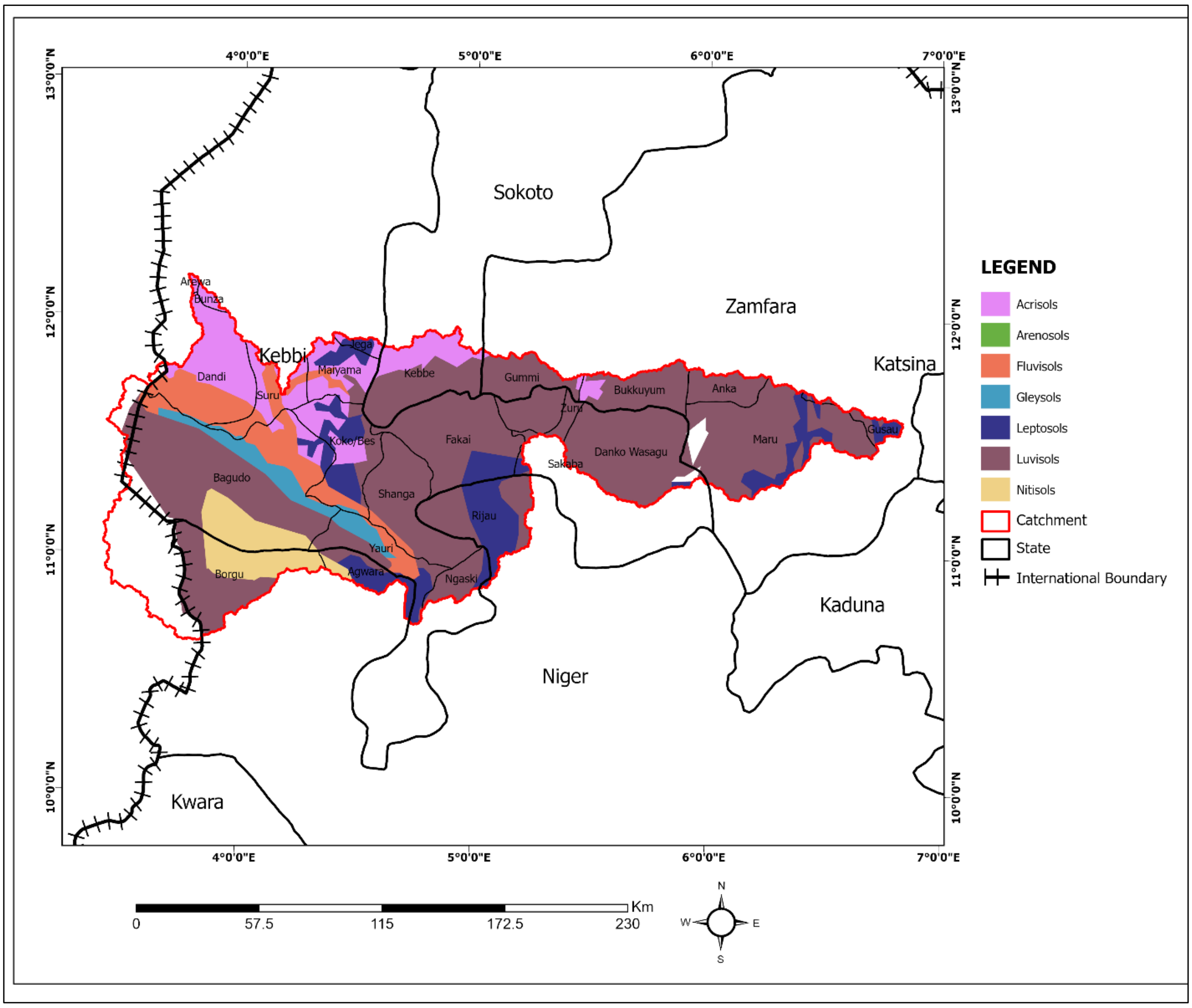
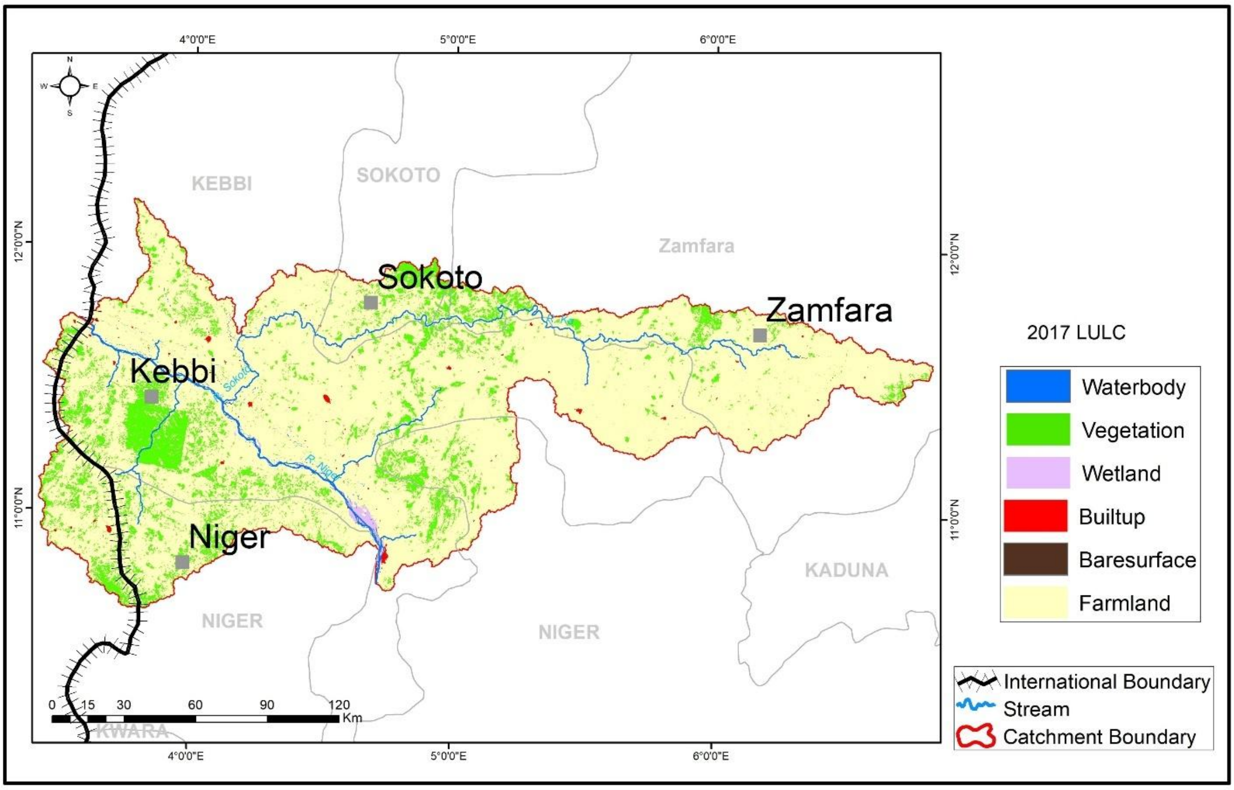


Figure 2.11: Soil Map of Gulbin-Ka Catchment (Source: MSL, 2025)

2.4 Land Use and Land Cover

The Gulbin-Ka Catchment covers a diverse landscape shaped by both natural processes and human activities. The land use and land cover (LULC) shown in Figure 2.12 within this catchment are influenced by various factors, including climate, geology, hydrology, and socio-economic activities. Agriculture, livestock grazing, wetlands, and human settlements are key components that define the land use dynamics in the region. Over time, human-induced land cover changes, including deforestation and the expansion of cultivated land, have altered the natural landscape, with significant implications for the environment and water resources.



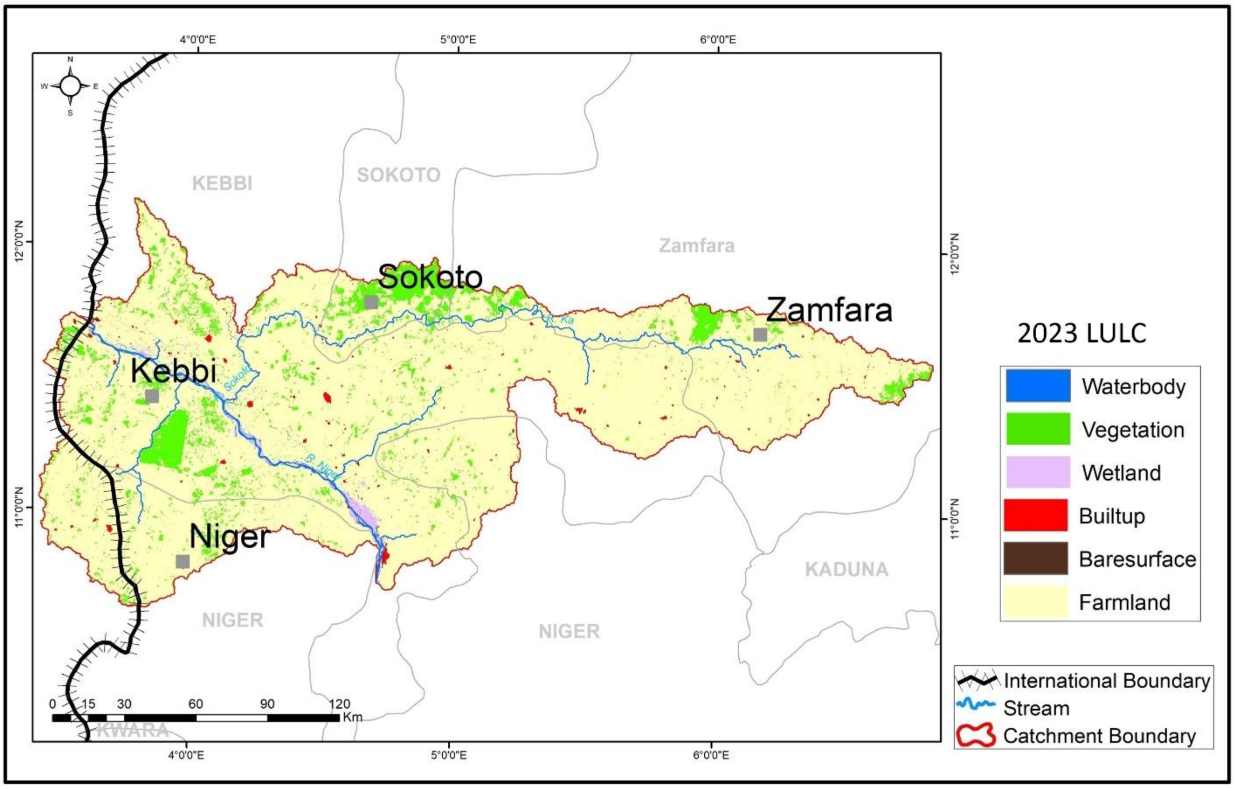


Figure 2.12: Land Use and Land Cover of Gulbin Ka Catchment 2017 & 2023 (Source: MSL, 2025)

2.4.1 Natural Vegetation

The natural vegetation cover of the Gulbin-Ka Catchment (see Figure 2.13) varies from north to south, influenced largely by climatic gradients and soil types.

- Northern Area (Kebbi and Kebbe LGA of Sokoto State)

  The northern part of the catchment, particularly in Kebbi and Kebbe LGA of Sokoto State, is dominated by Sudan savannah vegetation. This semi-arid region consists of scattered trees, mainly Acacia species, and extensive grasslands. The dry climate and sandy soils limit dense vegetation growth, making the area suitable for grazing by pastoral communities. However, desertification, overgrazing, and human activities such as fuelwood collection have contributed to vegetation degradation in some areas.

- Central Area (Zamfara State)

  The central part of the catchment, covering Zamfara State, exhibits a transitional zone between the Sudan savannah and Guinea savannah. This area supports a mix of grasslands and scattered trees such as baobab, shea butter, and tamarind. The slightly higher rainfall compared to the north allows for a richer vegetation cover, though land clearing for agriculture is a major factor reducing natural vegetation.

- Southern Area (Niger State)

  The southern parts of the catchment, particularly in Niger State, fall within the Guinea savannah zone, which supports a denser and more diverse range of plant species. Trees such as neem, locust bean, and shea butter dominate the landscape, along with a mixture of tall grasses. The relatively higher rainfall and better soil quality favor agriculture, leading to increasing deforestation and land conversion for farming.

2.4.2 Agricultural Land Use

Agriculture is the dominant land use in the Gulbin-Ka Catchment. Over the past several decades, the expansion of agricultural activities has significantly transformed the landscape, particularly in the fertile regions along river floodplains.

i. **Rainfed Agriculture (Zamfara and Niger States)**
Most of the agriculture in the catchment is rainfed, particularly in Zamfara and Niger States, where the soils (especially Alfisols and Arenosols) are more suitable for crop cultivation. Key crops grown in these areas include millet, sorghum, maize, groundnuts, and cowpeas. However, the reliance on seasonal rainfall makes these farming systems vulnerable to climatic variability, particularly in the drier northern parts, where periodic droughts can significantly impact productivity.

ii. **Irrigated Agriculture (Kebbi and Zamfara States)**
The floodplains of the Ka River and its tributaries in Kebbi and Zamfara States provide suitable conditions for irrigated farming. Irrigation schemes are used to cultivate high-value crops such as rice, vegetables, onions, and wheat, which require more water than rainfed crops. While irrigation has enhanced agricultural productivity in these areas, it has also placed pressure on water resources, especially during the dry season, leading to conflicts over water use among farmers and pastoralists.

iii. **Fallow and Shifting Cultivation (Northern Kebbi and Parts of Zamfara State)**
In some areas with poorer soils, particularly in northern Kebbi and parts of Zamfara State, fallow and shifting cultivation practices are still observed. Farmers allow land to rest and regenerate before cultivation, but increasing population pressure has led to shorter fallow periods, resulting in soil degradation and declining yields.

2.4.3 Wetlands

The wetlands of the Gulbin-Ka catchment are significant land cover features, particularly in Kebbi, Niger, and Zamfara States, as well as Kebbe LGA in Sokoto State. These wetlands are fed by the Gulbin-Ka River and its tributaries, playing a crucial role in supporting biodiversity and local livelihoods.

Ecological Significance (Kebbi, Niger, Zamfara States, and Kebbe LGA in Sokoto State)

The wetlands provide a habitat for various bird species, aquatic plants, and fish populations, making them essential breeding and feeding grounds. They also act as natural flood regulators, storing excess water during the rainy season and gradually releasing it during the dry season. This hydrological function helps maintain water availability for surrounding communities and ecosystems.

Agricultural Use (Kebbi, Niger, Zamfara States, and Kebbe LGA in Sokoto State)

Wetland agriculture, particularly rice farming, is a common practice in the floodplains of the Gulbin-Ka River. The seasonal flooding replenishes soil nutrients and ensures moisture availability for crops even in drier months. However, increasing pressure from unsustainable farming practices, overgrazing, and upstream water diversion for irrigation poses a threat to the long-term viability of these wetlands

2.4.4 Grazing Land and Pastoralism

Livestock Grazing

Livestock grazing is a major land use in the Gulbin-Ka catchment, particularly in Kebbi, Niger, and Zamfara States, as well as Kebbe LGA in Sokoto State. Pastoralism is an essential livelihood activity, with nomadic and semi-nomadic herders moving across the region in search of pasture for their cattle, sheep, and goats. Grazing lands include the natural grasslands of the savannah and areas of marginal land not suitable for crop cultivation.

Pastoralism in Northern Areas

The drier northern regions of the Gulbin-Ka catchment, particularly in Niger and Zamfara States, support large numbers of pastoralists. However, overgrazing has led to land degradation and the loss of vegetation cover in some areas. This situation is worsened by climatic factors such as reduced rainfall and an increased frequency of droughts, which further limit available pasture.

Conflict with Agricultural Land

The expansion of croplands into traditional grazing areas has led to increasing competition for land and resources between farmers and herders. Conflicts over land use are becoming more common as both groups struggle to access fertile land and water, particularly during the dry season. In some cases, these tensions have escalated, impacting local livelihoods and food security.

2.4.5 Human Settlements

Human settlements in the Gulbin-Ka Catchment are concentrated around river systems and fertile agricultural zones. The population density is higher in the southern and central parts of the catchment, particularly in Kebbi, Niger, and Zamfara States, as well as Kebbe LGA in Sokoto State, where major urban and rural settlements are located.

Urban Areas

Major urban centers such as Birnin Kebbi, Kontagora, and Gusau serve as hubs for economic activities, including trade, manufacturing, and services. The expansion of these urban areas is putting pressure on surrounding agricultural and grazing lands. In recent years, urban sprawl has led to the conversion of peri-urban agricultural land into residential and commercial developments, reducing available farmland and altering traditional land-use patterns.

Rural Settlements

Small villages or hamlets that are closely tied to agricultural production and livestock rearing. Access to basic infrastructure such as roads, schools, and healthcare facilities is limited in many rural areas, impacting the socio-economic development of these regions. Seasonal migration and reliance on traditional farming techniques remain common in rural communities.

2.4.6 Forest and Woodland Areas

Forest and Woodland Areas

Small patches of forests and woodlands are found in the southern parts of the Gulbin-Ka catchment, particularly in Kebbi and parts of Niger State. These areas are mostly located in protected reserves or exist as remnants of the original savannah woodlands.

Deforestation (Kebbi and Niger States) Deforestation has been widespread across the catchment due to agricultural expansion, high demand for firewood, and charcoal production. This has led to biodiversity loss, increased soil erosion, and the degradation of water catchment areas, making the land more vulnerable to desertification.

Reforestation Efforts (Kebbi, Niger, and Zamfara States) in response to deforestation, several reforestation and afforestation projects have been introduced, particularly in areas at risk of desertification, such as northern Kebbi and Niger States. These efforts focus on restoring degraded lands, improving soil fertility, and enhancing water retention in the landscape, often through tree-planting initiatives and sustainable land management practices.

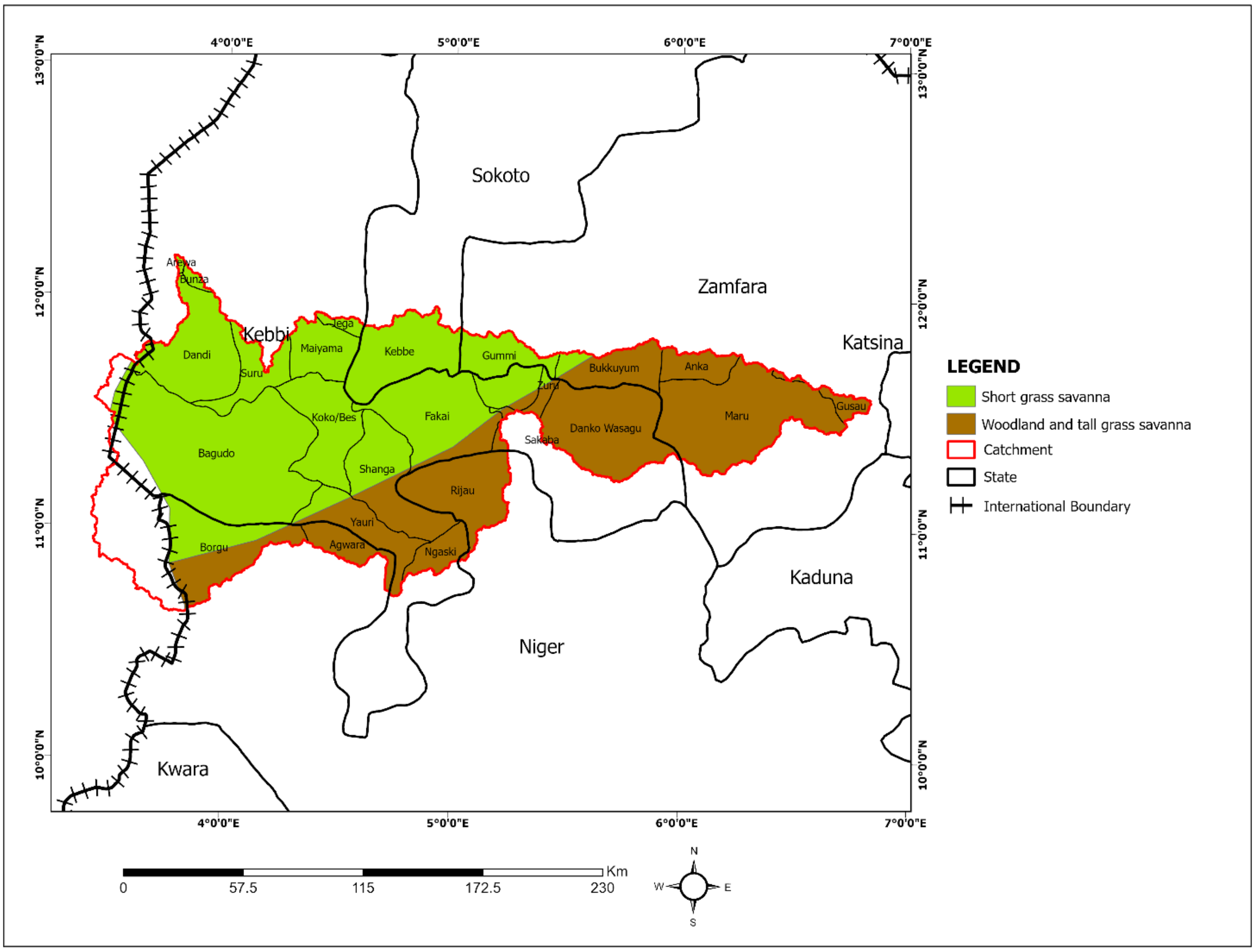


Figure 2.13: Vegetation Map of Gulbin-Ka Catchment (Source: MSL, 2025)

2.4.7 Biodiversity

Component	**Description**
Ecological Zones	- Predominantly Sudan and Sahel Savannas. - Transition to riverine wetlands along the Gulbin-Ka and Rima Rivers. - Seasonal floodplains and scattered gallery forests.
Major Ecosystems	- **Savanna woodlands** with multipurpose tree species (e.g., baobab, shea, neem). - **Riverine and wetland systems**, including permanent and seasonal water bodies. - **Floodplain agriculture zones** supporting wild and cultivated rice. - **Community forests**, sacred groves, and grazing lands.
Flora (Plant Diversity)	- **Savanna trees**: *Acacia nilotica*, *Acacia seyal*, *Vitellaria paradoxa*, *Adansonia digitata*, *Azadirachta indica*. - **Grasses**: *Andropogon gayanus*, *Hyparrhenia rufa* (used for fodder and erosion control).

	- **Wetland species**: *Typha domingensis*, *Oryza longistaminata* (wild rice), *Nymphaea lotus* (water lily). - **Agro-biodiversity**: Millet, sorghum, maize, rice, groundnut, sesame, indigenous fruit trees.
Fauna (Wildlife)	- **Mammals**: Leopard (*Panthera pardus*) [rare], Roan antelope (*Hippotragus equinus*), Warthog (*Phacochoerus africanus*). - **Birds**: Black-crowned crane (*Balearica pavonina*), Abyssinian ground hornbill (*Bucorvus abyssinicus*), Marabou stork (*Leptoptilos crumenifer*). - **Fish**: Nile tilapia (*Oreochromis niloticus*), Catfish (*Clarias gariepinus*), Heterotis (*Heterotis niloticus*). - **Reptiles/Amphibians**: Nile crocodile (*Crocodylus niloticus*), Monitor lizard (*Varanus niloticus*), African bullfrog (*Pyxicephalus adspersus*).
Wetland & Aquatic Ecosystems	- Support seasonal agriculture, fish breeding, and migratory birds. - Provide water storage, flood buffering, nutrient cycling, and habitat connectivity. - Threatened by: dam construction, Typha invasion, and land-use conversion for farming.
Agro-biodiversity	- Staple crops: millet, sorghum, maize, floodplain rice. - Cash crops: groundnut, cowpea, sesame. - Indigenous fruit trees (shea, baobab) contribute to food, medicine, and income. - Livestock: Cattle, sheep, goats, and poultry — mostly resilient indigenous breeds.
Ecosystem Services	- Soil fertility, erosion control, and climate regulation (e.g., carbon sequestration). - Pollination and pest control. - Source of food, forage, fuelwood, and traditional medicines. - Supports local livelihoods and drought resilience.
Key Threats	- Habitat degradation from farming expansion and overgrazing. - Deforestation for fuelwood and charcoal. - Poaching and species loss (e.g., decline of large mammals). - Invasive species (e.g., *Typha domingensis* in wetlands). - Climate variability and declining water flows.
Conservation Opportunities	- Wetland restoration and invasive species control. - Agroforestry and sustainable grazing management. - Community-based wildlife protection and awareness. - Integration of biodiversity into local land use and catchment planning.

2.5 Hydrology and Water Resources

2.5.1 Hydrology

The hydrology of the Gulbin-Ka catchment is defined by its intricate river network, seasonal flood patterns, underlying groundwater reserves, and associated wetlands. The Gulbin-Ka River serves as the principal watercourse, playing a vital role in regulating the area's water availability. This river system significantly influences agricultural activities, domestic water supply, and the ecological balance of surrounding floodplains.

2.5.2 Hydrograph/Water Budget of The Catchment

The hydrographs and water budgets of the Gulbin-Ka strategic catchment provide valuable insights into its hydrological characteristics. As illustrated in Figure 2.14 to 2.18 and Table 2.6 to 2.7, the catchment exhibits homogeneous hydrologic characteristics, with runoff primarily generated during the wet season. Peak flows occur in August and September, with significant discharge recorded from April to November. Notably, it takes five months for the catchment to reach peak flow, followed by a four-month dry season.

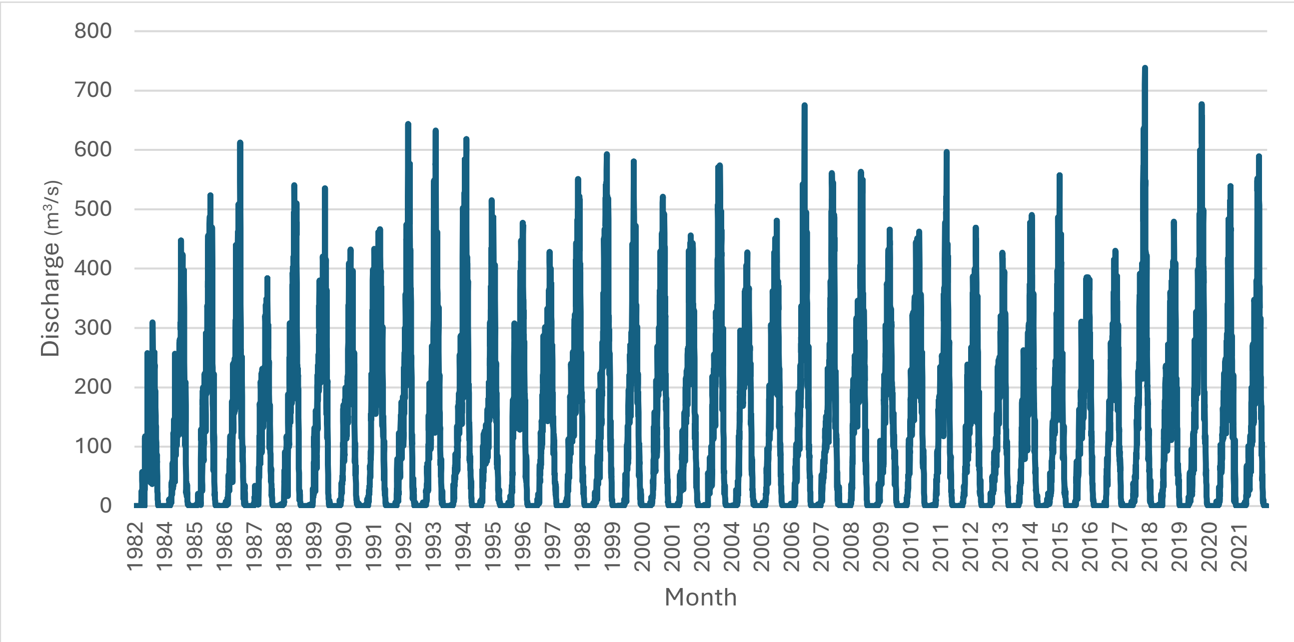


Figure 2.14: Hydrograph of Gublin-Ka Strategic Catchment

Based on HEC-HMS modelling for Strategic catchment.

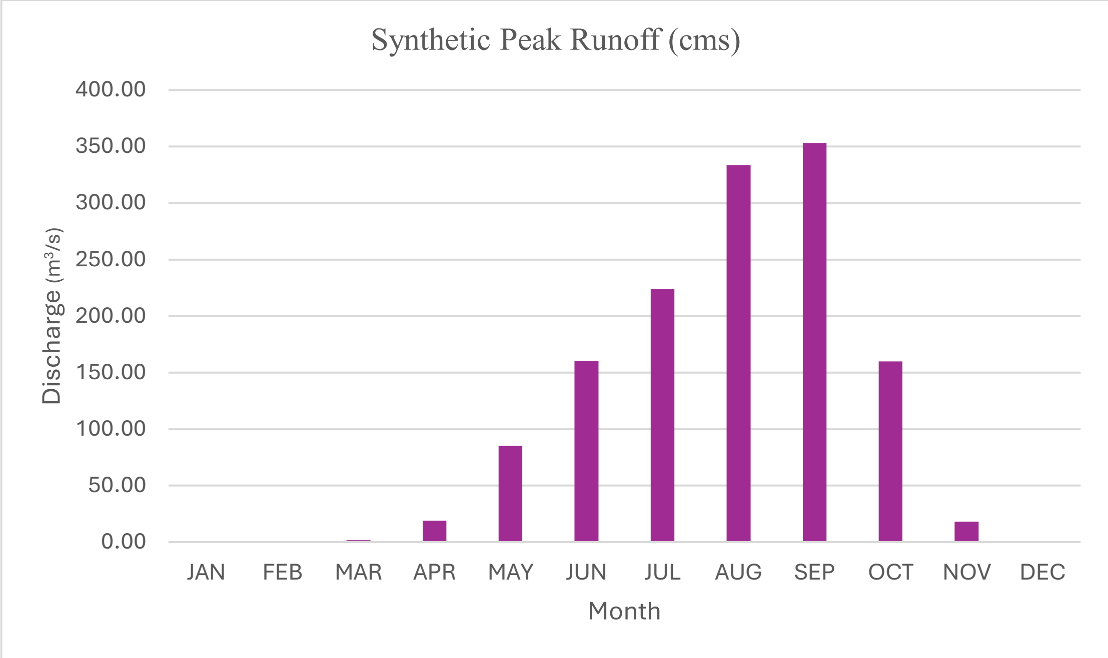


Figure 2.15 40 - Year Summary Hydrograph of Gublin-Ka Strategic Catchment

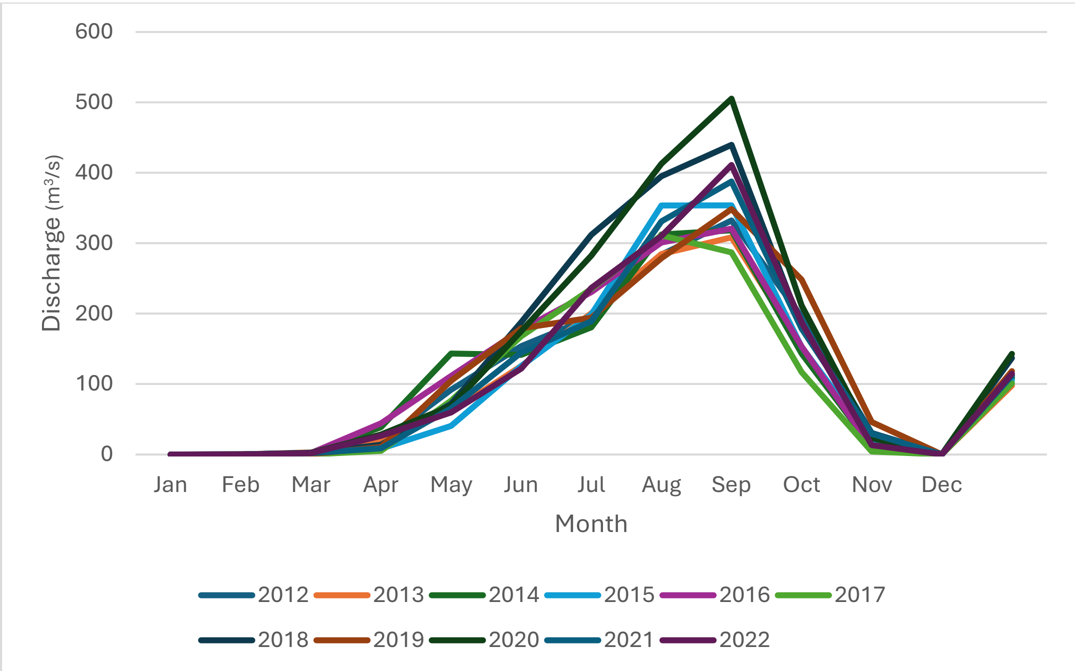


Figure 2.16: Hydrograph of Gulbin-Ka Strategic Catchment for Specific Year

The water budget, as shown in Figure 4.5, reveals that evapotranspiration exceeds precipitation for most of the year, resulting in a remarkably low average water budget of 158.33mm. Table 4.1 highlights a summary of hydrologic catchment parameters. Furthermore, water surplus occurs for only four months, indicating prolonged water shortages and emphasizing the need for alternative water supply solutions.

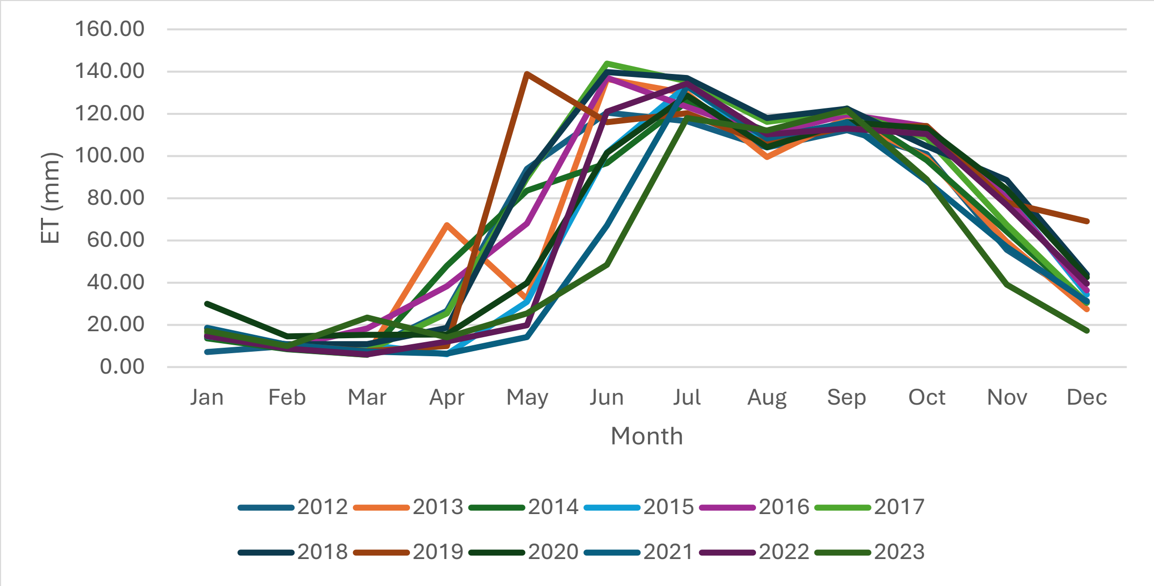


Figure 2.17: Monthly Actual Evapotranspiration Distribution for the Catchment

Source: TerraClimate

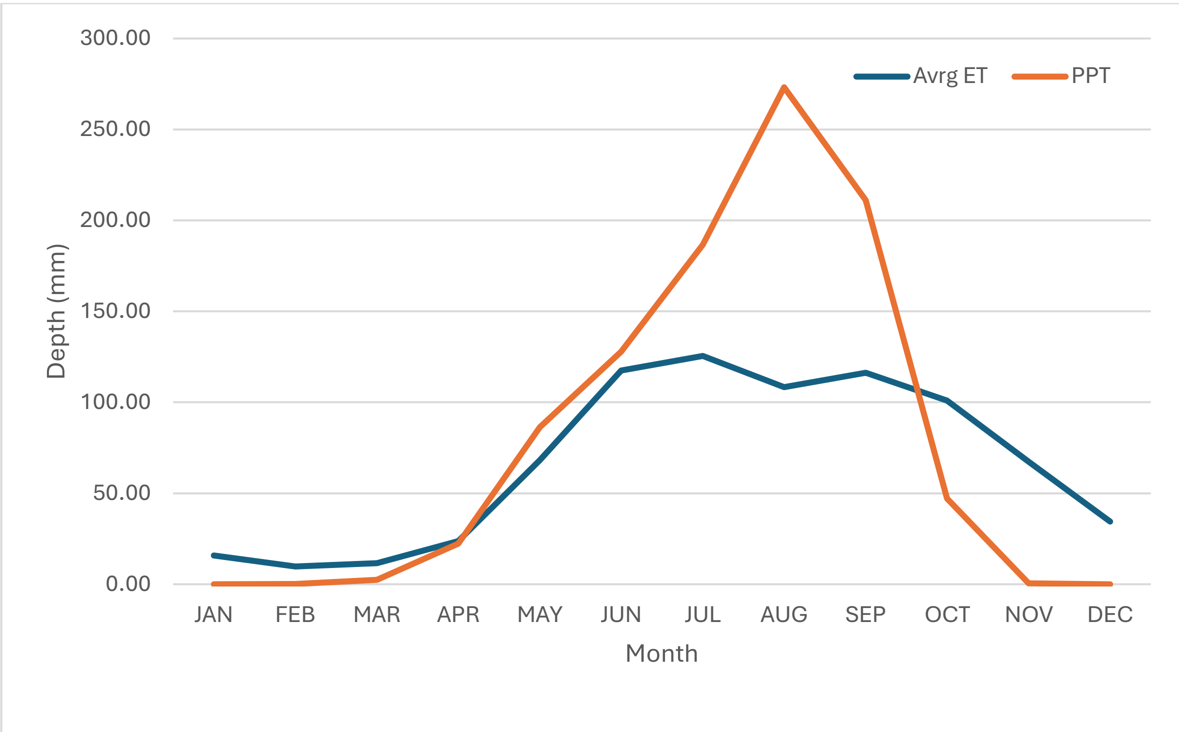


Figure 2.18: Water Budget for Gublin-Ka Strategic Catchment

Table 2.6: Summary of Discharge, Rainfall and Evapotranspiration Data for Gulbin-Ka Strategic Catchment

Month	PPT	ET	Synthetic Peak Runoff (CMS)
JAN	0.01	15.82	0.01
FEB	0.14	9.77	0.09
MAR	2.37	11.51	1.54
APR	22.36	23.76	18.84
MAY	86.42	68.24	85.02
JUN	127.90	117.45	160.43
JUL	186.71	125.51	224.21
AUG	273.21	108.40	333.61
SEP	211.03	116.19	353.30
OCT	47.07	100.89	159.77
NOV	0.46	67.38	18.13
DEC	0.02	34.45	0.15

Prospects

- The major potential here is for irrigation development, supporting agricultural growth in the region and can be developed as a source of clean water for local communities.
- Groundwater exploration and management.
- Watershed restoration and protection involve revitalizing and preserving the natural functions of the watershed to maintain its ecological integrity, water quality, and biodiversity can help alleviate water scarcity issues in the region.

2.5.2.1 The Gulbin-Ka Strategic Catchment

The Gublin-Ka Strategic catchment is a complex network of sub-catchments, comprising the Rivers Kanunu, Karkasi, and Samba. Located in the southern regions of Zamfara, Sokoto, and Kebbi states in Nigeria, this catchment plays a vital role in the country's hydrology. The Gublin-Ka River flows into the Sokoto River, which ultimately empties into the River Niger. The catchment's hydrology is characterized by a semi-arid climate, marked by high temperatures and low rainfall. Seasonal rainfall patterns dominate, with most precipitation occurring between June and October. As a result, evapotranspiration rates are high due to the combination of high temperatures and low humidity. The hydrology of the Gublin-Ka Strategic catchment is shaped by various factors, including its river system's seasonal flooding and groundwater availability. These factors contribute to the catchment's unique hydrological characteristics, making it an important area of study for water resource management and sustainable development.

2.5.2.2 Water Resources Assessment Concept in the Catchment

Water demand within the Gulbin Ka Catchment is increasingly surpassing available supply, creating challenges for sustainable water management. The catchment, which spans parts of Kebbi, Niger, and Zamfara States, is critical for agriculture, domestic use, and livestock farming. However, factors such as climatic variability, uncoordinated water management strategies, and increasing water abstraction have intensified pressure on available resources. The expansion of irrigation schemes, particularly along the banks of the Gulbin Ka River and its tributaries, has led to localized conflicts over water allocation, particularly during the dry season when resources are most scarce.

The hydrological regime of the catchment has been altered by human activities such as dam construction, deforestation, and the expansion of farmlands into floodplains. Sedimentation, vegetation encroachment, and the spread of invasive aquatic plants such as typha grass have further impeded water flow, affecting downstream users. Addressing these challenges requires an integrated water resource management approach that accounts for ecological sustainability, hydrological variability, and the competing demands of multiple water users. The following sections provide an overview of the water quantity and hydrological characteristics of the Gulbin Ka Catchment.

2.5.2.3 Stream Flow and Seasonal Variability

The hydrological cycle within the Gulbin Ka Catchment is heavily influenced by seasonal rainfall patterns. River discharge and groundwater recharge are highly variable, with significant differences between the wet and dry seasons.

During the wet season (June to September), heavy monsoonal rains generate increased surface runoff, leading to peak flows in the Gulbin Ka River and its tributaries. The upstream sections of the catchment, particularly in Kebbi and Niger States, experience significant runoff contributions from the undulating terrain, feeding into major tributaries such as the Yauri, Shanga, and Sakaba Rivers. Flooding is common along the lower sections of the Gulbin Ka River, where expansive floodplains serve as temporary storage areas for excess water. Peak discharge is typically recorded between July and September, sustaining seasonal flood-recession agriculture, known locally as fadama farming, which supports livelihoods in riparian communities.

During the dry season (October to April), river flow decreases significantly as rainfall ceases. Water availability becomes heavily reliant on groundwater contributions, wetland storage, and regulated releases from reservoirs. Flow rates in the main river channel drop drastically, sometimes falling below 10 cubic meters per second (m^3/s) in the driest months. This decline in surface water availability poses serious challenges for dry-season irrigation and livestock watering, particularly in downstream areas.

Dams and reservoirs within the catchment, such as those near Yauri and Zuru, play a crucial role in regulating dry-season flows by storing water during the wet season and gradually releasing it. However, increasing upstream abstraction for irrigation has reduced water availability for downstream users, leading to periodic disputes over water access. Additionally, the retreat of floodplains due to hydrological changes has impacted wetland-dependent farming, further exacerbating water scarcity issues.

2.5.2.4 Discharge Measurements

Monitoring river discharge in the Gulbin Ka Catchment is essential for effective water resource management, especially given its strong seasonal variations. Discharge measurements help in assessing water availability, predicting flood risks, and developing long-term water management strategies. The Nigeria Hydrological Services Agency (NIHSA) and other relevant agencies conduct periodic flow assessments across key hydrological stations in the catchment. These measurements provide critical data for decision-making regarding irrigation scheduling, reservoir operations, and flood mitigation efforts. However, gaps in hydrological data collection remain a challenge, limiting the ability to develop accurate predictive models for water resource planning.

2.5.2.5 Surface Water Resource Potential

The Gulbin Ka Catchment lies within Hydrological Area 1 (HA-1), which receives an average annual precipitation of 767 mm. However, only about 24% of this precipitation contributes to surface runoff, with the rest lost to evapotranspiration and other forms of abstraction. Within HA-1, the total internally generated runoff is estimated at 10.7 billion cubic meters (BCM) per year, while the overall surface water resource potential is approximately 35.1 BCM per year.

The total water resources potential is assessed by considering both internal generation and external inflows. The internal total water resources potential is estimated at 8.4 BCM per year, while the total water resources potential, including inflows from neighbouring countries, stands at 37.4 BCM per year. A significant portion of this water approximately 26.7 BCM per year enters Nigeria through transboundary rivers such as the River Niger and Gulbin Ka River, highlighting the country's reliance on external water sources.

Groundwater recharge within the Gulbin Ka Catchment is estimated at 5 BCM per year as a renewable resource. However, the increasing dependence on groundwater abstraction for irrigation and domestic use is placing pressure on aquifer reserves. More comprehensive hydrological data collection is needed at the catchment scale to fully understand the sustainability of groundwater extraction and to inform effective water management policies.

The Gulbin Ka Catchment is an essential water resource area within Hydrological Area 1, along with the Rima, Sokoto-Zamfara, and Malenda Catchments. As such, the current surface and groundwater potential at the HA-1 level represents a cumulative total of these catchments. Sustainable water management practices, including improved irrigation efficiency, enhanced watershed protection, and better hydrological monitoring, will be critical in ensuring long-term water security for communities dependent on the Gulbin Ka River system.

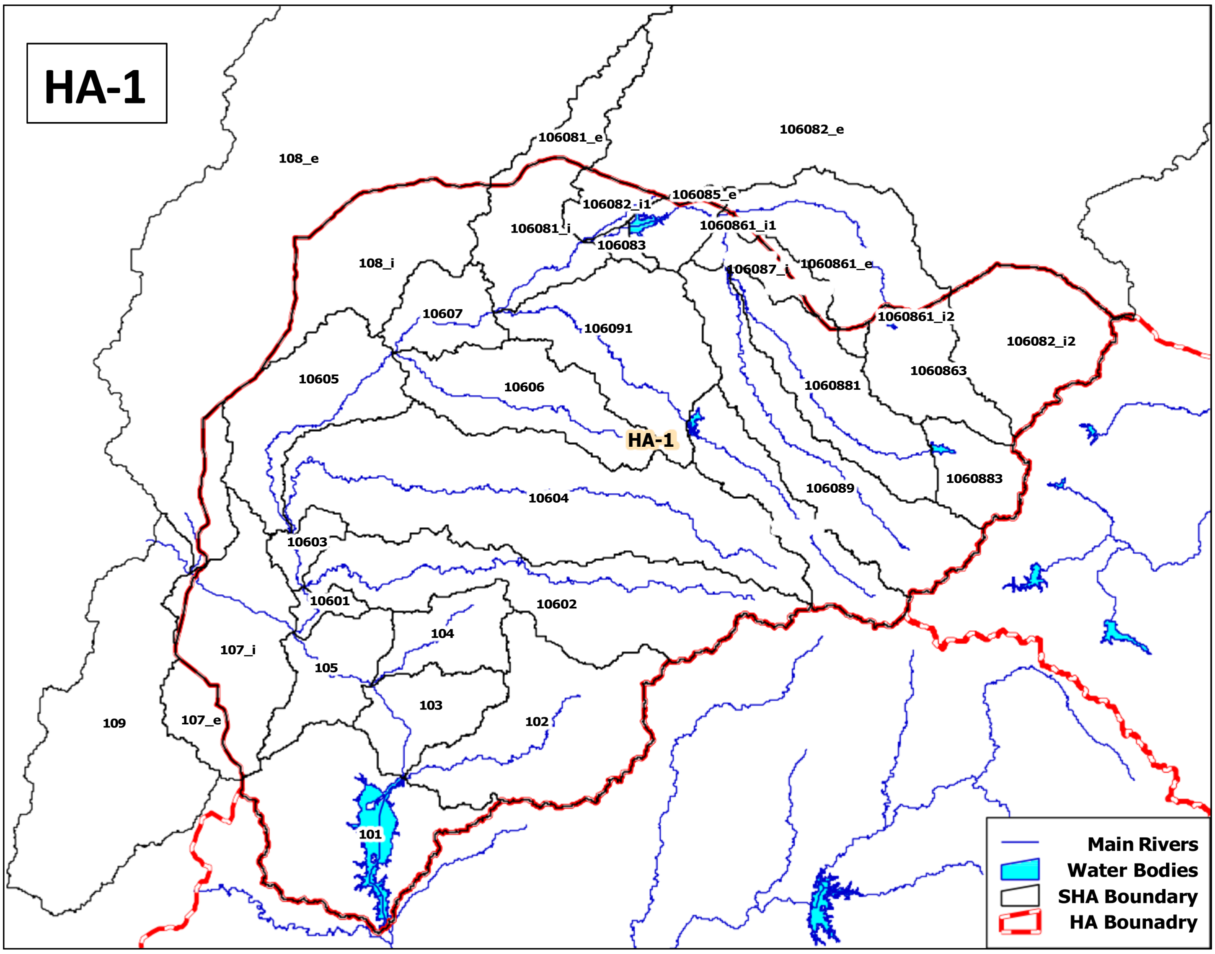


Figure 2.19:Water Resources of the catchment

Table 2.7: Water resource potential for HA-1

		HA-1
Water Resources Potential		
Total Water Resources Potential		
Including inflow from outside Nigeria	(BCM /year)	37.4
Only internal generation in Nigeria	(BCM /year)	10.7
Surface Water Resources Potential		
Including inflow from outside Nigeria	(BCM /year)	35.1
Only internal generation in Nigeria	(BCM /year)	8.4
Groundwater Resources Potential		
Groundwater Recharge	(BCM /year)	5
Runoff Condition（Only internal generation in Nigeria）		

Precipitation (P)	(mm/ year)	767
Total Runoff (RO)	(mm/ year)	62
Groundwater Recharge (GRE)	(mm/ year)	37
Loss of Recharge (LOS)	(mm/ year)	18
Runoff Rate (RO/P)	(%)	8.1
Recharge Rate (GRE/P)	(%)	4.8
Loss Rate (LOS/P)	(%)	2.3
Total Water Res. Rate ((RO+LOS)/P)	(%)	10.4

Source： JICA Project Team

2.5.2.6 Run off yield

Table 2.8 and 2.9 shows the Runoff Yield and Surface Water Resources in Quasi-Natural Condition at the Downstream End of SHAs of the Gulbin-Ka catchment respectively.

Table 2.8: Runoff Yield

HA	SHA	SHA divided by National Boundary	Area (km2)	Average Monthly Runoff Yield (Height) (mm/month)												Average Annual Runoff Yield (mm/year)	Average Annual Precipitation (mm/year)	Average Runoff Rate (%)
				1	2	3	4	5	6	7	8	9	10	11	12			
1	103	103	3,387.30	1.2	0.5	0.2	0.1	0.7	4.5	10.9	32.7	43.8	14.9	6.4	2.8	119	940	12.6
	104	104	2,933.60	1.3	0.5	0.2	0.1	0.3	2.9	9.2	33.1	45.8	15.7	6.8	2.9	119	909	13.1
	105	105	3,456.60	0.8	0.3	0.1	0.1	0.4	4.3	9.4	26.7	31.2	9.7	4.2	1.8	89	945	9.4
	10601	10601	689.1	2.1	1.4	0.9	0.6	0.5	1.7	3.6	10.7	13.3	6.8	4.5	3.1	49	887	5.6
	10602	10602	10,960.30	3.1	2	1.3	0.9	0.8	2.4	6.4	24.3	35.6	15.2	8.4	5	105	922	11.4
	10603	10603	1,084.90	0.9	0.6	0.4	0.3	0.3	1.2	3.3	6.9	7.2	3	2	1.3	27	828	3.3
	107	107_e	1,924.10	3.7	2.5	1.7	1.1	1.1	2.8	4.3	14.4	22	12.3	8.3	5.5	80	1,028	7.8
		107_i	6,223.40	2.1	1.4	0.9	0.6	0.6	2	3.8	10.5	13.6	6.9	4.6	3.1	50	930	5.4
	108	108_e	63,517.40	0	0	0	0	0	0	0.4	0.9	0.1	0	0	0	1	337	0.4
		108_i	7,724.90	0.1	0	0	0	0	0.1	1.3	2.7	0.7	0.2	0.1	0.1	5	514	1
	109	109	14,037.50	3.6	2.4	1.6	1.1	1.4	3	4.7	12.9	21.2	12	8	5.4	77	1,006	7.7

Source JICA 2014 MP

Table 2.9: Surface Water Resources in Quasi-Natural Condition at the Downstream End of SHAs

HA	SHA	SHA divided by National Boundary	Area (km2)	Average Monthly Discharge (m3/s)												Average Discharge (m3/s)	Q80M (m3/s)	Q97DS90%Y (m3/s)
				1	2	3	4	5	6	7	8	9	10	11	12			
1	103	103	3,387	1,389	1,019	481	167	88	140	487	1,618	2,281	1,677	1,484	1,494	1,027.20	162.7	17
	104	104	2,934	1	1	0	0	0	3	10	36	52	17	8	3	11	0.1	0
	105	105	3,457	1,386	1,018	480	167	87	131	464	1,540	2,172	1,640	1,467	1,488	1,003.40	158.1	17
	10601	10601	689	27	19	11	7	8	35	183	518	542	172	87	46	138.5	6.5	0.5
	10602	10602	10,960	13	9	5	4	3	10	26	99	150	62	35	20	36.6	3.9	0.4
	10603	10603	1,085	14	9	5	3	5	25	155	415	389	108	50	24	100.8	2	0.1
	107	107_e	1,924	3	2	1	1	1	2	3	10	16	9	6	4	4.9	0.7	0
		107_i	6,223	1,358	999	469	159	78	90	269	988	1,588	1,455	1,375	1,440	855.2	127.1	15.4
	108	108_e	63,517	0	0	0	0	0	0	14	30	5	1	0	0	4.3	0	0
		108_i	7,725	0	0	0	0	0	0	10	22	3	0	0	0	3	0	0
	109	109	14,037	1,351	993	466	157	76	83	243	924	1,534	1,430	1,357	1,428	836.1	113.5	14.3

2.5.3 Groundwater Recharge

Groundwater recharge within the Gulbin Ka Catchment has been experiencing a gradual decline, primarily due to climate variability, increasing water abstraction, and land-use changes. The extent of this decline varies across the catchment, with certain areas more severely affected than others. Given the region's significant reliance on groundwater for domestic use, livestock watering, and dry-season irrigation, understanding spatial variations in recharge rates is essential for sustainable water resource management.

Recharge rates tend to be higher in areas with greater precipitation and where surface water bodies contribute to infiltration. However, in semi-arid regions of the catchment, such as parts of Kebbi and Niger States, groundwater recharge is relatively low, making these areas more vulnerable to declining water tables. The increasing expansion of irrigation activities and deforestation of key recharge zones have further exacerbated groundwater depletion concerns.

2.5.4 Hydrogeological Disposition of the Catchment

The hydrogeological disposition of the catchment and its hydrogeological units and aquiferous layers make up part of the water resources of the catchment, as seen and explained in Figure 2.20.

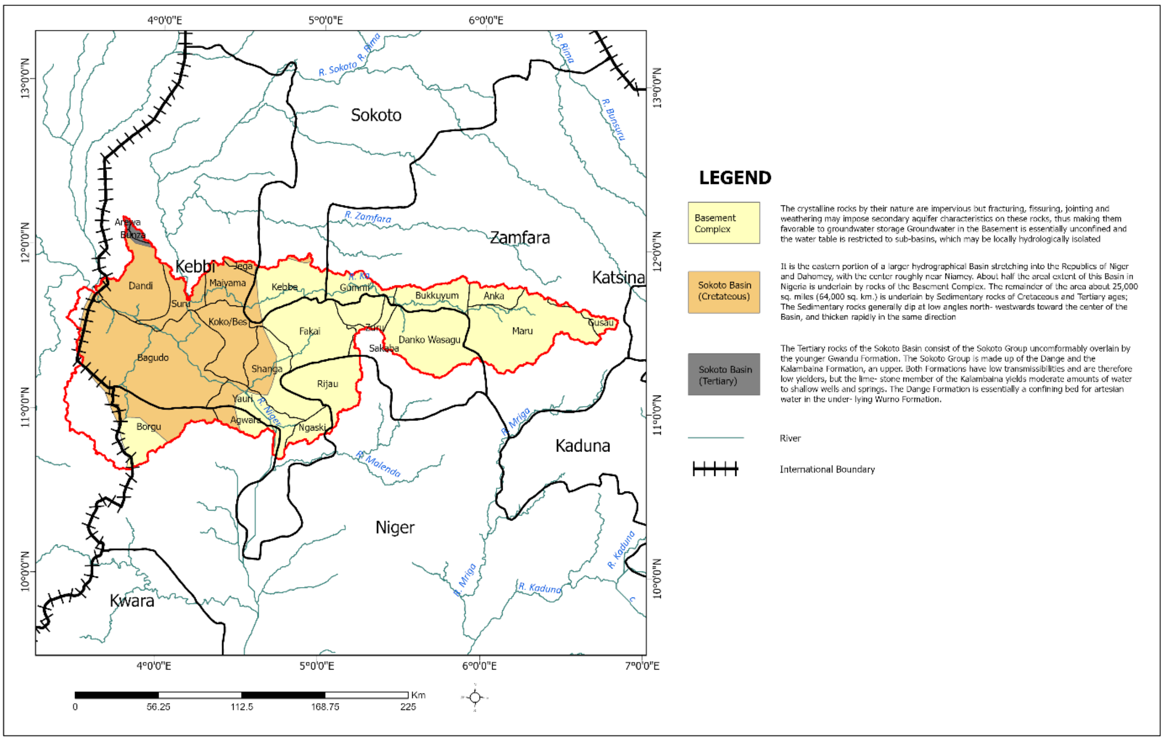


Figure 2.20: Hydrogeological province Map of the Catchment (Source: MSL, 2025)

2.6 Water Demand for Gulbin-Ka Catchment

2.6.1 Water Availability by Sub-Basin

Water availability for the Gulbin-Ka catchment is subdivided into the following:

i. **Surface Water Resources**

- **Seasonal Rivers**: The Gulbin-Ka River and its tributaries are predominantly seasonal, experiencing significant flow during the rainy season (May–October) and minimal to no flow during the dry season (November–April). This seasonality affects water availability for agriculture, domestic use, and livestock.
- **Rainfall Patterns**: The region receives an average annual rainfall ranging from 600 mm to 1000 mm, with variability across the catchment. This rainfall supports surface water bodies during the wet season but is insufficient to sustain them year-round.

ii. **Groundwater Resources**

- **Aquifer Characteristics**: The catchment lies within the Sokoto Basin, characterized by sedimentary formations that host aquifers of varying depths. Groundwater is accessed through shallow wells and deep boreholes.
- **Water Quality**: Studies indicate that groundwater quality varies across the catchment. In some areas, parameters such as nitrate concentrations exceed WHO permissible limits, posing health risks.
- **Recharge Rates**: Groundwater recharge is primarily dependent on rainfall infiltration, which is limited due to the semi-arid climate and soil characteristics, leading to low recharge rates and potential over-extraction concerns.

iii. **Rainwater Harvesting Potential**

- **Feasibility**: Given the seasonal nature of rainfall, rainwater harvesting presents a viable option to augment water availability. Techniques such as rooftop collection and small-scale reservoirs can be implemented at the household and community levels.
- **Benefits**: Rainwater harvesting can reduce pressure on surface and groundwater resources, provide a reliable water source during dry periods, and improve water security for domestic and agricultural purposes.

2.6.2 Water Use and Demands

Current and future water demands were estimated for the Golbin-Ka 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 shown in Figure 2.21. The States considered are part of Sokoto, Zamfara, Kebbi and Niger.

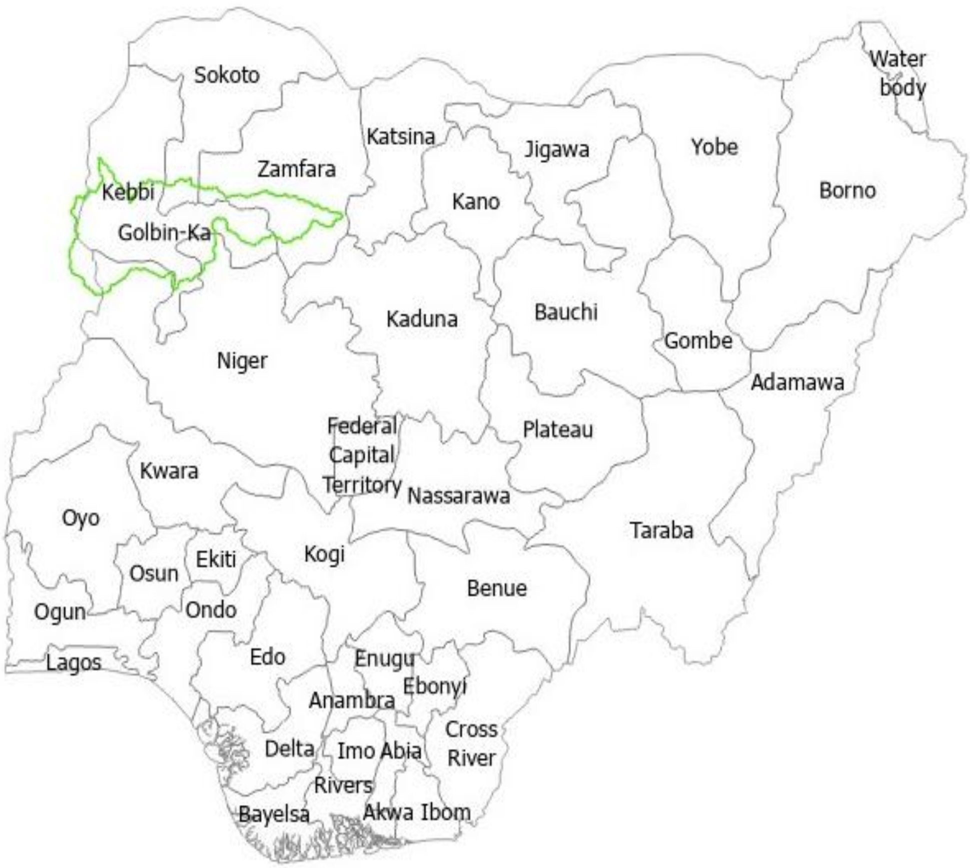


Figure 2.21 Map Showing Golbin-Ka Catchment on Nigeria Map

The water demand in the Gulbin-Ka catchment is divided into the following categories:

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

2.6.3 Municipal water demand

Municipal water demand is a combination of urban domestic demand, Semi-Urban/Small Town (SU/ST) domestic water demand, rural domestic water demand, commercial demand and industrial demand. Some of the states considered are only partly located in the Gulbin-Ka-basin. Consequently, not the entire water demand of a state can be attributed to the basin. To determine the water demand per SHA, the demands per state are firstly scaled down to LGA level based on the population per LGA (City Population, 2006). Using the NWRMP methodology, projections are made for the demands in 2035 and 2065 as shown in the Table 2.10 and Figure 2.22 below.

Table 2.10: Water Demand per Annum per Location within the Catchment

Per Capita Damand = 70 L/Day									
WATER DEMAND PER ANNUM PER LOCATION WITHIN THE CATCHMENT									
State	LGA	Water Demand m3/d 2006	2022	2025	2030	2035	2040	2045	2050
Sokoto	Kebbe	8621	12599	13528	15232	17149	19308	21739	24476
Zamfara	Anka	10055	14695	15778	17765	20002	22520	25355	28547
Zamfara	Bukkuyum	15144	22134	23766	26758	30127	33920	38190	42998
Zamfara	Gummi	14470	21149	22708	25567	28786	32410	36491	41085
Zamfara	Gusau	26860	39256	42150	47457	53432	60159	67733	76261
Zamfara	Maru	20520	29990	32201	36255	40820	45959	51746	58260
Kebbi	Bagudu	16661	24350	26146	29437	33144	37316	42014	47304
Kebbi	Dandi	10235	14958	16061	18083	20360	22923	25809	29059
Kebbi	Fakai	8384	12253	13157	14813	16678	18778	21142	23804
Kebbi	Koko/Besse	10837	15839	17007	19148	21558	24273	27329	30769
Kebbi	Maiyama	12163	17776	19087	21490	24196	27242	30672	34534
Kebbi	Ngaski	8827	12901	13852	15596	17560	19771	22260	25062
Kebbi	Shanga	8900	13007	13966	15725	17705	19934	22443	25269
Kebbi	Suru	10393	15190	16310	18363	20675	23278	26209	29508
Kebbi	Wasagu/ Danko	18569	27139	29140	32809	36939	41590	46826	52721
Kebbi	Yauri	7039	10288	11047	12438	14004	15767	17752	19987
Kebbi	Zuru	11573	16915	18162	20449	23023	25922	29185	32859
Niger	Agwara	4014	5867	6300	7093	7986	8991	10123	11397
Niger	Borgu	12098	17682	18986	21376	24067	27097	30509	34350
Niger	Rijau	12334	18026	19355	21792	24536	27625	31103	35019
TOTAL		247,699	362,012	388,708	437,646	492,746	554,782	624,629	703,270

Source NPC 2006 Projected to 2050

Figure 2.22, 2.23 and Table 2.11 shows the Gulbin Ka catchment water demand and capacity respectively.

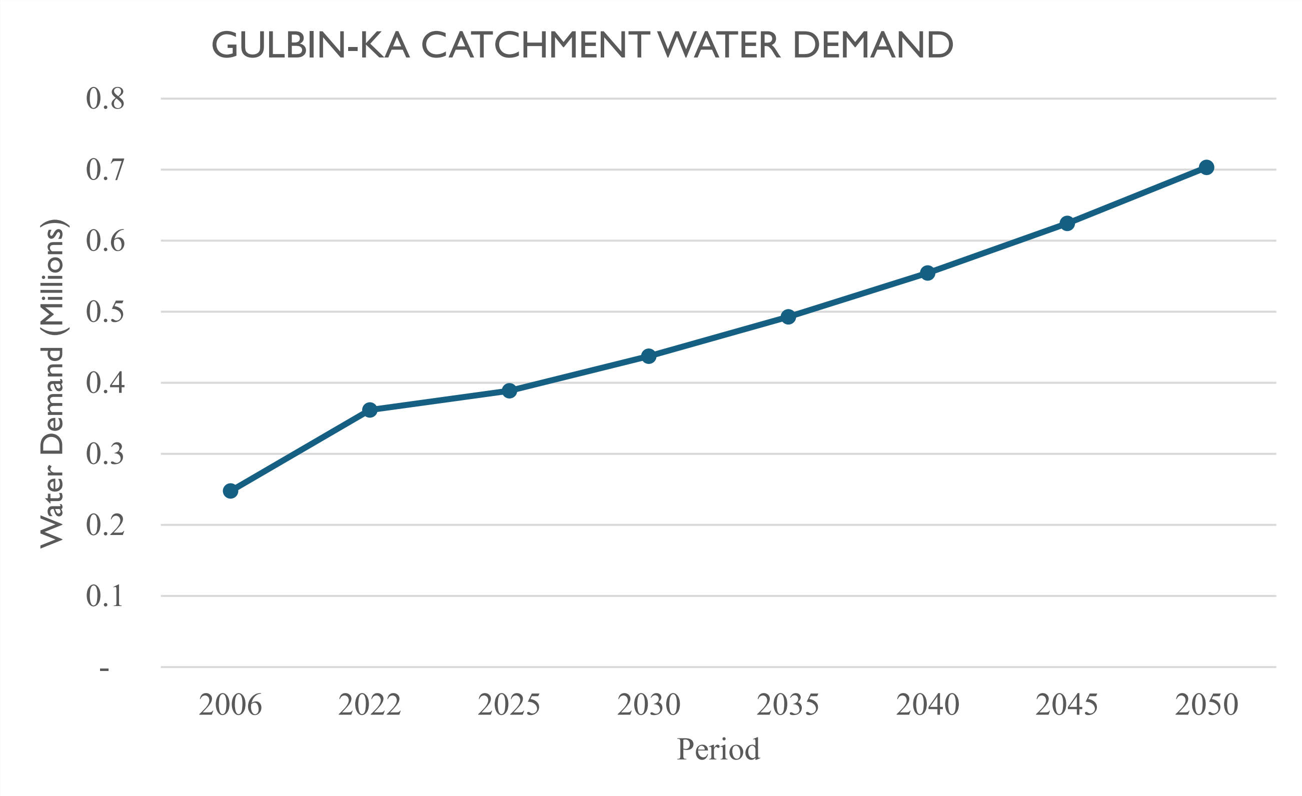


Figure 2.22 Gulbin Ka catchment water demand

Table 2.11 Water Capacity for Gulbin-Ka Catchment

WATER CAPACITY PER ANNUM PER LOCATION WITHIN THE CATCHMENT									
State	LGA	Water Capacity m^3/d 2006	2022	2025	2030	2035	2040	2045	2050
Sokoto	Kebbe	11207	16379	17587	19801	22294	25101	28261	31819
Zamfara	Anka	13071	19103	20512	23094	26002	29276	32961	37111
Zamfara	Bukkuyum	19688	28774	30895	34785	39165	44095	49647	55897
Zamfara	Gummi	18812	27493	29521	33237	37422	42133	47438	53410
Zamfara	Gusau	34918	51032	54796	61694	69462	78207	88053	99139
Zamfara	Maru	26676	38987	41862	47132	53066	59747	67269	75738
Kebbi	Bagudu	21659	31655	33989	38269	43087	48511	54619	61495
Kebbi	Dandi	13305	19446	20880	23508	26468	29800	33552	37776
Kebbi	Fakai	10899	15929	17104	19257	21682	24412	27485	30945
Kebbi	Koko/ Besse	14088	20590	22109	24892	28026	31555	35527	40000
Kebbi	Maiyama	15812	23109	24813	27938	31455	35415	39874	44894
Kebbi	Ngaski	11475	16771	18008	20275	22828	25702	28938	32581

Kebbi	Shanga	11570	16909	18156	20442	23016	25914	29176	32849
Kebbi	Suru	13511	19747	21203	23872	26878	30261	34071	38361
Kebbi	Wasagu/ Danko	24140	35280	37882	42651	48021	54067	60874	68538
Kebbi	Yauri	9151	13375	14361	16169	18205	20497	23077	25983
Kebbi	Zuru	15045	21989	23611	26583	29930	33698	37941	42717
Niger	Agwara	5219	7627	8189	9220	10381	11688	13160	14817
Niger	Borgu	15728	22986	24682	27789	31288	35227	39662	44655
Niger	Rijau	16034	23434	25162	28330	31897	35912	40434	45524
TOTAL		**322,009**	**470,616**	**505,320**	**568,940**	**640,569**	**721,217**	**812,018**	**914,251**

Source NPC 2006 Projected to 2050

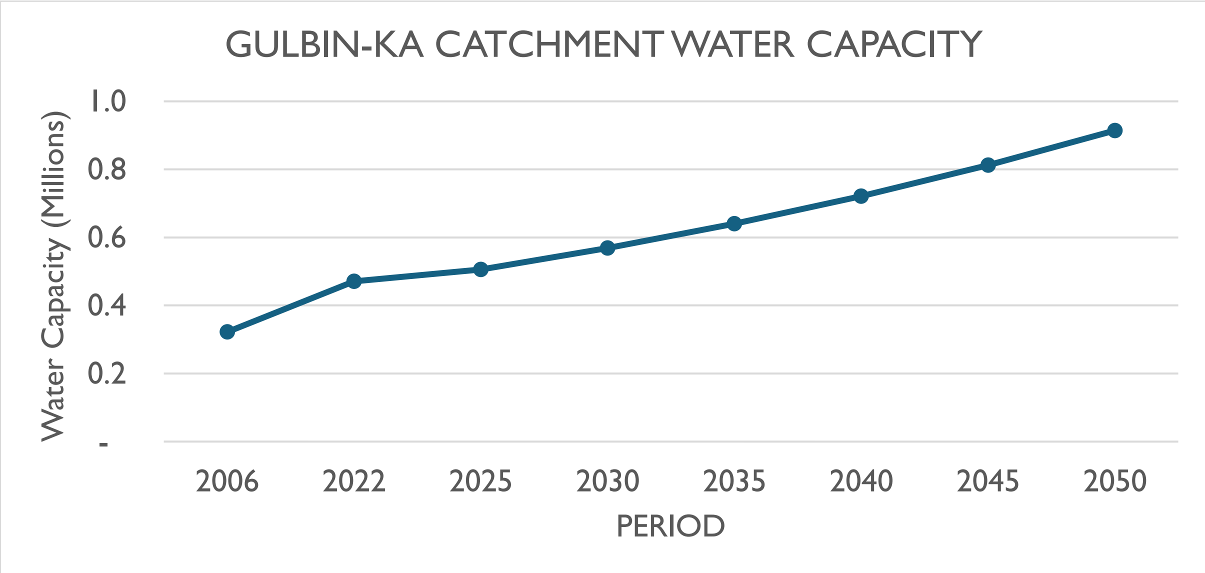


Figure 2.23: Water Capacity for Gulbin Ka Catchment

2.6.4 Livestock Indices and Water Demand

The number of livestock shown in Table 2.12 to 2.18 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. 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. Thus, livestock ought to rely on well water as its last resort. Water consumption of livestock is a function of atmospheric temperature, live weight and availability of grazing grass. Because 80% of the weight of grazing grass is nothing but water, and if a cattle graze and browse 20 kg/day, it is equivalent to drink 16 liter of water that can maintain a day of an adult cow with her live weight of 240kg (0.15 l / kg live weight). In an extreme drought year, with an annual rainfall of 400mm or less, grass cover becomes so thinner over grazing field that adult cattle cannot graze more than 5kg a day. In such a case it should drink at least 11 liter of water at watering spots a day to maintain its body. Moreover, moving/ walking livestock require more water, about double as much as the staying one. That the reason why adult cattle need 25 ~ 35 liter of water per day on average depending on its live weight and its activities. As to other ruminants like goats and sheep. The situations are similar to the case of cattle. The following table shows a standard of livestock water requirement in the tropical zone shown in one of livestock guidebook published by FAO in 1960s. Of course, domestically kept livestock and nomadic one has different standard in a strict sense:

Table 2.12 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 (m^3) requirement
Cattle	250	60	38.4	21.6	**7.9**
Goat	30	6.6	4.3	2.3	**0.8**
Sheep	40	8.8	6.8	2.0	**0.7**
Pig	90	20	16.7	3.3	**1.2**
Donkey	110	24	15.6	8.4	**3.1**
Camel	350	80	55.4	24.6	**9.0**
Horse	300	70	47.8	22.2	**8.1**
Fowl	**2**	**0.4**	**0.292**	**0.108**	**0.039**

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

Table 2.13 Recent trend of livestock herd size in Nigeria

Specie	1995	1999	2000 ~2005	2006 / 07	07/ 08	08/ 09	2009/ 10
Cattle	16,577,962	15,071,237	n.a	16,278,946	16,537,748	16,488,085	16,699,939
Goat	56,524,075	43,079,529	n.a	51,208,000	52,489,243	54,200,434	55,145,439
Sheep	35,519,759	27,363,427	n.a	32,308,632	27,390,700	33,683,100	34,686,165
Pig	7,471, 730	2,426,747	n.a	9,298,275	9,554,900	9,808,289	10,108,258
Donkey	1,084,770	-	n.a	-	-	-	279,093
Camel	49,810	-	n.a	-	-	-	109,421
Horse	-	-	n.a	-	-	-	783,303
Fowl	192,13,325	112,441,618	n.a	92,035,038	84,781,229	86,600,907	96,606,920

Source: Water Resource Master Plan 1995, NBS abstract and Funso Agricultural Data

Table 2.14 Number of livestock heads/ fowls for Gulbin-Ka Catchment in 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Kebbi	440,469	1,974,189	1,063,894	140,500	3,598,760	14,726	18,057	**4,174**
Niger	529,067	2,290,808	843,860	64,000	4,734,575	2,572	0	**0**

Sokoto	1,427,080	3,155,584	3,194,837	35,000	3,848,501	73,107	20,162	**0**
Zamfara	**458,720**	**2,334,979**	**2,115,105**	**12,975**	**6,941,239**	**13,748**	**44,421**	**96,285**

Source: Water Resource Master Plan 1995

Table 2.15 Corresponding livestock water requirement n 2009 / 2010

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Kebbi	3,467,812	1,674,112	789,409	167,757	140,352	45,312	162,134	33,517
Niger	4,165,344	1,942,605	626,144	76,416	184,648	7,914	0	0
Sokoto	11,235,401	2,675,935	2,370,569	41,790	150,092	224,950	181,035	0
Zamfara	3,611,503	1,980,062	1,569,408	15,492	270,708	42,303	398,856	773,169

Source: Water Resource Master Plan 1995

Table 2.16 Estimated growth rate of livestock heads during the period 2010 ~ 2030

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

Source: JICA 2014

Table 2.17 Number of livestock heads/ fowls projected in 2030

Livestock Heads	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Kebbi	504,281	2,947,521	1,886,254	214,902	4,357,800	14,726	18,057	4,174
Niger	605,714	3,420,243	1,496,140	97,891	5,733,178	2,572	0	0
Sokoto	1,633,825	4,711,378	5,664,357	53,534	4,660,216	73,107	20,162	0
Zamfara	525,176	3,486,191	3,750,022	19,846	8,405,265	13,748	44,421	96,285

Source: JICA 2014

Table 2.18 Corresponding livestock water requirement projected in 2030

Livestock Water	Cattle	Goats	Sheep	Pigs	Poultry	Donkeys	Camels	Horses
Kebbi	3,975,751	2,475,918	1,376,966	258,957	169,954	45,150	162,134	33,822
Niger	4,775,452	2,873,004	1,092,182	117,959	223,594	7,886	0	0
Sokoto	12,881,075	3,957,558	4,134,980	64,509	181,748	224,146	181,035	0
Zamfara	4,140,487	2,928,401	2,737,516	23,914	327,805	42,151	398,856	780,197

Source: JICA 2014

2.6.5 Aquaculture water demand

Basic Data for 2030 projection: Area of farm ponds by Fishery Statistics as shown in Table 2.19 and 2.20 of Nigeria, Inventory of Private and Government Fish Harm and Hatcheries (Dec. 2004) published in 2007

Table 2.19 Fish Farm Pond in Gulbin-Ka Catchment

State	Number of Fish Farm	Water Area of Farm Pond (ha)	Brackish Water Area of Farm Pond (ha)
KEBBI	56	57.7	**0.0**
NIGER	29	29.0	**0.0**
SOKOTO	9	14.2	**0.0**
ZAMFARA	9	37.5	**0.0**
TOTAL	**103**	**138.4**	**0**

Source: JICA 2014

Table 2.20 Projected Water Demand for Inland Aquaculture

HA	Water Demand (MCM)	
	2010	2030
1	17.9	28.6

Source: JICA 2014

2.6.6 Irrigation water demand

The Government of Nigeria has placed rice as an important commodity item for national food security as well for exportable commodity in future and tackles for improving its productivity (refer to Table 2.21 to 2.27). However, current domestic annual rice production remains at 5.23 million ton (as of 2023) as paddy.

Among the vast Nigerian territory, the area suitable for rice production is estimated at 4.6 million ha, accounting for around 5% of the national territory. Currently, rice is produced on 1.8 million ha. The area of irrigable farmland has been conceived as wide as 3.14 million ha, but in reality, the irrigated perimeter is only measured at 47,799 ha. Current rice production share of rain-fed upland, rain-fed lowland and irrigated lowland consists of 24%, 71% and 5%, respectively. It follows that rice cultivation under rain-fed condition occupies majority, with very low rate of irrigated lowland. In general, 6-9ton/ha of paddy yield can be expected at maximum in the case of production in irrigated lowland, and this is why rehabilitation of existing irrigation schemes and newly reclaimed ones have so far been challenged in Nigeria.

According to "National Rice Development Strategy (NRDS)", the targets of rice cropping area and production are issued as following:

Table 2.21 Targets on paddy cropping area, yield levels and production quantity

	Rain-fed upland			**Rain-fed lowland**			**Irrigated lowland**		
	Area (ha)	Yield (t/ha)	Production (ton)	Area (ha)	Yield (t/ha)	Production (ton)	Area (ha)	Yield (t/ha)	Production (ton)
2008	510,050	1.62	826,281	1,243,151	1.99	2,473,870	47,799	3.50	167,297
2013	714,927	1.72	1,229,674	1,663,271	2.20	3,659,196	269,802	4.50	1,214,109
2018	875,000	2.00	1,750,000	2,065,000	3.40	7,021,000	560,000	8,00	4,480,000

Source: Jica Team 2014

Table 2.22 Summarized targeted annual growth rate of cropping area and crop yield

	Total		
	Area (ha)	Yield (t/ha)	**Production(ton)**
2008	1,801,000	1.92	**3,467,448**
2013	2,648,000	2.30	**6,102,979**
2018	3,500,000	3.79	**13,251,000**
2050	**Projection?**		

Source: National Rice Development Strategy (NRDS)

Table 2.1.2 above summarizes the targeted annual growth rate of cropping area and crop yield. Judging from hitherto performances on budgetary provision, mechanisms of project/ scheme implementation and development process of agricultural development in Nigeria, the rate of annual yield increment given in this table, i.e., 9.10% and that of cropping area expansion, i.e., 14.4% seem to too much diverged from what has been experienced so far, thus it is understood exceedingly difficult to attain these targets until 2018.

Table 2.23 Targeted annual increment rates of rice cropping acreage and yield (%/year)

	Rain-fed upland		**Rain-fed lowland**		**Irrigated lowland**	
	Area	Yield	Area	Yield	Area	**Yield**
2008→2013	6.99	1.21	6.00	2.03	41.4	**5.15**
2013→2018	4.12	3.06	4.42	9.10	15.7	**12.2**
2018 =2050?	**Projection**					

Source: JICA Team

Annual growth rates of cropping areas and yields of rain-fed upland and lowland rice

The trends of rice cropping area, yield and production obtained from the statistical data by NBS and state-wise information are given in the table 2.1.4 below: Table 2.1.3 above shows cropping area comprises mainly rain-fed upland and lowland with very limited area under irrigated lowland.

Table 2.24 Trend of rice cropping area, yield and production

Crop year	Cropping area(ha)	Yield (ton/ha)	Production (ton)
1994/95	1,518,781	1.31	1,994,020
1995/96	1,449,543	2.15	3,120,940
1996/97	1,494,013	1.95	2,911,060
1997/98	1,469,341	1.92	2,826,540
1998/99	1,549,932	1.92	2,974,210
1999/2000	1,633,202	2.05	3,343,760
2000/01	1,547,396	2.04	3,159,650
2001/02	1,479,610	1.95	2,879,530
2002/03	1,362,370	2.01	2,757,610
2003/04	1,346,520	2.13	2,874,080
2004/05	1,454,570	2.19	3,183,390
2005/06	1,609,890	2.04	3,286,500
2006/07	1,508,000	2.18	3,281,990
2007/08	1,640,730	2.13	3,499,760
2008/09	1,685,330	1.96	3,311,070
2009/10	1,836,880	1.90	3,481,620
2010= 2050?			

Source: JICA 2014

2.6.7 Existing and Potential Irrigation Areas

Gulbin-Ka Catchment located within HA-1 in northern Nigeria belongs to semi-arid zone with scanty annual rainfall, however, rice cultivation during rainy season is widely practiced with so far learnt ample experiences/ performances. In dry season, wheat and other cereal crops as well as vegetables are mainly cultivated because of huge water requirement for rice cultivation and high cost of diesel to fuel the water generators.

Current Cropping Pattern

The following table shows the current cropping rate set based on RBDA's materials and cropping acreages of large-scale irrigation schemes.

Table 2.25 : Current Cropping Pattern (%)

HA	Irrigation scheme (%)				Small-scale private irrigation (%)			
	Wet Season		Dry Season		Wet Season		Dry Season	
	Paddy	Upland	Paddy	Upland	Paddy	Upland	Paddy	Upland
1	40	25	5	60	20	50	0	70

Table 2.26 : HA-1 Existing Cropping Pattern

Scheme	Crop	Wet season Area (ha)	Dry season Area (ha)	Crop intensity Wet (%)	Crop intensity Dry (%)	Developed Area (ha)
Shagari	Rice	50	0	25	0	**200**
	Others	110	80	55	40	
Middle Rima Valley	Rice	80	0	7	0	**1,188**
	Others	1,000	950	84	80	
Bakalori	Rice	7,200	0	90	0	**8,000**
	Others	800	4,000	10	50	
Jibiya	Rice	0		0	0	**3,000**
	Others	2,700	1,500	90	50	
Zauro Polder	Rice	85	0	85	0	**100**
	Others	15	15	15	15	
Niger Valley	Rice	0	700	0	10	**7,000**
	Others	1,400	6,300	20	90	
Total	Rice	7,335	700	38	4	**19,488**
	Others	**5,025**	**11,895**	**26**	**61**	

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

Table 2.27 Proposed Cropping Pattern (%)

HA	Irrigation scheme (%)				Small-scale private irrigation (%)			
	Wet Season		Dry Season		Wet Season		**Dry Season**	
	Paddy	Upland	Paddy	Upland	Paddy	Paddy	Upland	**Paddy**
1	**40**	**60**	**0**	**50**	**10**	**75**	**0**	**75**

Source: JICA TEAM

a) Crop coefficient (Kc)

Crop coefficient (Kc) on growth stage is selected based on FAO technical text. Wind condition is clam or weak.

Rice

HA	Season	Initial stage(1) First month 15 days	Initial stage(2) Second month 30 days	Middle stage 30 days	Tardive stage 30 days
Common	Wet	1.1	1.1	1.05	**0.95**
Common	**Dry**	**1.1**	**1.1**	**1.25**	**1.0**

Maize

HA	Season	Sowing time	ETo (mm / day)	Irrigation interval	Initial stage (1) 30days	Initial stage (2) 30days	Middle stage 30days	Tardive stage 30days
HA-1	Wet	May	5.8	7	0.44	0.75	1.05	**0.55**
	Dry	**Nov.**	**3.2**	**7**	**0.58**	**0.87**	**1.15**	**0.60**

Wheat

HA	Season	Sowing time	ETo (mm /day)	Irrigation interval	Initial stage (1) 30days	Initial stage (2) 30days	Middle stage 30days	Tardive stage 30days
HA-1	**Dry**	**Dec.**	**2.7**	**7**	**0.6**	**0.88**	**1.15**	**0.2**

2.6.8 Total Water Demand

Table *2.28* below shows the Water Balance Analysis for Gulbin Ka Catchment

Table 2.28 Water Balance Analysis for Gulbin Ka Catchment

WATER BALANCE ANALYSIS FOR GULBIN-KA CATCHMENT			
WATER DEMAND (CUBIC METER)		**2025**	**2050**
MUNICIPAL		141,878,358	256,693,617
LIVESTOCK		48,332,389	71,850,264
AQUACULTURE		6,951,468	8,027,596
IRRIGATION		36,200,000	101,100,000
TOTAL		**233,362,216**	**437,671,477**
AVAILABLE WATER RESOURCES (CUBIC METER)		**3,921,841,600**	**3,921,841,600**
WATER BALANCE (CUBIC METER)		**3,688,479,384**	**3,484,170,123**

SOURCE : JICA 2014 MP AND GHI Water and Watershed Management 2022

2.6.9 Infrastructure and Assets

Table 2.29 shows the different Infrastructure and Assets of the Gulbin Catchment

Table 2.29: Infrastructure and Assets of Gulbin Catchment

Infrastructure	Location	Importance	Risk Factor
Zobe Dam & Irrigation Scheme	Dutsinma LGA, Katsina State	Provides irrigation water for approximately 5,000 hectares and supplies domestic water to surrounding communities. Despite its capacity, the irrigation facilities and canal networks downstream were not installed as initially planned.	The absence of downstream irrigation infrastructure limits the dam's utility, posing a risk to agricultural productivity and water resource optimization.
Sabke Dam & Irrigation Scheme	Mai'adua LGA, Katsina State	Supplies irrigation water to 3,000 hectares of farmland and provides potable water to Daura and Mai'adua communities. The dam was completed after years of abandonment.	Although completed, the irrigation scheme has yet to become operational due to incomplete canal networks, risking underutilization of the water resource.
Dallaji Irrigation Project	Bindawa LGA, Katsina State	Intended to support agricultural activities through irrigation, contributing to food security and livelihoods.	The project is among several irrigation schemes that are either non-operational or underperforming, posing a risk to their intended agricultural benefits.
Stormwater Drainage Systems	Katsina, Funtua, Malumfashi, and Jibia LGAs, Katsina State	Constructed to manage stormwater and control erosion under the Nigeria Erosion and Watershed Management Project (NEWMAP).	While completed in several LGAs, the effectiveness of these systems depends on maintenance; lack thereof could lead to renewed erosion and flooding issues.

Water Supply Projects	Dutsi and Mashi LGAs, Katsina State	Each water scheme provides about 250,000 gallons of treated water to their respective communities, enhancing access to potable water.	Sustaining these water supply systems requires ongoing maintenance and management; neglect could compromise water quality and availability.
Fadama Irrigation Areas	Various locations across Katsina State	Encompasses approximately 36,200 hectares of floodplain areas suitable for irrigation, supporting small-scale farming and livelihoods.	These areas are susceptible to flooding and require proper management to prevent land degradation and ensure sustainable agricultural use.

2.7 Water Quality

2.7.1 Surface Water Quality

Water quality in the Gulbin-Ka Catchment, spanning parts of Kebbi, Niger, and Zamfara States, is influenced by both natural and human factors, including seasonal river flows, agricultural practices, artisanal mining, and poor sanitation. The Gulbin-Ka River, a major tributary of the Niger River, serves as a critical source of drinking water, irrigation, fishing, and livestock support. However, these water bodies face increasing pressure from sedimentation, agrochemical runoff, heavy metal contamination, and microbial pollution.

Water quality assessment in Gulbin-Ka considers physical, chemical, and biological parameters, which determine the suitability of water for human consumption, agriculture, and ecosystem health.

2.7.1.1 Physical Parameters

Physical water quality parameters influence water clarity, aesthetics, and aquatic life. They are essential for assessing suitability for domestic and agricultural use.

a) Temperature

Water temperatures in Gulbin-Ka Catchment range from 24°C to 33°C, with peak values during the dry season (March–May). Shallow water bodies and reservoirs in areas like Yauri and Zuru experience higher temperatures, leading to faster evaporation and lower dissolved oxygen levels. The southern portions of the catchment (Niger State) have slightly lower water temperatures due to denser vegetation and increased cloud cover during the wet season.

b) Turbidity

Turbidity levels vary with seasonal river flows and increase significantly during the rainy season (June–September) due to soil erosion and surface runoff. The Niger River tributaries in Ngaski and Shanga LGAs show higher turbidity due to intensive farming and deforestation along riverbanks. Turbidity values typically range from 15 to 220 NTU, with peaks in areas of active mining and flood-prone regions.

c) Colour

Water in Gulbin-Ka appears yellowish to brown, particularly in the upper reaches near Zuru and Sakaba, where lateritic soils contribute to discoloration. In lowland floodplain areas (Bagudo, Ngaski), the presence of decaying vegetation and organic matter further influences watercolor, particularly during flooding.

d) Total Suspended Solids (TSS)

High Total Suspended Solids (TSS) levels, ranging between 50 and 350 mg/L, are recorded in mining and deforested zones, where sediment transport is increased by unregulated land use. Reservoirs such as the Yauri section of the Kainji Lake experience seasonal sediment accumulation, affecting hydroelectric power generation and aquatic habitats.

e) Total Dissolved Solids (TDS)

Total Dissolved Solids (TDS) concentrations range from 180 to 800 mg/L, with higher values in groundwater sources due to underlying mineral-rich geological formations. Increased salinity is observed in parts of Danko-Wasagu and Fakai LGAs, where groundwater exhibits higher concentrations of dissolved salts and minerals.

f) Electrical Conductivity (EC)

Electrical Conductivity (EC) levels in surface waters of Gulbin-Ka range from 120 to 1,700 µS/cm, with elevated values near mining zones and agricultural areas with irrigation return flows. Groundwater sources in Kebbi State, particularly in Bagudo and Suru, show naturally higher EC due to prolonged contact with mineral-rich formations.

2.7.1.2 Chemical Parameters

Chemical water quality indicators determine the suitability of water for drinking, irrigation, and aquatic ecosystems. Chemical characteristics are influenced by natural geology, agricultural runoff, and human activities such as fertilizer use, wastewater discharge, and artisanal mining.

a) pH Levels

pH values in Gulbin-Ka range from 6.2 to 8.4, which is generally suitable for drinking and irrigation. However, localized acidic conditions (pH below 6.5) are observed in mining zones, where mine tailings and acidic runoff affect water chemistry.

b) Nitrates (NO_3^-)

Nitrate concentrations range from 8 to 60 mg/L, with peaks in irrigated farmlands around Bunza, Argungu, and Yauri. High nitrate levels contribute to eutrophication in floodplain wetlands, reducing water quality and harming fish populations.

c) Chlorides (Cl^-)

Chloride concentrations vary between 12 and 280 mg/L, with higher levels in areas affected by irrigation return flows and saline groundwater. Water sources in parts of Bagudo and Yauri LGAs experience elevated chloride levels, impacting water taste and agricultural use.

d) Sulphates (SO_4^{2-})

Sulphate levels in Gulbin-Ka range from 7 to 110 mg/L, with higher values in areas influenced by mining activities. In artisanal mining regions near Zuru and Fakai, sulphate-bearing mineral leaching raises sulphate concentrations in nearby water sources.

Mining areas in Danko-Wasagu, Fakai, and Zuru contribute to localized contamination of surface water with lead (Pb), mercury (Hg), and cadmium (Cd). Lead levels in some water bodies exceed 0.02 mg/L, surpassing safe drinking water limits and posing risks of bioaccumulation in fish and human populations.

2.7.1.3 Biological Parameters

Biological contaminants provide critical insights into water safety, particularly for drinking and domestic use. In the Gulbin-Ka Catchment, microbial contamination is a significant issue, especially in areas with poor sanitation and untreated sewage discharge.

Coliform counts in Gulbin-Ka Catchment frequently exceed 600 CFU/100 mL, particularly near informal settlements and livestock watering points. High microbial loads occur during the wet season, when floodwaters mix with wastewater, open defecation sites, and manure from grazing lands. Common waterborne diseases in the catchment include cholera, dysentery, and typhoid fever, especially in densely populated areas with poor sanitation.

E. coli levels exceed 250 CFU/100 mL in water sources near agricultural zones and livestock corridors. High E. coli contamination is common in Suru, Bagudo, and Shanga LGAs, where many communities rely on unprotected surface water sources.

Helminth infections such as schistosomiasis and ascariasis are prevalent in rural areas where untreated water is used for bathing and drinking. Giardia and Cryptosporidium cysts are detected in wetland and floodplain areas, where contamination from cattle grazing and human settlements is high.

Biochemical Oxygen Demand (BOD) levels in polluted water bodies range from 4 to 12 mg/L, with higher values recorded in areas impacted by wastewater discharge and agricultural runoff. Floodplain wetlands near Yauri and Ngaski experience seasonal increases in organic matter, reducing dissolved oxygen and affecting fish populations.

2.7.2 Groundwater Quality

Groundwater is the primary source of water for domestic, agricultural, and livestock use in the Gulbin-Ka Catchment. However, its quality varies significantly depending on geological formations, aquifer depth, and proximity to pollution sources.

2.7.2.1 Groundwater Electrical Conductivity (EC)

Electrical conductivity (EC), which measures total dissolved salts (TDS), is an important indicator of groundwater quality. The aquifer system in the region consists of sedimentary formations such as the Nupe Sandstone and Gwandu formations, which generally exhibit moderate EC levels ranging from 250 to 700 µS/cm, indicating relatively fresh water. However, areas close to mining activities, particularly in Sakaba and Fakai, show much higher EC values exceeding 1,000 µS/cm due to dissolved heavy metals and the infiltration of mining waste. In the Yauri floodplain, shallow aquifers have slightly elevated EC levels, likely due to irrigation return flows contributing to increased salinity.

2.7.2.2 Fluoride Distribution

Fluoride distribution in groundwater is generally within safe limits across most of the catchment, with concentrations below the WHO permissible limit of 1.5 mg/L. However, in localized areas, particularly in the basement complex regions of Zuru and Sakaba, fluoride concentrations above 2.0 mg/L have been recorded, leading to cases of dental and skeletal fluorosis. Communities in these areas may require alternative water sources or defluoridation treatment to ensure safe drinking water.

2.7.2.3 Nitrate Distribution

Nitrate contamination is another concern in the region, primarily linked to fertilizer application and poor sanitation in rural settlements. The highest nitrate concentrations, exceeding 80 mg/L, have been recorded in shallow wells near agricultural zones in Bagudo and Yauri. In some cases, nitrate levels surpass the WHO limit of 50 mg/L, posing health risks, especially to infants. The correlation between high nitrate levels and areas with extensive use of chemical fertilizers and pit latrines suggests that better waste disposal systems and controlled fertilizer application are needed to mitigate groundwater contamination.

2.7.2.4 Heavy Metals and Other Metals

Heavy metal contamination in groundwater is largely a result of mining activities, natural geological formations, and small-scale industrial processes. Lead and mercury pollution is particularly high in Fakai and Danko Wasagu due to artisanal gold mining. Mercury, which is used in gold extraction, has been detected in water sources in mining communities, raising concerns over its impact on human health, including neurological disorders and kidney damage.

Chromium and cadmium contamination is lower compared to urban-industrial areas like Sokoto. However, localized cases have been reported near metal workshops and tanneries in Maiyama and Bunza. Arsenic contamination has also been identified in areas with extensive pesticide use, particularly in agricultural zones along the Gulbin-Ka River.

Iron and manganese levels in groundwater vary across the catchment. Elevated iron concentrations, often exceeding 0.3 mg/L, have been recorded in boreholes, particularly in areas with lateritic soil formations. Manganese levels above 0.1 mg/L have been detected in some wells in Suru and Bunza, affecting the taste and usability of the water.

To mitigate these risks, industrial wastewater treatment, mine waste management, and stricter environmental regulations should be enforced across the catchment.

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

Table 2.30 below:

Table 2.30: Health risks of heavy metals in ground water

Heavy metal	Recommended Limits (mg/l)	Impacts on Humans (Long-term exposure)
Arsenic	0.01	Cancer of the bladder, lungs, skin, kidney, liver and more Death
Cadmium	0.003	Renaldys function, lung disease and lung cancer, bone defects, and high blood pressure
Chromium	0.05	Skin irritation, ulceration, liver and kidney damage, Damage to circulatory and nervous tissue
Lead	0.01	Problems in the synthesis of hemoglobin, 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: SAP by SMEC 2019

Groundwater quality assessments in the Gulbin Ka Catchment have focused primarily on urban centers with high groundwater exploitation due to population density, industrial activities, and agricultural practices. Laboratory analysis indicates contamination by heavy metals in several areas, with the highest levels recorded in major urban centers and regions influenced by industrial discharge and mining activities.

2.7.3 Surface Water Resources

The Gulbin Ka Catchment lies within Hydrological Area 1 (HA-1), which receives an average annual precipitation of 767 mm. However, only about 24% of this precipitation contributes to surface runoff, with the rest lost to evapotranspiration and other forms of abstraction. Within HA-1, the total internally generated runoff is estimated at 10.7 billion cubic meters (BCM) per year, while the overall surface water resource potential is approximately 35.1 BCM per year.

The total water resources potential is assessed by considering both internal generation and external inflows. The internal total water resources potential is estimated at 8.4 BCM per year, while the total water resources potential, including inflows from neighbouring countries, stands at 37.4 BCM per year. A significant portion of this water approximately 26.7 BCM per year enters Nigeria through transboundary rivers such as the River Niger and Gulbin Ka River, highlighting the country's reliance on external water sources.

Groundwater recharge within the Gulbin Ka Catchment is estimated at 5 BCM per year as a renewable resource. However, the increasing dependence on groundwater abstraction for irrigation and domestic use is placing pressure on aquifer reserves. More comprehensive hydrological data collection is needed at the catchment scale to fully understand the sustainability of groundwater extraction and to inform effective water management policies.

The Gulbin Ka Catchment is an essential water resource area (refer to Figure 2.24and Table 2.31) within Hydrological Area 1, along with the Rima, Sokoto-Zamfara, and Malenda Catchments. As such, the current surface and groundwater potential at the HA-1 level represents a cumulative total of these catchments. Sustainable water management practices, including improved irrigation efficiency, enhanced watershed protection, and better hydrological monitoring, will be critical in ensuring long-term water security for communities dependent on the Gulbin Ka River system.

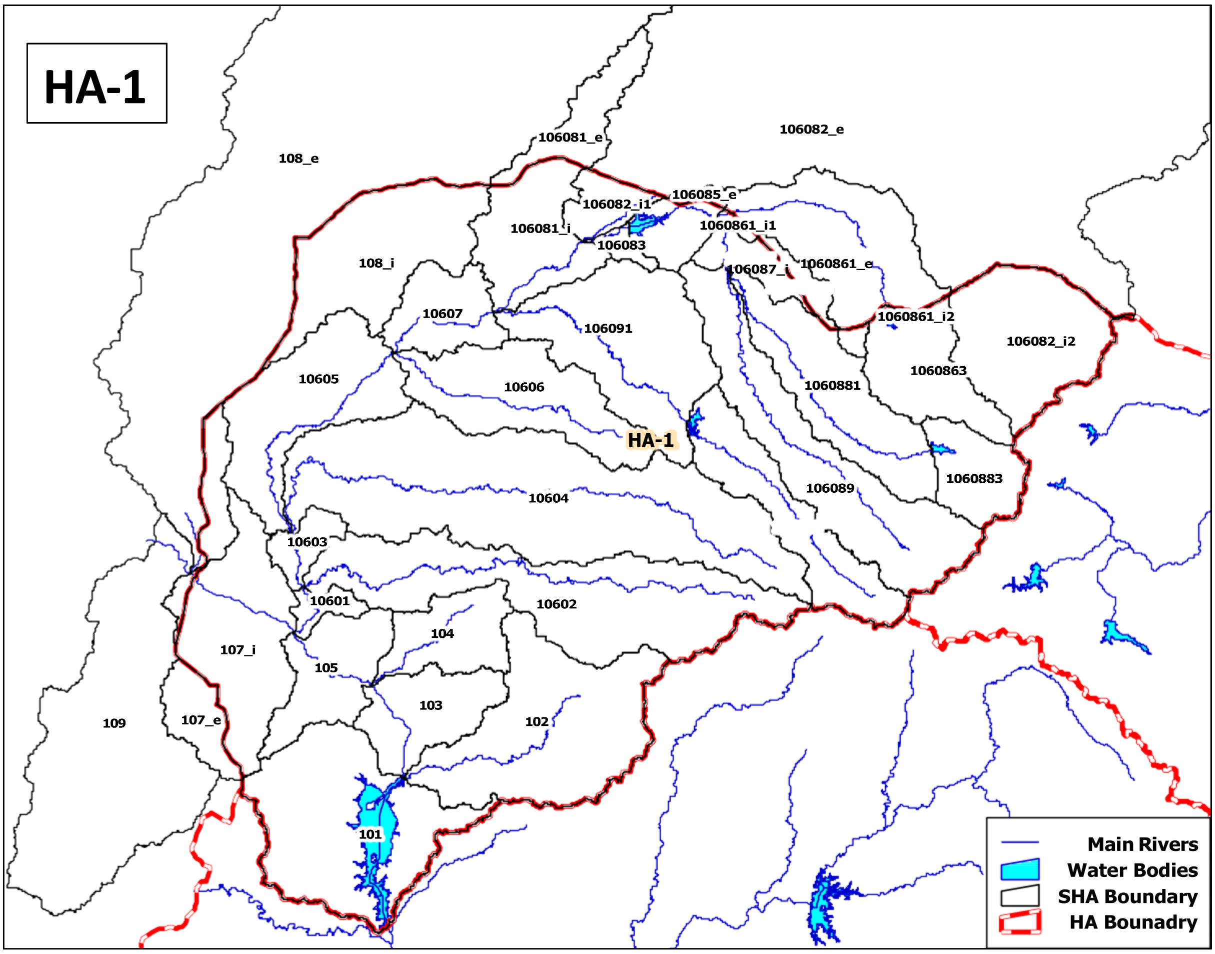


Figure 2.24 Water Resources of the catchment

Table 2.31 Water resource potential for HA-1

		HA-1
Water Resources Potential		
Total Water Resources Potential		
Including inflow from outside Nigeria	(BCM /year)	37.4
Only internal generation in Nigeria	(BCM /year)	10.7
Surface Water Resources Potential		
Including inflow from outside Nigeria	(BCM /year)	35.1
Only internal generation in Nigeria	(BCM /year)	8.4

Groundwater Resources Potential		
Groundwater Recharge	(BCM /year)	5
Runoff Condition（Only internal generation in Nigeria）		
Precipitation (P)	(mm/ year)	767
Total Runoff (RO)	(mm/ year)	62
Groundwater Recharge (GRE)	(mm/ year)	37
Loss of Recharge (LOS)	(mm/ year)	18
Runoff Rate (RO/P)	(%)	8.1
Recharge Rate (GRE/P)	(%)	4.8
Loss Rate (LOS/P)	(%)	2.3
Total Water Res. Rate ((RO+LOS)/P)	(%)	10.4

Source：JICA Project Team

2.7.3.1 River flow patterns

The Gulbin Ka Catchment, a vital sub-unit within Hydrological Area 1 (HA1), is characterized by pronounced seasonal river flow patterns shaped by rainfall intensity, catchment morphology, and human land use activities. The Gulbin Ka River, a key tributary feeding into the larger Sokoto-Rima Basin, experiences its highest flows during the rainy season, typically from June to September, when heavy rainfall and runoff from surrounding uplands significantly boost river discharge. During the dry season (October to May), flow levels drop sharply as shown in Figure 2.25Figure 2.25 , with many minor tributaries and seasonal streams ceasing entirely due to minimal precipitation and elevated evaporation rates.

The river system in Gulbin Ka is primarily dependent on rainfall, making it highly vulnerable to fluctuations in annual precipitation. Areas in the southern and central zones of the catchment receive relatively more rainfall, helping sustain moderate river flows. In contrast, northern sections, especially those bordering drier regions, frequently endure prolonged periods of low flow or complete stream cessation. Groundwater–surface water interactions are crucial for maintaining baseflow in parts of the catchment, particularly where floodplains and alluvial soils facilitate sub-surface water exchange. However, intensive groundwater abstraction for irrigation, household consumption, and aquaculture has significantly reduced natural baseflows, especially during the dry months.

A number of dams and irrigation schemes, such as the Bakolori Dam, have been constructed in the Gulbin Ka Catchment to manage water availability and support agricultural productivity. While these infrastructures help buffer seasonal water shortages, they also disrupt natural flow regimes by reducing downstream discharge, altering sediment transport, and affecting the ecological integrity of wetlands and floodplains.

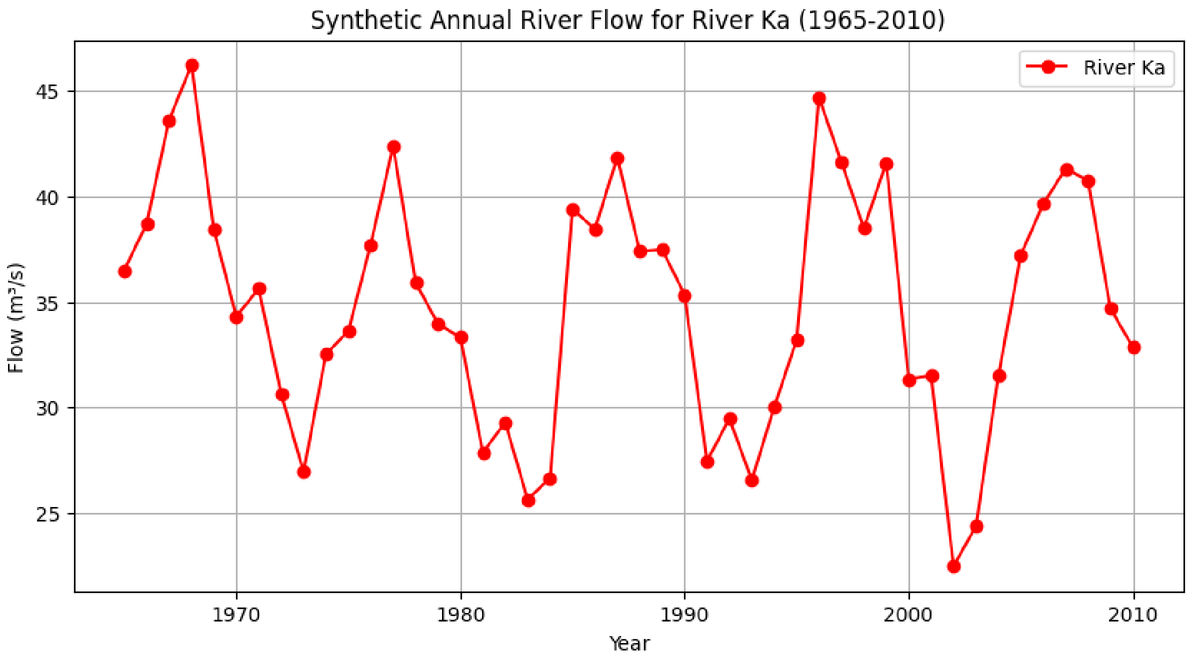


Figure 2.25 River flow graph for the catchment (Source: MSL 2025)

2.7.3.2 Relation between flows and floodplain infiltration

In the Gulbin Ka Catchment, floodplains are essential for sustaining groundwater systems, moderating floods, and supporting local ecosystems. During the rainy season, rivers frequently overflow their banks, spreading water across floodplain areas where it infiltrates the soil and contributes to aquifer recharge. This natural infiltration process plays a key role in maintaining groundwater levels, which support dry-season baseflows in adjacent river channels and provide water for domestic and agricultural needs.

The rate and effectiveness of infiltration in Gulbin Ka floodplains depend on several factors, including soil composition, vegetation cover, and land use practices. Zones with sandy or loamy soils, particularly along riverbanks and wetland edges, show higher infiltration rates and better groundwater recharge potential. Conversely, areas dominated by compacted clayey soils, often worsened by overgrazing and machinery use, have lower infiltration, resulting in increased surface runoff and reduced water retention.

In recent years, land degradation through deforestation, over-cultivation, and sediment accumulation has reduced the ability of floodplains to absorb water effectively. Human activities such as river channelization and embankment construction have also interfered with the natural connectivity between rivers and their floodplains, limiting seasonal inundation and restricting groundwater replenishment. While some irrigation systems in the catchment have adapted by utilizing residual floodplain moisture, this has often led to the modification of hydrological regimes and altered natural recharge processes.

2.7.3.3 Impact of changed flow patterns

The Gulbin Ka Catchment has experienced considerable shifts in flow dynamics, largely driven by climatic changes, increasing human demand for water, and expansion of hydraulic infrastructure. These changes have far-reaching implications for the environment, agriculture, and rural livelihoods.

- Increased Flow Irregularity: The region is witnessing more erratic rainfall patterns due to climate change, resulting in extended dry spells interspersed with short, intense rainfall events. This has led to unpredictable river discharge, making water availability for farming and livestock more unreliable.

- Declining Baseflow during Dry Seasons: Unregulated groundwater extraction, coupled with land degradation, has weakened the rivers' ability to sustain dry-season flow. Many streams and tributaries now dry up completely for months, increasing water stress in rural communities.

- Escalating Flood and Erosion Risks: As surface runoff intensifies, particularly in upland areas with degraded vegetation, the catchment faces frequent flash floods and soil erosion. These events damage farmlands, reduce soil fertility, and threaten infrastructure and settlements in downstream zones.

- Hydrological Impacts of Dams and Water Diversions: Dams like Bakolori, though vital for irrigation and municipal supply, alter the natural flood pulse, disrupt downstream wetlands, and impact aquatic biodiversity. Reduced sediment flow also affects soil replenishment on floodplains, making agriculture less productive.

To address these challenges, the Gulbin Ka Catchment requires adaptive water governance frameworks, including:

- Enforcing sustainable groundwater withdrawal limits,
- Promoting reforestation and soil conservation,
- Expanding the use of climate-smart irrigation technologies,
- And enhancing community-based water resource management.

2.7.4 Groundwater Resources

Groundwater that flows across the boundary is called as trans-boundary groundwater. Groundwater flows following regional topography and aquifer structure. If aquifer extends beyond boundary, there is a possibility that groundwater can flow through the boundary. In case of Nigeria, trans-boundary groundwater is limited in sedimentary rock area because:

Aquifer system in Basement Complex is divided into isolated small aquifers. Therefore, groundwater cannot flow in regional scale passing through boundary within small aquifers.

Aquifers extend in large area in sedimentary rock area. Therefore, groundwater can flow passing through the boundary in large scale (Table 2.32 to 2.34).

Table 2.32 Ground water recharge.

Item	Hydrological area
	HA-1
Area(km2)	135,128
Average	768
precipitation (mm/year)	
Average groundwater recharge	
(mm/year)	37

Percentage of precipitation to recharge (%)	4.8

Source: JICA Project Team

Table 2.33 Groundwater Recharge by Aquifer;

Age	Formation	Groundwater Recharge (mm/year)
HA-1		
Eocene	Gwandu Formation	24
Paleocene	Kalambaina FormationSokoto group)	1
	Dange Formation (Sokoto group)	1
	Wurno Formation (Rima Group)	18
Maestrichitian	Dukamaje Formation (Rima Group)	34
	Taloka Formation (Rima Group)	6
	Ill Formation	10
	Gundumi Formation	10
Pre-Cambria	Basement complex	40

Source: JICA 2014 MP

2.7.5 Sokoto Basin (HA-1)

Situation on trans-boundary groundwater is explained below on Sokoto basin and Chad basin where groundwater is flowing in large scale.

Sokoto Basin

There is multiple aquifer system in Sokoto Bain as shown in Table 2.34.

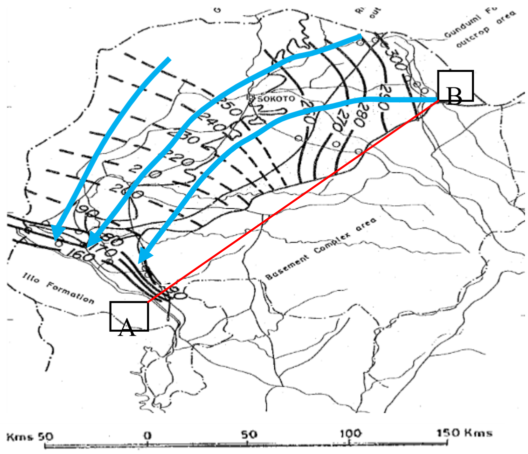
Table 2.34 Aquifer of Sokoto Basin

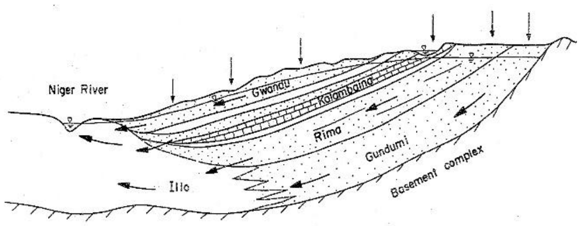
Period	Formation	Lithology
Tertiary	Gwandu Formation	Partially consolidated sand and clay
	Kalambaina Formation (Sokoto Group)	Limestone and volcanic shale
	Wurno Formation (Rima Group)	Fine sandstone, silt
Cretaceous	Illo Formation	Sandstone, conglomerate
	Gundumi Formation	Sandstone, conglomerate

Source: JICA Project Team

Judging from groundwater level contour map in Figure 2.26, it was assumed that groundwater is flowing form NE to SW direction and finally flows into Niger River (1990 JICA Sokoto

Study). Aquifer in Sokoto Basin extends to Republic of Niger so that groundwater is flowing form Niger.





Section A - B
Source: The Study for Groundwater Development in Sokoto State, 1990, JICA

Figure 2.26 Groundwater Flow in Sokoto Basin

Table 2.35 to 2.38 show the aquifer potentials of the catchment.

Table 2.35 Aquifer Model

Model	Symbol		Aquifer type	Thickness of aquifer	Permeability coefficient(k or K)	Static groundwater level
Weathered aquifer	Weathered High permeability	WH	Weathered Basement rock and weathered part of the other type rocks	50m	0.86 m/day	**GL-10m**
	Weathered Middle permeability	WM			0.17 m/day	
	Weathered Low permeability	WL			0.086 m/day	
Multiple aquifer	Multiple High permeability	MH	Sandstone or sandy formation within alternation of sandstone and shale	200m	0.43 m/day	**GL-50m**
	Multiple Middle permeability	MM			0.086 m/day	
	Multiple Low permeability	**ML**			**0.043 m/day**	

Source: JICA Project Team

Table 2.36 Relation between Aquifer Type and Aquifer Model

Age	Permeability	Aquifer scale	Aquifer model
Quaternary	Large	Large (sand/clay alternation of coastal plain)	MH
	Middle	Middle (san/clay alternation of coastal plain)	MM
	Middle	Small sand layer (alluvial plain along river)	WH-WM
	small	Small (silt/clay alternation)	WL
Tertiary	Large	Large (sandstone/claystone alternation)	MH
	Middle	Middle (sandstone/ claystone alternation)	MM
	Middle	Small (sandstone)	WH-WM
	Small	Small (claystone)	WL
Cretaceous	Large	Large (sandstone/shale alternation)	MM
	Middle	Middle (sandstone/shale alternation)	ML
	Middle	Small (sandstone)	WH-WM
	Small	Small (shale)	WL
Basement	Middle	Weathered rock	WM
Volcanic	High	Small	WH

Source: JICA Project Team

Table 2.37 Groundwater Development Potential by Aquifer

Age	Formation	Lithology	Aquifer Characteristics	Ground-water recharge (mm/year)	Aquifer Model
HA-1 : Niger North					
Eocene	Gwandu Formation	Sand and clay.	Aquifer with large outcropping area of maximum thickness of 300m. Basal sandstone form good aquifer.	24	MM
Paleocene	Kalambaina Formation (Sokoto group)	Limestone, calcareous shale.	Sandstone form perched aquifers, which provide groundwater to shallow wells.	1	ML
	Dange Formation （Sokoto group ）	Shale and limestone at bottom.	Aquitard confining underlying aquifer.	1	WL
	Wurno Formation	Fine sandstone and Dukamaje	Confined aquifer of medium to coarse	18	MM

	(Rima Group)	clay stone at the top.	sand with recharge area of 330 km^2.		
Maestri-chitian	Dukamaje Formation (Rima Group)	Shale, limestone, clay stone.	Aquitard with thickness of less than 20m.	34	WL
	Taloka Formation (Rima Group)	Sandstone and claystone.	Argillaceous aquifer with low capacity of 1～5m^3/hours. Maximum thickness is 180m.	6	ML
	Ill Formation	Sandstone	Unconfined and confined aquifer with wide recharge area.	10	MM
	Gundumi Formation	Sandstone and conglomerate.	Unconfined and confined aquifer with wide recharge area.	10	MM
Pre-Cambria	Basement complex	Granite, gneiss, schist, phyllite, quartzite.	Meta-sedimentary rock form better aquifer than gneiss and migmatite	40	WM

Source: JICA 2014 MP

Table 2.38 Optimum Yield of Borehole Field

Aquifer type	**Urban/small urban/small town**	
	Motorized pump	
	Optimum yield of boreholes field (m^3/day)	**Population to be supplied (persons)**
WH	1,000	**10,000**
WM	500	**5,000**
WL	400	**4,000**
MH	1,500	**15,000**
MM	1,000	**10,000**
ML	**900**	**9,000**

Source: JICA Project Team. What is WH,WM,WL,MH,MM and ML

Numbers of Boreholes in States Covering Gulbin-Ka Catchment

Figure 2.27 and Table 2.39 show image of borehole field distribution. Density of dots shows density of distribution of borehole fields.

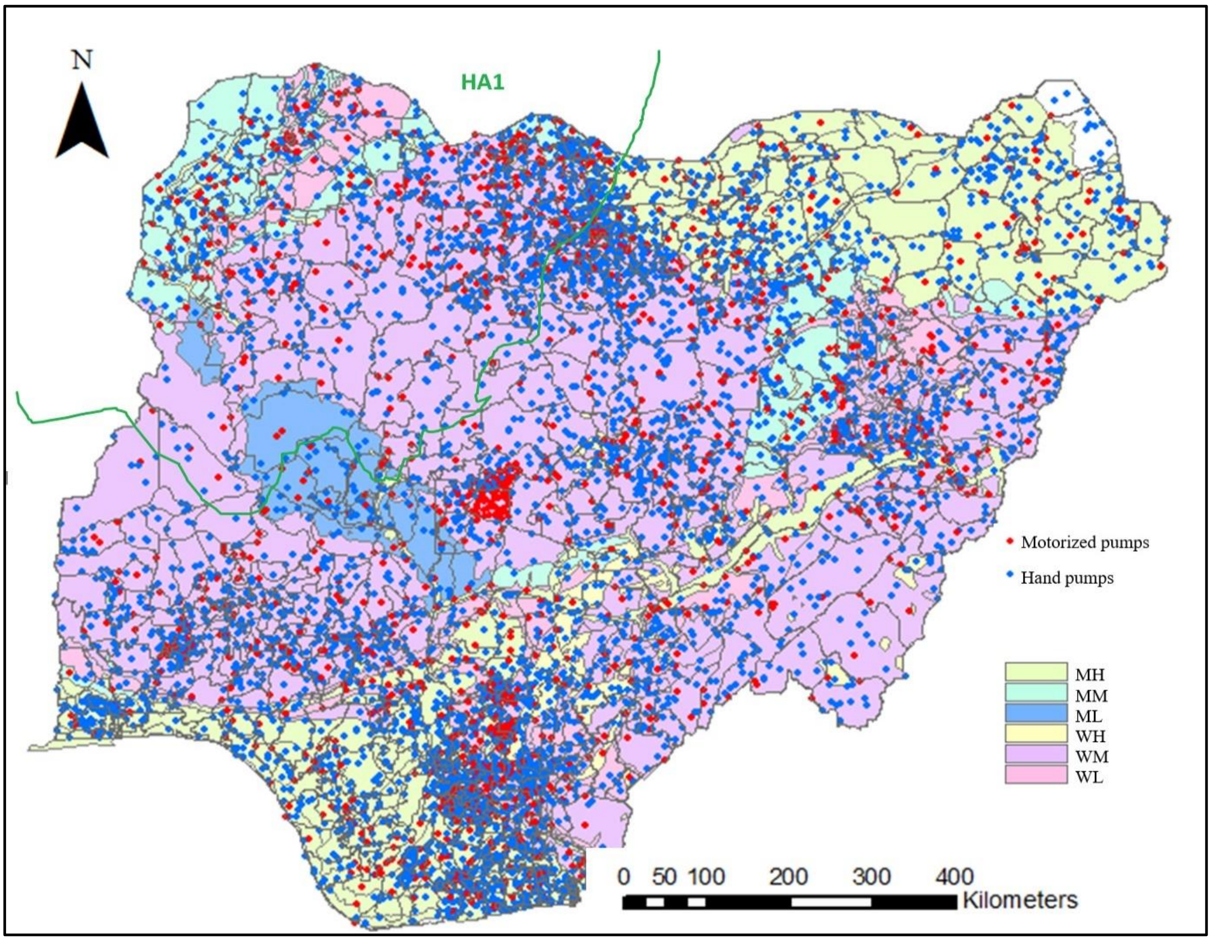


Figure 2.27 Density of Distribution of Borehole Fields (2030) by LGA at Sokoto basin/Gulbin-Ka

Source: JICA Project Team

Table 2.39 Density of Distribution of Borehole Fields (2030) by LGA at Sokoto basin/Gulbin-Ka

State	LGA Name	Groundwater	Aquifer Area (km²)						Urban, small urban, town			Rural	
			MH	MM	ML	WH	WM	WL	No. of boreholes	No of boreholes by	No. of motorized	No of	**No of**
Kebbi	Suru	10	118	1,158	66	0	0	11	9	2	18	12	**116**
Kebbi	Koko/Besse	20	57	668	0	0	18	557	12	1	13	8	**78**
Kebbi	Augie	9	293	894	0	0	0	0	11	3	15	12	**107**

Kebbi	Shanga	54	104	36	0	0	1,426	77	20	3	39	10	**88**
Kebbi	Wasagu/ Danko	60	0	0	0	0	4,019	0	10	3	18	12	**106**
Kebbi	Bagudo	23	525	3,277	420	0	565	1	7	5	11	10	**72**
Kebbi	Fakai	59	0	0	0	0	2,224	25	12	1	13	10	**95**
Kebbi	Dandi	11	29	1,878	0	0	0	98	4	3	7	7	**65**
Kebbi	Ngaski	59	0	0	3	0	2,633	0	11	5	19	10	**73**
Kebbi	Zuru	59	0	0	0	0	654	0	10	7	38	9	**81**
Kebbi	Yauri	45	251	23	359	0	758	0	7	6	14	10	**81**
Kebbi	Maiyama	13	0	892	24	0	1	112	14	3	27	12	**105**
Niger	Agwara	54	0	0	440	0	1,100	0	8	1	9	7	**63**
Niger	Rijau	59	0	0	0	0	3,198	0	6	1	7	9	**86**
Niger	Borgu	84	0	295	2,154	0	8,831	0	7	2	8	8	**69**
Sokoto	Kebbe	31	0	511	751	0	964	394	6	8	15	8	**67**
Zamfara	Anka	59	0	22	0	0	2,726	0	4	1	4	7	**63**
Zamfara	Maru	97	0	0	0	0	6,657	0	4	2	8	8	**70**
Zamfara	Gummi	34	141	870	414	0	1,187	0	11	3	21	15	**134**
Zamfara	Gusau	74	0	0	0	0	3,366	0	15	1	16	20	**195**
Zamfara	**Bukkuyum**	**55**	**109**	**181**	**0**	**0**	**2,927**	**0**	**12**	**3**	**22**	**16**	**148**

Source: JICA Project Team

2.8 Climate Change Impact On Water and Land Resources

2.8.1 Historical and Future Climatic Trends

Temperature and rainfall trends for the Gulbin-Ka catchment were projected for the period 2023 to 2050, using historical monthly and annual datasets spanning 1981 to 2022 for temperature and rainfall, and 1990 to 2022 for evapotranspiration. The projections were developed using a simple growth rate approach implemented in Microsoft Excel.

The applied growth rate formula is defined as:

Growth Rate (%) = [(Ending Value – Beginning Value) / Beginning Value] × 100

This calculated rate was then used to extrapolate future values by multiplying it with the last known data point, thereby creating a time series where each subsequent value is linked to the previous one. This method enables a straightforward visualization of projected climate trends over time.

The analysis adopted simple growth rather than exponential growth, reflecting the relatively linear characteristics observed in the historical data over sequential time intervals.

While Excel was utilized to graphically illustrate the trend of projected temperature increases, the actual forecasting was based on the underlying historical data and the applied growth model not on Excel's built-in forecasting functions.

All temperature and rainfall data used in this study were obtained from the NASA Data Access Viewer and cross-checked for consistency with local climatic records provided by the Nigerian Meteorological Agency (NiMet). This ensures that the projections align with both international datasets and region-specific climatic patterns observed in the Gulbin-Ka catchment.

2.8.2 Annual Rainfall and Temperature for Gulbin-Ka Catchment

2.8.2.1 Temperature Trends for Gulbin-Ka Catchment

Temperature and rainfall trends for the Gulbin Ka (Watershed-Upper Niger) Catchment were forecast (projected) from 2023 to 2050 based on the monthly and annual data from 1981 to 2022 (for temperature and rainfall) and 1990 to 2022 (for evapotranspiration), deploying the growth rate schema in Excel. It is of the following specifications:

Growth Rate = (ending value - beginning value/beginning value) x 100.

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

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

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

2.8.3 Monthly Mean Temperature for the Gulbin Ka Catchment

Figure 2.28 and Table *2.40* shows the Mean monthly temperature for Gulbin Ka (Watershed-Upper Niger) Catchment for 1981-2022 and 2023-2050.

Table 2.40 Mean monthly temperature for Gulbin Ka (Watershed-Upper Niger) Catchment for 1981-2022 and 2023-2050

Month	**Mean monthly temperature ^oC 1981-2022**	**Mean monthly temperature ^oC 2023-2050**
January	24.1	22.9
February	27.18	26.2
March	30.52	30.4
April	31.89	31.18
May	30.25	29.94
June	28.29	27.88
July	26.66	26.82
August	25.85	25.93
September	26.2	26.26
October	26.81	26.9
November	25.56	25.61
December	23.85	22.36
Maximum	31.89	31.18
Minimum	23.85	22.36

Mean	27.26	26.87

Table 3.3 provides a comparison of the mean monthly temperatures for Gulbin Ka (Watershed-Upper Niger) Catchment over two distinct periods: the historical period 1981-2022 and a projected period of 2023-2050.

The historical pattern shows that the highest mean monthly temperature occurs in April (31.89°C), marking the peak of the hot season. The lowest mean monthly temperature occurs in December (23.85°C), indicating the coolest month. There is a clear warming trend from January to April, followed by a decline towards August, and a slight warming from September to October before cooling again in November and December. The overall mean temperature for 1981-2022 is 27.26°C. This aligns with the annual temperature trends observed in Figure 2.28, where the long-term means remain relatively stable with slight variations.

The projected period (1923-2050) follows a similar pattern. The highest recorded mean monthly temperature is in April (31.18°C), followed closely by March (30.4°C) and May (29.94°C). This suggests that the late dry season (March- April- May) experiences peak temperatures. The mid-year months (June–September) show moderate temperatures ranging from 25.93°C to 27.88°C, likely due to cloud cover and rainfall moderating temperatures.

The mean monthly temperatures for 2023-2050 are generally lower than those for 1981-2022 across most months. The maximum temperature decreased slightly from 31.89°C (1981-2022) to 31.18°C (2023-2050). The minimum temperature dropped from 23.85°C (1981-2022) to 22.36°C (2023-2050). The annual mean temperature decreased from 27.26°C (1981-2022) to 26.87°C (2023-2050).

There is a general cooling trend in the catchment that contrasts with global warming expectations. However, this could be due to catchment climate variability (e.g., increased cloud cover, rainfall changes); the rainfall in the catchment shows an increasing trend contrary to the general out. This could also be due to model uncertainties or specific local factors (e.g., land use changes, aerosols).

The pattern is reflected in Figure 2.28

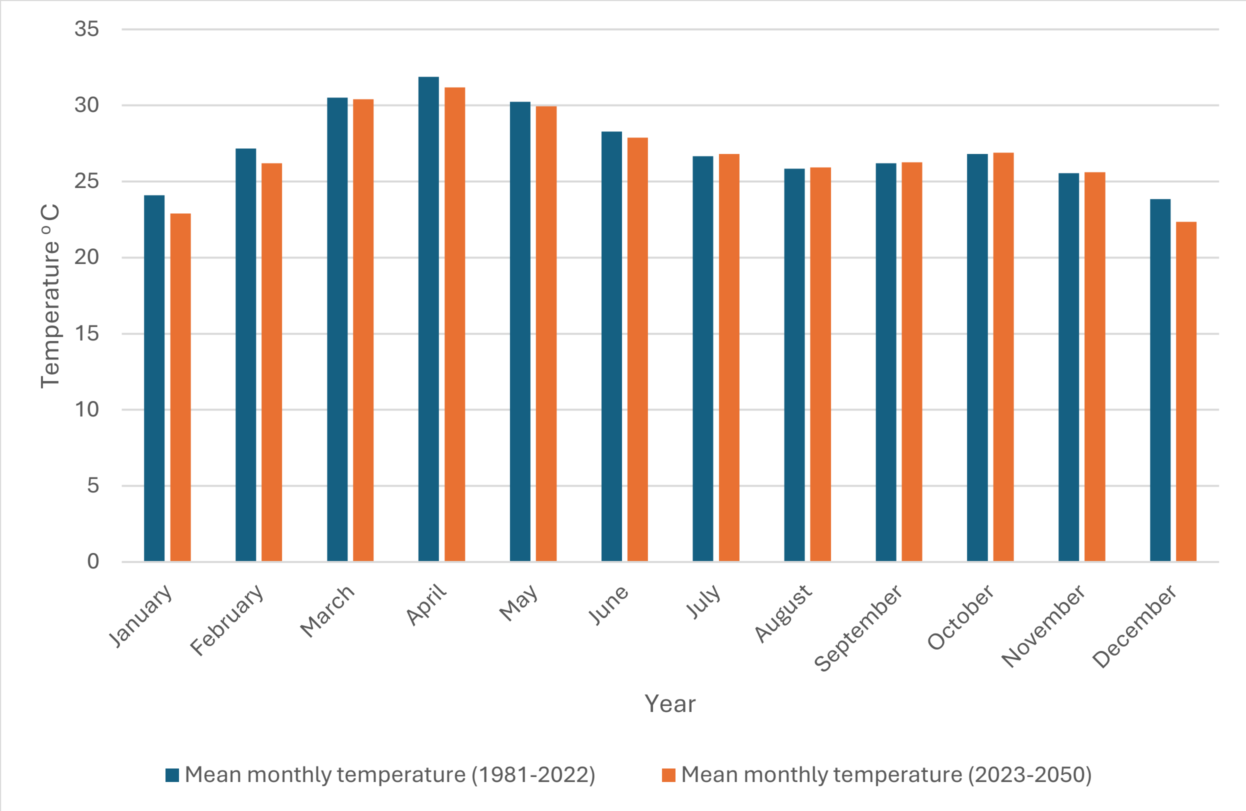


Figure 2.28: Mean monthly temperature for Gulbin Ka (Watershed-Upper Niger) Catchment (1981-2022 and 2023-2050)

2.8.4 Projected Mean Annual Temperature for Gulbin-Ka Catchment

Figure 2.29 presents a time series analysis of temperature trends from 1981 to 2022, with projections extending to 2050.

Figure 2.29 shows that the annual mean temperature for the Gulbin Ka (Watershed-Upper Niger) Catchment from 1981 to 2050 is slightly decreasing with a slope of -0.0099, which indicates that temperatures are rising at an average rate of 0.0099°C per year.

An R^2 of 0.191 suggests that approximately 19.1 % of the variability in temperature is explained by the trend, meaning that while temperature is generally decreasing, significant variability exists, and other factors such as local climate variability and land use.

The cooling trend contradicts global warming projections, suggesting localized factors (e.g., increased cloud cover, land-use changes, or aerosol effects). This might benefit some crops but could delay maturation for heat-dependent varieties. Reduced evaporation could alter water storage in the watershed, affecting river flows and groundwater recharge.

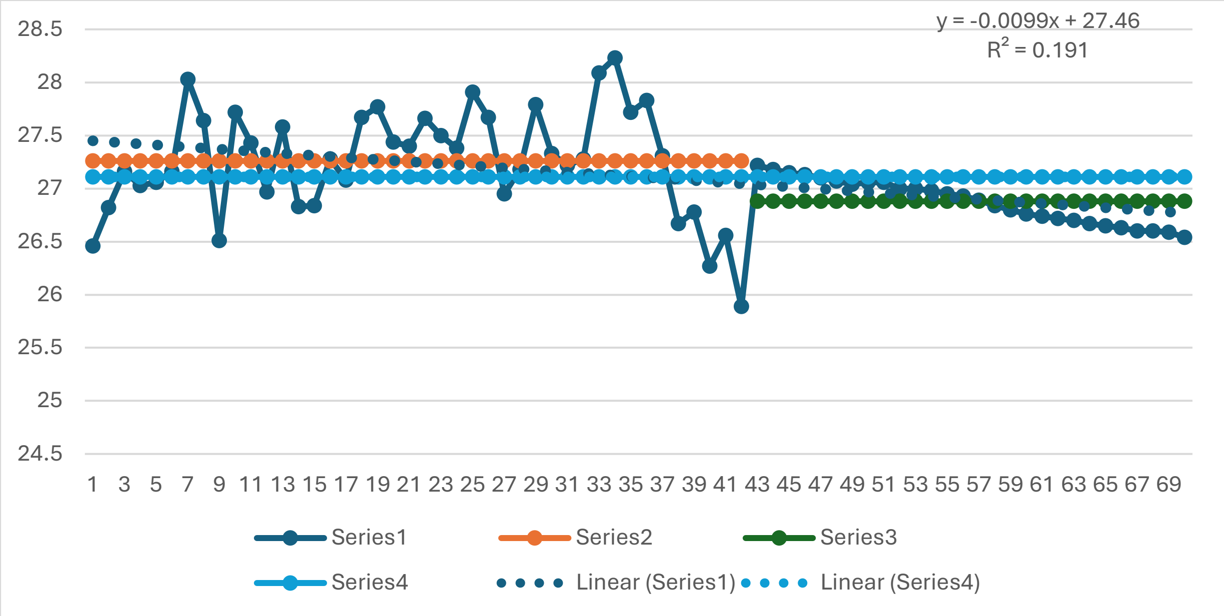


Figure 2.29 Trends in mean annual temperature for Gulbin Ka (Watershed-Upper Niger) Catchment (1981-2050)

2.8.5 Projected Annual Rainfall Trends for the Gulbin Ka Catchment

Figure 2.30 is the annual rainfall trend for the Gulbin Ka (Watershed-Upper Niger) Catchment (1981-2050). From the figure, the slope of 11.447 indicates a strong increasing trend in annual rainfall over time (1981-2050). On average, rainfall increases by 11.45 mm per year during the rainy season.

An R^2 of 0.738 suggests that approximately 35.22% of the variability in rainfall is explained by the trend, meaning that while rainfall is generally increasing, significant variability exists, and other factors may influence rainfall patterns. Comparison of Historical and Projected Periods

The increasing trend in rainfall could have implications for agriculture, water resources, and flood risks in the region. Increased rainfall may improve water availability for agriculture, hydropower, and ecosystems. Higher rainfall could enhance soil moisture and support crop production, provided that variability does not lead to extreme flooding.

If the increasing trend continues, it could lead to a higher risk of seasonal flooding, which may threaten infrastructure, settlements, and farmlands. Variability in rainfall, including droughts and extreme wet periods, may still pose challenges for water resource management.

While increasing rainfall could benefit agriculture and water availability, managing extreme events such as droughts and floods will be critical for sustainable development in the region.

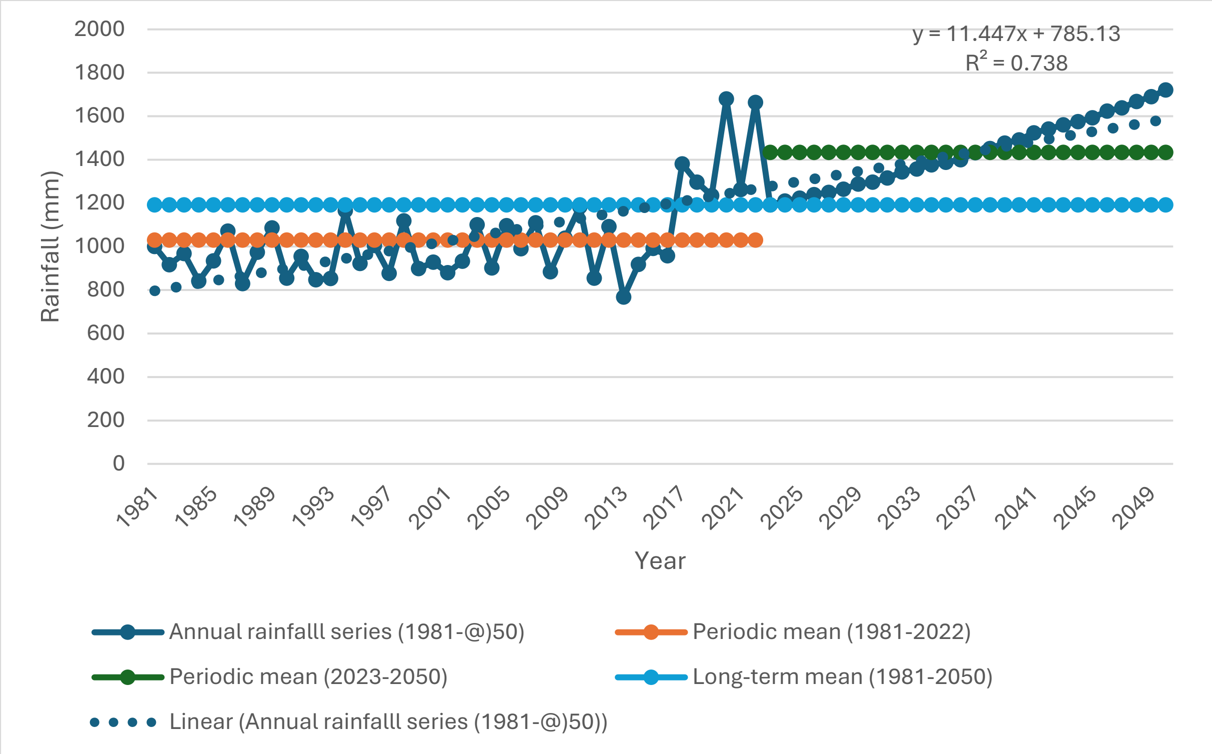


Figure 2.30 Annual rainfall trend for Gulbin Ka (Watershed-Upper Niger) Catchment (1981-2050).

2.8.6 Evapotranspiration Trends for the Gulbin Ka Catchment

Figure 2.31 depicts the annual evapotranspiration (ET) trend for the Gulbin Ka (Watershed-Upper Niger) Catchment from 1990 to 2050.

Figure 2.31 presents the annual evapotranspiration trend for Gulbin Ka (Watershed-Upper Niger) Catchment from 1990 to 2050. From the figure, the slope of -0.5066 indicates a declining trend in annual evapotranspiration over time (1990-2050). On average, evapotranspiration increases by 0.51 mm per year.

An R^2 of 0.0734 suggests that approximately 7.34% of the variability in evapotranspiration is explained by the trend, indicating that other environmental factors (such as climate variability, land-use changes, and soil moisture) influence evapotranspiration.

The periodic mean for 2023–2050 (871.67mm) is slightly lower than the 1990–2022 (888.80mm) mean, suggesting that future evapotranspiration levels are expected to increase slightly. A declining ET trend may indicate reduced soil moisture loss, which could be beneficial for crop water retention. However, if this decrease is due to lower temperatures or reduced vegetation cover, it may impact plant transpiration rates and agricultural productivity. A decrease in ET could suggest lower atmospheric demand for moisture, possibly due to slight cooling or increased humidity. Changes in rainfall patterns and land use/land cover (LULC) changes (e.g., deforestation, urbanization) might be influencing this trend.

ET plays a critical role in maintaining ecosystem stability by regulating water balance in rivers, wetlands, and soils. A decline in ET could reduce water recycling in the atmosphere, potentially impacting catchment rainfall patterns.

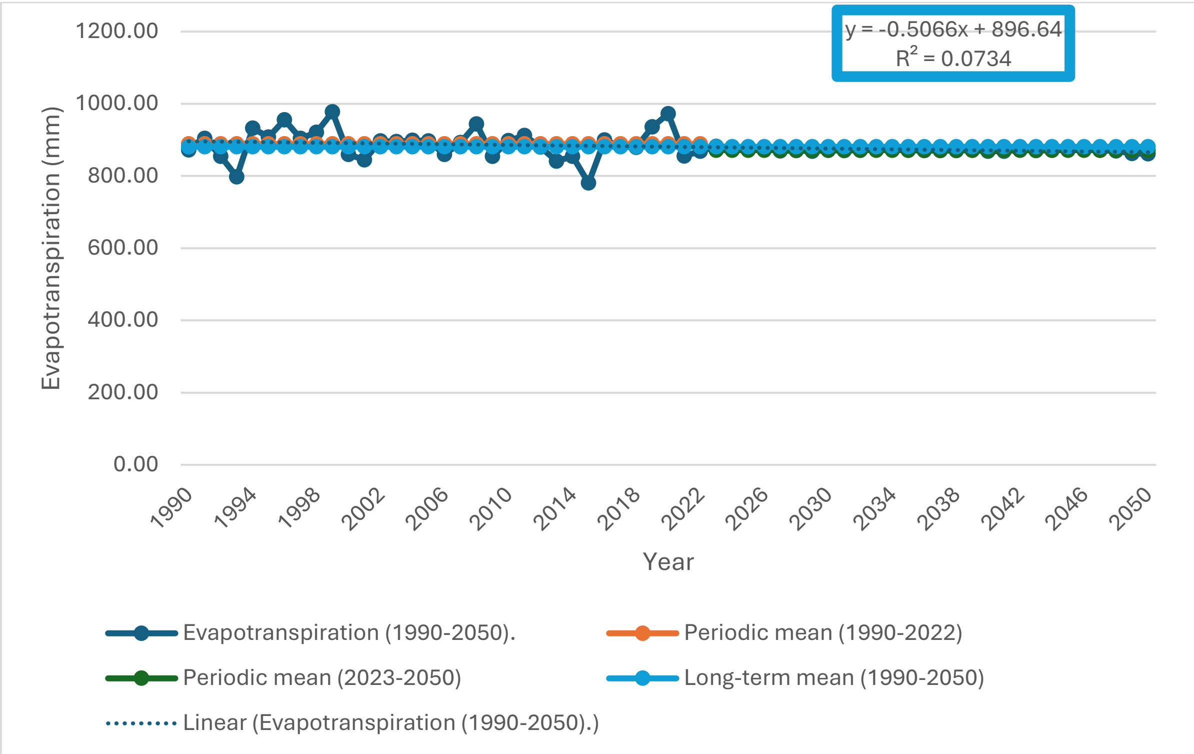


Figure 2.31 Annual evapotranspiration (ET) trend for Gulbin Ka (Watershed-Upper Niger) Catchment (1990-2050).

2.8.7 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 CCAFS, are analyzed. The statistical downscaling as well as bias correction was conducted utilizing the spatial distribution of parameters provided by Worldclim[3] 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 globalization
- B1: Low economic growth with globalization

At this moment, the down scaled output of the following seven (7) GCM are available for download.

- CCCMA-GCM3.1
- CRIRO-MK3.0
- IPSL-CM4
- MPI-ECHAM5
- MRI-CCSM3.0
- UKMO-HADCM3
- UKMO-HADGEM1

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

In order to explore the possible change in climate conditions in the future, the statistically downscaled output of seven Global Climate Models (GCMs) has been analyzed using emission scenario A1B. This scenario assumes high economic growth with globalization utilizing balanced energy sources. The change in precipitation and temperature averaged over the 7 GCM results for three-time horizons are shown in Figure 43and Figure 44 respectively.

The approach used in NWRMP for identifying the representative 30 year running average time frame is also followed in this study. The target years of this study are 2035 and 2065. Considering that the project life time is usually 50 years for civil works, it means that 2035 plus 50 years should be the longest time frame to be considered. For the average condition of the time horizon between 2015 and 2085(=2035+50), the results for 2050s from the output of the GCMs can be applied. These GCM results describe the 30-year running average of 2040 to 2069. Similarly, for the average condition of the time horizon between 2015 and 2115

(=2065+50), the results for 2080s from the output of the GCMs can be applied. These results describe the 30-year running average of 2070 to 2099.

This study assumes that the change in precipitation for each season is set at the average value of the output of the GCMs. The change in annual mean air temperature is set at the annual average value of the output of the GCMs. The change factors are summarized in below Table 2.41 and Figure 2.32 2.33.

Table 2.41: Overview of change factors for the two target years

Parameter	Season	2035	2065
P (%)	DJF	+12.3	+17.1
	MAM	-0.5	-2.1
	JJA	+7.9	+12.0
	SON	+7.6	+11.7
T (°C)	Annual	+2.5	+3.9

Source: JICA 2014 MP

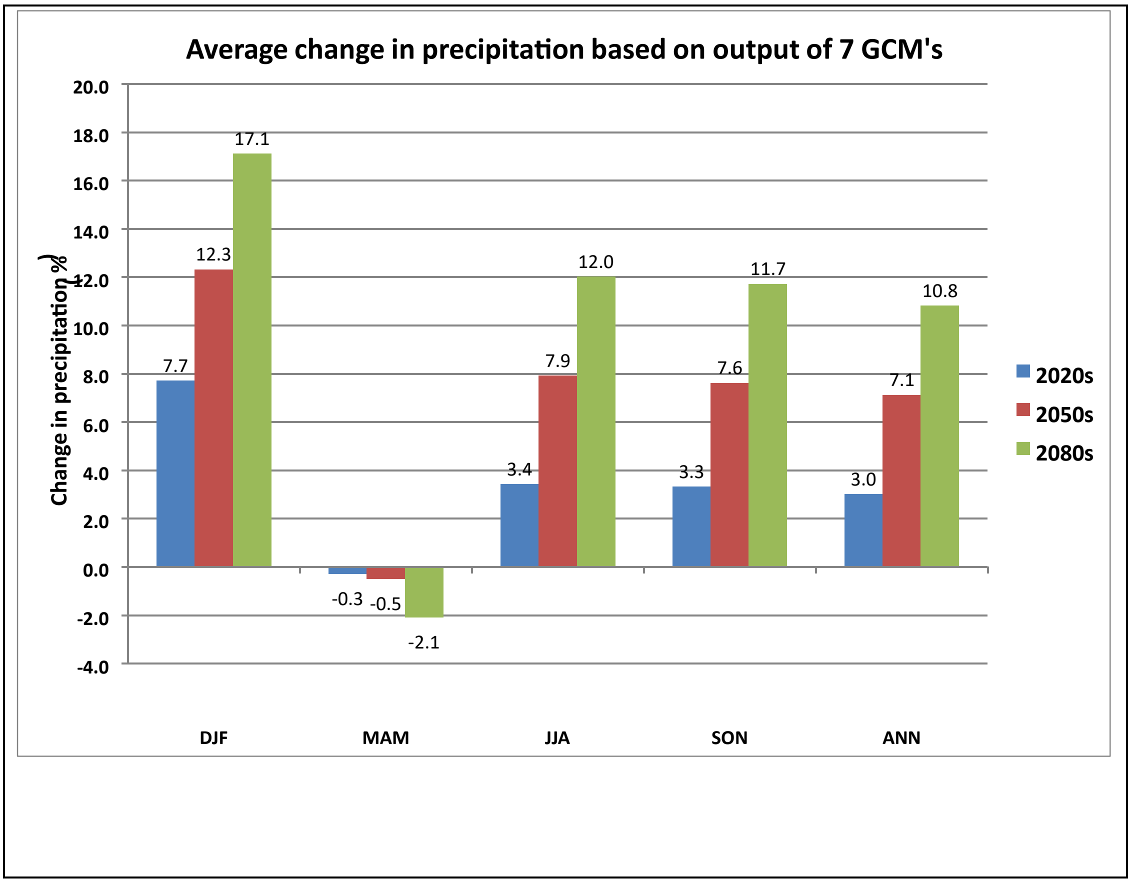


Figure 2.32: Average changes in precipitation derived from outputs of 7 GCMs (source: JICA,2014)

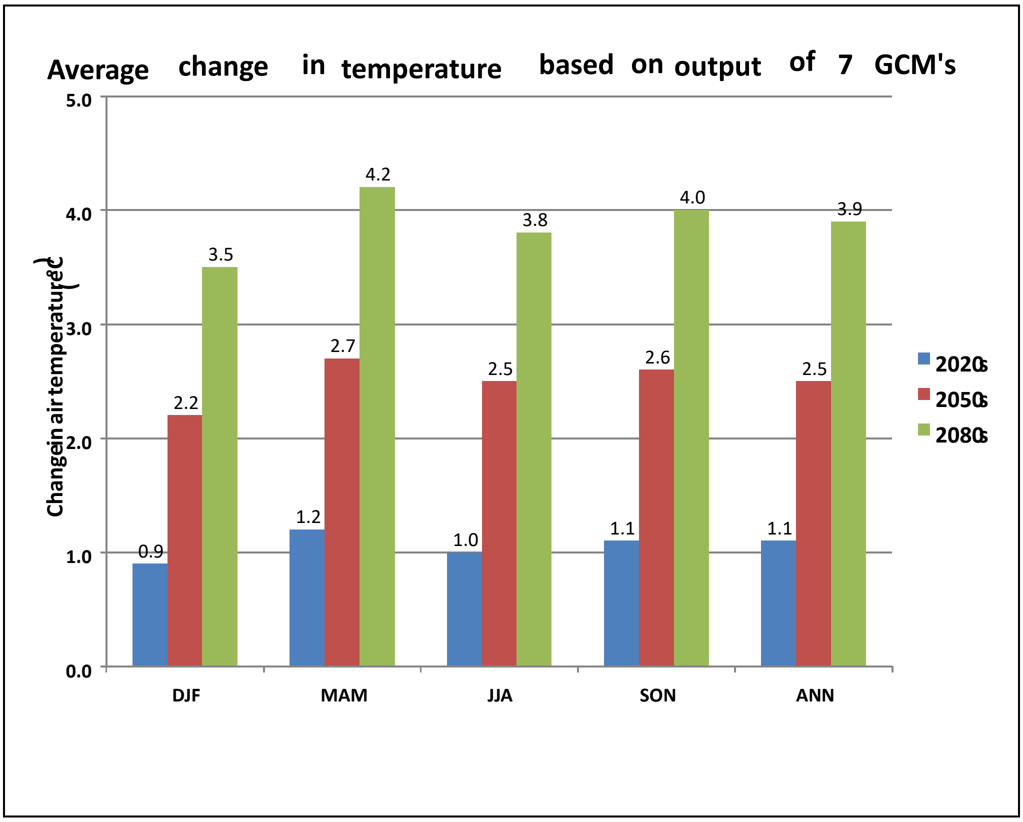


Figure 2.33: Average changes in temperature derived from outputs of 7 GCMs (source: JICA 2014),

2.8.8 Evapotranspiration

Evapotranspiration rates in Gulbin-Ka are high due to intense solar radiation and dry conditions, particularly during the dry season.

- In the northern areas, annual evapotranspiration can reach 2,000 to 2,500 mm, often exceeding annual rainfall, leading to persistent water deficits.
- The high evaporation rates accelerate water loss from rivers, reservoirs, and soil, making irrigation and drought-resistant crops essential for agriculture.
- In drier years, seasonal rivers and water bodies shrink significantly, increasing reliance on groundwater extraction for both domestic and agricultural use.

This climate variability significantly influences water availability, agricultural productivity, and rural livelihoods, necessitating adaptive water management strategies to sustain food production and ecosystem health in the Gulbin-Ka Catchment.

2.8.9 Major Impacts of Climate Change

Climate change presents serious and widespread challenges across various sectors within the Gulbin-Ka catchment, with growing consequences for livelihoods, public health, and core infrastructure. These impacts are becoming increasingly apparent through declining agricultural yields, rising vulnerability among rural communities, and mounting pressure on water and social services.

The observed and projected climate-related effects summarized in Table 2.42 highlight the urgency of adopting integrated, adaptive strategies that can enhance resilience and ensure sustainable development across the catchment area.

Table 2.42: Key Impacts of Climate Change

Impact	Details
Decline in Crop Yields	Increased temperatures, erratic rainfall patterns, and frequent flooding have led to reduced agricultural productivity. Farmers report that harvested crops often do not sustain them for extended periods, necessitating alternative income sources.
Water Shortages	Communities experience prolonged dry spells, leading to decreased water availability for domestic and agricultural use. Observations include long queues at water points and reliance on water vendors, indicating stress on existing water resources.
Decrease in Soil Fertility	Deforestation, bush burning, and overuse of chemicals have degraded soil quality, reducing its fertility and agricultural potential. This degradation contributes to lower crop yields and increased food insecurity.
Rural-Urban Migration	Diminishing agricultural returns and degraded natural resources compel residents, especially the youth, to migrate to urban areas in search of better opportunities, leading to labour shortages in rural farming communities.
Increased Flood Incidences	Heavy and unpredictable rainfall events have resulted in frequent flooding, damaging crops, infrastructure, and homes. Floods also contribute to the spread of waterborne diseases and disrupt community livelihoods.
Crop Infestation and Diseases	Changing climatic conditions have led to the proliferation of pests and diseases, affecting crop health and yields. Farmers report increased incidences of infestations that were previously uncommon in the region.

Decline in Forest Resources	Overexploitation of forest resources for fuel and construction, combined with climate-induced stress, has led to a significant reduction in forest cover, affecting biodiversity and ecosystem services.
Increased Cost of Food Crops	Reduced agricultural output due to climate stressors has led to higher food prices, exacerbating food insecurity among vulnerable populations.
Health Impacts	Climate change has contributed to the spread of diseases such as malaria and cholera, especially during flood events. Additionally, heat stress and poor nutrition due to food scarcity adversely affect community health.
Livestock Mortality	Extreme weather conditions, including heatwaves and droughts, have increased livestock deaths, impacting pastoral livelihoods and meat supply.

2.8.10 National and International Climate Change Frameworks/Agreements

The NWRMP (JICA,2014) investigated the climate change effects on 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 show evidence of long-term temperature increase.
- Annual rainfall showed a decrease of 2 to 8mm/ year across many parts of the country.

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

2.8.10.1 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. Itis difficult to conclude the general tendency for the change in precipitation.

2.8.10.2 Nigeria's First National Communication on Climate Change

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

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

2.8.10.3 Nigeria's Second National Communication on Climate Change

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

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

i. Greenhouse Gas (GHG) Inventory and Emissions Trends

ii. Vulnerability and Impacts of Climate Change

iii. Adaptation Measures and Challenges

iv. Mitigation Strategies and Potential

v. Barriers to Climate Action

vi. International Cooperation and Support Needs

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

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

2.8.10.4 Nigeria's Third National Communication on Climate Change

To build on the insights successes from the previous communications and to provide an updated assessment of the country's greenhouse gas (GHG) emissions, climate vulnerabilities, and strategies for adaptation and mitigation, the Third National Communication on climate change was held to also reflects Nigeria's ongoing commitment to climate action and sustainable development, presenting a comprehensive review of its climate policies, measures undertaken, and future directions for a climate-resilient and low-carbon economy. It was noted that emissions in Nigeria are primarily driven by the Agriculture, Forestry, and Other Land Use (AFOLU) sector, which contributed 60.1% of emissions, followed by the energy sector at 33.9%. Without intervention, emissions were projected to increase by over 58% by 2035. Nigeria faces significant climate vulnerabilities, including risks of drought, desertification, flooding, water scarcity, and reduced agricultural productivity.

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

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

2.8.10.5 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 shown in Figure 2.34 was performed through GIS analysis to determine the vulnerable locations using the weighted Overlay process. Weighted vulnerability analysis allows us to answer questions that are impacted by many factors and assign varying weights to each of the factors. The result gives more information than binary analysis, as it ranks locations based on the vulnerability rather than giving only a vulnerable/not vulnerable result.

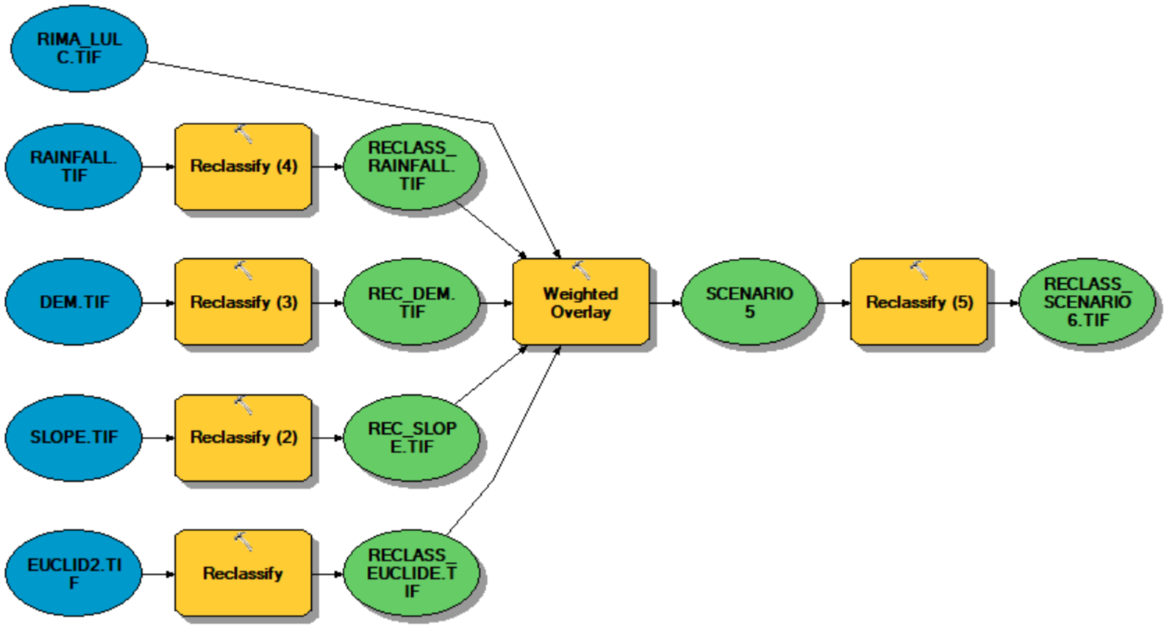


Figure 2.34: The flow chat of the methodology

Various factors that influence or contribute to flooding were incorporated into the model for determining vulnerable areas. For this study, slope, elevation, proximity to rivers, Land use/Land cover and rain fall datasets were used. Before performing the weighted overlay, standardization is carried out by reclassifying each layer. This gives the layers a common scale (i.e. 1 to 5, 1 to 9, etc.) that will be preserved in the final overlay. Finally, the weight of each layer is assigned, the layers are combined in a weighted overlay, and the results are analysed. See Fig. 1 for a graphical depiction of the model used to carry out the flood vulnerability model exercise.

2.9.1 Elevation

Elevation is one of the most critical factors in flood modelling, as it directly influences the flow, direction, and extent of floodwaters. Flood models rely on elevation data to simulate how water moves across a landscape, where it accumulates, and which areas are most vulnerable to inundation. Elevation (Figure 2.35) determines the slope and gradient of the terrain, which dictate the direction and speed of water flow. Water naturally flows from higher to lower elevations due to gravity.

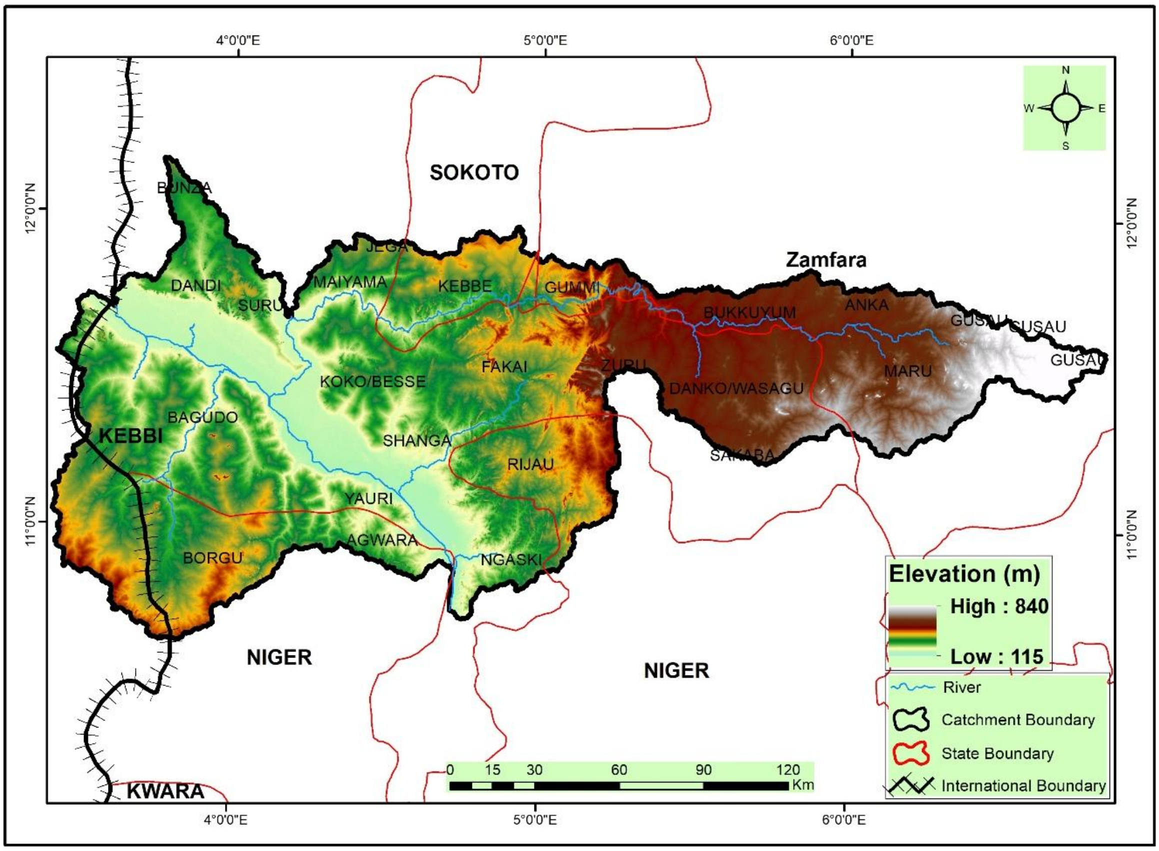


Figure 2.35 Digital Elevation Model of the Catchment (Source: MSL, 2025)

Steeper slopes can lead to faster-moving floodwaters, increasing the risk of flash floods, while flatter areas may experience slower-moving but more widespread flooding.

The light grey areas from the legend above indicate areas with higher elevations while the green to the light green shows lower elevation areas. The general elevation of the catchment ranges between 115m to 840m above sea level particularly in the eastern part of the catchment also serving as the source of most of the rivers in the catchment.

2.9.2 Rainfall

Rainfall is a critical factor in flood vulnerability modelling due to its direct and significant impact on the likelihood, severity, and extent of flooding events. As a key driver of surface runoff and river discharge, rainfall plays an integral role in determining flood risk, particularly in regions prone to heavy or intense precipitation.

The amount and intensity of rainfall (refer to *Figure 2.36*)within a specific time frame are essential for predicting flash floods, urban floods, and riverine floods. Short, intense rainfall events can overwhelm drainage systems, causing rapid runoff and localized flooding. Long-duration, moderate rainfall can saturate the soil, increasing the likelihood of river and lake basin flooding.

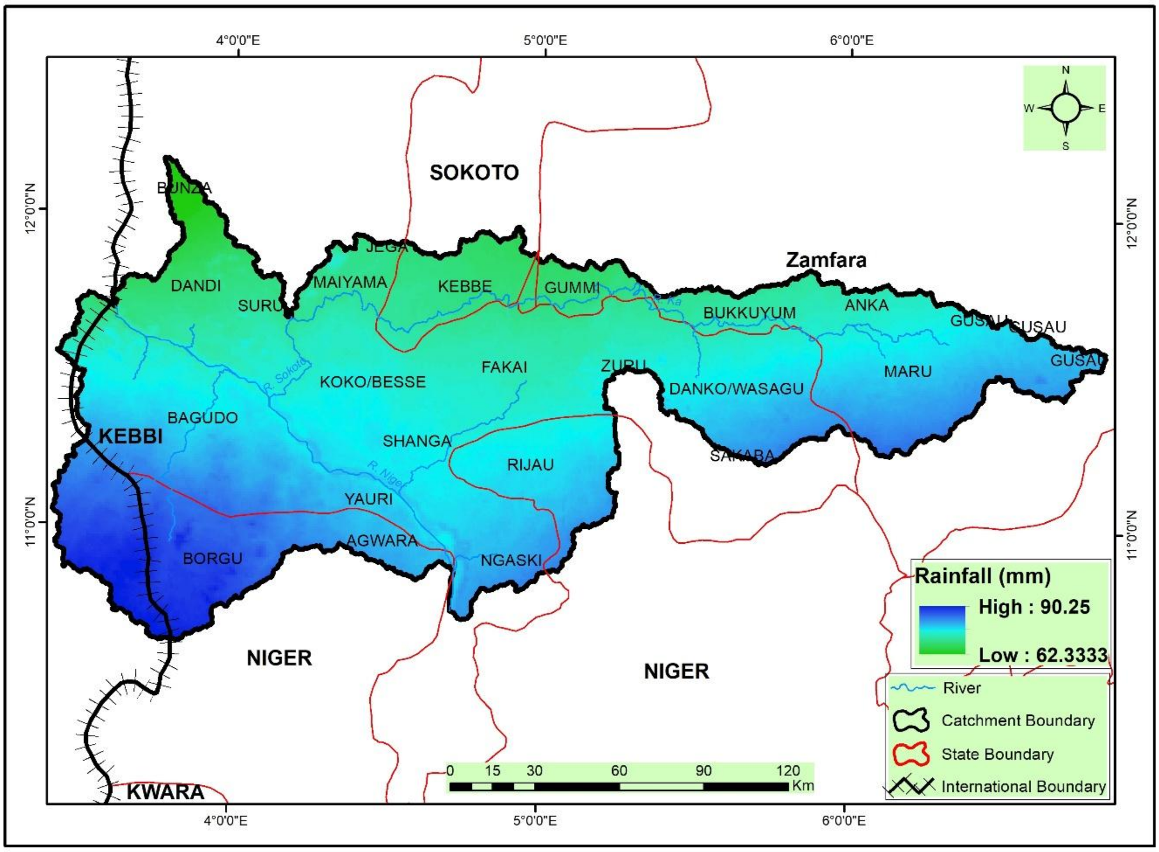


Figure 2.36 Rainfall Map of the Catchment (Source: MSL, 2025)

Rainfall varies significantly across geographic regions, and the impacts of rainfall on flood vulnerability can differ based on topography, land use, and local climate. In mountainous regions, for instance, rainfall can lead to rapid runoff down steep slopes, causing flash floods in valleys and foothills.

The rainfall map of the catchment revealed a-somewhat moderate range of rainfall distribution, with the values showing gradual variation in spatial distribution from 90.3mm to 62.33mm annual rainfall in the catchment area.

2.9.3 Slope

Slope affects the speed and volume of surface runoff. Like elevation, in areas with steep slopes, rainfall tends to flow faster due to gravity, resulting in higher velocity runoff. This rapid movement of water can lead to flash flooding (see Figure 2.37), particularly in mountainous or hilly regions, where water moves quickly downstream, overwhelming drainage systems and causing damage to infrastructure. On the other hand, flatter areas tend to experience slower runoff, which may allow for better water infiltration and less immediate flooding. However, even in flatter areas, accumulated water can eventually overwhelm drainage systems if the capacity to handle runoff is exceeded.

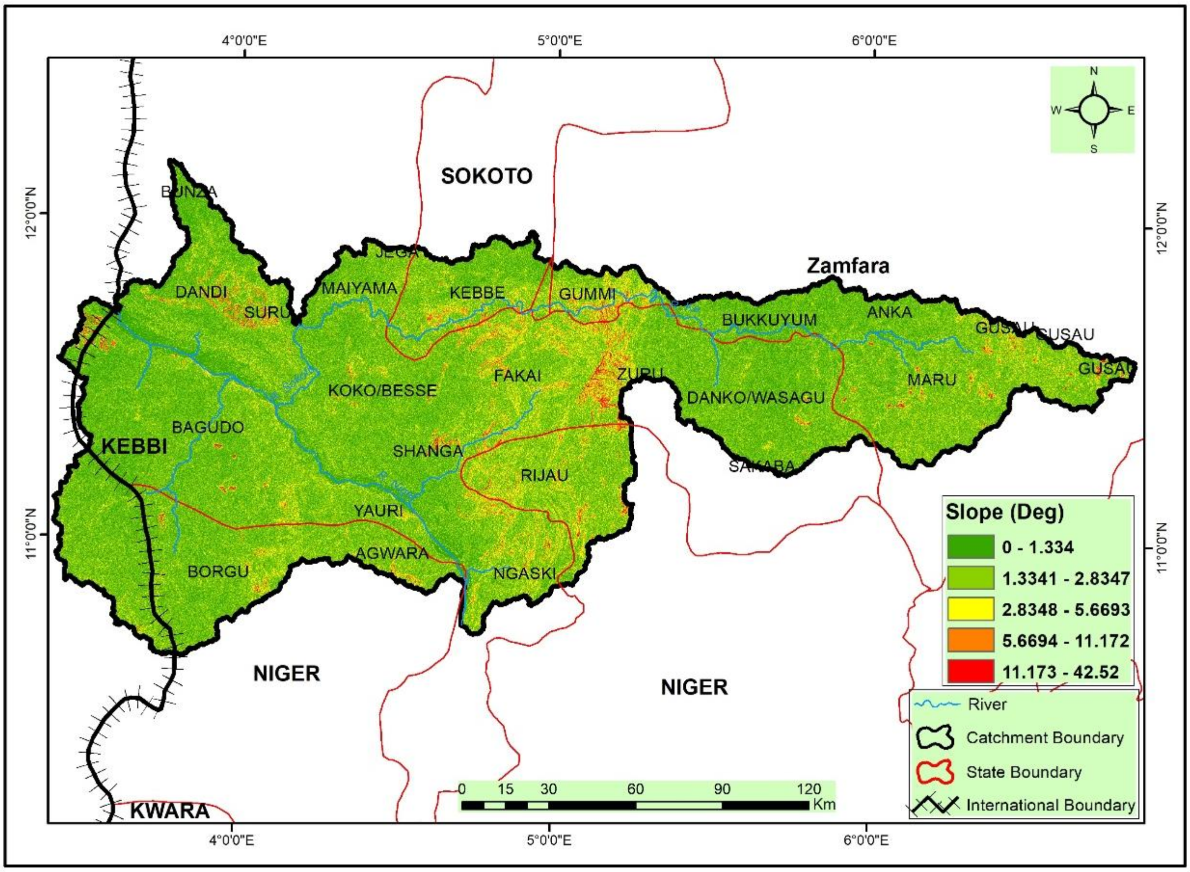


Figure 2.37 Slope Map of the Catchment (Source: MSL, 2025)

The map delineates various levels of inclination in the terrain, providing insights into the landscape's characteristics. Areas with flat to very gentle slopes (0–1.3^0) are predominantly flat, increasing the likelihood of water pooling and slower drainage, potentially leading to flooding during heavy rainfall. Regions with gentle slopes (1.3–2.8^0) facilitate better water runoff compared with flatter areas but still pose a moderate risk of water accumulation. Areas with moderate slopes (2.8–5.7^0) exhibit a moderate steepness, promoting more rapid surface runoff, reducing water retention, and heightening the risk of soil erosion.

Steep slopes (5.7–11.2^0) are susceptible to swift runoff and increased erosion, potentially causing the displacement of sediment and accelerated downstream water flow. Very steep slopes in this catchment (11.2-42.5^0) represent the steepest gradients in the area where the velocity of runoff is at its maximum.

2.9.4 Proximity to River

Distance is a critical factor in flood modelling because it directly influences how floodwaters spread, the time it takes for flooding to impact specific areas, and the severity of the flood's effects. Distance determines how quickly floodwaters travel from the source (a river, dam breach, or coastal area) to downstream or inland locations as shown Figure 2.38. The distance from the flood source influences the spatial extent of inundation.

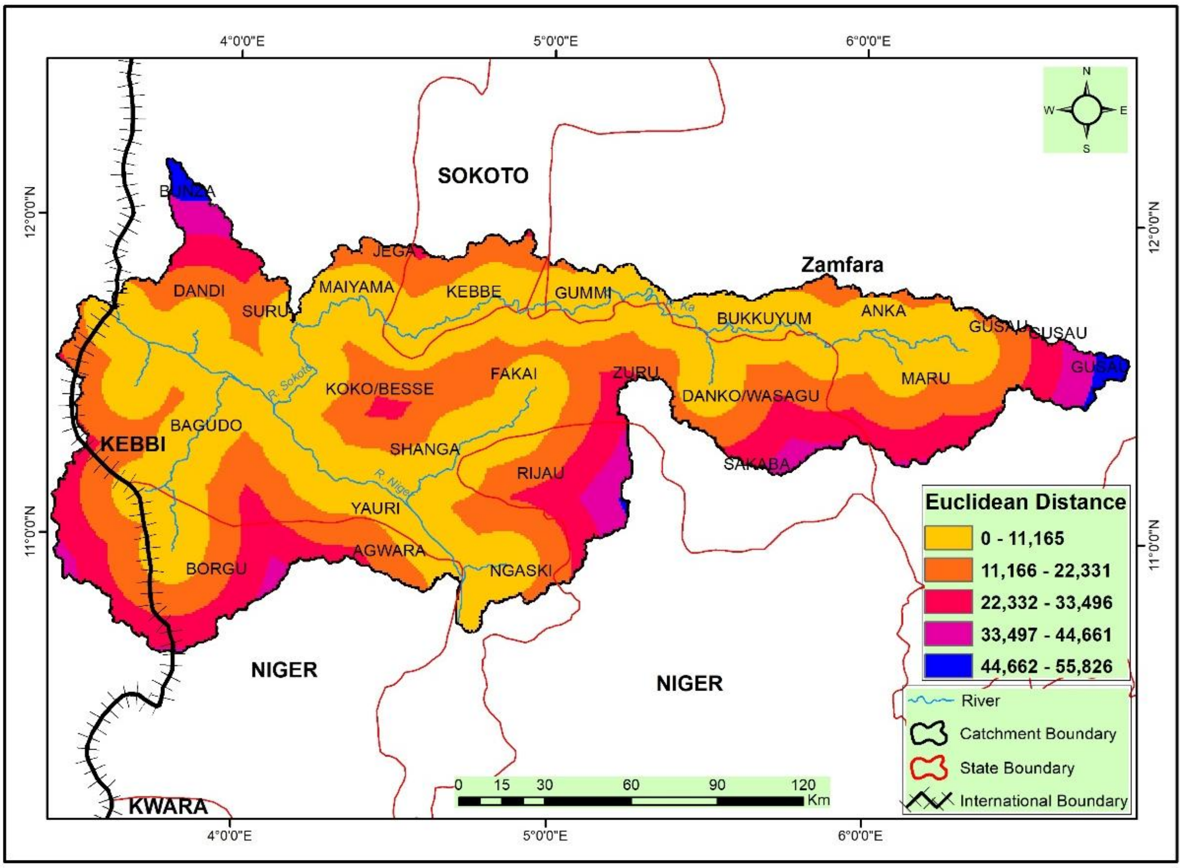


Figure 2.38 Proximity to River Map of the Catchment (Source: MSL, 2025)

Topography also tends to interact with distance to influence the behaviour. In hilly or mountainous regions, floodwaters may travel longer distances but at slower speeds due to elevation changes. In flat areas, floodwaters can spread quickly over large distances. Flood models incorporate distance and elevation data to simulate these dynamics accurately. Euclidean distance can identify areas within a certain radius of a river, lake, or coastline that are likely to be affected during a flood event. This information is crucial for zoning regulations and insurance purposes

2.9.5 Land Use and Land Cover

Land use (refer Figure 2.39) types influence how water moves across the landscape. Natural, undeveloped areas such as forests, wetlands, and grasslands have a higher capacity to absorb rainfall, reducing the volume of surface runoff. In contrast, urbanized areas with impervious surfaces like roads, buildings, and parking lots prevent water from being absorbed, leading to higher runoff. Urbanization, particularly in floodplains and other vulnerable areas, exacerbates flood risk by increasing the rate and volume of runoff, which can overwhelm drainage systems and lead to flash flooding. Modelling the distribution of land use types helps to predict runoff patterns, which is crucial for assessing flood risk.

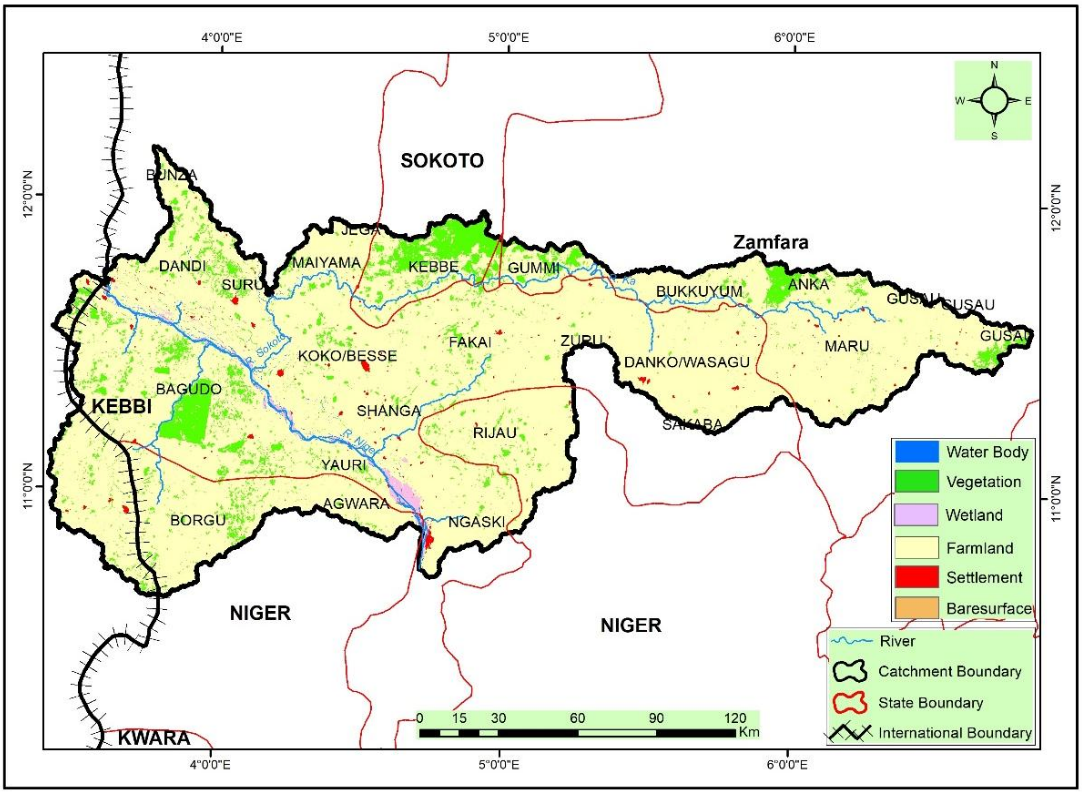


Figure 2.39 LULC Map of the Catchment (Source: MSL, 2025)

Human activities, such as urbanization and agriculture, often involve altering natural drainage systems to facilitate land development. The construction of roads, buildings, and infrastructure can obstruct or divert natural watercourses, leading to changes in the flow paths and velocities of rivers and streams. In some cases, floodplains may be filled in or levees may be constructed thereby changing the natural flood behaviour of the area. These alterations to the landscape can significantly increase flood risk, especially in areas where natural flood control mechanisms (e.g., wetlands, forests, or floodplains) have been disrupted.

2.9.6 Flood Vulnerability

The study deployed a weighted overlay analysis to assess the potential flood vulnerabilities across the catchment shown in Figure 2.40, 2.41 and Table 2.43. The composite flood vulnerability map resulted from overlaying datasets, including the DEM, Proximity to rivers, precipitation, slope, and Land use Land cover. Prior to the overlay analysis, the layers underwent categorization, weighting, and scoring on a 1– 9 scale. Proximity to rivers received the highest weight, followed by elevation, precipitation, slope and Land use.

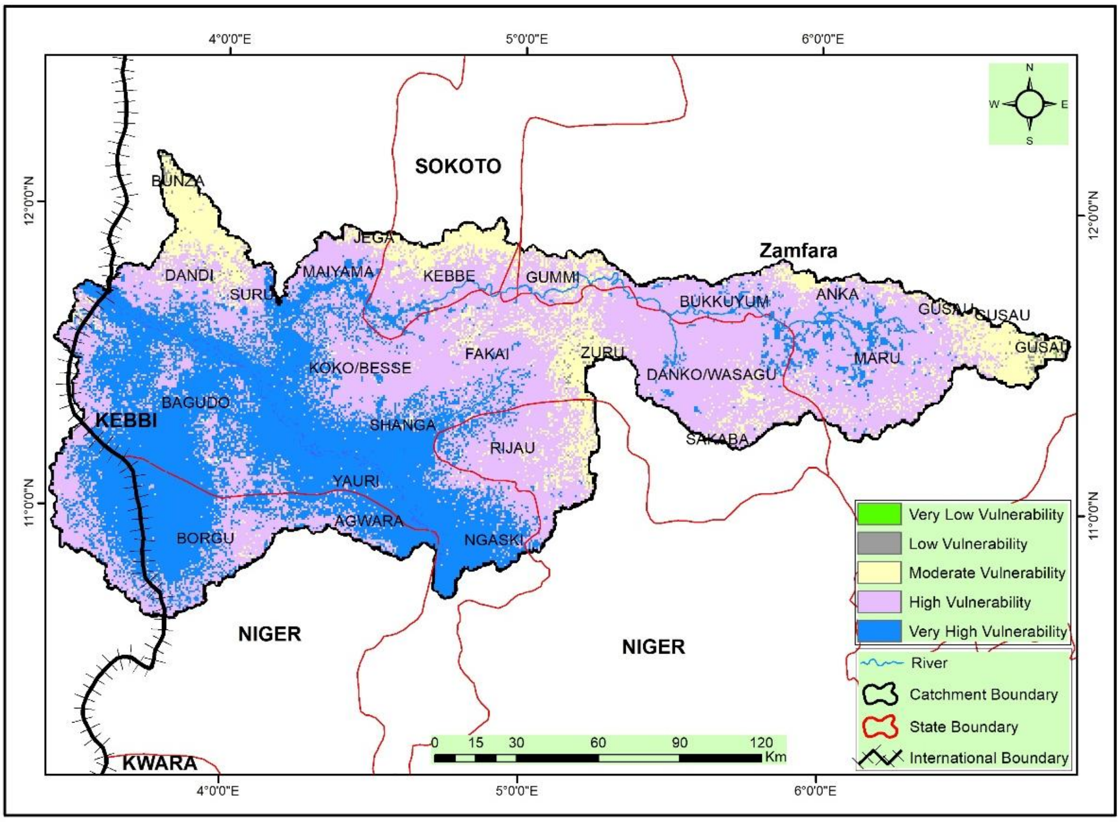


Figure 2.40: Flood Vulnerability Map of the Catchment (Source: MSL, 2025)

The vulnerability risk map delineates various potential flood zones within the catchment area, classified into five risk levels: Very low vulnerability, Low Vulnerability, Moderate

Vulnerability, High Vulnerability, and Very high Vulnerability (Figure above). The total study area spans about 2,962,946.887Ha.

Areas with low flood risk areas are primarily located in high-elevation regions. Low flood vulnerability zones are also mostly found immediately after the highest areas. While these areas are not as susceptible to severe flooding as the high-risk areas, they still pose high potential for moderate flooding, particularly during heavy rainfall events. High and very high flood vulnerability zones are predominantly concentrated in areas with lower elevation. These areas face a greater risk of flooding due to its adjoining proximity with the highlands and are characterized by large flood plains.

Table 2.43 Flood Vulnerability Analysis of the catchment

Value	Ha	%
Very Low Vulnerability	187.1424	0.006411181
Low Vulnerability	12398.18	0.424740748
Moderate Vulnerability	354447.7	12.142777
High Vulnerability	1537515	52.67266112
Very High Vulnerability	1014452	34.75340995
Total	2919000	100

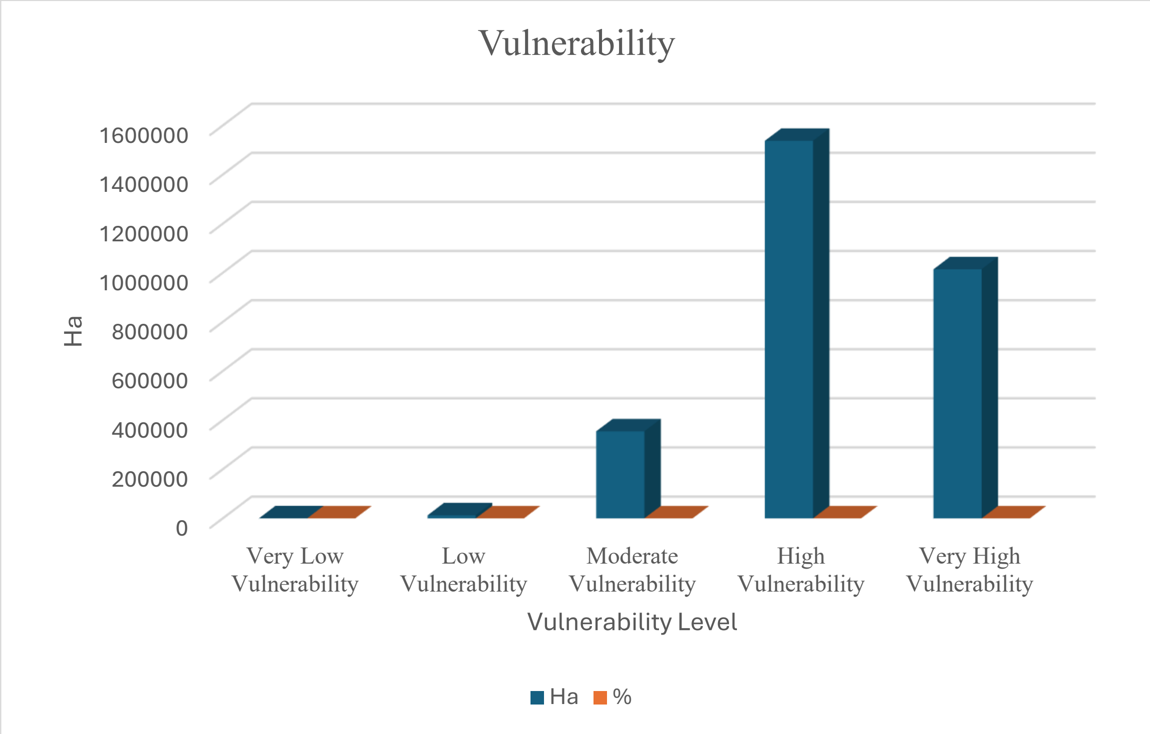


Figure 2.41 Flood Vulnerability Chart of the Catchment

2.9.7 Flood Risk

The flood risk map is derived by extracting the optimal flood vulnerable zones and extracting from the land use to estimate landuse at higher risk to flooding. This analysis depicts areas and land uses within the critical zone are at high risk to flooding as shown Figure 2.42, 2.43 and Table 2.44 below.

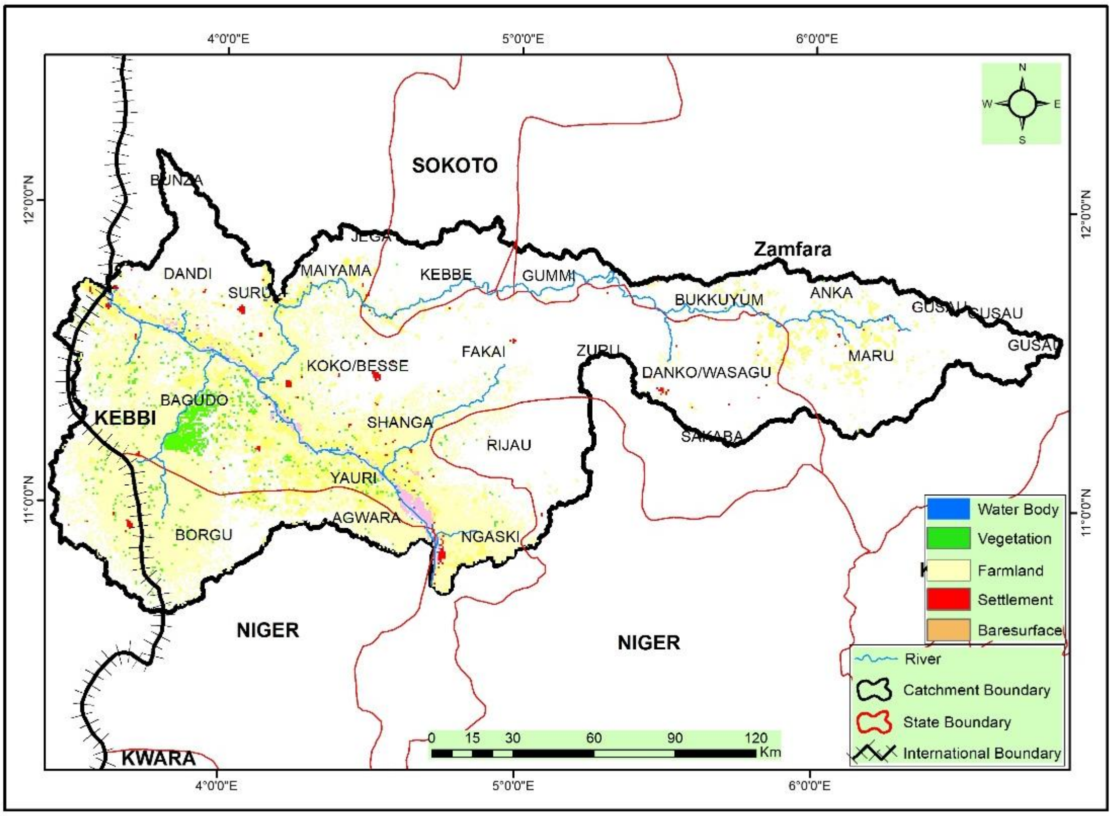


Figure 2.42 Flood Risk Map of the Catchment (Source: MSL, 2025)

The land use at risk in the Gulbin Ka catchment is predominantly farmland at 196.5ha which is 91.3% of the total land use at risk withing the vulnerable area. Flooding in the Golbin Ka catchment is majorly influenced by the relief and proximity to rivers within the catchment area.

Table 2.44 Flood Risk Analysis of the catchment

Value	**Ha**	**%**
Waterbody	1.8	0.835965
Forest	10.49	4.871819
Wetland	4.15	1.927364
Farmland	196.48	91.25023
Settlement	2.3	1.068178
Baresurface	0.1	0.046443
Total	215.32	100

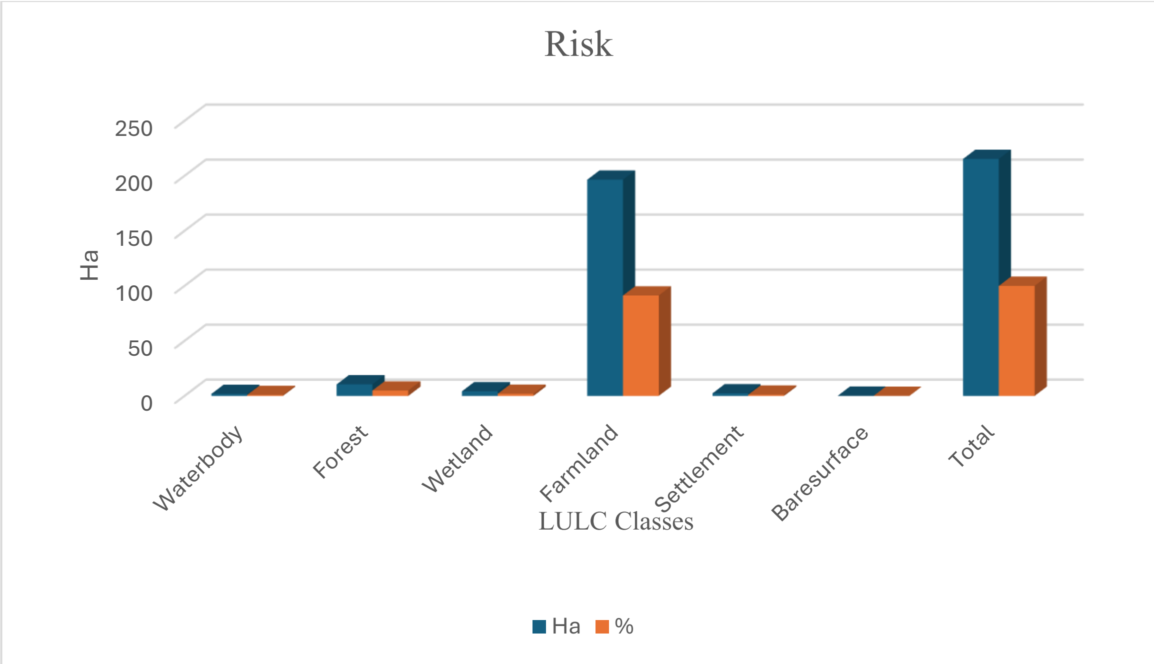


Figure 2.43 Flood Risk LULC analysis of the Catchment (Source: MSL, 2025)

2.10 Socio-Economic Dynamics

2.10.1 Population Distribution and Growth

The Project estimates shown Figure 2.44 the population by Sub-Catchment Areas as the smallest unit.

Categorization of Settlement and Categorization on Water Demand Projection

The categorization of settlement by population size, consisting of three categories for water supply planning, has been defined by the Federal Ministry of Water Resources (FMWR). This Project, in principle, conforms to this categorization and, per capita consumption of domestic water by this categorization is applied in the water demand projection.

However, water demand projection by settlement category based on population size only may cause inaccuracy because there is a mixture of various water supply schemes, various living or water usage situations, and various income groups on the ground in settlement. In the process of water demand projection, this Project put an additional category and allocated population based on referenced indicators such as households using flush toilets.

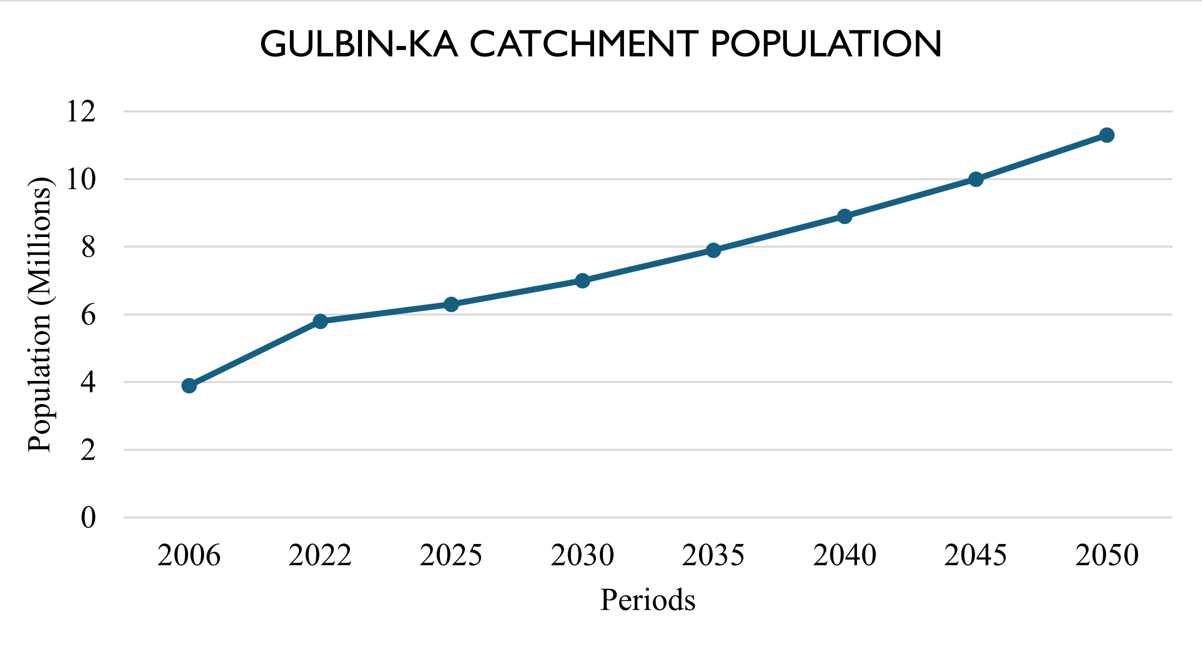


Figure 2.44: Gulbin Ka Catchment population from 2006 - 2050

Table 2.45, 2.46 and Figure 2.45 shows the Population Projection for Gulbin-Ka Catchment

Table 2.45: Population Projection for Gulbin-Ka Catchment

State	Estimated Population (2025)	Growth Trend	Population Density (people/km²)	Urbanization (%)	Key Observations
Kebbi	~5.56 million	Steady growth; ~2.5% annually	~151.2	~30%	Predominantly rural with agriculture as the mainstay; urban centers like Birnin Kebbi are growing.
Sokoto	~5.5 million	Moderate growth; ~2.7% annually	~211.7	~35%	Urbanization driven by Sokoto city; challenges include infrastructure strain and service delivery.
Zamfara	~6 million	Moderate growth; ~2.6% annually	~150.9	~25%	Rural dominance with limited urban centers; security issues impact population dynamics.

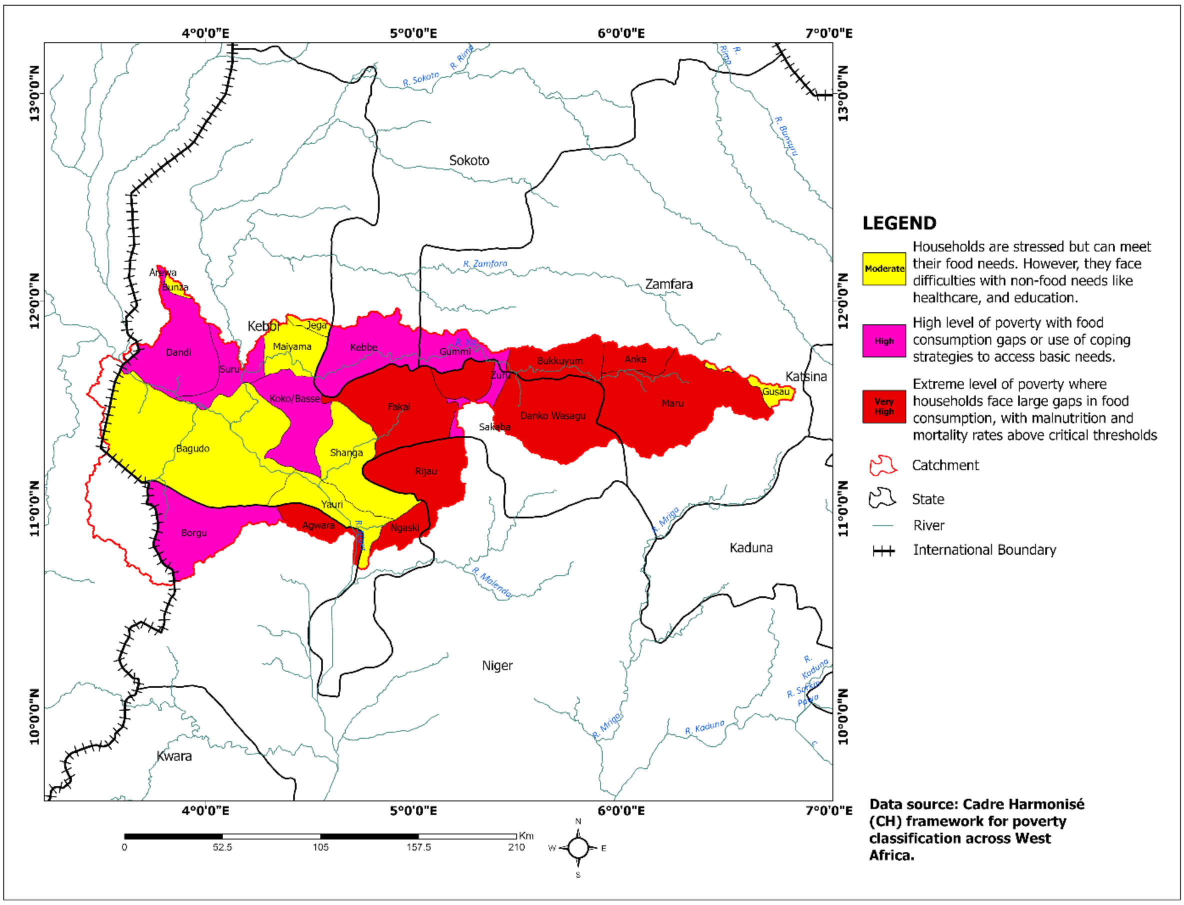


Figure 2.45: Poverty Level map of the Catchment (Source: MSL, 2025)

Table 2.46: Summary of the characteristics of Gulbin-Ka Catchment

NAME	STATES	POPULATION	GEOGRAPHY	GEOLOGY	HYDROGEOLOGY	VEGETATION	SOCIAL ECONOMICS
Gulbin-ka Catchment	Kebbi, Zamfara, Niger, Sokoto.	Estimated to be over 5 million	Location: Northwestern Nigeria, covering parts Kebbi, and Zamfara states. Topography: Primarily flat plains with some low hills and ridges	Underlying rock formations: Primarily consist of sedimentary rocks like sandstones and shales, with some igneous intrusions in specific areas. Geologic vulnerability: Certain areas might be susceptible to erosion due to the type of underlying rock and soil composition	Groundwater resources: Underlying aquifers provide essential water for domestic use, irrigation, and livestock. However, these resources are under pressure due to increasing demand and potential salinization	Predominant vegetation: Sudanian savanna with woodlands and grasslands. Vegetation degradation: Overgrazing, deforestation, and desertification threaten the natural vegetation cover, impacting soil quality and water retention	Livelihoods: Agriculture (rain-fed and irrigated farming), livestock rearing, fishing (along the river), and some trade and commerce. Water dependence: Communities heavily rely on the Rima River and groundwater resources for their survival and economic activities. Challenges: Poverty, water scarcity (seasonal), environmental degradation, and limited infrastructure

							development in some rural areas

2.10.2 Demographics and Poverty

Table *2.47* shows Gulbin-Ka Catchment Demographics and Poverty.

Table 2.47: Catchment Demographics and Poverty

State	Demographics	Poverty Indicators
Kebbi	- Population: Approximately 5.56 million (2025 estimate)- Age Distribution: Predominantly youthful, with over 60% under 25 years- Household Size: Average of 6.0 persons per household- Literacy Rate: Adult literacy around 38.7%; female literacy lower due to cultural factors- Urbanization: Approximately 30% urban population	- Multidimensional Poverty Rate: 79.1% - Child Poverty: Over 95% of children are multidimensionally poor - Out-of-School Children: High rates, particularly among girls due to early marriage and cultural practices
Sokoto	- Population: Approximately 5.5 million (2025 estimate)- Age Distribution: Youthful population, with a high dependency ratio- Household Size: Average of 6.5 persons per household- Literacy Rate: Adult literacy around 35.8%; female literacy significantly lower- Urbanization: Approximately 35% urban population, with Sokoto city as the major urban center	- Multidimensional Poverty Rate: 90.5%, highest in Nigeria - Child Poverty: Over 95% of children are multidimensionally poor - Out-of-School Children: High rates, with only 22.4% completing secondary school - Early Marriage: 53.9% of women married before age 18, impacting education and economic opportunities
Zamfara	- Population: Approximately 6 million (2025 estimate)- Age Distribution: Youthful population, with a high dependency ratio- Household Size: Average of 6.8 persons per household- Literacy Rate: Adult literacy around 33.5%; female literacy significantly lower- Urbanization: Approximately 25% urban population	- Multidimensional Poverty Rate: 82.7% - Child Poverty: High rates, with significant numbers of out-of-school children - Poor and Vulnerable Population: Highest in Nigeria, with 3,836,484 individuals from 825,337 households - Security Challenges: Banditry and insecurity exacerbate poverty and hinder access to services

2.10.2.1 Unsustainable Livelihoods

The Gulbin-Ka Catchment is grappling with serious challenges stemming from unsustainable livelihood practices, which are increasingly undermining the region's ecological balance and socio-economic stability. These issues are shaped by a mix of environmental pressures, economic hardship, and social dynamics, all of which constrain the catchment's capacity to sustainably support its growing population.

1. **Overgrazing and Nomadic Pastoralism**

- Land degradation and desertification as continuous grazing removes vegetative cover.
- Soil compaction reduces water infiltration, worsening drought effects.
- Resource conflicts, particularly between herders and crop farmers, have escalated in frequency and violence.

2. **Unsustainable Agricultural Practices**

- Soil erosion, especially on sloped land.
- Nutrient depletion leading to declining productivity.
- Deforestation to open new land for cultivation, particularly in upland areas.
- Reduced agricultural resilience to climate shocks.

3. **Deforestation for Fuelwood and Charcoal Production**

- Rapid loss of tree cover, affecting microclimates and increasing temperature.
- Decline in biodiversity, including habitat destruction for many native species.
- Increased carbon emissions, contributing to climate change.

4. **Unregulated Sand Mining and Natural Resource Extraction**

- Riverbank erosion and siltation, leading to altered river courses and reduced water flow.
- Aquatic habitat destruction, affecting fisheries and biodiversity.
- Increased flood risk during the rainy season due to destabilized floodplains.

5. **Artisanal and Small-Scale Mining (ASM)**

- Severe land degradation from excavation and unregulated digging.
- Water pollution from toxic substances like mercury and lead.
- Public health crises, such as the 2010 lead poisoning outbreak in Zamfara, which killed over 400 children.
- Long-term livelihood disruption due to polluted soils and unusable farmland.

2.10.3 Gender Issues

1. Educational Disparities

In the Gulbin-Ka Catchment, girls face significant barriers to education. Cultural norms and economic constraints often prioritize boys' education over girls'. Early marriage is prevalent, particularly in rural areas, leading to high dropout rates among adolescent girls. Additionally, inadequate school infrastructure, such as lack of separate sanitation facilities, further discourages girls' attendance.

2. Economic Inequality

Women in the catchment area have limited access to economic resources. Land ownership is predominantly male-dominated, and women often lack access to credit facilities and agricultural inputs. This economic marginalization restricts women's ability to contribute to and benefit from agricultural and other income-generating activities.

3. Health Challenges

Gender disparities in health access are pronounced. Women often have limited autonomy in making health-related decisions, leading to lower utilization of maternal and reproductive health services. Cultural beliefs and lack of female healthcare providers further hinder women's access to quality healthcare

4. Gender-Based Violence (GBV)

GBV is a significant concern in the region. Societal norms often perpetuate silence around domestic violence, and victims have limited access to support services. The lack of legal awareness and enforcement mechanisms exacerbates the issue, leaving many women vulnerable

5. Political and Decision-Making Exclusion

Women's participation in political and community decision-making processes is minimal. Traditional leadership structures are predominantly male, and women's voices are often underrepresented in governance, limiting their influence on policies affecting their lives.

CHAPTER 3 : STAKEHOLDER ENGAGEMENT AND GOVERNANCE

3.1 Methodology

The Gulbin-Ka Catchment is characterized by a complex interplay of socio-political dynamics, environmental challenges, and diverse economic activities. A wide range of stakeholders including government agencies, international development partners, local communities, and private sector actors have significant interests in the catchment's development and stability. Understanding these stakeholders, their roles, and their interests is critical for promoting effective governance, resolving conflicts, and driving sustainable development across the Gulbin-Ka Catchment.

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
- Past and Present Interventions

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

Sokoto State:

i. Sokoto-Rima River Basin Development Authority
ii. Farmers association/ pastoralists of the State
iii. Rural Water Supply and Sanitation Agency (RUWASA)
iv. State Ministry of Environment,
v. State Ministry of Agriculture and Food Security
vi. State Ministry of Water Resources
vii. State Ministry of Lands, Housing and Survey
viii. State Ministry of Women Affairs,
ix. State Ministry of Solid Mineral Resources

x. State Miners Association
xi. Sokoto Leather Goods Producers Association.
xii. Center for Environment and Gender Studies (Usman Dan Fodio University)
xiii. Dr. Murtala Dangulla, PhD Environmental Quality and Conservation
xiv. Prof. Murtala Abubakar Gada, PhD Hydrology and Water Resources Mgt
xv. Dr. Nura Bello, PhD Environmental Hydrology

Zamfara State:

i. Nigeria Integrated Water Resources Management Commission **Gusau**
ii. Farmers association/ pastoralists of the State
iii. Rural Water Supply and Sanitation Agency (RUWASA)
iv. State Ministry of Water Resources
v. State Ministry of Lands, Housing and Survey
vi. State Ministry of Women Affairs,
vii. State Ministry of Solid Mineral Resources
viii. State Miners Association
ix. Borehole Drilling Association of Nigeria (BORDAN)
x. Association of Water Well Drilling Rig Owners and Practitioners. (AWDROP)
xi. Zamfara State Emergency Management Agency (ZEMA)
xii. Directorate of Rural Water Supply
xiii. Zamfara State Water Users Association
xiv. Zamfara State Water Cooperation
xv. Zamfara State Rural Water Sanitation and Hygiene
xvi. Zamfara State Ministry Environment and Natural Resources
xvii. Zamfara State Ministry of Agriculture
xviii. National Environmental Standard Regulation and Enforcement Agency (NESREA) zonal office
xix. Zamfara State Culture and Tourism
xx. Zamfara Geographic Information System (ZAGIS)
xxi. Department of Geography Federal University, Gusau
xxii. Department of Biological Science Federal University, Gusau

Niger State:

1. Niger Rural Water Supply and Sanitation Agency (RUWASA)

2. Niger State Ministry of Environment
3. Niger State Ministry of Agriculture and Food Security
4. Niger State Ministry of Water Resources
5. Environmental Health and Safety Center, FUT Minna
6. Center for Disaster, Risk Management and Development Studies
7. Sarkin Bauchi Rijau
8. Focal Non-Governmental Organization

Kebbi State:

i. Farmers Association/ Pastoralists of the State

ii. Rural Water Supply and Sanitation Agency (RUWASA)

iii. State Ministry of Environment,

iv. State Ministry of Agriculture and Food Security

v. State Ministry of Water Resources

vi. State Ministry of Lands, Housing and Survey

vii. State Ministry of Women Affairs,

viii. State Ministry of Solid Mineral Resources

ix. State Miners Association

x. Abdullahi Fidio University of Science Technology Aliero, Kebbi State

xi. The National Fresh Water Fisheries Research Institute - Yauri LGA

xii. Livestock Research And Development Centre At Kebbi State Polytechnic Dakingari LGA

xiii. Agricultural Machinery Development Institute (AMEDI) - Ambursa Birnin Kebbi

xiv. Professor Gona Ayuba (08137206544; ayubagona@gmail.com) EXPERT

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

3.3 Major Topics for Stakeholder Discussions

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

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

The discussions covered issues and potential best practices around:

- Water Resources Management
- Agricultural Systems
- Environmental Sustainability
- Socio-Economic Challenges
- Governance and Policy

More specific topics included:

- Seasonal Variability
- Water Quality
- Infrastructure
- Limited access to irrigation facilities
- Seed Access
- Climate Change
- Significant loss of forest cover
- Land Degradation
- Biodiversity Loss
- High poverty rates
- Gender Disparities
- Youth Unemployment
- Lack of coordination among state agencies
- Policy Implementation
- Community Involvement

3.4 Key Points from the Stakeholders Engagement

Based on the stakeholder engagement information from Annex 2 on strategic issues and opportunities, the stakeholder consultations in the Gulbin-Ka Catchment identified critical concerns related to water resources, agriculture, environmental sustainability, and socio-economic issues. The following detailed points were developed around the key topics of interest identified in the previous section:

1. **Water Resources Management**
   - ***Availability and Access:*** There are significant concerns about the seasonal variability and overall scarcity of water. Water availability peaks during the rainy season (June–September) but declines sharply during the dry months, leading to water shortages for irrigation and domestic use.
   - ***Water Quality:*** Water quality is a major issue, particularly in areas with mining activities. There is a high level of contamination from heavy metals and agrochemicals, impacting both human health and aquatic ecosystems.
   - ***Infrastructure and Conflicts:*** Inadequate water infrastructure in the catchment has been identified as a significant challenge. Conflicts over water use between farmers and pastoralists are common, particularly during the dry season when water is scarce.
2. **Agricultural Systems**
   - ***Irrigation and Seed Access:*** There are limited access to irrigation facilities and high-quality seeds, which hampers agricultural productivity. Only a small fraction of arable land is equipped with irrigation systems.
   - ***Climate-Smart Practices and Grazing Pressures:*** The need for climate-smart agricultural practices to cope with unpredictable weather patterns has been emphasized by the stakeholders. Overgrazing by livestock is also a significant issue, leading to land degradation and reduced agricultural productivity.
3. **Environmental Sustainability**
   - ***Deforestation and Erosion:*** Deforestation driven by agricultural expansion and fuelwood collection is a major issue, leading to soil erosion and loss of biodiversity.
   - ***Biodiversity and Land Degradation:*** There are concerns about the decline in biodiversity and increasing land degradation. Wetlands and floodplains are under threat from agricultural encroachment and invasive species.
4. **Socio-Economic Challenges**
   - ***Poverty and Gender Disparities:*** High poverty rates and significant gender disparities are prevalent across the catchment. Women often have less access to land, resources, and decision-making processes.
   - ***Insecurity and Displacement:*** Insecurity, including banditry and farmer-herder conflicts, has led to displacement and disrupted livelihoods.

- ***Youth Employment:*** High youth unemployment is a significant challenge, with limited opportunities for skill development and employment.

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 environmental aspects of the catchment plan 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): 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 the biophysical and socio-economic assessments, alongside comprehensive stakeholder engagement, the agreed strategic vision for the Gulbin-Ka Catchment places strong emphasis on sustainable water resources management, land and ecosystem protection, strengthening community resilience to climate and environmental risks, and advancing governance reforms for effective and inclusive catchment management.

The strategic vision for the Gulbin-Ka Catchment is:

"To achieve sustainable development through integrated water resources management, environmental conservation, and socio-economic development".

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

Table 4.1: Gulbin-Ka Catchment's Strategic Goals and Objectives for Sustainable Catchment Development

Short-Term Strategic Goals (0–5 Years)	**KPIs for Short-Term Goals**	**Long-Term Strategic Goals (5+ Years)**	**KPIs for Long-Term Goals**	**Expected Outcomes and Measurable Targets**
Implement climate-smart agriculture practices across major farming communities.	• Percentage of farmers trained in CSA. • Percentage reduction in soil erosion rates (annual)	Achieve widespread adoption of sustainable agriculture across the entire catchment.	• Percentage of total farmland under certified sustainable practices. • Trend in rural income growth.	Increased food security enhanced rural incomes, and reduced land degradation. 50% of farmers adopt CSA practices within 5 years; 75% adoption within 10 years.

Rehabilitate critical wetlands and degraded lands.	• Hectares of wetlands restored annually. • No. of species reintroduced.	Maintain and expand protected ecosystems and biodiversity zones.	• Percentage of catchment area under formal protection. • Biodiversity index score (e.g species richness)	Restoration of wetland ecosystems and improved biodiversity. 30% increase in wetland areas restored; 60% under formal protection by 2035.
Establish and operationalize Catchment Management Committees (CMCs) at LGA and community levels.	• No. of functional CMCs established. • Percentage of conflicts resolved via CMCs	Fully institutionalize participatory catchment governance structures.	• Existence of national policy mandating CMCs. • Percentage of resource decisions involving CMCs.	Improved decision-making, conflict resolution, and resource management. 70% of LGAs establish functional CMCs; full operationalization in all LGAs within 10 years.
Expand rural water infrastructure (boreholes, rainwater harvesting systems, irrigation canals).	• No. of new water points constructed. • Percentage reduction in water-related conflicts.	Achieve universal access to safe water for agriculture, livestock, and domestic use.	• Percentage of population with reliable water access. • Water stress index (demand vs. supply).	Increased water availability, reduced conflict over water resources. 60% increase in functional water points by 2028; 90% by 2035.
Promote afforestation, agroforestry, and reforestation programs.	• Hectares reforested annually. • Survival rate of planted trees (percentage)	Rebuild forest ecosystems and enhance carbon sequestration.	• Carbon sequestration rate (tons CO_2/year). • Percentage increase in forest cover.	Reduced desertification and improved climate resilience. 10,000 hectares reforested by 2028; 25,000 hectares reforested by 2035.
Mainstream Gender Equality and Social Inclusion (GESI) in all programs.	• Percentage of GESI-focused programs implemented.	Achieve gender-balanced participation in catchment management and resource governance.	• Percentage leadership roles held by women/youth. • Gender parity index in resource access.	Empowered women, youth, and marginalized groups. 40% leadership representation of women and vulnerable groups by 2028; 50% by 2035.

	• No. of women/youth in training programs.			
Install early warning systems for floods and droughts.	• Percentage of high-risk areas with EWS. • No. of disaster drills conducted.	Fully integrated climate risk management and disaster preparedness.	• Economic losses avoided due to EWS (USD/year). • Community preparedness index.	Reduced economic losses and community displacement due to climate events. Early warning coverage extended to 70% of high-risk areas within 5 years; 100% by 2035.
Strengthen enforcement against illegal mining, logging, and land degradation.	• Number of enforcement actions taken. • Percentage reduction in reported illegal activities.	Institutionalize sustainable natural resource use laws and enforcement mechanisms.	• Existence of independent monitoring body. • Conviction rate for environmental crimes.	Decrease in environmental degradation and illegal activities. 50% reduction in illegal activities by 2028; 80% reduction by 2035.
Build capacity of local institutions for data management, monitoring, and evaluation.	• Number of staff trained in data collection. • Frequency of M&E reports.	Data-driven adaptive management for catchment sustainability.	Percentage of policies revised based on M&E data. Data accuracy score (audit results).	Reliable environmental and socio-economic data to guide interventions. Annual environmental and M&E reports published for Gulbin Ka Catchment starting 2026.

CHAPTER 5 : STRATEGIC CHALLENGES AND PRIORITY INTERVENTIONS

Stakeholder engagement and biophysical assessment revealed the following key challenges faced by the Gulbin-Ka Catchment:

5.1 Key Issues

1. **Water Scarcity and Poor Water Management**

- Severe water shortages during dry seasons impacting agriculture, livestock, and domestic use.
- Inefficient water infrastructure and lack of integrated water resource management systems.
- Sedimentation of rivers and reservoirs reducing storage capacity.

2. **Frequent Flooding and Disaster Risk**

- Seasonal floods damaging farmland, displacing communities, and disrupting livelihoods.
- Lack of robust flood management infrastructure such as levees, early warning systems, and stormwater drainage.
- Farmland is the most at-risk land use type, constituting over 91% of flood-prone areas.

3. **Land Degradation and Desertification**

- Overgrazing, deforestation, and unsustainable farming practices have accelerated soil erosion.
- Expansion of barren land and loss of fertile soils threaten food security and rural livelihoods.

4. **Natural Resource Overexploitation**

- Over-mining of mineral resources (gold, limestone) without adequate environmental controls.
- Excessive logging, bush burning, and illegal land conversion impacting forest and wetland ecosystems.

5. **Biodiversity Loss and Ecosystem Degradation**

- Encroachment into wetlands and forest reserves leading to loss of critical habitats for fisheries and wildlife.
- Declining ecosystem services such as water filtration, carbon sequestration, and flood mitigation.

6. **Climate Change Impacts**

- Increased frequency of droughts, erratic rainfall patterns, rising temperatures, and extreme weather events.
- Greater vulnerability of farming communities and ecosystems to climate-induced shocks.

7. **Weak Governance and Institutional Capacity**

- Poor enforcement of environmental and water resource regulations.
- Fragmented policy frameworks between national, state, and local agencies.
- Limited funding for catchment management, monitoring, and enforcement.

8. **Socio-economic Vulnerability**

- High poverty levels across the catchment area, especially among rural communities.
- Limited access to infrastructure, basic services (health, education), and credit facilities.
- Youth unemployment and underemployment exacerbate rural-urban migration pressures.

9. **Conflict and Insecurity**

- Farmer-herder conflicts over access to land and water resources.
- Banditry, cattle rustling, and kidnapping further destabilize communities and hinder development projects.

10. **Gender Inequality and Social Exclusion**

- Women and marginalized groups have limited access to land, decision-making processes, and resources.
- Gender-based barriers weaken the inclusive management of the catchment's resources.

5.2 Strategic Interventions

i. **Enhance Water Resources Management and Supply Systems:** Improve water availability, efficiency, and access across sectors (agriculture, domestic, livestock).

ii. **Promote Climate-Resilient and Sustainable Agriculture:** Enhance food security and rural livelihoods under changing climate conditions.

iii. **Ecosystem Restoration and Biodiversity Conservation:** Protect and rehabilitate critical ecosystems, wetlands, forests, and degraded lands.

iv. **Strengthen Disaster Risk Management (Flood and Drought) :** Minimize the adverse impacts of climate-related disasters on communities and ecosystems.

v. **Improve Rural Livelihoods and Socio-Economic Development:** Reduce poverty, enhance resilience, and diversify rural economies.

vi. **Governance, Institutional Capacity, and Policy Reforms:** Foster integrated, transparent, and accountable catchment governance.

vii. **Gender Equality and Social Inclusion (GESI) Mainstreaming :** Ensure equitable participation and benefits for women, youth, and marginalized groups.

Figure 5.1 to 5.8 shows the Strategic Catchment Management Plan of Gulbin-Ka catchment.

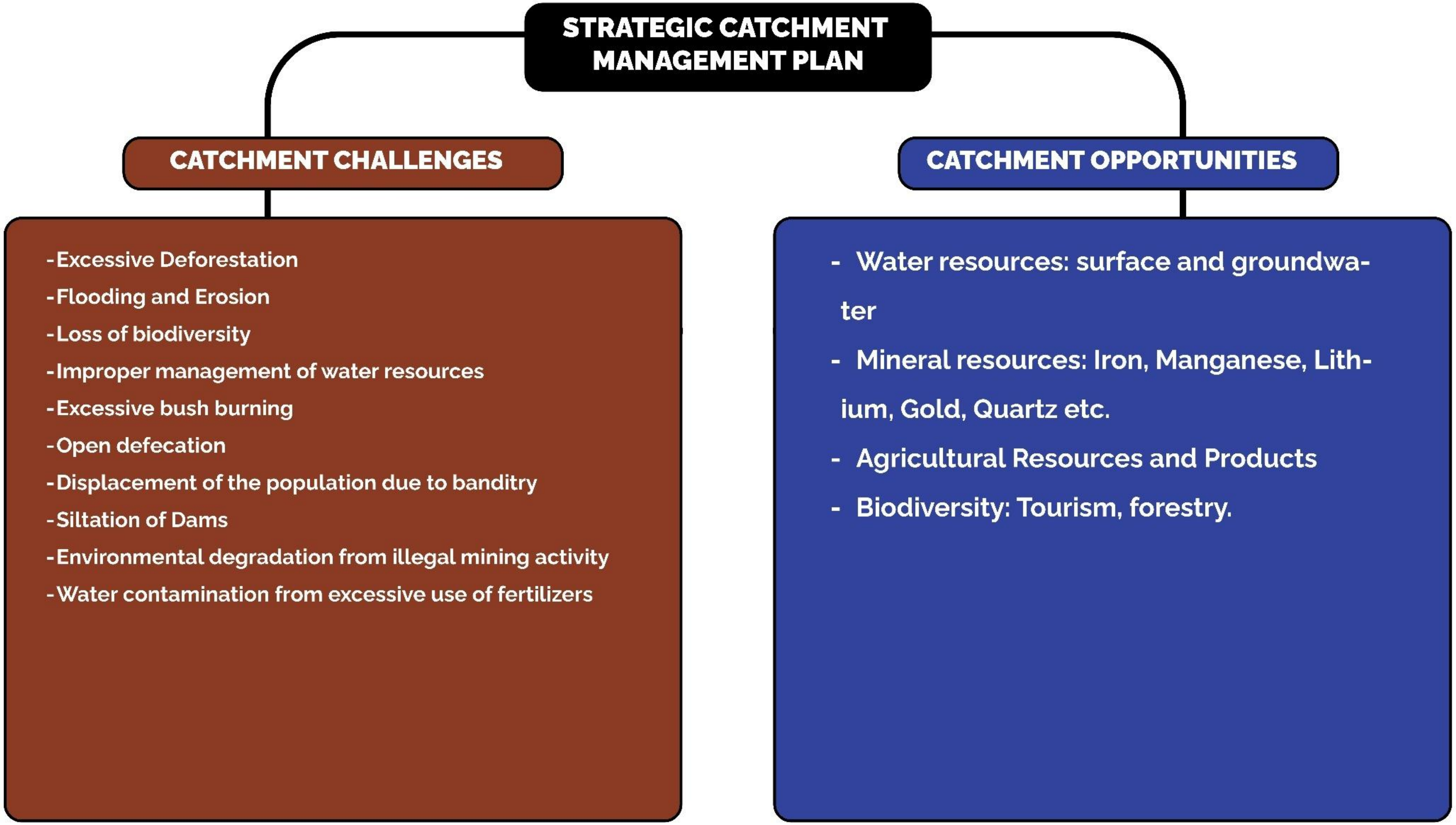


Figure 5.1: Strategic Catchment Management Plan

INTERVENTIONS FOR COMPONENT 1

Sustainable Conservation Management and Use of Water Resources

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Identification and mapping of water resources and facilities.	✓			Percentage of catchment area mapped; number of water facilities identified	State Ministries of Water Resources, RBDAs	Supported for better planning and resource allocation.	Conduct detailed geo-mapping exercises with community validation.
Rehabilitation and maintenance of dams, reservoirs, and irrigation canals.	✓	✓		Number of rehabilitated infrastructures; Increase in irrigation coverage	RBDAs, State Water Boards	Critical to improve water storage and dry season farming.	Prioritize rehabilitation of small-scale community dams.
Establishment and strengthening of Water User Associations (WUAs).	✓			Number of active WUAs; percentage of community participation	LGAs, NGOs, Community Leaders	Essential for local water management ownership.	Provide capacity-building and legal backing for WUAs.
Enforcement and review of water resource policies.	✓	✓		Revised policies enacted; number of enforcement actions taken	State Legislatures, Ministries of Justice	Mixed reactions; communities fear overregulation.	Ensure policies are participatory and community-driven.
Construction of water harvesting structures (rainwater collection systems, small reservoirs).	✓	✓		Volume of additional water stored; number of structures built	LGAs, RBDAs, Donors	Highly supported due to frequent water scarcity.	Implement cost-effective, community-managed structures.
Promotion of efficient irrigation technologies (drip, sprinkler systems).	✓	✓		Percentage of area under improved irrigation methods	Ministries of Agriculture, ADPs	Positive reception, but concerns about affordability.	Provide subsidies and technical training.
Monitoring of groundwater extraction and recharge.	✓	✓	✓	Groundwater table levels; number of monitoring points established	Hydrological Services Agencies, NIWRMC	Seen as necessary but capacity gaps exist.	Set up community-based groundwater monitoring cells.
Installation of flood early warning systems.	✓			Number of functional warning stations installed	NIMET, State Emergency Agencies	Strongly demanded to prevent recurring flood losses.	Use mobile technology and local alert networks.
Public sensitization on water conservation and pollution prevention.	✓	✓	✓	Number of awareness campaigns; change in knowledge/behavior metrics	LGAs, CBOs, NGOs	Welcomed across communities.	Integrate into school curricula and local radio programs.
Enhancement of data collection and integrated information systems (hydrology, water quality, usage patterns).	✓	✓	✓	Comprehensive Water Information System operational	RBDAs, NIWRMC, Universities	Identified as crucial for evidence-based planning.	Build a centralized catchment water database.

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

INTERVENTIONS FOR COMPONENT 2

Preservation and Restoration of Critical Ecosystems and services for Sustainable land Use

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Establish community woodlots and reforest degraded areas using native species.	✓	✓		- Number of hectares reforested - Survival rate of planted trees	- State Ministries of Environment, Local Government Authorities (LGAs), Community-Based Organizations (CBOs)	Communities are supportive, recognizing benefits for fuelwood supply and erosion control.	Provide seedlings and training; involve local communities in maintenance and monitoring.
Rehabilitate degraded wetlands to restore ecological functions.	✓	✓		- Area of wetlands restored - Biodiversity indices improvement	- National Parks Service, State Environmental Agencies, NGOs	Fisherfolk and farmers express interest due to improved water availability and fish stocks.	Implement participatory wetland management plans; monitor ecological changes.
Implement measures to prevent desertification in vulnerable areas.	✓	✓		- Kilometers of dunes stabilized - Reduction in sand encroachment incidents	- ACReSAL Project Units, State Ministries of Environment	Pastoralists are concerned about grazing land loss; require alternative fodder sources.	Combine stabilization with fodder crop cultivation; engage pastoralist communities in planning.
Integrate trees into farming systems to enhance productivity and sustainability.	✓	✓		- Number of farmers adopting agroforestry - Increase in farm yields	- Agricultural Extension Services, NGOs, Farmer Cooperatives	Farmers show interest but need technical support and market access.	Provide training on agroforestry practices; link farmers to markets for tree products.
Implement controlled grazing and reseeding to restore degraded pastures.	✓	✓	✓	- Hectares of rangeland rehabilitated - Livestock productivity metrics	- State Ministries of Agriculture, Pastoralist Associations	Pastoralists are willing to participate if assured of long-term benefits.	Develop grazing schedules; establish fodder banks; involve pastoralists in decision-making.
Construct terraces, check dams, and plant cover crops to reduce erosion.	✓			- Number of erosion control structures built - Reduction in soil loss rates	- LGAs, Community Development Committees	Farmers acknowledge the need but require resources and technical guidance.	Mobilize community labor; provide materials and training for construction and maintenance.
Strengthen management of existing protected areas to conserve biodiversity.	✓	✓	✓	- Increase in protected area coverage - Improvement in species population data	- National Parks Service, State Environmental Agencies	Conservationists and local communities seek collaborative management approaches.	Implement co-management frameworks; conduct regular biodiversity assessments.
Raise awareness on sustainable land use and conservation practices.	✓	✓	✓	- Number of awareness events held - Change in community attitudes and practices	- NGOs, Educational Institutions, Media Outlets	Communities are receptive to information that links conservation to livelihood benefits.	Utilize local languages and culturally appropriate messaging; involve community leaders.

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

INTERVENTIONS FOR COMPONENT 3

Improved Diversification for Enhanced Sustainable Livelihoods and Well-Being

Activities	Timelines			Key Indicators	Responsibilities	Stakeholders' View	Recommendations
	S	M	L				
Provide training in trades such as tailoring, carpentry, and mechanics.	✓			- Number of individuals trained - Employment rate post-training	- State Ministries of Youth and Employment- NGOs- Vocational Training Centers	Youth express strong interest in acquiring skills for alternative livelihoods.	Establish community-based training centers; offer certification programs.
Support SME entrepreneurship through access to finance and markets.	✓	✓		- Number of SMEs established - Increase in household incomes	- State Ministries of Commerce - Microfinance Institutions- Business Development Services	Entrepreneurs face challenges in accessing capital and markets.	Provide microcredit schemes: facilitate market linkages and mentorship programs.
Enhance processing, storage, and marketing of agricultural products.	✓	✓		- Reduction in post-harvest losses - Increase in value-added products	- State Ministries of Agriculture- Farmer Cooperatives- Agribusinesses	Farmers are eager to increase profits through value addition.	Invest in processing facilities; train farmers in quality standards and packaging.
Support women-led income-generating activities.	✓	✓		- Number of women entrepreneurs supported - Improvement in women's income levels	- Women's Affairs Departments- NGOs- Women's Cooperatives	Women seek opportunities to contribute economically to their households.	Provide targeted training; ensure access to credit and markets for women.
Involve youth in environmental conservation and sustainable agriculture.	✓			- Number of youth engaged - Youth-led initiatives implemented	- Youth Councils- Environmental NGOs- Educational Institutions	Youth are interested in contributing to community development.	Develop youth clubs; integrate environmental education into school curricula.
Promote tourism based on natural and cultural heritage.	✓	✓	✓	- Increase in tourist visits - Revenue generated from tourism	- Tourism Boards- Local Communities- Private Sector	Communities are open to tourism if it benefits them economically.	Develop eco-tourism sites: train locals as guides and service providers.
Enhance infrastructure to connect producers to markets.	✓	✓		- Reduction in transportation time - Increase in market participation	- Ministries of Works and Transport- Local Governments- Traders' Associations	Farmers and traders face difficulties in transporting goods.	Upgrade rural roads; establish market information systems.
Implement safety nets for vulnerable populations.	✓			- Number of beneficiaries covered - Reduction in poverty levels	- Social Welfare Departments- NGOs- Community Leaders	Vulnerable groups need support during shocks and lean periods.	Provide cash transfers; link beneficiaries to livelihood programs.

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

INTERVENTIONS FOR COMPONENT 4

Climate Change, Disaster Risk Management, and Climate Resilient Infrastructure

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Conduct comprehensive assessments to identify climate vulnerabilities and hazard-prone areas.	✓			- Completion of risk maps - Number of stakeholders trained in risk assessment	- State Ministries of Environment - National Emergency Management Agency (NEMA) - Local Government Authorities (LGAs)	Communities recognize the importance of understanding risks but require accessible information.	Utilize participatory approaches; disseminate findings in local languages and formats.
Implement systems to provide timely alerts for floods, droughts, and other climate hazards.	✓	✓		- Number of functional EWS installed - Reduction in disaster response time	- Nigerian Meteorological Agency (NiMet)- NEMA- Community-Based Organizations (CBOs)	High demand for timely and reliable warnings; trust in technology varies.	Combine technological solutions with traditional knowledge; conduct regular drills.
Design and construct infrastructure (e.g., roads, bridges, water systems) that can withstand climate extremes.	✓	✓	✓	- Number of infrastructure projects completed - Infrastructure performance during climate events	- Ministries of Works and Housing- State Infrastructure Agencies- Private Sector Partners	Stakeholders emphasize the need for durable infrastructure; concerns about maintenance.	Adopt standards for climate-resilient design; ensure maintenance plans are in place.
Implement ecosystem-based approaches such as reforestation and wetland restoration for disaster risk reduction.	✓	✓		- Area covered by NbS projects - Improvement in ecosystem services	- State Ministries of Environment- NGOs- Community Groups	Positive reception; communities value co-benefits like improved livelihoods.	Integrate NbS into local development plans; provide incentives for community participation.
Educate communities on climate risks and adaptive practices.	✓	✓	✓	- Number of training sessions conducted - Increase in community knowledge and preparedness	- NEMA- Educational Institutions- Media Outlets	Communities are eager to learn but face barriers such as literacy levels.	Tailor programs to local contexts; use diverse communication channels.
Incorporate climate risk assessments into land use and development planning.	✓	✓		- Number of plans updated with climate considerations - Adoption of climate-smart policies	- Planning Commissions- LGAs- Traditional Authorities	Planners acknowledge the need but require technical support.	Provide training and tools for climate-informed planning; engage stakeholders in the process.
Develop and strengthen systems for effective disaster response and recovery.	✓			- Formation of emergency response teams - Response time during disasters	- NEMA- LGAs- Health Services	Communities desire rapid and coordinated responses; trust in authorities varies.	Establish clear protocols; conduct regular simulations and evaluations.
Monitoring and Evaluation of Climate Adaptation Initiatives - Track the effectiveness of implemented measures and adjust strategies accordingly.	✓	✓	✓	- Development of M&E frameworks- Periodic evaluation reports	- State Ministries of Environment- Research Institutions- Donor Agencies	Stakeholders seek transparency and accountability in adaptation efforts.	Involve communities in M&E processes; share findings openly to inform future actions.

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

INTERVENTIONS FOR COMPONENT 5

Strengthening Institutional Mechanisms and Project Coordination Mechanisms

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Form multi-stakeholder committees to oversee catchment management.	✓			- Number of Catchment Management Committees established - Frequency of meetings held	- State Ministries of Environment- Local Government Authorities (LGAs)- Community Leaders	Communities desire inclusive decision-making structures.	Ensure representation from all relevant stakeholders; provide clear mandates.
Development of Integrated Catchment Management Plans (ICMPs) Create comprehensive plans incorporating environmental, social, and economic aspects.	✓	✓		- Completion and approval of ICMPs - Implementation rate of planned activities	- State Ministries of Environment- Planning Commissions- NGOs	Stakeholders seek coordinated and strategic approaches.	Engage stakeholders in plan development; align with national policies.
Provide training on catchment management, governance, and technical skills.	✓	✓	✓	- Number of personnel trained - Improvement in institutional performance metrics	- Training Institutes- NGOs- Donor Agencies	Institutions acknowledge the need for enhanced capacities.	Conduct regular training needs assessments; develop tailored programs.
Implement platforms for data collection, sharing, and analysis.	✓	✓		- Operational data management systems - Number of data-driven decisions made	- NIHSA- Research Institutions- ICT Departments	Stakeholders emphasize the importance of reliable data.	Develop interoperable systems; ensure data accessibility and security.
Review and update laws and policies to support catchment management.	✓	✓		- Number of policies revised - Level of policy enforcement	- State Assemblies- Legal Departments- Environmental Agencies	Legal clarity is essential for effective governance.	Harmonize policies across sectors; involve legal experts in reviews.
Facilitate collaboration among various government agencies and stakeholders.	✓	✓		- Number of joint initiatives - Reduction in overlapping functions	- Inter-Ministerial Committees- LGAs- NGOs	Agencies recognize the need for better coordination.	Establish formal coordination bodies; define roles and responsibilities.
Create systems to track progress and assess outcomes of interventions.	✓			- M&E frameworks developed - Regular publication of progress reports	- M&E Units- Donor Agencies- Civil Society Organizations	Transparency and accountability are highly valued.	Involve stakeholders in M&E processes; use findings for adaptive management.
Educate and involve communities in catchment management activities.	✓	✓	✓	- Number of outreach programs conducted - Increase in community participation rates	- LGAs- NGOs- Community-Based Organizations (CBOs)	Communities are eager to participate when informed.	Utilize local media and languages; tailor messages to community contexts.

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

INTERVENTIONS FOR COMPONENT 6

Mainstreaming gender equality and social inclusion (GESI) mechanism

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Conduct GESI Analysis and Mapping to identify gender and social inclusion gaps in catchment communities.	✓			- Completion of GESI analysis report - Number of stakeholders engaged	- State Ministries of Environment and Women Affairs- NGOs- Community-Based Organizations (CBOs)	Communities express the need to understand existing inequalities.	Utilize participatory approaches; ensure data is disaggregated by gender, age, and disability.
Create targeted strategies to address identified GESI gaps.	✓	✓		- Number of action plans developed - Implementation rate of planned activities	- Catchment Management Committees- LGAs- NGOs	Stakeholders seek structured approaches to promote inclusion.	Align action plans with national GESI policies; involve marginalized groups in planning.
Train stakeholders on gender equality and social inclusion concepts.	✓	✓	✓	- Number of training sessions conducted - Increase in stakeholder knowledge levels	- Training Institutes- NGOs- Donor Agencies	Participants desire practical knowledge to apply GESI principles.	Develop context-specific training materials; include success stories to illustrate impact.
Establish GESI Monitoring and Evaluation Frameworks to Track progress and outcomes of GESI initiatives.	✓	✓		- M&E frameworks developed - Regular publication of GESI progress reports	- M&E Units- Donor Agencies- Civil Society Organizations	Emphasis on transparency and accountability in GESI efforts.	Incorporate GESI indicators into existing M&E systems; engage communities in evaluations.
Encourage women's involvement in decision-making processes.	✓	✓		- Percentage increase in women holding leadership positions - Number of women participating in meetings	- LGAs- Traditional Authorities- Women's Groups	Women express interest in leadership roles but face cultural barriers.	Implement mentorship programs; engage male allies to support women's participation.
Facilitate equitable access to land, water, and other resources.	✓	✓	✓	- Number of marginalized individuals accessing resources - Reduction in resource-related conflicts	- Resource Management Agencies- NGOs- Community Leaders	Marginalized groups report challenges in accessing essential resources.	Review and reform policies to remove discriminatory practices; provide legal support where necessary.
Allocate resources to address GESI priorities effectively.	✓	✓		- Budget allocations reflecting GESI priorities - Expenditure tracking reports	- Finance Departments- Planning Commissions- Donor Agencies	Need for financial commitment to GESI initiatives.	Train budget officers on gender-responsive budgeting; involve stakeholders in budget planning.
Educate communities on the importance of gender equality and social inclusion.	✓	✓	✓	- Number of campaigns conducted- Increase in community awareness levels	- Media Outlets- NGOs- Educational Institutions	Communities are open to learning but require culturally sensitive messaging.	Utilize local languages and culturally appropriate materials; engage local influencers.

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

INTERVENTIONS FOR COMPONENT 7

Research and Extension

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Engage communities in identifying and testing sustainable land and water management practices.	✓	✓		- Number of participatory research initiatives conducted - Adoption rate of sustainable practices	- National Agricultural Research Institutes - State Ministries of Agriculture- NGOs	Communities express interest in practices that improve yields and conserve resources.	Ensure research addresses local challenges; involve farmers in the research process.
Enhance the capacity of extension agents to disseminate research findings and best practices.	✓	✓		- Number of extension agents trained - Frequency of farmer-extension interactions	- State Agricultural Development Programs- NGOs- Donor Agencies	Farmers desire timely and relevant information to improve practices.	Provide continuous training for extension agents; utilize ICT tools for wider reach.
Establish Demonstration Plots and Farmer Field School Set up practical learning sites to showcase sustainable practices.	✓	✓		- Number of demonstration plots established- Farmer participation rates	- Agricultural Research Institutes- NGOs- Community Leaders	Hands-on learning is preferred for understanding new techniques.	Select accessible locations; involve local champions to lead initiatives.
Create forums for stakeholders to exchange information and experiences.	✓	✓		- Number of knowledge-sharing events held - Diversity of stakeholder participation	- State Ministries of Agriculture- NGOs- Farmer Associations	Stakeholders value opportunities to learn from each other.	Organize regular workshops and field days; encourage peer-to-peer learning.
Leverage digital tools to disseminate information and gather feedback.	✓	✓	✓	- Number of ICT tools developed and utilized - User engagement metrics	- ICT Departments- NGOs- Private Sector Partners	Access to timely information is crucial for decision-making.	Develop user-friendly applications; ensure content is in local languages.
Monitor and Evaluate Research and Extension Activities Assess the effectiveness of initiatives and adapt accordingly.	✓	✓	✓	- M&E frameworks established - Regular publication of evaluation reports	- M&E Units- Donor Agencies- Civil Society Organizations	Continuous improvement is essential for success.	Incorporate feedback mechanisms; adjust strategies based on findings.

Figure 5.8: Component 7 (Research and Extension)

INTERVENTIONS FOR COMPONENT 8

Effective Coordinated monitoring, and reporting mechanism and system

Activities	Timelines S	Timelines M	Timelines L	Key Indicators	Responsibilities	Stakeholders' View	Recommendations
Develop an integrated platform for data collection, storage, and analysis related to catchment activities.	✓			- System operational - Number of datasets integrated	- Nigeria Hydrological Services Agency (NIHSA)- State Ministries of Environment- River Basin Development Authorities (RBDAs)	Stakeholders emphasize the need for accessible and reliable data.	Ensure interoperability with existing systems; provide training for users.
Develop Standardized Monitoring and Evaluation (M&E) Frameworks Create uniform indicators and methodologies for assessing project performance.	✓	✓		- M&E framework documents developed - Adoption rate across agencies	- Federal Ministry of Water Resources- Donor Agencies- NGOs	Consistency in evaluation methods is crucial for comparability.	Align with national and international best practices; involve stakeholders in development.
Enhance the capacity of staff involved in monitoring and reporting activities.	✓	✓	✓	- Number of personnel trained - Improvement in data quality and reporting timeliness	- Training Institutes- NGOs- Donor Agencies	Continuous learning is essential to keep up with evolving methodologies.	Implement refresher courses; incorporate practical sessions.
Engage local communities in tracking environmental and social indicators.	✓	✓		- Number of community monitors trained - Frequency of community reports submitted	- Local Government Authorities (LGAs)- Community-Based Organizations (CBOs)- NGOs	Community involvement fosters ownership and timely data collection.	Provide incentives; ensure feedback loops to communities.
Create channels for stakeholders to provide input and receive updates on catchment management.	✓	✓		- Number of feedback sessions held - Stakeholder satisfaction levels	- State Ministries of Environment- NGOs- Donor Agencies	Transparent communication builds trust and facilitates collaboration.	Utilize multiple platforms (e.g., meetings, digital tools); document and act on feedback.
Assess the effectiveness and efficiency of catchment management interventions.	✓	✓	✓	- Evaluation reports published - Implementation of audit recommendations	- Independent Auditors- Donor Agencies- Civil Society Organizations	Regular assessments help in identifying areas for improvement.	Schedule evaluations at key project milestones; share findings publicly.
Utilize remote sensing, GIS, and other tools for timely data collection and analysis.	✓	✓		- Number of technological tools deployed - Reduction in data collection time	- ICT Departments- Research Institutions- Private Sector Partners	Technology enhances accuracy and efficiency in monitoring.	Invest in user-friendly tools; provide technical support.
Integrate Monitoring Systems Across Sectors Ensure coordination among water, agriculture, environment, and other relevant sectors.	✓	✓	✓	- Number of integrated systems operational - Reduction in data duplication	- Federal and State Ministries- RBDAs- NGOs	Integrated systems prevent siloed operations and promote synergy.	Establish inter-agency committees; develop shared protocols.

Figure 5.9: Component 8 (Effective Coordinated Monitoring , and Reporting Mechanism and System)

5.3 Expected Outcomes

1. **Environmental Sustainability**

- Reforestation and Afforestation: Increased Forest cover, improved soil fertility, enhanced carbon sequestration, and reduced soil erosion.
- Wetland Restoration: Improved water quality, enhanced biodiversity, and restored ecosystem services such as flood control and water filtration.
- Sustainable Land Management: Reduced soil erosion enhanced agricultural productivity, and improved land resilience to climate change.

2. **Water Resources Management**

- Improved Irrigation Systems: Enhanced water use efficiency increased agricultural productivity, and reduced water wastage.
- Water Quality Improvement: Reduced pollution levels, improved water quality, and healthier aquatic ecosystems.
- Climate Resilience: Enhanced resilience to climate change impacts, reduced vulnerability to droughts and floods.

3. **Socio-Economic Development**

- Agricultural Productivity: Increased crop yields, reduced poverty, and improved food security.
- Diversification of Livelihoods: Reduced dependence on natural resources, improved economic stability, and diversified income sources.
- Conflict Mitigation: Reduced tensions between farmers and herders, improved social cohesion, and peaceful coexistence.

4. **Governance and Institutional Strengthening**

- Stakeholder Engagement: Enhanced stakeholder participation, improved decision-making processes, and inclusive management.
- Policy and Regulatory Frameworks: Updated and enforced policies, improved governance, and legal support for sustainable practices.
- Capacity Building: Enhanced institutional capacity, improved governance, and skilled workforce.

CHAPTER 6 : MONITORING, EVALUATION AND LEARNING

The Gulbin-Ka Catchment stands as a critical hydrological and socio-economic area in Northern Nigeria, yet it faces significant environmental pressures, including climate variability, extensive land degradation, deforestation, and growing water scarcity. These challenges increasingly threaten the livelihoods of local communities, the health of ecosystems, and the long-term resilience of the region.

To ensure that the Gulbin-Ka Strategic Catchment Management Plan (SCMP) successfully achieves its goals, a strong commitment to continuous monitoring and evaluation is vital. This process not only measures the progress of implementation but also supports a dynamic approach to learning, adaptation, and timely adjustments as conditions evolve.

The establishment of a comprehensive Monitoring, Evaluation, and Learning (MEL) framework will enable systematic tracking of outcomes, identification of emerging challenges, and documentation of valuable lessons. Such a framework is crucial for promoting evidence-based decision-making and adaptive management of land, water, and ecosystem resources across the catchment.

When properly executed, the structured MEL shown in Table 6.1 system proposed for the Gulbin-Ka Catchment will provide a solid foundation for performance tracking, stakeholder engagement, and safeguarding the long-term sustainability of its critical water and environmental assets.

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 Gulbin-Ka Catchment

S/No.	Monitoring Tools and Techniques	Target/Output	Monitoring	Evaluation	Responsibility
	Hydrological Monitoring Stations Installation of gauging stations to measure river flow and water levels.	Accurate data on surface water availability and flow patterns.	Continuous data collection on water levels and flow rates.	Annual assessment of water resource trends and anomalies.	Nigeria Hydrological Services Agency (NIHSA); River Basin Development Authorities (RBDAs)
	Remote Sensing and GIS Mapping Utilization of satellite imagery to monitor land use changes and vegetation cover.	Up-to-date land use and land cover maps; detection of deforestation and land degradation.	Bi-annual analysis of satellite data to identify changes.	Evaluation of land use trends and effectiveness of reforestation efforts.	National Space Research and Development Agency (NASRDA); State Ministries of Environment
	Water Quality Testing Regular sampling of water bodies to assess parameters like pH, turbidity, and contaminants.	Data on water quality status across the catchment.	Monthly sampling and analysis at designated points.	Quarterly review to identify pollution sources and assess mitigation measures.	State Water Agencies; Environmental Protection Agencies
	Community-Based Monitoring Engagement of local communities in data	Enhanced local participation and real-time data on environmental changes.	Training of community members and	Semi-annual evaluation of community reports and integration into broader assessments.	Local Government Authorities (LGAs); Community-Based Organizations (CBOs)

collection on environmental indicators.		regular data collection.		
Biodiversity Surveys Periodic assessments of flora and fauna to monitor ecosystem health.	Inventory of species and identification of biodiversity hotspots.	Seasonal field surveys and data recording.	Annual evaluation to detect changes in biodiversity and inform conservation strategies.	National Parks Service; NGOs; Research Institutions
Socio-Economic Survey Collection of data on livelihoods, income levels, and resource use.	Understanding of socio-economic dynamics and impacts of interventions.	Annual household surveys and focus group discussions.	Analysis of socio-economic trends and effectiveness of livelihood programs.	National Bureau of Statistics (NBS); NGOs; Donor Agencies
Infrastructure Performance Monitoring Assessment of the functionality and impact of water-related infrastructure.	Data on the operational status and efficiency of infrastructure projects.	Regular inspections and maintenance reports.	Mid-term and end-term evaluations to assess infrastructure performance and sustainability.	Federal Ministry of Water Resources; RBDAs; Contractors
Integrated Data Management System Development of a centralized database for storing and analysing M&E data.	Consolidated and accessible data repository for informed decision-making.	Continuous data entry and validation.	Periodic audits to ensure data quality and system effectiveness.	Federal Ministry of Water Resources; NIHSA; IT Departments

Stakeholder Feedback Mechanisms Platforms for stakeholders to provide input and receive updates.	Improved stakeholder engagement and responsiveness to concerns.	Regular stakeholder meetings and feedback sessions.	Evaluation of stakeholder satisfaction and incorporation of feedback into planning.	State Ministries of Environment; NGOs; Donor Agencies
Periodic Review Workshop Sessions to assess progress, share lessons, and plan adjustments.	Adaptive management and continuous improvement of SCMP implementation.	Bi-annual workshops with all relevant stakeholders.	Documentation of lessons learned, and revision of strategies as needed.	Federal Ministry of Water Resources; State Governments; Donor Agencies

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.

6.5 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 Gulbin-Ka Catchment, covering approximately 2.96 million hectares across Kebbi, Zamfara, Niger, and Sokoto states in northwestern Nigeria, forms part of the Sokoto-Rima Basin and plays a vital ecological and socio-economic role. Its landscape transitions from elevated rocky terrains in the southeast to expansive floodplains in the northwest, dominated by the Gulbin-Ka River, a key tributary of the Niger River. The catchment supports diverse ecosystems, including Sudan and Guinea savannahs and wetlands, which underpin local livelihoods centred on agriculture, livestock rearing, fishing, and trade. However, the region faces mounting pressures from land degradation, water scarcity, deforestation, climate change, insecurity, and rapid population growth projected through 2050. Geologically, it comprises Precambrian Basement Complex rocks in the south and Sokoto Basin Sediments in the north, shaping soil types and groundwater dynamics.

In response to these challenges, the Gulbin-Ka Catchment Management Plan (GCMP) has been developed in alignment with the Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) initiative. Its vision is to sustainably manage land and water resources to enhance environmental conservation, resilience, and livelihoods. The GCMP aims to restore degraded landscapes and wetlands, improve water resource management for multiple uses, build climate resilience across agricultural and pastoral systems, and strengthen institutional frameworks for integrated catchment management.

Key strategic interventions proposed include the development of small- and medium-scale irrigation systems, the restoration of traditional flood-recession agriculture, improvement of groundwater recharge through managed aquifer recharge (MAR), and the rehabilitation and construction of water storage infrastructure. Ecosystem restoration efforts will focus on reforestation, the protection and rehabilitation of wetlands, and the promotion of agroforestry and sustainable grazing practices. To build climate resilience, the plan supports the adoption of climate-smart agriculture, the establishment of early warning systems for floods and droughts, and the enhancement of rainwater harvesting and soil moisture conservation techniques. Sustainable livelihoods will be promoted through diversification into aquaculture, apiculture, and non-timber forest product harvesting, as well as support for women’s cooperatives and capacity-building in sustainable agricultural practices and value chain development.

The financial and institutional strategy includes mobilising resources from ACReSAL, the African Development Bank, national budgets, and public-private partnerships (PPPs), alongside community-based funding mechanisms. Institutional arrangements propose the establishment of Catchment Management Committees (CMCs), capacity strengthening of State Ministries of Water Resources, Agriculture, and Environment, and the mainstreaming of integrated water resources management (IWRM) into local and state policies. Defined roles for partners include federal and state governments providing policy and oversight, NGOs and CSOs leading community mobilisation, research institutions offering technical support, and international agencies contributing technical and financial assistance.

A participatory governance model is central to the GCMP, featuring extensive stakeholder consultations with communities, traditional leaders, women's groups, and pastoralist associations. Multi-sectoral steering committees will drive coordination across sectors, supported by robust Monitoring and Evaluation (M&E) systems and grievance redress mechanisms. Continuous capacity building for local institutions in resource governance and conflict resolution will further strengthen implementation.

In conclusion, the Gulbin-Ka Catchment Management Plan offers a transformative opportunity to address environmental degradation, water scarcity, and socio-economic vulnerabilities. Through coordinated, integrated interventions and strong governance frameworks, the catchment can become a model for climate resilience and sustainable development in Nigeria’s semi-arid regions.

7.2 Recommendations for Aligning with Broader National and Regional Programs

The Gulbin-Ka Catchment Management Plan (GCMP) is a strategic initiative aimed at promoting sustainable water and land resource management across northwestern Nigeria, particularly within parts of Kebbi, Zamfara, Niger, and Sokoto states. Given the environmental vulnerabilities identified in the Gulbin-Ka Baseline Report including land degradation, water scarcity, climate variability, and socio-economic pressures aligning the GCMP with broader national and regional development frameworks is essential to ensure its effectiveness, sustainability, and resilience. The following recommendations are proposed:

1. National Water Resources Master Plan (NWRMP, 2013)

- The GCMP and the NWRMP share a common vision of promoting Integrated Water Resources Management (IWRM) and ensuring the sustainable use of surface and groundwater resources.
- GCMP's priorities on rehabilitating and expanding irrigation infrastructure, constructing small and medium-scale water storage systems, and enhancing flood management strongly align with NWRMP's objectives.
- It is recommended that the GCMP incorporate specific provisions from the NWRMP on managing transboundary water systems, especially considering Gulbin-Ka's linkages to the broader Sokoto-Rima and Niger River systems.
- Establishing joint monitoring, data sharing, and resource management mechanisms with neighbouring catchments will foster cross-boundary cooperation and optimize basin-wide water governance.

2. National Adaptation Plan (NAP) Framework

- Both the GCMP and the National Adaptation Plan emphasize climate-resilient agricultural systems, sustainable land management, and the protection of vulnerable ecosystems.
- The GCMP should place stronger emphasis on community-based adaptation strategies, including the promotion of drought-resilient crops, soil conservation measures, and water harvesting technologies tailored to semi-arid landscapes.
- To address the complex socio-economic impacts of climate change evident in the Gulbin-Ka catchment, the GCMP should integrate specific strategies for managing climate-induced migration, public health risks, and food security challenges.
- Collaboration with national NAP implementation bodies will allow access to technical expertise, adaptation finance, and national reporting platforms under Nigeria's UNFCCC obligations.

3. Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) Project

- The GCMP is strongly aligned with ACReSAL's goals of restoring degraded lands, promoting sustainable agriculture, enhancing community resilience, and advancing nature-based solutions to climate risks.

- To maximize synergies, the GCMP should formally align its Monitoring and Evaluation (M&E) framework with ACReSAL's standards, ensuring consistency in measuring impacts on land restoration, water management, and livelihood resilience.
- Adopting ACReSAL's proven tools for monitoring land health (e.g., remote sensing NDVI tracking), climate risk assessment, and socio-economic outcomes will strengthen GCMP reporting and evaluation processes.
- Full integration into ACReSAL's technical assistance and funding mechanisms will provide critical support for scaling up interventions and sustaining implementation momentum.

4. ECOWAS Water Resources Coordination

- The GCMP's focus on equitable water access, sustainable land management, and climate resilience aligns closely with ECOWAS's regional water management strategies.
- To strengthen regional integration, the GCMP should establish formal partnerships with the ECOWAS Water Resources Coordination Centre (WRCC) to facilitate knowledge exchange, technical capacity building, and participation in regional early warning and data sharing systems.
- Active involvement in ECOWAS-led initiatives on transboundary water management will position the Gulbin-Ka Catchment as a key contributor to regional water security and climate resilience efforts across West Africa.

7.3 Catchment Policy For Interstate River Systems

The Gulbin-Ka Catchment, spanning approximately 2.96 million hectares across Kebbi, Zamfara, Niger, and Sokoto states, is an integral sub-basin of the broader Sokoto-Rima River Basin, itself part of the transboundary Niger River Basin. Its strategic geographical and hydrological position underscores the importance of managing water resources, land use, and ecosystems in alignment with both national legislation and international frameworks governing shared river systems.

Given its hydrological connection to a shared international watercourse, any interventions such as dam construction, irrigation expansion, water abstraction, or land conversion within the Gulbin-Ka Catchment have potential downstream impacts on water availability, ecosystem integrity, and livelihoods, not only within Nigeria but also in neighbouring Niger Basin countries. Therefore, the catchment's management falls under several binding and non-binding regional and international agreements.

International and Regional Legal and Policy Frameworks

1. Niger Basin Authority (NBA) and the 2008 Niger Basin Water Charter

As a riparian state of the Niger River, Nigeria, alongside eight other countries, is a signatory to the Niger Basin Water Charter (2008), which establishes principles for equitable and reasonable use, cooperation, data sharing, and dispute prevention across the basin. The GCMP must be implemented in a manner that respects these obligations, including providing prior notification of major water infrastructure developments and ensuring activities do not cause significant harm to other riparian states.

2. Other Key International Water Treaties

Nigeria's obligations under global water governance frameworks also apply to the Gulbin-Ka Catchment:

- **1997 UN Convention on the Law of the Non-Navigational Uses of International Watercourses** (emphasizing equitable use, no significant harm, and cooperation).
- **1992 UNECE Water Convention** (though primarily regional, its principles of prevention, control, and reduction of transboundary impacts are globally influential).
- **Vienna Convention on the Law of Treaties (1969), Article 26** (mandating compliance with treaty obligations in good faith).

3. ECOWAS Water Resources Policy (2008)

The GCMP should align with ECOWAS principles promoting Integrated Water Resources Management (IWRM), basin-level planning, regional cooperation, sustainable financing mechanisms, gender equity, and the polluter-pays principle. Engagement with ECOWAS-led initiatives can strengthen regional resilience and institutional capacity.

4. Relevant "Soft Law" Instruments

Though non-binding, these frameworks heavily influence sustainable management approaches:

- **1971 Stockholm Declaration** (Principle 21: States must avoid harming environments beyond their jurisdiction).
- **1992 Rio Declaration and Agenda 21** (including precautionary and polluter-pays principles, and Environmental Impact Assessments).

- **1992 Dublin Principles** (promotion of IWRM, water as an economic good, and participatory management).
- **Draft Articles on the Law of Transboundary Aquifers** (applicable for managing groundwater resources critical in parts of the Gulbin-Ka Catchment).

Five Core Principles of International Water Law Relevant to Gulbin-Ka Catchment Management

1. **Equitable and Reasonable Utilization**
   (UN Watercourses Convention, Article 5): Gulbin-Ka's water and land use activities must fairly balance Nigeria's needs with those of other Niger Basin countries, considering ecological health, population demands, and sustainable development goals.
2. **Obligation Not to Cause Significant Harm**
   (Helsinki Rules; UN Watercourses Convention, Article 7): Water extraction, damming, irrigation expansion, or pollution within Gulbin-Ka must avoid causing environmental, economic, or social harm downstream.
3. **Prior Notification and Consultation**
   (Reflected in multiple treaties, including the Indus Waters Treaty): Nigeria must notify Niger Basin neighbors of planned projects within Gulbin-Ka that could materially alter water flows or quality.
4. **Cooperation and Information Exchange**
   (UN Watercourses Convention, Article 9): Regular data sharing and joint monitoring activities with Niger Basin Authority institutions are crucial for transparency and trust-building.
5. **Peaceful Settlement of Disputes**
   (Berlin Rules, UN Watercourses Convention): Any disputes arising from water use impacts must be settled through dialogue, mediation, or recognized international mechanisms, reinforcing regional stability.

National Legal and Policy Frameworks Governing Gulbin-Ka Catchment

At the national level, management of the Gulbin-Ka Catchment is shaped by the following instruments:

1. **National Water Resources Policy (2016)**

- Emphasizes **IWRM**, catchment-based planning, stakeholder engagement, and pollution control.
- Calls for systematic licensing of water abstractions and promotion of environmental flow standards aligned with the GCMP's goals.

2. **Water Resources Act (2004) (Pending updated legislation)**

- Provides a legal framework for regulating water use, protecting water quality, and managing groundwater and surface water sustainably.
- Supports permitting systems, groundwater protection, and the zonation of floodplains critical to the Gulbin-Ka's agricultural and ecological functions.

3. **State-Level Frameworks**

Given that the catchment covers multiple states, coordination across state laws and policies is essential:

- **Kebbi State**: Emphasizes rural water supply development and irrigation sustainability.
- **Zamfara State**: Enforces environmental regulations related to agriculture and grazing that impact catchment health.
- **Niger State**: Strengthens watershed protection and land-use zoning frameworks.
- **Sokoto State**: Focuses on water quality standards and public health protections in rural water management.

7.4 High-Level Funding Strategies and Partnership Opportunities

1. **Domestic Funding Mechanism**

a. ***Federal and State Budget Allocations:*** The Gulbin-Ka Catchment Management Plan can leverage allocations from Nigeria's National Development Plan (NDP) 2021–2025, which emphasizes infrastructure development, environmental sustainability, and climate resilience. Federal and state governments can earmark funds specifically for water resource management, afforestation, and climate adaptation projects within the catchment area. This alignment ensures that budgetary provisions are directed towards integrated projects that address both socio-economic and environmental challenges.

b. ***Catchment Development Funds:*** Establishing dedicated catchment development funds can pool resources from federal, state, and local governments. These funds can be utilized for projects such as dam rehabilitation, small-scale irrigation systems, and community-based watershed management initiatives. This approach ensures a dedicated financial resource base for the catchment's specific needs, enhancing the sustainability and impact of interventions.

c. ***Sectoral Allocations:*** Budgetary provisions from sectors like agriculture, environment, and water resources can be aligned to support integrated projects within the catchment. For instance, funds allocated for agricultural development can be directed towards climate-smart agriculture practices that also contribute to water conservation. This sectoral integration ensures that resources are used efficiently and effectively, addressing multiple objectives simultaneously.

2. International and Multilateral Funding Sources

a. ***World Bank:*** The Agro-Climatic Resilience in Semi-Arid Landscapes (ACReSAL) project, supported by a $700 million credit from the World Bank, aims to enhance sustainable landscape management in northern Nigeria. The Gulbin-Ka Catchment can benefit from this initiative by aligning its projects with ACReSAL's objectives, such as afforestation, climate-resilient agriculture, and watershed management. This alignment can facilitate access to significant funding and technical support.

b. ***African Development Bank (AfDB):*** AfDB has approved loans for water and sanitation projects in Nigeria, including a $124.2 million loan for Akure and a $205 million loan for Port-Harcourt. These projects focus on improving access to safe drinking water and sanitation, which are critical components of catchment management. The Gulbin-Ka Catchment can seek similar funding for water infrastructure projects, enhancing overall water management and public health.

c. ***Green Climate Fund (GCF) and Global Environment Facility (GEF):*** These funds provide financial resources for projects that address climate change and environmental degradation. The Gulbin-Ka Catchment Management Plan can seek funding for initiatives like reforestation, renewable energy integration, and sustainable land management. These projects can significantly enhance the catchment's resilience to climate change and improve environmental sustainability.

d. ***ECOWAS Regional Funds:*** ECOWAS supports regional integration and development projects. Funding can be sought for transboundary water management initiatives, especially considering the Sokoto-Rima River Basin's significance in the region. This regional approach can enhance cooperation and resource mobilization for large-scale projects.

3. Public-Private Partnerships (PPPs) and Private Sector Investment

a. ***Infrastructure Development:*** Engaging private sector partners in the development and maintenance of water infrastructure, such as dams and irrigation systems, can enhance efficiency and sustainability. PPPs can bring in additional resources and expertise, ensuring the long-term viability of these critical assets.

b. ***Agro-Ecological Resilience Projects:*** Private investments can be attracted to support climate-smart agriculture, agroforestry, and sustainable land use practices that contribute to both economic development and environmental conservation. These projects can improve agricultural productivity while reducing environmental impact.

c. ***Renewable Energy Initiatives:*** The catchment area has potential for renewable energy projects, such as solar-powered irrigation and mini-hydropower plants. PPPs can facilitate the financing and implementation of these projects, contributing to energy access and sustainability. This approach can also reduce reliance on fossil fuels and enhance energy security.

4. Strategic Institutional and Donor Partnerships

a. ***Technical Assistance and Capacity Building:*** Partnerships with institutions like the World Bank, AfDB, and international NGOs can provide technical expertise, training, and capacity-building programs for local stakeholders involved in catchment management. This support can enhance the effectiveness and sustainability of interventions.

b. ***Co-Financing Opportunities:*** Collaborative funding arrangements with development partners can enhance resource mobilization for large-scale projects. For instance, co-financing agreements can be established for integrated water resource management programs that align with both national and donor priorities. This approach can leverage additional funding and support for ambitious projects.

5. Alignment with National and Regional Development Frameworks

a. ***Nigeria's National Development Plan (NDP) 2021–2025:*** The NDP emphasizes sustainable development, infrastructure expansion, and environmental protection. Aligning the catchment management plan with the NDP can facilitate access to national funding and policy support. This alignment ensures that the catchment's needs are integrated into broader national development goals.

b. ***ACReSAL Program:*** By integrating the catchment management initiatives with the ACReSAL program, the plan can benefit from existing frameworks and funding mechanisms aimed at enhancing climate resilience in semi-arid regions. This integration can provide a structured approach to addressing climate change impacts and improving environmental sustainability.

c. ***ECOWAS Environmental Policies:*** Adhering to ECOWAS policies on water resource management and environmental sustainability can open avenues for regional cooperation and funding. This alignment can also enhance the transboundary management of the Sokoto-Rima River Basin, ensuring coordinated efforts across the region.

6. Inclusive, Climate-Resilient, and Scalable Financing Strategies

a. ***Community Participation:*** Ensuring active involvement of local communities in project planning and implementation enhances ownership and sustainability. Community-based financing mechanisms, such as cooperatives and microfinance schemes, can support small-scale initiatives. This approach ensures that projects are tailored to local needs and are more likely to succeed.

b. ***Climate Resilience:*** Investments should prioritize projects that enhance the catchment's resilience to climate change impacts, such as drought-resistant agriculture, flood control measures, and ecosystem restoration. This focus ensures that projects are sustainable in the long term and can withstand future climate variability.

c. ***Scalability:*** Pilot projects with successful outcomes can be scaled up across the catchment area. Documenting best practices and lessons learned facilitates replication and attracts further investment. This approach ensures that successful interventions can be expanded to achieve broader impact.

7.5 Moving Forward with the Catchment Plan

The Gulbin-Ka Catchment Management Plan (GKCMP) is a dynamic and evolving tool designed to guide long-term sustainable management of the catchment's land, water, and natural resources. It marks the transition from planning to implementation, setting the stage for integrated, inclusive, and climate-resilient development. To remain effective and relevant, the GKCMP must be reviewed and updated regularly, reflecting new scientific insights, policy developments, environmental changes, and socio-economic dynamics within the catchment.

Both the Federal Project Management Unit (FPMU) and national technical consultants, alongside state-level stakeholders, should maintain continuous access to the plan and its supporting knowledge base. To ensure transparency, accessibility, and collaborative management, the GKCMP should eventually be transformed into a digital e-Plan platform allowing real-time updates, data sharing, and stakeholder interaction.

Key Priorities for Keeping the GKCMP Active and Impactful

Environmental Awareness and Stewardship: Promote environmental awareness through education and community engagement to support local stewardship of biodiversity and natural resources.

Policy Strengthening and Enforcement: Strengthen and enforce environmental policies through collaboration with government, ensuring alignment with Integrated Water Resources Management (IWRM) and adequate resourcing: Improved compliance with environmental regulations and sustainable resource use.

Inter-Agency Coordination: Enhance inter-agency coordination by equipping and funding key regulatory bodies to jointly enforce environmental protection laws.

Open Data and Monitoring: Implement an open, catchment-wide monitoring system to share environmental data and support evidence-based decision-making.

Ecosystem and Resource Integration: Adopt holistic, long-term environmental policies that integrate water, soil, vegetation, and biodiversity management across the entire catchment system.

Scale-Appropriate Partnerships: Promote multi-stakeholder collaboration and decentralized implementation by engaging civil society, research bodies, private investors, and communities from micro-catchments to the full Gulbin-Ka Basin.

Diversified Funding Approaches: Adopt a blended finance approach combining public funds, donor support, private investment, and community contributions to ensure resilient and inclusive implementation.

Simplified and Enabling Regulation: Simplify environmental regulations to enhance compliance and enable timely action while maintaining essential safeguards.

Improved Compliance and Deterrents: Strengthen enforcement of environmental violations through clear penalties and restoration mandates, backed by sufficient funding for agencies and local authorities.

Sustainable Agricultural Practices: Promote sustainable farming by adopting alternatives to conventional pesticides, including Integrated Pest Management (IPM), organic practices, precision agriculture, and locally tailored innovations like biochar and cover cropping.

Capacity Building and Awareness on Land Use Impacts: Educate stakeholders on the hydrological and ecological impacts of land use changes and integrate this knowledge into development and land-use planning.

Support for Nature-Based Solutions (NbS): Promote ecosystem-based solutions like reforestation and wetland restoration for flood control, erosion prevention, and groundwater recharge.

Catchment-Wide Perspective: Integrate systems thinking into policy and practice to address upstream-downstream linkages across hydrology, ecology, and community well-being.

Green Infrastructure and Urban Integration: Promote sustainable urban drainage systems (SUDS), permeable surfaces, and green corridors in urban centers like Sokoto and Gusau to enhance stormwater management and biodiversity.

Riparian and Floodplain Protection: Identify and protect key riparian corridors and floodplain areas, implementing development controls to preserve ecological and hydraulic functions.

Groundwater and Baseflow Enhancement: Protect recharge zones and promote infiltration practices to sustain aquifers and stream baseflows, particularly during dry seasons.

Protection of Aquatic Habitat: Maintain stream connectivity, water quality, and fish passage infrastructure, particularly in areas affected by dams or road crossings.

Sediment and Erosion Control: Implement on-site (primary) and off-site (secondary) erosion and sediment control measures during development, including terracing, check dams, and silt traps.

Stormwater Quality Management: Apply targeted source control techniques for pollutants (e.g., oil, heavy metals) and implement catchment-wide pollutant reduction strategies.

Ongoing Communication and Stakeholder Engagement: Sustain momentum by regularly communicating progress, challenges, and achievements to stakeholders. Use inclusive forums, town halls, and digital platforms.

Adaptive Management and Flexibility: Ensure the plan is adaptable to new research, community feedback, and changing conditions, with continuous learning embedded in governance.

7.6 Conclusion

The Gulbin-Ka Strategic Catchment Management Plan aims to transform the catchment through strategic interventions in environmental sustainability, socio-economic development, institutional strengthening, and technical advancements. Key goals include reducing water wastage by 30%, increasing forest cover by 20%, and enhancing agricultural productivity by 25% by 2030. The plan also focuses on reducing poverty, improving access to clean water and sanitation, and strengthening governance through inter-agency coordination and community participation. Technical advancements will modernize irrigation infrastructure and establish robust monitoring systems. Community engagement will empower local communities, especially women and youth, through conservation initiatives and vocational training. Grounded in evidence from biophysical assessments and stakeholder consultations, the plan addresses water scarcity, land degradation, and climate change impacts. Successful implementation will require coordinated efforts from federal, state, and local stakeholders, leading to sustainable development and enhanced resilience for future generations.

ANNEXES

ANNEX 1: DETAILED POPULATION STATISTICS FOR THE CATCHMENT

Table A-1 1:Population Projection for Gulbin-Ka Catchment

POPULATION PROJECTION FROM 2006 - 2050									
State	LGA	2006	2022	2025	2030	2035	2040	2045	2050
Sokoto	Kebbe	123,154	179,990	193263	217594	244989	275834	310561	349661
Zamfara	Anka	143,637	209,926	225406	253785	285736	321710	362214	407816
Zamfara	Bukkuyum	216,348	316,193	339510	382254	430380	484564	545571	614258
Zamfara	Gummi	206,721	302,123	324402	365244	411229	463002	521294	586925
Zamfara	Gusau	383,712	560,796	602150	677960	763316	859417	967617	1089440
Zamfara	Maru	293,141	428,426	460019	517935	583143	656561	739222	832290
Kebbi	Bagudu	238,014	347,858	373510	420534	473480	533091	600207	675773
Kebbi	Dandi	146,211	213,688	229445	258332	290857	327475	368704	415124
Kebbi	Fakai	119,772	175,047	187955	211619	238262	268259	302032	340058
Kebbi	Koko/Besse	154,818	226,267	242952	273540	307978	346753	390409	439561
Kebbi	Maiyama	173,759	253,949	272676	307006	345658	389176	438173	493339
Kebbi	Ngaski	126,102	184,298	197889	222803	250854	282436	317995	358031
Kebbi	Shanga	127,142	185,818	199521	224640	252923	284766	320618	360983
Kebbi	Suru	148,474	216,995	232997	262331	295358	332544	374411	421549
Kebbi	Wasagu/ Danko	265,271	387,694	416283	468693	527702	594139	668941	753161
Kebbi	100,564	146,974	157813		177681	200051	225238	253595	285523

Kebbi	Zuru	165,335	241,637	259456	292122	328900	370308	416930	469421
Niger	Agwara	57,347	83,813	89993	101323	114080	128443	144614	162820
Niger	Borgu	172,835	252,599	271226	305373	343819	387106	435843	490716
Niger	Rijau	176,199	257,515	276505	311317	350511	394641	444326	500267
TOTAL		3,538,556	5,171,605	5,552,969	6,252,087	7,039,224	7,925,462	8,923,277	10,046,717

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

Table A-1 2: Threats, Challenges, Socio-Economics and Policies Linked to Water Infrastructure in the Catchment from Stakeholders

Natural Resources *(Water reservoirs, aquifers, minerals, biodiversity)*	Agriculture	Threats and Challenges	Socioeconomics	Policies	Past & Present Interventions
Kebbi State - Yauri Dam - Zuru Earth Dam - Gold (Suru), Manganese (Bagudo), Lithium (Ngaski) - Biodiversity-rich wetlands (Yauri)	- Rice (Bagudo, Yauri) - Maize, millet (Maiyama) - Livestock in Danko Wasagu	- Flooding (Yauri floodplain) - Water overuse for irrigation - Deforestation due to charcoal - Wetland degradation	- High dependence on agriculture - Youth unemployment in rural LGAs - Poor road access to farms	- Water Users Association Law (2024) - Environmental Protection Policy	- ACReSAL (ongoing) - Fadama III+ (21 LGAs) - NG-CARES - Desilting/levee projects
Zamfara State - Bukkuyum Dam - Gold (Anka, Bakura), Kaolin (Faskari) - Baobab, Gum Arabic, Locust Bean	- Millet, sorghum, onion (Bungudu, Gusau) - Irrigated vegetables	- Banditry, insecurity (Talata-Mafara, Anka) - Land degradation from mining - River siltation near Bakolori Dam	- Informal mining a major income source - Farming productivity reduced by insecurity - Limited irrigation access for women	- Forestry Conservation Law (2015) - Zamfara Gender Policy	- ACReSAL (irrigation focus) - NEWMAP (Sokoto-Zamfara only partially covered) - Rural WASH (RUWASA) programs

Niger State - Kainji Dam (Borgu) - Iron (Agwara), Mica (Rijau) - Guinea savannah flora and fauna - Borgu Game Reserve	- Rice (Shiroro, Borgu) - Cassava, yams, maize - Pastoralism in Rijau, Magama	- Soil salinization from irrigation - Flooding in Agwara, Borgu - Farmer-pastoralist conflict (Mashegu, Rijau)	- Economic reliance on agriculture and fishing - Urban expansion threatening arable land (Kontagora)	- National Environmental Policy (2017) - Land Use Act (federal)	- Flood Early Warning Systems (Agwara) - Fadama III support to rural cooperatives - IFAD agri-support (2008–2020)
Sokoto State (Kebbe LGA) - Goronyo Dam - Groundwater aquifers for dry-season farming - Shea butter, lemon grass - Sokoto Red Goat (faunal heritage)	- Onion and tomatoes (Wurno, Gwadabawa) - Dry-season vegetables	- Droughts, dry spells (Rabah, Wurno) - Typha grass infestation along riverbanks - Conflicts over grazing rights	- Gender-based livelihood gaps - Low access to credit for rural women - Overdependence on traditional farming	- Sokoto Water & Sanitation Law (2010) - Sokoto State Forestry Law (2018) - Sokoto Climate Change Policy (2021)	- ACReSAL women-led farm pilots - Gender mainstreaming through VAPP Law - WASH infrastructure by RUWASA

ANNEX 3

Shared Strategic Vision and Goals

GOAL

The goal of the Gulbin-Ka Catchment shared vision is to ensure sustainable utilization, conservation and management of natural resources within the Catchment.

OBJECTIVES

i. To implement effective climate smart agricultural practices for improved food and nutrition security.
ii. To ensure sustainable restoration of the ecosystem for socio-economic development of the catchment.
iii. To mitigate climate change impact through efficient and sustainable use of renewable energy and other innovative solutions.
iv. To develop and implement effective integrated water resources management practices in Gulbin-Ka catchment.
v. To mainstream gender and inclusion of vulnerable groups especially those with special needs in decision making and other processes.
vi. To develop and implement effective and efficient mechanism for Participatory Project Monitoring and Evaluation.
vii. To ensure community participation in the protection and management of natural resources in the catchment.
viii. To develop and implement an effective conflict resolution mechanism within the catchment.

1. STAKEHOLDERS ENGAGEMENT

i. Identification and analysis of relevant stakeholders
ii. Conducting quarterly townhall meetings
iii. Publish or develop communication channels on stakeholders resolutions for public hearing and press release
iv. Regular sensitization, awareness creation and continuous engagement among the stakeholders within the catchment
v. Conducting regular stakeholder's feedback mechanism to assess project performance.

2. WATER MANAGEMENT

i. Identification and mapping of water resources and facilities within the catchment for effective planning and management.

ii. Reviewing and domesticating existing policies for enforcement by regulatory bodies within the catchment

iii. Identify and strengthen Water Users Association and Action Groups for proper management within the catchment.

iv. Establishment of a standard operating and maintenance procedure for water facilities management in the catchment

v. Enhance collection of water resources data for informed decision making.

3. LAND USE

i. Integrated soil fertility management practices

ii. Review the land use policy to meet the current realities, particularly the Land Use Act of 1976

iii. Enforcement of mining policies within the catchment

iv. Strengthening dispute resolution mechanisms in the catchment

4. ENVIRONMENTAL PROTECTION

i. Development and implementation of deliberate action plan on forest resource management

ii. Advocacy and sensitization on the dangers of environmental degradation

iii. Development and enforcement of sustainable safeguard instrument

iv. Establishment of an integrated waste management mechanism in the catchment

v. Creating awareness, sensitization and enforcing effective waste management

5. COMMUNITY BENEFITS

i. Engagement of youths and vulnerable groups in the implementation of projects within the catchment to reduce crime and political thuggery there by improving their social livelihood

ii. Ecosystem sustainability with resultant increase in air quality, water and food supply, recreation and improvement of livelihood

iii. Access to enhanced WASH services (safe water, sanitation and hygiene)

6. ECONOMIC DEVELOPMENT

i. Capacity building of stakeholders on business and management models

ii. Improve access to credit facilities at a single digit interest rate

iii. Access to sustainable community revolving fund

iv. Establishment of agricultural free trade zone within the catchment

v. Investment in infrastructure and social services within the catchment

7. CLIMATE CHANGE RESILIENCE

i. Create awareness on climate change; it's impacts, mitigations and adaptation actions within the catchment

ii. Encourage climate smart agricultural practices and technologies

iii. Promote the development of climate resilient infrastructure within the catchment

iv. Installation of smart climate readers, hydrological and meteorological stations for early warning information

v. Enforcement of insurance policies within the catchment

8. MONITORING AND EVALUATION/ ALIGNMENT OF POLICIES

i. Design and implement effective M&E mechanism within the catchment

ii. Develop effective real-time data base of stakeholders within the catchment for monitoring basis.

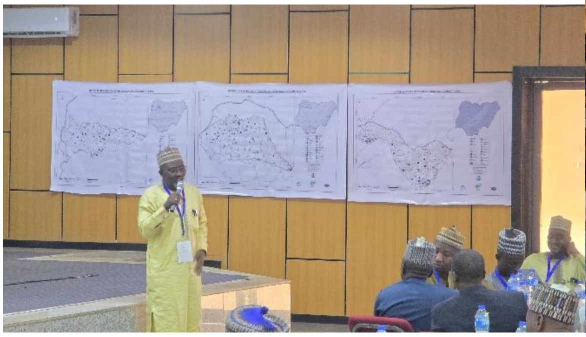
iii. Develop logical framework with clear target and key performance indicators within the catchment

iv. Ensure synergy between MDAs responsible for policy formulation and implementation

Prof. Mairo Muhammed
Chairman

Aaron Adetide Adeola
Secretary

STAKEHOLDER ENGAGEMENT PHOTOGRAPHS



GLOSSARY

Glossary of Key Terms

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

Climate Mitigation	Efforts to reduce or prevent greenhouse gas emissions, such as using renewable energy, improving energy efficiency, or reforestation.
Climate Resilience	The ability of a system, community, or ecosystem to anticipate, prepare for, and adapt to climate-related risks and recover from their impacts.
Community-Based Organizations (CBOs)	Local groups or associations that work to address community needs and challenges, often playing a key role in implementing development projects.
Desertification	The process by which fertile land becomes desert, typically due to drought, deforestation, or inappropriate agriculture.
Discharge	The volume of water flowing through a river or stream per unit of time (e.g., cubic meters per second).
Ecological Footprint	A measure of human demand on Earth's ecosystems, comparing the resources consumed to the planet's capacity to regenerate them.
Ecosystem Services	The benefits that humans derive from ecosystems, such as clean water, air, food, and climate regulation.
Environmental Degradation	The deterioration of the environment through depletion of resources, destruction of ecosystems, and pollution, often caused by human activities.
Environmental Impact Assessment (EIA)	A process used to evaluate the potential environmental effects of a proposed project or development before it is carried out.
Erosion	The process by which soil and rock are removed from the Earth's surface by natural forces such as wind, water, or human activities, often leading to land degradation.
Eutrophication	The excessive growth of algae and other plants in water bodies due to nutrient pollution, often leading to oxygen depletion and harm to aquatic life.
Evapotranspiration (ET)	The combined process of water evaporation from soil and transpiration from plants, a key component of the water cycle.
Floodplain	A flat area of land adjacent to a river or stream that is prone to flooding, often rich in biodiversity and fertile soil.
Geographic Information System (GIS)	A computer-based tool for mapping and analyzing spatial data, widely used in catchment management.
Greenhouse Gas (GHG)	Gases that trap heat in the atmosphere, contributing to global warming and climate change. Examples include carbon dioxide (CO_2), methane (CH_4), and nitrous oxide (N_2O).
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.